United States
Department of
Agriculture

Forest Service

Pacific Southwest
Research Station

General Technical
Report
PSW-GTR-191

June 2005

Bird Conservation Implementation and Integration in the Americas: Proceedings of the Third International Partners in Flight Conference

March 20-24, 2002 **Asilomar, California**

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Abstract

C. John Ralph and Terrell D. Rich, editors. 2005. **Bird Conservation Implementation and Integration in the Americas: Proceedings of the Third International Partners in Flight Conference.** 2002 March 20-24; Asilomar, California, Volume 1 and 2. Gen. Tech. Rep. PSW-GTR-191. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture; 1296 p.

These two volumes contain in part papers presented at the Third International Partners in Flight Conference: A Workshop on Bird Conservation Implementation and Integration, which was held 20-24 March 2002 at the Asilomar Conference Center in Monterey, California. The conference gathered together researchers, educators, foresters, monitoring specialists, planners, and land managers to discuss the past, present, and future directions of conservation, land planning, and research for birds in North and South America, with a primary focus on landbirds. The papers in these volumes represent a broad array of subjects, including management planning, conservation, educational outreach programs, ornithological research, research methodologies, along with the some of the newest technologies for research and dissemination of information.

Retrieval Terms: bird populations, conservation, planning, monitoring, education, management, ecology, migration

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Cover art by Sophie Webb

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Bird Conservation Implementation and Integration in the Americas: Proceedings of the Third International Partners in Flight Conference

C. John Ralph and Terrell D. Rich
editors

March 20 - 24, 2002
Asilomar, California

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Third International Partners in Flight Conference: A Workshop on Bird Conservation Implementation and Integration March 2002

The State of the Art and the State of the Science: Partners in Flight in the 21st Century

C. John Ralph[1] and Terrell D. Rich[2]

In March 2002 some 700 people gathered at the Asilomar Conference Grounds near Monterey, a site long-renowned for innovative conferences, to celebrate, calibrate, and confabulate on the bird initiative called Partners in Flight (PIF). This conference had some background, an understanding of which may help readers put this volume into perspective.

Brief Historical Perspective of PIF

The first bird 'Initiative' was for waterfowl - the North American Waterfowl Plan (1986). It was well-structured through its implementation arms, called "Joint Ventures," and it was relatively well-funded through legislative earmarks to the U.S. Fish and Wildlife Service, Canadian Wildlife Service, and state programs. Its success encouraged several far-seeing entities and individuals, most notably the National Fish and Wildlife Foundation, to start a landbird initiative in 1990–four short years later–changing the landscape of landbird conservation.

From almost the start, Partners in Flight (Compañeros en Vuelo and Partenaires d'Envol) was a different 'organization' than any before it. It was, first of all, a support group for landbirds, and it concentrated on a broad spectrum of birds. "Landbirds" were defined as all those species of birds other than waterfowl, shorebirds, waterbirds, and seabirds. "Landbirds" is not an exclusive designation, however, and many of these other taxa found a home in PIF's deliberations and products. They also found a home in many of the papers of this volume, at the least to provide exemplary or cautionary tales.

PIF is also a highly-interactive and non-hierarchical group of people and organizations. One point as a field guide to people unaccustomed to PIF is that it has a unique organizational hierarchy – that is, a relative lack thereof. It is multifaceted and interacting, with country groups, state groups, regional groups, specialist and technical groups, habitat groups, and Bird Conservation Regions. Anyone can have a seat at any of the multitude of tables and can, if he or she is able, contribute markedly to bird conservation. It is also a visionary and flexible coalition, with various organizational units adapting as necessary to meet new needs and opportunities. And finally, it is an international group, with parallel, joint, and overlapping groups, as appropriate, in Canada, the U.S., and Mexico. This coalescence of diversity is represented in this volume.

To paraphrase from our web site (http://www.partnersinflight.org), Partners in Flight is a cooperative partnership among federal, state and local government agencies, philanthropic foundations, professional organizations, conservation groups, industry, the academic community, and private individuals. PIF focuses resources on the improvement of monitoring and inventory, research, management, and education programs involving birds and their habitats. Its central premise is that the resources of public and private organizations in the Western Hemisphere must be combined, coordinated, and increased in order to achieve the greatest success in conserving bird populations in this hemisphere. The power of PIF lies in the synergy that builds when diverse, committed groups who care about birds work together for a common goal. Indeed, this conference aimed to foster progress toward this lofty goal.

History of the Conference

By the late 1990s, the landscapes of bird conservation had irreversibly changed, we think for the better: (1) following on the success of PIF, other bird initiatives had come into being; (2) PIF had regional coordinators who encouraged and oversaw the concept of Bird Conservation Plans, more than 70 documents in all tied into major biomes, regions, and states; (3) the North American Bird Conservation Initiative had been cre-

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ated (an umbrella organization to help garner support for the various bird initiatives); and (4) various regional and national monitoring programs had been rapidly implemented. Now, it seemed time to move ahead.

Thus, early in 2000, several of us found ourselves at a clear juncture in the history of PIF. Implementation of objectives laid out in Bird Conservation Plans seemed to be developing into more of a North American Bird Conservation Initiative (NABCI) activity tied to Bird Conservation Regions. There were questions as to the appropriate role of PIF into the future. We thought that this evolving role could center on continuing to expand the conceptual boundaries of bird conservation.

We had learned an extraordinary amount since PIF began in 1990 covering: (1) advances in monitoring; (2) our understanding of what limits bird populations; (3) the relationships between population phenomena, landscapes, and management practices; and (4) the nature of bird conservation planning. Additionally, it was abundantly clear that there was a great deal that we either didn't understand or had yet to reach consensus on. We felt that the future of bird populations on this continent and elsewhere depended to a large extent on efforts to dramatically improve our knowledge base.

At such junctions in the past, PIF held a national meeting to conduct a status assessment and set objectives for the future. Conferences were held at Estes Park, Colorado in 1992 (Finch and Stangel 1993, Martin and Finch 1995), and at Cape May, New Jersey in 1995 (Bonney et al. 2000). These gatherings greatly increased the level of enthusiasm and provided opportunities to exchange new information regarding many aspects of bird science and conservation. Monterey was a forum for presentation of all that we have learned since Cape May, and like Cape May and Estes Park, we felt it would provide fertile ground from which our direction for the next several years could spring.

PIF has always been poised between science and management. As both the conservation community and management agencies were really taking PIF products seriously, the urgency of strengthening the conceptual ground on which we stand had greatly increased. The Monterey Workshop was a celebration of this realization, a reaffirmation of the linkage between science and management, and a statement of the relevance of PIF for the future.

Venue and Organization of the Meeting

We held the meeting at the Asilomar Conference Center, just south of historic and beautiful Monterey. This was a great venue with abundant landbirds, and for an ecumenical touch, sea otters, shorebirds, sea ducks, and rocky shorebirds a very short walk from the center.

Monterey was a PIF workshop, focused primarily on landbirds. Relevant perspectives regarding other groups of birds were welcomed and necessary.

Program

We faced the problem of integrating a multidimensional hyperspace of programs, species, and objectives into seven parallel, concurrent sessions that were linear in time and content. The resulting program attracted some 350 oral papers and 75 poster presentations.

Our general guidelines were:

(1) As a Partners in Flight conference we wanted to feature the significance of upland habitat projects that primarily benefit landbirds. We also desired some content that was decidedly "all-bird" in scope. While many examples of projects, education, outreach and research presented in sessions inevitably concerned only a subset of species, we tried to balance sessions to provide examples from a broad array of taxa.

(2) We wanted to focus all sessions on putting conservation action on the ground. What has worked? What has not worked? How did you do it? Who helped? What did you learn? Although we obviously also were interested in what is possible or what might be done, we wanted speakers to focus on what has worked and the experience of our partners.

(3) We designed the sessions to be as interdisciplinary and international as possible. We wanted researchers, educators, tree planters, monitoring specialists, planners, and land managers to participate together. We made ample opportunities, especially in the evenings, for groups to meet with colleagues within their own disciplines.

(4) Although papers were largely invited by the organizing committee, acknowledged below, we also put out a call for papers and posters. Many came forward to reveal partners and project examples that we were not aware of. All presenters of papers or posters were given an opportunity to submit papers to these proceedings. That so many accepted was a bit of a challenge in processing them. All papers

were put through peer review and then reviewed by the chairs of various sessions, as well as by us. A few papers were contributed after the conference as authors, chairs, and we found relevant work that had not been part of the program. This has helped to round out the proceedings.

The People

From the inception, David Pashley of the American Bird Conservancy, Geoff Geupel of the Point Reyes Bird Observatory, and Art Martell of Ducks Unlimited, Canada provided us with inspiration and a plethora of great ideas. All three, in many and sundry ways, provided inspiration and energy for the conference and for PIF from their own unique perspectives. The entire bird conservation community owes them deeply. Our Steering Committee was quickly formed with folks from across North America, and with frequent conference calls and occasional meetings, this committee made the conference, and subsequently this volume, a reality. Committee members included the three above, along with Carol Beardmore, Humberto Berlanga, Greg Butcher, Dean Demarest, Naomi Edelson, Judith Kennedy, Mila Plavsic, Ken Rosenberg, Sandy Scoggin, and Steve Wendt. We are all in their debt.

We thank Martha Shibata and Joan Cravens for the great job from the Research Information Services of the U.S. Forest Service's Pacific Southwest Research Station in Albany, California in finalizing this volume.

Finally, Linda L. Long spent much of the past four years helping us put together the conference, working with Point Reyes Bird Observatory, planning and compiling the program, contacting and cajoling the authors, helping coordinate logistics, and most of all, tracking, editing, and formatting these papers. We would be nowhere without Linda.

Outlook

We trust you will find much in the volumes to interest you and to move Partners in Flight onto greater efforts and bird conservation onto greater successes in the coming years. There are many unique opportunities for personal and institutional involvement in our joint efforts.

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Opening Remarks[1]

Ellie M. Cohen[2]

Welcome to the Third International Partners in Flight Conference! On behalf of everyone at PRBO, we are honored to be your local hosts for this historic event that brings together all of you–esteemed representatives from all the major bird conservation initiatives, from all over the Western Hemisphere and beyond!

PRBO Conservation Science was founded as Point Reyes Bird Observatory in 1965 with a half-time biologist working on the point of Point Reyes National Seashore. Today we have 55 staff biologists and another 50 seasonal biologists working throughout California and the West, from Central America to Alaska.

As all of you know, birds can be excellent indicators of ecosystem function and key to wise stewardship. Working throughout the West, our 55 staff scientists and more than 50 seasonal biologists study birds and ecosystems to protect and enhance biodiversity.

PRBO is actively engaged in all the major bird conservation initiatives–for songbirds, shorebirds, waterbirds and waterfowl–on a regional and national scale. We study and work to protect individual threatened and endangered species. We also work to keep common birds common, as the Partners in Flight maxim goes! We evaluate the health of marine, wetlands and terrestrial habitats and ecosystems; and from this information, we provide management and restoration recommendations to hundreds of government agencies, nonprofits and private interests.

Our guiding philosophy for successful conservation is based on three key strategies:

1. **Partnerships**. My belief is that there should be no competitors when it comes to conserving biodiversity. We must work together because we are exponentially more effective when we do. Policy makers and funders applaud this approach as well!

2. **Ecosystem level, multi-species approach.** While PRBO conducts research and protects endangered and threatened species, we also focus on suites of species to give us more insights into how an entire ecosystem is functioning. We investigate not only the target habitat type, but also adjacent habitats that factor into successful productivity and survival of birds and other wildlife. We also evaluate multiple species and vegetation on a landscape level, vastly increasing our conservation effectiveness.

3. **Ongoing, standardized scientific monitoring and feedback.** Or what we at PRBO call Adaptive Conservation Planning. The concept of adaptive management is often given lip service but rarely put into practice. Our field experience shows that ongoing scientific monitoring with a direct and regular feedback loop to habitat and wildlife managers is critical to conservation success–as many of you attending this conference can confirm! It must be based on sound science and the approach must be standardized so we can compare across sites, states and even continents to most effectively evaluate our findings and implement conservation measures.

Our vision at PRBO is that bird conservation science should be guiding habitat restoration and management everywhere. I am not referring only to bird banding or mist netting but ongoing population studies on productivity, survival and dispersal as well as vegetation studies and landscape level analyses that help ensure the most effective conservation.

We at PRBO have found that applying bird conservation science on an ecosystem scale translates into what I like to call: **getting the most biodiversity bang for every conservation buck invested!**

We are all here together today–the duckheads (one of my colleagues told me it was OK to say that!), the LBJs, and the shorebird, seabird and other waterbird folks! The time has come for us all to work together as the theme of this conference states – Bird Conservation, Implementation and *Integration*. Working together we will exponentially increase our effectiveness and our chances for conservation success.

Finally, I would like to acknowledge Logistics Chair Sandy Scoggin, Logistics Co-Chair Missy Wipf, Terrestrial Program Geoff Geupel and all the PRBO staff who have done such an outstanding job organizing this wonderful conference. Thanks to you all!

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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Partners in Flight – Working for Bird Conservation Implementation and Integration in the Western Hemisphere[1]

Terrell Rich[2]

In 1990, a group of far-sighted individuals from the National Fish and Wildlife Foundation and the U.S. Forest Service launched the Neotropical Migratory Bird Conservation Initiative. At the time, few people noticed. New programs are launched all the time. In government, at least, it is easy to become cynical about the initiative *du jour*, the latest vision statement, the fresh reorganization, and the coolest new fad in management. Initiatives come and go. Most seem to be missing something essential, some internal spark that strikes a chord with people. If we're lucky, they just fade away. Very few new ideas can say that they have grown steadily for 11 years and fewer yet can claim to having been instrumental in spawning yet further initiatives. Partners in Flight can say both.

In 2002, we have wall-to-wall Bird Conservation Plans in the United States.

We have Partners in Flight in Canada and Central America, and our partners in Mexico and the Caribbean are selecting from PIF those ideas and processes that work best with their own resources, issues, cultures and objectives.

Partners in Flight has expanded from a focus on long-distance migrants that inhabit eastern deciduous forests to essentially all birds in all habitats.

We have a Species Assessment Database for all birds that forms the cornerstone of a very wide variety of actions by partners in the U.S. And we're working with Canada and Mexico to continually refine the database, to include ever more species, to make it work better for everybody.

Few people realize that this decade-plus of progress has been made by people who do not work for Partners in Flight. Indeed, Partners in Flight secured its first full-time, securely funded position only at the beginning of 2001 – fully 11 years after the idea was crafted. All of the progress to date, all of the advances in bird conservation thinking that have formed the backbone of PIF, were made by people and organizations using their own capacities. Thus, while more paid staff and more operational money are always welcome, a good idea will move forward on its own internal, self-evident rightness. People find ways to make it happen – with, without and, sometimes, despite, organizational support. Bird conservation strikes a chord.

Here are a few of the things we need to do now.

1) We need to secure permanent, long-term funding for Partners in Flight Regional Coordinators in the U.S. We are working with the North American Bird Conservation Initiative on a number of fronts to secure these and a few other permanent positions.

2) We need to put conservation action on the ground. As John Fitzpatrick pointed out in his closing remarks at the Cape May Partners in Flight conference in 1995, all of this activity is great. But if we don't have more birds at some point down the line, then we will have failed. Our specific challenge is to create more habitat, to improve habitat quality, and to take other actions that lead directly to more birds. PIF must accept the challenge of our colleagues in the Joint Ventures to bring new partners to the table and to make improvements in the real world.

3) We need to motivate the tens of millions of people who feed birds and watch birds to become active in conservation. We should make people who are comfortable only enjoying birds, slightly uncomfortable. Since you began reading this, the population of the planet has increased by about 1000 people. We now have less habitat, fewer natural resources and more problems for birds. We need more people doing more, and doing it sooner.

4) We need to secure long-term funding for landbird projects. This will be through expanding the scope of North American Wetlands Conservation Act, expanding the funding of the Neotropical Migratory Bird Conservation Act, succeeding in getting a Conservation and Reinvestment Act, taking advantage of opportunities in the Farm Bills, and a host of other actions.

5) We need to be very generous in our thinking about geographic priorities. Look for the opportunities and the priorities at the largest scale. Maybe your greatest opportunity to make a difference tomorrow is not in Idaho or Georgia, not on your forest or in your park,

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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not on your block – maybe it's in Chiapas or Costa Rica or the Atlantic rainforest of Brasil. Think big and expand the partnership. Globalization is more than a term for Wall Street. It's a fundamental understanding that we really are all connected and that the loss of a species is tragic, no matter where it occurs. And it's doubly tragic if we had capacity but did nothing.

I look forward to a terrific conference. All of you have been active in various bird conservation arenas up to this point. But I don't think we've ever had such a productive mix of people from conservation and academia, from water birds to and desert birds, and from north to south. Let's take advantage of this week to meet new people, exchange ideas and create bold strategies for the future of bird conservation.

Defining the Demands and Meeting the Challenges of Integrated Bird Conservation[1]

Charles K. Baxter[2]

Introduction

I thank you for the honor and the opportunity you have accorded me in addressing you this morning. I thank you for the honor, because I consider your invitation to be an acknowledgment of the work of Lower Mississippi Valley Joint Venture (LMVJV) partners to comprehend and apply the principles of integrated bird conservation. I thank you for the opportunity, because this venue has forced me to think more critically of the concept and the challenges of integrated bird conservation.

This notion of critical thinking lies at the heart of what I have to say this morning. There was a time in the not too distant past when the challenge confronting integrated bird conservation (at least in Canada and the US) was largely ideological and philosophical. It was a question of *if* and *to what extent* potentially competing bird conservation initiatives would be integrated. That challenge has been met. We no longer face a question of "if," but rather one of "how and how well." We no longer have the need or the luxury of debating philosophical opinions and ideological leanings rooted in the traditional game/non-game paradigm. Our intellectual energies must now be turned to defining the process and products of biological planning; to discerning the means and methods of conservation at ecoregional scales; and to articulating the concepts, models, and approaches that will ultimately define integrated bird conservation.

Herein lies the premise of my remarks: the concept, the goal, the vision of integrated bird conservation presupposes new ways of doing business. Dealing with the "how and how well" will place new demands upon established, traditional approaches to the business of bird conservation. I want to briefly define those demands and then offer my insight on the challenges that, if met, will bring us to those new ways of doing business.

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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The Demands of Integrated Bird Conservation

Understanding the demands of integration bird conservation begins with a critical assessment of the North American Bird Conservation Initiative's (NABCI) goal.

- "Regionally-based, biologically-driven, landscape-oriented partnerships delivering the full spectrum of bird conservation across the entirety of North America."

"Regionally-based...Partnerships"

Consider for a moment the call for *regionally-based partnerships*. This element of the goal presumes that habitat objectives and conservation strategies will emanate from ecologically-defined units that reflect our best understanding of how birds respond to habitats at broad spatial scales. The hierarchical framework of ecoregion delineation adopted by NABCI gives us not only a common spatial language but also a geographic framework for conservation at multiple spatial scales. Just as flyways have provided the unifying geographic theme for the regulation of harvest, Bird Conservation Regions (BCRs) will provide the geographic framework for the planning, implementation, and delivery of bird conservation programs and the geographic foundation for partnerships that will be increasingly interstate and international in focus.

"Biologically-driven...Partnerships"

The demands of a *biologically-driven partnership* are perhaps best understood by considering its converse – opportunity-based conservation. In a biologically driven partnership, conservation does not operate on the basis of an opportunistic pursuit of habitat gains; it is driven by specified biological objectives and spatially explicit priorities. A biologically driven partnership demands a departure from the traditional programmatic, opportunistic approach to conservation in at least three key areas.

First, it requires that habitat objectives be linked to population response at multiple scales. The *unifying biological theme* of integrated bird conservation is population management. We should not forget that what brings us here today as continental conservationists is not simply a bird conservation initiative. We are united, even enjoined, by a treaty between three

sovereign nations; and the purpose of that treaty is the conservation of bird populations. On the question of whether we will have population-based habitat objectives, there is little room for debate.

Secondly, a biologically driven partnership is planning intensive, but it is planning of a non-traditional sort. The agenda for this conference calls for discussions on the tradeoffs between planning and implementation. For at least the first ten years of its life, the NAWMP suffered from imprecise thinking on this very question. The debate within the waterfowl community failed to draw a clear distinction between: 1) the biological planning demanded by a population-driven approach to conservation; 2) the conservation planning required to "design" sustainable landscapes; and 3) the programmatic planning traditional to opportunity-based conservation. In the traditional planning/implementation paradigm, if we plan at all, we plan programmatically. Do not misunderstand me. There are legitimate needs, even legal requirements, for programmatic planning; and they generally lie within the realm of administrative and economic efficiencies. However, one of the most fundamental challenges facing us is the need to redefine the planning/implementation paradigm, drawing a clear distinction between biological planning, landscape planning and design, and programmatic planning. Only then can we define the proper balance between planning and implementation.

In this regard, biological planning and landscape planning have siblings. One is called "monitoring;" one, "evaluation;" and the other, "research." They will remain runaways until those planning distinctions are drawn. Therein lies the third demand of a biologically driven partnership: creating a clear linkage between science and management. That linkage, long sought but seldom attained, is within our grasp. It is nothing more, and nothing less, than explicitly stated, testable assumptions as to how populations are responding to habitat manipulations. If we will articulate, as conceptual models, the assumptions upon which management operates, we will provide focus for research and a framework for monitoring and evaluation. We must realize that in a programmatic, opportunistic approach to conservation, monitoring and evaluation are, in fact, largely non-essential. We need do little more than track accomplishments. However, when management operates on the basis of explicitly stated, testable assumptions regarding population/habitat interrelationships; when management seeks not simply to gain habitat but to sustain populations; monitoring and evaluation are suddenly essential. Until then, they will be viewed as a largely superfluous diversion of limited resources from the opportunistic pursuit of habitat gain, and will not be missed at the conservation table.

"Landscape-oriented...Partnerships"

A landscape-oriented approach to conservation demands that conservation delivery be discriminatory. By this I mean delivery programs operate in tandem, in awareness of one another, discriminating between and among landscape features and priorities, pursuing a pre-established design of predicted sustainability. Again, what is the converse of a discriminating approach to conservation? It is the traditional opportunity-based approach.

"Delivering the Full Spectrum of Bird Conservation..."

"The full spectrum of bird conservation" – at first glance, we might assume the phrase means simply "all birds and all habitats." But let's assume for a moment it means something more, that it speaks to the *full spectrum of the bird conservation enterprise*. Traditionally, as an enterprise, bird conservation has operated in two broad realms, science and management. Two realms, too often separated. Now there is a third, something that lies between and that can potentially connect the two – the process of assessing, modeling, predicting, and planning sustainable landscapes. If we are to deliver these three spheres of bird conservation, perhaps we need a framework for organizing the parts and pieces into a comprehensive whole. But if our focus is the *enterprise* of bird conservation, should we be thinking less of a framework and more of a model, a business model for regionally-based, biologically-driven, landscape-oriented partnerships – a business model that allows us to apply existing resources to new ways of doing business.

The Challenges of Integrated Bird Conservation

But I'm getting ahead of myself. Let me summarize the demands of integrated bird conservation and speak to the challenges. In doing so, I will return to my original premise: the concept, the goal, the vision of integrated bird conservation presupposes new ways of doing business. At the most basic level, the challenge facing us is one of shifting the conservation paradigm away from opportunity-based conservation to conservation driven by specified objectives and spatially explicit priorities – in short, a conservation paradigm based not on opportunity but on predicted sustainability. But a challenge stated so broadly is unmanageable and largely unattainable. We must break it down into more manageable parts that can perhaps guide our collective actions.

Challenge: Redefine the Planning/ Implementation Paradigm

In this regard, our first challenge is to redefine the planning/implementation paradigm. We should begin with a clear characterization of the current paradigm: "program-specific planning in support of opportunity-based implementation." Opportunity-based conservation, no matter how well it picks and chooses among the opportunities of the moment, is largely insensitive to population/habitat interrelationships or the ability of a constantly shifting landscape to sustain populations at prescribed levels. For this reason, it is largely insensitive to the principles of landscape ecology, population ecology, and adaptive resource management. Integrated bird conservation requires a new planning/implementation paradigm in which *biological planning and conservation design support a programmatic pursuit of predicted sustainability*. Conservation will always be delivered through agency-specific programs. But in the new paradigm, program delivery will be supported by biological planning and guided by a conservation "blueprint," that "pre-established design of predicted sustainability."

Where might we begin ushering in this new paradigm? I believe we begin in the traditional forum of program planning. One of the sessions of this conference deals with "Integrating Bird Conservation Objectives into Federal Land Use Plans." I suspect the experiences that will be recounted reflect an attempt to infuse one of the principal *products* of biological planning (population-based habitat objectives) into the *process* of programmatic planning. While doing so is critically important, we cannot stop there. There are in fact three processes that must be integrated. We must establish within the minds of administrators and on-the-ground managers a clear relationship between biological planning, conservation design, and the program planning traditionally associated with conservation delivery. Only then will we be operating under a new planning/implementation paradigm.

Challenge: Define the Process and Products of Biological Planning

Our second challenge is that of clearly articulating the process and the products of biological planning. This challenge is closely allied with the first, because it will be difficult to redefine the planning/implementation paradigm without a well-established process of biological planning and without well-defined (and anticipated) products. I suggest we begin with critical thinking on the concept of a sound biological foundation. The phrase "establish a sound biological foundation" is at risk of becoming a cliché unless we more clearly articulate process and products. As regards products, here is the best answer to date of LMV partners. We operate under the assumption that the LMV Joint Venture will not have a sound biological foundation until these products are in place – thus attaining the products serves as a goal for our collective efforts.

Challenge: Define the Methods and Create the Capacity for Landscape-Level Planning and Assessment

In defining the challenge associated with biological planning, I used the words *process* and *products*. The challenge associated with landscape-level planning requires different words: *methods* and *capacity*. *Our challenge is to define the methods and create the capacity for landscape-level planning and assessment.* As regards methods, I believe we face a special urgency in defining how conceptual models of population/habitat interrelationships can be used in tandem with readily available, though imperfect, spatial data on land use and land cover to characterize, predict, and model the ability of a landscape to sustain priority species. Why the urgency? Because until we demonstrate this capability, we will not be successful in shifting the conservation paradigm from the opportunistic pursuit of habitat gain to conservation by design. The principles of landscape ecology and ecosystem management, which lie at the heart of integrated bird conservation, will remain largely esoteric abstractions until we demonstrate the power of conceptual models and geospatial data in multi-scale assessment and planning.

In this regard, creating a capacity for landscape-level planning and assessment is nearly synonymous with integrating geospatial and information management technologies into the business of bird conservation. We could say that this aspect of integration is out of our hands, that it hinges on the budgetary priorities of administrators. While this proposition contains an element of truth, it is on the whole false. We have the power of partnerships, and we should redouble our efforts to develop within Joint Ventures and Bird Conservation Regions geospatial and information technology (IT) partnerships. In doing so, let's not mistake the tools for the products. The product we seek is not simply "GIS" (Geographic Information System). Our IT partnerships should be focusing on products such as decision support models, conservation planning atlases, and web-enabled population monitoring programs.

Challenge: Articulate the Business Model(s) that Will Support a Fully Integrated Bird Conservation Enterprise

If we accept the premise that the vision of integrated bird conservation assumes, requires, or even implies new approaches to the business of bird conservation, it is only a short jump to the realization that existing resources must somehow be applied to those new ways of doing business. The demands and challenges enumerated herein are at

once and the same fundamental and complex. We find ourselves no longer operating simply within the hierarchy of our respective organizations. Integrated bird conservation thrusts us into a new web of interrelationships. Yet complexity does not preclude order; and the order we seek we must create within the concept of a business model that encompasses and encapsulates the web. Here is the model that currently guides partners in the Lower Mississippi Valley.

A Business Model for Integrated Bird Conservation

Foundational to the model is the idea of three distinct but interrelated spheres of bird conservation and the building of a partnership infrastructure that maximizes the energies and resources within each sphere and increases the connectivity between the spheres. In that regard, let's look first within each sphere and then at the connecting infrastructure. As we look inside each sphere, think of the people who populate it, their purpose in the bird conservation enterprise, the products of their efforts, and the partnership infrastructure internal to that sphere.

The Biological Foundation Sphere

In the broadest sense, it is the science community that resides within the biological foundation sphere. From this community, an integrated bird conservation partnership will draw biologists with specialized knowledge of species/habitat interrelationships, schooled in the testing of hypotheses and assumptions or experienced in the techniques of monitoring and assessment. Their singular focus would be the process and products of a sound biological foundation. The partnership infrastructure within this sphere generally would be one of working groups specific to the taxonomic focus of each of the major bird conservation initiatives. These working groups would be recognized at the national level by their respective initiatives thus clarifying the relationship between those initiatives and the Joint Venture in question. It is worth noting that integration of the initiatives within this sphere is limited to energy and ideas, not biology. A sound biological foundation will be specific to the ecological demands of the major species groups.

The Conservation Design Sphere

The people operating within this sphere merit the label *conservation planners.* Recognizing however, that the transition from opportunity-based conservation to a conservation-by-design paradigm is in its infancy, this sphere of bird conservation tends to be sparsely populated. Ideally it is filled with planning-oriented biologists with geospatial analytical skills and with broad knowledge of landscape conditions, programmatic capabilities, and multi-scale relationships. Their focus is one of translating conceptual models of population/ habitat interrelationships into spatially explicit priorities at multiple scales and developing decision support models and conservation blue-prints that can guide the delivery of conservation programs.

The concepts of sustainability and integration are at the forefront of this sphere's concerns. The stock and trade of its populace is spatial analysis of the habitat variables considered most responsible for population response and the GIS modeling required to build geospatial decision support models.

The Conservation Delivery Sphere

The bulk of any Joint Venture's conservation infrastructure will reside within this sphere. It is populated by the management-oriented biologists responsible for on-the-ground delivery of conservation programs. While integrated bird conservation seeks something as fundamental as a shift in the conservation paradigm, it must be stressed that it does not require a departure from program-based conservation. It requires, simply but fundamentally, a departure from opportunity-based delivery to delivery driven by a pre-established design of predicted sustainability. In that regard, it seeks not a change in the internal processes or procedures of programs but rather a change in their external orientation. However, integrated bird conservation demands something more of the on-the-ground manager. Let's think for a moment of their role in a regionally based, biologically driven, landscape-oriented partnership.

There are three things needed from the on-the-ground manager without which integrated bird conservation will not work:

- *Site-scale management decisions that address species-specific biological needs at multiple spatial and temporal scales.* Managing at multiple scales is perhaps the most fundamental principle of landscape ecology or ecosystem management; yet it is confounded by the fact that in an absolute sense habitat change can be accomplished at only one scale – the site scale. The demand is for site-scale decisions that reflect multi-scale considerations. Providing the information necessary for those decisions must be the overriding focus of those that reside within the biological foundation and conservation design spheres.

- *Site-level resolution of inter-specific conflicts.* There is no small number of managers and administrators operating under the misconception that integrated bird conservation requires that the needs of all birds be met on every acre or even every management area. We need to help managers realize that not only is this not so, they are on the front lines of resolving the potentially competing needs

of the myriad species using the landscape. They are, however, held to an extremely high level of accountability – their collective site-specific decisions must contribute to a landscape that sustains all endemic species.

- *Assistance in tracking habitat change and popula-tion response.* It is, after all, the on-the-ground manager who is on the ground where habitat change and population response are occurring. If given well-designed procedures and protocols for tracking and monitoring and the ease of web-enabled reporting, they can provide the information critical to a biologically driven, landscape-oriented partnership.

In that regard, I think I speak for all LMV partners in saying that our experiences indicate that managers are ready and willing to meet the demands and challenges of integrated bird conservation if those of us residing in the other spheres give them the requisite tools.

Connectivity and Interrelationships Between the Three Spheres of Bird Conservation

Hopefully it is apparent that the relationship between the three spheres is cyclic, iterative, and nonlinear. As just alluded, it is the process of tracking and monitoring habitat change and population response that provides the most direct connection between the biological foundation and conservation delivery spheres. Data on habitat change and population response provide the information for testing assumptions that provide the knowledge for refining population/ habitat models, which reconnect the biological foundation sphere to the conservation design sphere. Better population/habitat models in turn provide the biological basis for reiterative refinements of the "pre-established design of predicted sustainability" which in turn reconnects the conservation design sphere to the conservation delivery sphere. (At this point I should note that not only information moves between spheres, but sometimes people. The key requirement of this model is that the individual be cognizant of the need to change role and focus when moving to a different sphere.)

The connectivity demanded by this model requires a partnership infrastructure of its own: an administrative, policy-level partnership; and a technology partnership. The policy-level infrastructure comes in the form of a management board. Ultimately it is the responsibility of the wildlife administrators that sit on a Joint Venture Management Board to oversee the business and to ensure that all facets of the bird conservation enterprise are functioning in a cyclic, iterative manner. In a perfect world they will have at their command a fully staffed Joint Venture Office that can, on a day-to-day basis, guide, facilitate, and nurture the myriad people and partnerships operating within a "regionally-based, biologically-driven, landscape-oriented partnership."

As to technology, the "Digital Revolution" that is enveloping our society is in many respects a revolution in connectivity; and through the information technology partnerships alluded to earlier, we must harness the power of that connectivity. In the LMV, we are seeking to build technology partnerships through the concept of a "geomatics network." The idea is simple enough – focus the GIS and information management resources of Joint Venture partners on the development of specific products that will move data and information between and among the three spheres. I cannot overemphasize the importance of being product oriented (after all, this is the *business* of bird conservation we are talking about.) At the moment, the LMVJV Geomatics Network is focused on four products directly related to connectivity: a "Conservation Planning Atlas" for each of the two BCR's that encompass most of our Joint Venture (Mississippi Alluvial Valley and West Gulf Coastal Plain/Ouachitas); a web-enabled Reforestation Tracking System; and a web-enabled Shorebird Tracking System.

In Summary...

In closing, I want to relate an anecdotal experience that to me captures the essence of Partners in Flight's contribution thus far to the cause of bird conservation. A few years back when those of us in the US were still locked in the game/nongame paradigm and when the question of integrating bird conservation initiatives was still very much unanswered, in a quiet conversation between just us, my very dear and very astute friend Scott Yaich made an observation that brought order and clarity to all that was swirling around us. His observation was this: Until the emergence of Partners in Flight (PIF), the conservation of nongame wildlife was relegated to backyard wildlife programs and nature trails; but those days were rapidly drawing to a close. PIF's ecoregional planning was beginning to produce the science-based population goals and habitat objectives that would allow us to move the conservation of nongame birds into the mainstream of wildlife conservation.

This accomplishment cannot be overstated, and the people responsible for it are largely those of you here today in this room. Through your efforts, bird conservation has been the seminal force in transcending the game/nongame paradigm. Moreover, your efforts have positioned bird conservation for something even larger. *The demands* of integrated bird conservation engage us in a continent-wide experiment in applying the principles of ecosystem management, landscape ecology, adaptive resource management, and sustainable use. *The challenges* provide us an opportunity to make integrated bird conservation the seminal force in

bringing these long sought principles into the conservation mainstream. The organizers of this conference have created a forum that can once again galvanize your ideas and energies for the challenges ahead. Let us now be about the business that brought us here. Thank you.

Bird Conservation as a Flagship for Global Diversity Conservation[1]

David Brackett[2]

It is a pleasure to be here at the Third International meeting of Partners in Flight (PIF) – and the international aspect is important. Bird conservation is a global problem. Building on the work of BirdLife International and other partners, the 2000 IUCN Red List of Threatened Species listed more than 12 percent of the world's known species as at risk. Bird conservation is also a national accountability. Partners in Flight has been a leader in helping countries acknowledge their share of that accountability, but it is important that the responsibility is shared.

That leads to the need – no, the imperative – for international co-operation if we are to be effective. But the need is not just government-to-government cooperation. We talk about a landscape approach to managing habitat, about considering solutions at an ecosystem level. Well, there are ecosystem-like connections in the organizational world as well. We need to make the connections between regulators and the regulated; between the scientists and the policy makers; between the grantors and the grantees, and between bird conservation projects and initiatives. The best way forward in the near term, in my opinion, is the North American Bird Conservation Initiative (NABCI). Eventually, we need to see NABCI as only a step towards a true hemispheric effort and as one of a series of such efforts globally. There are organizations working at that level now: BirdLife International, Wetlands International, The Convention on Migratory Species, The European Union's Birds Directive, and so on.

I would like to spend a few minutes talking about activities in Canada. The Canadian Wildlife Service (CWS) has a 10-year strategic plan to guide its activities. Its mission statement is to: *Conserve wildlife and the ecosystems of which they are a part, with a particular focus on migratory birds and species at risk*. Conservation of birds is an important part of the CWS mandate. In fact, conservation of migratory bird populations is the first of three main CWS roles (the other two being leading the protection of species at risk, and the conservation of habitat for migratory birds and species at risk). These roles are strongly interrelated; we must strengthen the linkages across the conservation spectrum from maintaining the diversity in common species of birds (across their natural ranges) to recovery of species at risk (often in greatly restricted ranges by the time they are listed). Many of the underlying habitat objectives are shared by abundant and rare species alike. Integrated delivery of habitat objectives, then, is the only option. PIF and NABCI exemplify partnerships working to achieve a common goal of bird conservation, and they share a larger vision of biodiversity conservation.

Another area to which Canadians have devoted a lot of effort in the past couple of years is the development of Species at Risk legislation. Many of you here may have commented throughout this process; some of you might even have understood the issues. The proposed Species at Risk Act (SARA) to protect wildlife at risk from becoming extinct or lost from the wild recognizes shared responsibility among federal, provincial and territorial governments. This leads to mandatory partnerships to develop recovery strategies/action plans for endangered and threatened species, and management plans for species of special concern. The legislation also requires us to identify critical habitat and protect it through conservation agreements, provincial or territorial legislation, or federal prohibitions. As part of SARA, a Habitat Stewardship Program provides funding for voluntary conservation activities by individuals, organizations, communities, businesses or governments that protect species and habitats. Many such activities are already under way in Canada. We need to maximize opportunities to piggyback bird conservation onto these efforts for species at risk and critical habitat, and this will require coordination with Partners in Flight and NABCI programs.

Finally, I'd like to say a few words about an issue that is occupying an increasing amount of my personal time: We need to find better ways of managing the data that are generated from our conservation programs and of turning those data into information, the information into knowledge, and the knowledge into action. While most, if not all, of our programs and projects pay attention to data compilation, management, and retrieval, too often that attention is focused a little too narrowly, a little too locally. There is a growing realization in the biodiversity conservation community that we need to improve the integration of our data and its derivatives. Governments are certainly engaged through initiatives like NBII in the USA, CISE in Canada, leading edge efforts by CONABIO in Mexico, initiatives under the

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California**

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Commission on Environmental Cooperation (NABIN), the Global Biodiversity Information Facility, and many, many more.

Many of these initiatives focus on making what is already collected better accessible, leading to a focus on museum collections and taxonomic issues. These are important, but there are also some pressing conservation problems to be dealt with.

On the non-governmental side, the Species Survival Commission of the IUCN – which I chair just at the moment – is developing the Species Information Service. The SIS will be a web-based system that will allow field biologists and researchers around the globe to link their real-time information through a standardized database to allow the better integration of geo-referenced, peer reviewed information – quite a mouthful, but it is hard to capture the complexity of the project in a single sentence. The vision of the project is "A world in which current and universally accessible biodiversity information encourages and promotes the achievement of effective conservation and sustainable forms of development". We plan to bring this about through a novel approach to partnerships for conservation, where the IT industry provides the hardware and software resources, foundations and governments provide the financial resources, and the conservation community provides the expert participation and the data (i.e. the content).

We expect this will lead to concrete recommendations for site-specific conservation actions.

I have had a chance to look through the program for this meeting, and I am impressed with the range of topics that will be covered, and with the commitment to effective collaboration and integration that is reflected in so many of the presentations. I know the first two international meetings helped us along the path noted by Humberto Berlanga – taking the idea of integrated bird conservation from the novel to the obvious. I am confident this meeting will do more of the same.

A Context for Bird Conservation in México: Challenges and Opportunities[1]

Eduardo Santana C.[2]

Introduction

With over 1,060 species of birds, México is among the most important countries for the conservation of birds in the world. Within the American continent it harbors the highest wintering diversity and abundance of Nearctic-Neotropical migratory land birds that breed in Canada and the U.S., as well as an exceptionally high number of endemic species (Hutto 1986 1992; Escalante et al. 1993, Howell and Webb 1995, Stotz et al. 1996, Hernandez-Banos et al. 1995). México suffers a rapid rate of environmental degradation that consists of problems such as of the loss of forests and wetlands, desertification and soil erosion, invasive species in islands and freshwater systems, overharvesting of wildlife by hunting or capturing animals for the pet trade, and environmental pollution (Simeon 1995, Challenger 1998). These problems contribute to the endangerment of bird populations. About 180 species are considered endangered, threatened or fragile, and some 20 additional species or endemic subspecies are considered extinct or extirpated from the country (Arizmendi and Valdermar 2000, Cevallos and Marquez 2000, DGVS 2003).

Avian conservation in México, as elsewhere, is much more than just researching the ecology of bird species and monitoring bird populations It involves social and political processes at local, national, and international scales that influence people's behavior. Effective resource management (harvesting, preserving, and restoring) occurs at the interphase between ecosystems and social systems, and understanding one type of system is as relevant as understanding the other (Gallopin 1994, 1997). Changing people's behavior is the name of the game in conservation; from that of the politician who drafts environmental laws and sets aside protected areas, to those of the local peasant or housewife who manages an agricultural plot or the consumption of household non-recyclables. People's behavior changes when a concept either touches them in an ethical-emotional way, or they see a personal or collective benefit from their change in behavior, or they are coerced into behaving differently by social or legal pressure. All three methods must be promoted to achieve conservation, and their application falls in the realm of the social sciences, which need to be understood by ornithologists who are concerned with conservation.

There have been various analyses of the problems and solutions of bird conservation in México. México's largest ornithological organization, CIPAMEX ("Consejo Internacional para la Conservación de las Aves") held a workshop in 1998 to identify and propose solutions to the most urgent problems relating to bird conservation (CIPAMEX 2003). The main problems identified in the workshop were these:

1. Lack of general information about the Mexican avifauna
2. Lack of information about population abundance, trends, and distribution
3. Lack of information about species conservation status
4. Lack of information about the status of bird habitats
5. Lack of local and regional field research
6. Lack of communication among ornithologists
7. Lack of regional opportunities for ornithological work;
8. Lack of communication of research results
9. Lack of funding
10. Lack of trained researchers, managers, and educators in bird conservation
11. Lack of information on the use and management of wild birds in protected areas
12. Lack of organization and planning for bird conservation at the national level

Some of the problems in the list are strategically important to achieve conservation objectives (e.g., lack of information about bird populations), whereas others seem to be more related to the dynamics and condition of the Mexican academic ornithological community (e.g., lack of communication among ornithologists). Key issues such as those pertaining to the socioeconomic and institutional structures and mechanisms for

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California**.

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land resource management, although recognized, were not discussed in detail.

One of the most dynamic bird conservation processes in the country revolves around the North American Bird Conservation Initiative (NABCI 2003). NABCI is a result of the environmental programs promoted by the trinational Commission for Environmental Cooperation (CEC; Berlanga 2001a). The CEC was created as a side agreement of the North America Free Trade Agreement (NAFTA), and despite NAFTA's negative effects on various sectors of Mexican development (Arroyo Picard 2003, Nader 1993, RMALC 2003), positive outcomes have come out of the CEC program. In the process of designing a continent-wide bird conservation strategy, Mexican ornithologists and government administrators began to evaluate and systematize the existing bird conservation programs and the knowledge of birds in the country. This same process also occurred within the U.S. and Canada. Thus, NABCI has not only served to coordinate bird conservation programs among the three countries, but it also has served to catalyze new bird conservation initiatives *within* each individual country and formalize short, medium, and long-term national bird conservation strategies.

México's NABCI coordinating committee developed a preliminary national bird conservation strategy building on CIPAMEX's and other national conservation diagnoses (Berlanga 2001b). This preliminary document describes nine strategic lines of action:

1. Develop demonstration sites for bird conservation
2. Promote field research and the generation of knowledge for priority conservation actions
3. Contribute to the consolidation of México's Natural Protected Areas System
4. Promote communication, environmental education and dissemination of bird conservation information among professionals and among the general public
5. Promote training and educational opportunities
6. Promote bird conservation actions
7. Develop financing schemes for bird conservation
8. Strengthen and improve environmental legislation
9. Promote institutional strengthening activities

This essay attempts to contribute to understanding some of the limitations for implementing effective bird conservation programs in México and suggests possible strategies and actions. This non-exhaustive analysis is based mostly on the day-to-day experiences encountered while creating and consolidating the Sierra de Manantlán Biosphere Reserve, a complex project that integrates research, conservation, education, and local development. It is complemented with analyses conducted with colleagues from the ornithological and natural resource management sectors (Santana C. et al. 1987, 1996, 2002a; Jardel P. 1992, 1995; Graf et al. 1995, 2001; Jardel P. et al. 1996, in press a; Santana C. 2000).

Lack of Understanding Complex Ecosystems

México harbors extraordinarily complex and species-rich ecosystems that are the product of ecological, biogeographical, and historical natural and human-induced processes (Challenger 1998). We have inadequate knowledge of how to model and manage complex systems in general, and this limitation is compounded when, as in the case of México, there is a paucity of information on the basic aspects of the functioning of the system as a whole, the species present in system, and their population dynamics. The lack of knowledge of the population status and trends of most bird species, as well as of their basic natural history and ecological needs for survival, do not allow us to evaluate the impact of environmental disturbances on bird populations, provide adequate management recommendations, and prioritize among species to address their conservation needs (Villaseñor G. and Santana C. 2002). In some cases valuable information is presently being generated on long-distance migratory birds through bilateral and trilateral projects with financial input from the U.S. and Canada. However, many non-migratory endemic species seem to be more vulnerable to habitat alterations, and the absence of information on these native species is greater than for migratory species (Stotz et al. 1996, Rappole 1995). Thus, a priority area in the ornithological research agenda of México should be the description of the status, trend and natural dynamics of non-migratory as well as migratory bird populations, monitoring the demographic responses of birds to habitat modifications, and characterizing their most important survival requirements.

In addition to academic research institutions, two government institutions have played and are playing, an important role in the generation of knowledge for the conservation and management of biological diversity: the Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (National Commission for the Knowledge and Use of Biodiversity, CONABIO 2003) and the Instituto Nacional de Ecología (National Institute of Ecology, INE 2003). They are young (not much more than a decade old) and their work contributes to the development of various knowledge areas such as the functioning of ecosystems, biological inventories, environmental risk assessment, endangered species recovery plans, trends in ecological restoration and degradation processes, effects

of global climate change, and identification of priority conservation areas and ecoregions, among others.

These two organizations should be strengthened so that they may have greater national impact. However, they also need to have a more focused approach on how to link their work to on-the-ground land resource and ecosystem management. The National Commission of Natural Protected Areas (CONANP 2003) is responsible for managing protected areas in the country and has initiated monitoring programs that should be generating valuable information on bird and other wildlife populations. Although research is not part of its management objectives, it is clear that for the CONANP to evaluate whether it is achieving its conservation mandate it must generate information on the status of natural resources in protected areas over time.

The Dirección General de Vida Silvestre (General Directorship of Wildlife, DGVS 2003) is an older agency directly responsible for wildlife management. This agency should be playing a national leadership role in bird conservation. Unfortunately, it has not lived up to expectations, having a "business as usual" approach toward wildlife conservation. This has limited its effectiveness and estranged it from more dynamic agencies and social stakeholders. The DGVS, being responsible for granting harvesting and import/export permits, has suffered from economic and political pressures that have limited its abilities to adequately perform its duties. Recently there has been an administrative turnover, and positive changes are expected. Support and reengineering of this agency to provide more dynamism to its programs are needed.

Lack of Trained Professionals to Meet the Conservation Challenge

The generation of knowledge described above requires a cadre of qualified vertebrate biologists and ecologists that can tackle the large diversity of bird species found in Mexican ecosystems. Despite the recent increase of trained ornithologists in the country, present numbers are insufficient to cope with the information demand. This can be exemplified by comparing an indicator of the number of ornithologists available to study birds in México with those in the U.S. The largest ornithological society in the U.S. is the American Ornithologist's Union (AOU 2003), which has some 3,500 resident members. Considering that the U.S. harbors about 800 species of birds, there are at least 4.4 ornithologists per bird species in that country. In México, CIPAMEX (2003), with 350 members, is by far the largest ornithological organization. México thus has a ratio of about 0.3 ornithologists per bird species. The difference between the two countries is even more dramatic when considering that the AOU has existed for over 120 years and CIPAMEX has operated for only 15 years as an active national organization.

From a conservation perspective, even more dramatic than the lack of researchers is the lack of trained managers/administrators of natural resources. México harbors some of the best ecological and biological university-based educational programs in Latin America. However, the lack of job opportunities in resource management and the type of academic professional advancement incentives that stimulate basic, specialized and rapidly publishable research over management-oriented research are some of the reasons for the paucity of natural resource management educational and training opportunities in the country's universities. Managers are a crucial link between researchers and the other social and political actors that define a nation's conservation agenda. Thus, educational programs are not only insufficient, but they also are not producing the type of professionals needed to meet the conservation needs of the country (Graf M. et al. 2001, in press; Jardel P. et al. in press a; Santana C. 1995).

There is a general need to strengthen and devote a greater share of México's gross national product towards advanced education and research. Additionally, international financial support for natural resource educational programs can have a multiplier effect throughout the country. Due to México's great ecological complexity, natural resource management/research programs should specialize in different ecosystems (e.g., lowland tropical rainforest, montane mixed coniferous forests, arid vegetation, etc.) and should integrate basic ecology with applied management, framed by an "adaptive management" approach. The focus should be directed toward "research for conservation and not conservation for research" (Santana C. and Jardel P. 1994). Achieving interdisciplinary integration in natural resources and linking basic science to its immediate application is a challenge in both developed and developing societies (sometimes more so in rich, developed societies). This can best be achieved through the participation of researchers, managers, and resource-owning stakeholders in the design and implementation of research/training agendas around a commonly defined problem in a specific ecosystem (Jardel P. et al. in press a). This is not something that should be left to individual researchers to decide; there must be formal institutional mechanisms in place to promote these types of interactions and insure that they occur. Support for new and established natural resource management educational programs is urgently needed in universities throughout the country (Santana C. 1995).

Lack of Employment Opportunities and Adequate Institutional Arrangements for Natural Resource Management at Local Levels

Analyzing the dynamics of some early NABCI meetings helps illustrate the differences in natural resource institutional arrangements between Canada, the U.S., and México. During various NABCI meetings the U.S. delegation usually took much longer to agree among themselves on policies and proposals than was the case for the Canadian or Mexican delegations. I don't believe this has to do with any cultural disabilities among our U.S. colleagues to achieve consensus, but was rather a result of the much greater number of participating stakeholders (NGOs, foundations, professional organizations, academic organizations, state agencies and federal agencies) from the U.S. whose opinions and interests needed to be heard and taken into account. With many fewer stakeholders, the Canadian delegation, and to a much greater extent the Mexican delegation, had briefer internal negotiations and could achieve consensus much faster. Differences among the countries were also reflected during NABCI discussions of ways to initiate bird conservation programs across North America. The U.S. proposed a continent-wide evaluation of the status and trends of all bird species in order to select the most threatened ones for "priority" action. México proposed a different scheme based on selecting species-rich ecosystems in pre-existing natural protected areas and Important Bird Areas (known as IBAs or AICAs for their Spanish acronym, Arizmendi and Valdemar 2000) to start conservation programs. The reasons for the different strategies became clear as the three countries deliberated on the best course of action.

The U.S. and Canada have various institutional tiers in their national natural resource management bureaucracy. At the top is the federal level, which covers the whole country and manages very large extensions of federal lands in national forests, wildlife refuges, parks, grazing lands, territories, and military bases. The second management tier administers resources at the state or provincial levels. Provinces and states can control large expanses of territory and directly regulate and manage natural resource harvesting and conservation programs. In many cases provincial/state conservation initiatives are much more important and have much greater impact on natural resources than do federal initiatives. Additionally, some private companies and NGOs control large expanses of land. There are numerous universities, NGOs, and environmental firms that hire large numbers of professionals in the field of natural resources. Thus, most management-oriented job opportunities occur not only at the federal level but also at state and provincial agencies or departments and are complemented by the academic and private sectors. Many discussions within the Canadian and U.S. delegations involved resolving differences in perceptions on the regulatory and implementation roles of the federal vis-a-vis the state/provincial levels of the resource management bureaucracy in those countries. The Mexican delegation had no such problems reaching internal agreements; state representatives have never actively participated at NABCI meetings. In fact, there are no state government representatives in the Mexican NABCI coordinating committee.

The Mexican constitution stipulates that natural resources, including birds, are the property of the nation. The federal government has the responsibility of managing these natural resources, and this responsibility has historically been centralized at that level. At the state level natural resource management programs are either very small or non-existent. Additionally, state governments do not own much land and, thus, have little direct land stewardship responsibilities. States do not manage wildlife resources, evaluate population levels, nor establish harvest quotas for hunting or capturing cage birds. These are all federal responsibilities. There are however, mechanisms (albeit at very early stages of implementation) in which these responsibilities can be delegated to the state governments as part of a nationwide drive towards decentralization and democratization. States are increasingly involved in managing local protected areas. The municipal level of government also can have an important role in promoting nature conservation. However, this has generally been ignored in governmental and NGO conservation initiatives. Since the municipality is the government level closest to its citizens and the one that must respond more immediately to their demands, new and innovative municipal conservation strategies (linked mostly to water/-watershed management and solid waste recycling programs) are now being explored and developed as part of the national decentralization process (García R. and Santana C. 2003, Martinez et al. 2002).

These differences in institutional arrangements and financial and human resources among the three countries explain the contrasting approaches toward bird conservation. For example, when a priority species for conservation in the U.S. or Canada is selected, it should be relatively easy to identify 5 to 20 researchers who have already studied the species, one to five NGO's that are concerned with its protection, and various provincial/state and federal government agencies that have the legal responsibility to assure its survival within dozens of parks, forests, and refuges in which they have on-site management operations. If you had a map of the U.S. where bulbs light up at sites where there was information, projects, or personnel that could attend to the selected bird species, you would get bulbs lighting up all over the map within the species range. That means that you may start working almost immediately for its conservation. However, in

México, the map would remain almost totally dark, and only a few bulbs would light up for only a few species. Large expanses of México are devoid of conservation/management/research initiatives as a result of the lack of state-level programs, the paucity of ornithological research in academic institutions, the low number of conservation NGOs in the country and the low funding priority for conservation.

Unlike the U.S. or Canada, México cannot tailor a management/conservation program for each species, especially in regions where there are neither institutions nor personnel to implement them. Scarce resources cannot be diluted over the landscape, but should be directed towards strengthening those sites with many bird species and existing conservation programs and towards creating new areas that can be adequately attended to. That is why programs that deal with the recovery of endangered species ("Programas de Recuperación de Especies Amenazadas" PREPS) are few in México (INE 2003). It is expensive to manage a single species, and the government has promoted species-specific conservation plans for only a few species or groups of species like the Golden Eagle, the Psittacines, and the California Condor. Thus, México's strategy has been directed toward developing bird conservation programs with a habitat or ecosystem perspective. It has centered on natural protected areas or AICAs where an institutional and sociopolitical commitment already exists and where human and financial resources that provide assurances of success are in place.

This is a logical and strategically important approach, considering that México's present National Protected Areas System ("Sistema Nacional de Areas Naturales Protegidas" SINAP) is only 8 years old and the federal National Commission of Natural Protected Areas (CONANP) which administers it was created only 3 years ago. The SINAP (CONANP 2003) has been the most effective conservation program in México's history. Previously, only a handful of protected areas in the country had any type of on-site management administration, and the national park "system" was used internationally as a prime example of a dysfunctional conservation program. Presently over 60 natural protected areas count with on-site administration and personnel (CONANP 2003). In some regions the CONANP works jointly with other programs like the Temporary Employment Program ("Programa de Empleo Temporal" PET) and the Regional Sustainable Development Program ("Programa de Desarrollo Regional Sustentable" PRODERS) to implement agriculture, forestry and conservation projects that, in addition to the benefits created by the projects themselves, also provide employment opportunities to rural communities within and adjacent to protected areas as part of an integrated regional conservation and poverty alleviation strategy. However, the CONANP can still be further improved, as it is understaffed, poorly financed, and its protected areas are implemented with a weak legal and institutional framework.

In general, the present scheme of centralization at the federal level, although more decentralized than in the past, is very ineffective, and this is recognized by México's conservationist community. Many resource management responsibilities are and should continue to be directed at the federal level, because this level is (somewhat) immune to the arbitrary effects of local political special interests. The federal government can assure that the benefits and values of protected areas to society at large are recognized and protected. This is more difficult to achieve at the state and municipal levels of government. However, to meet the magnitude of the conservation challenge the Mexican government should increase the financial and institutional commitment towards constructing not only national, but also state- and municipal-level natural resource management arrangements, and establish new protected areas that can achieve, through clearly established institutional mechanisms, their conservation goals. Each state should have its own specific legislation on protected areas and its own state systems of protected areas. México's recent Program of Areas for Sustainable Management of Wildlife ("Programa de Áreas de Manejo Sustentable de Vida Silvestre" PAMS) was created in 2001 as a new strategy to engage state and municipal governments in wildlife management and conservation (see below, DGVS 2003). Although, positive in contemplating the lower levels of government, it is presently being evaluated and might be dismantled due to denunciation of widespread corruption in its application and illegal structure.

Land Tenure Conflicts and Deprived Socioeconomic Conditions in Wilderness Areas

Some 80 percent of the forested lands of México as well as the areas that might be described as "wilderness" (meaning large expanses of forested lands, although in the case of México not necessarily devoid of people) fall within one of two types of communal tenure regimes: indigenous community or ejido (Perez 1995, Toledo et al. 2002). State and private lands constitute a smaller, less significant proportion of the forested area of the country. These tenure forms were created in the aftermath of the Mexican Revolution of 1910, when indigenous communal lands were "restituted" to ethnic groups that had been recognized as such since the days of the Spanish crown, and when ejidos were created by "endowing" land to peasants to foster the creation of economically viable, self-

sufficient communities (Merino and Segura 2002, Pederson and Lloyd 2002). However, many ejidos are, in reality, indigenous communities whose members have lived on their territories for centuries. Ejidos stress the collective use and benefit from the land, and decisions of land allotment and use are made by the ejido assembly, which is its highest level of community-level government.

Changes in the Mexican constitution now permit communally owned agricultural or grazing lands to change into private ownership through an assembly-approved process of land parceling and registration. This does not apply to forested lands (coniferous and humid tropical forests), which are held in common, but does affect tropical deciduous forests, which are legally considered "agostaderos" (grazing areas), and are important habitats for the conservation of Mexican endemic bird species. This change in the property laws should be monitored for its effect on the rate of deforestation of dry forests. Overall, the tenure situation is an aspect that affects the conservation of forests. Most wilderness areas are plagued with conflicts of overlapping land claims and undefined ownership, as well as by dysfunctional ejido governments that have been shaped by a paternalistic relationship with the state whose objective was creating a political clientele to win periodic elections (Merino and Segura 2002). These conditions obstruct the development of permanent conservation arrangements in most wilderness areas of the country. However, the situation is not hopeless, and there are many examples of local organization initiatives, sometimes linked to protected areas, that implement projects that favor the conservation of habitat and wildlife, as well as local development (Graf M. et al. 2001, in press; Jardel P. et al. 1996, in press b).

These rural communities own the land that holds most of México's valuable biodiversity, yet they have historically lived isolated and forgotten by governmental development programs that include health, educational and other social services. Additionally, corrupt and technically deficient schemes of natural resource exploitation have denied them the natural wealth of their own lands. They harbor few employment opportunities and suffer from the highest levels of poverty, illiteracy and infant mortality rates, undernourishment and violence in the country (Álvarez-Icaza et al. 1993, Perez 1995, Toledo et al. 2002). In these communities there is a long history of subsistence hunting and the use of birds as pets and ornaments. These communities also a store the last vestiges of indigenous languages, traditional culture and knowledge about natural resources, and of techniques of managing them that can contribute to more sustainable strategies of natural resource use (Aguirre B. 1967, Toledo et al.2002).

As a result of the Zapatista guerilla uprising in Chiapas in 1994, which forced the whole country to evaluate the situation of the indigenous people and devote more resources and attention to their socioeconomic and political demands, new democratization and socioeconomic development initiatives have been implemented by federal and state governments (Ramonet 1999, Russell 1995). But this sector of society remains the most vulnerable to the adverse impacts of macroeconomic policies and trade agreements (e.g., NAFTA) that exacerbate problems of production and commercialization of natural resources, having received little governmental attention toward long-term development and consolidation of their agriculture and natural resource production organization. It is precisely the poorest municipalities of México which have the biologically richest ecosystems, where economically induced changes in the pattern of land use can cause the most damage to bird habitats. Aside from the social or ethical considerations, there are pragmatic reasons for investing in co-management arrangements for conservation and development programs in communally owned lands wildlife (Graf M. et al. 2001, in press; Jardel P. et al. 1996, in press b).

In this general context any bird or wildlife conservation program that is intended to be implemented in these communal forested areas, must be part of a wider initiative that contemplates, in addition to conservation actions, socioeconomic development alternatives and environmental education/communication. Many protected areas in México, such as biosphere reserves, are in reality zoning regulations set upon a pre-existing tenure regime where the original owners retain land title. These reserves impose stiff controls on the use of natural resources by the landowners, but since the land is not bought or expropriated, the challenge is to provide "compensatory benefits" to the owners. (Expropriating the land does not automatically traduce to protecting it, since in many cases the state does not have the ability to manage it, and illegal activities, poaching, logging and production of drugs for the U.S. markets, begin to erode its conservation value.) Unless the process of creating and/or managing the reserve is participatory, and the reserve provides tangible development options that benefit the local communities, the conservation programs will be unstable and will be vigorously opposed and even sabotaged by local stakeholders. These are some of the reasons why integrated conservation and development projects are seen by many in México as the only way to achieve some level of protection in those areas where the state is unable achieve exclusive control of and adequately manage the land and its wildlife resources (Graf M. et al. 2001, in press; Jardel P. et al. in press b, Santana C. et al. 2002b).

Recognizing that the law governing wildlife (dating from 1955) was terribly obsolete because it dealt only with wildlife as it related to sport hunting and ignored the social context described above, and acknowledging that wildlife conservation in México must be an integral part of rural development and that state and federal governments have serious institutional and economic limitations to manage wildlife populations, the federal government created in 1996 the Program for Wildlife Conservation and Diversification of Productivity in the Rural Sector ("Programa para la Conservación de la Vida Silvestre y Diversificación Productiva en el Sector Rural") as well as México's first wildlife law in the year 2000 (DGVS 2003). This law enacted by congress is the first to deal explicitly with the conservation of México's biological diversity.

Under this new legal and institutional framework, rather than having the state evaluate wildlife populations and establish harvesting quotas, the state transferred this responsibility to the individual landowners. Wildlife harvesting programs can only be implemented in sites that have a formal, federally approved management plan that includes demographic information on the species population. With the authorization of a management plan the federal government approves the creation of Unit for the Conservation Management of Wildlife ("Unidad de Manejo para la Conservación de Vida Silvestre" UMA) where hunting, capturing birds for the pet trade, and other extractive and non-extractive activities are permitted (DGVS 2003). The animals harvested from UMAs must have special bands or markings that show they have been taken legally. Another recent initiative, targeted towards managing wildlife over wide landscape areas (from 20,000 hectares to over 12 million hectares per management area) is know as the Program of Areas for Sustainable Management of Wildlife (PAMS). It promotes wildlife management plans for large regions supervised by municipal and state governments, and in the absence of interest from these entities, by NGOs (DGVS 2003).

These programs have been initiated by providing, on a competitive basis, federal funds to help private land owners, ejidos, indigenous communities and municipal and state governments pay certified technical personnel to develop their wildlife management plans and monitor populations. State and municipal levels of government are increasingly participating in the establishment of these management units. As of April of 2003 some 5,135 management plans had been drafted in the UMAs and PAMS programs, covering an area of over 68 million hectares across México (DGVS 2003). Basically, the governmental bureaucracy that was previously responsible for managing wildlife populations (but could not actually do it) ceded that responsibility to the civil sector, and redirected its efforts towards supervising, monitoring and auditing the permit program and the management plans. This is an interesting social experiment, which in the short term has served to spark nation-wide interest in wildlife management, generated large amounts of field-based information on harvestable wildlife species, and has stimulated new, somewhat regulated, wildlife-based economic activities. Since all landowners must have a minimum of understanding of the management plan for the wildlife in their land, it has also served (perhaps unexpectedly) as a massive environmental education program by creating orientation and discussion opportunities for understanding the basic principles of ecology, population dynamics and wildlife management over a wide section of society.

However, since the system depends on population evaluations conducted by private companies or individuals whose salaries depend on there being high wildlife population numbers, various corruption related problems have emerged such as falsified data on wildlife populations, the use of federal funds to developed bogus management plans that will never be implemented, and the use of UMAs as "fronts" to sell species poached from the wild (personal observation and interviews with natural resource practitioners, Lopez-Medillin and Iñigo Elias 2003). UMAs seem to be more effective in Northern México where there is a greater tradition of sport hunting (of mostly doves, waterfowl and deer) and greater proximity to the U.S. hunting market than in tropical Southern México, where some conservationists believe that they might actually be doing more harm than good. The PAMS have lacked rigorous validation of the correlation between habitat parameters and the assumed wildlife population levels, and they are presently under scrutiny due to administrative and legal irregularities in their implementation. They seem to have an unrealistic expectation of the ability of private natural resource specialists to adequately monitor wildlife populations over large expanses of landscape. Ultimately the UMAs and PAMS systems will need to be objectively evaluated to determine whether it is more effective for the government to manage wildlife directly or try to do so indirectly as is being attempted under these new programs.

Participation of the Civil Sector in Policy and Funding of Nature Conservation

Mexican society has a rich history of linkage and appreciation of birds that spans thousands of years. Many species were and still are, considered valuable from a religious or magical perspective, others are used in traditional medicine, birds are highly valued as pets for their song and beauty, and they are also used as food, being and important dietary component in poor

rural communities (Perez Gil et al. 1995). In spite of this long tradition of valuing birds, especially in rural areas, modern Mexican society as it became evermore urban, steadily became estranged from nature in general and from birds in particular.

Due to economic, cultural, and educational factors linked to the availability and forms of leisure, the new emerging society does not have a tradition for outdoor activities like camping, bird watching, sport fishing, hunting and ecotourism. Although these activities are increasing and NGOs and conservation organizations are beginning to make inroads in Mexican society, until recently there has not been a critical mass of constituents, at either national or state levels, that could generate the social and political pressure necessary to induce government administrations and political parties to enact environmental conservation policies with adequate funding. The Mexican Green Party is not recognized as a political institution with expertise in environmental affairs (for example, although it won the last presidential elections in an alliance with Vicente Fox's Partido Acción Nacional, it was not granted any responsibilities in administering the country's environmental sector, and the votes it gathers seem to be more related to decisions based on "political balances" among parties than on its environmental platform). Those sectors that do have direct linkages to natural resources and have environmental awareness, like indigenous groups, are also marginalized and disenfranchised from political power and cannot exert political influence corresponding to their population numbers. NGOs and academic institutions have played and continue playing an important role as catalysts of conservation projects, but they do not have the resources or legal authority to conduct the large-scale conservation efforts needed to prevent the loss of bird species at a national scale. Successful conservation programs tend to be those that combine the collaboration of government agencies, conservation or development NGOs, academic institutions, and agrarian and social community organizations around commonly defined problems in forested areas.

Missing from the country is also a philanthropic "donor" culture. There is not much participation of the private sector in financing conservation in a significant way, either directly or through foundations and NGOs. The situation, however, is improving with the creation of the Fondo Mexicano para la Conservación de la Naturaleza (FMCN 2003), the growth of influential NGOs, and professional organizations like PRONATURA (2003) and CIPAMEX, and the inclusion of environmental components in the agenda of political parties. Recently private groups like the Bimbo Bakery and Fundación Gonzalo Río Arronte, among others, have donated millions of dollars toward management of natural protected areas, thanks to the work of committed conservationists in key government posts.

Final Considerations

The challenges confronting bird conservation in México are daunting. They include taking actions such as creating whole conservation bureaucracies at the state level, resolving historical land tenure problems, providing enough educational and training resources to academic institutions, and generating enough financial resources toward land acquisition and the creation of natural resource management projects that either directly or indirectly provide employment for the rural population associated to priority conservation habitats. Bird conservation initiatives in México will more likely be successful if they are implemented with a clear understanding of the socioeconomic and environmental context in which natural resource management develops, and if they integrate (or are integrated into) social and outreach programs. National analyses of bird conservation requirements superficially skim the issue of developing strong resource management instruments and institutions at state and municipal levels, yet these are strategic problems that need to be adequately addressed. Local municipal governments have a yet unrecognized importance in implementing conservation projects. But this importance cannot be detected if those promoting conservation have no real links to local government dynamics or to local citizen education/ participation processes. Universities have played and can continue to play an important role in promoting bird conservation, but the academic-professional incentive mechanisms, based on the accumulation of peer-reviewed publications, actually work against university participation in conservation. Linking academic institutions to effective on-the-ground conservation programs that include incentives for all involved will be elements for success and continuity in local conservation projects (Santana C. et al. 2002b).

Despite the challenges and the magnitude of environmental deterioration in México, it is clear that institutional conditions for bird conservation are improving. As part of this process there has been a steady professionalization of those working in the environmental sector and an increase in the number and quality of protected areas and conservation programs. The crucial question remains whether these positive changes are occurring fast enough to overcome the loss of habitat and the extinction of bird species (answer: they are not). "Context conditions" set the stage for local conservation actions, and the Mexican ecological and socioeconomic contexts require the generation of effective and particular conservation strategies that, although internationally compatible at a North American scale, will differ from those developed in the U.S.A. or in Canada. These strategies must be inclusive

of all the stakeholders in the country who affect and are affected by birds and their habitats. "Political will" and cooperation at national as well as international levels are essential to address the complex issues involved in the conservation of avian diversity. However, to adequately address this complexity at different scales, conservation efforts will have to be constructed by a community of people representing an equally complex array of places, races, cultures, religions, nationalities, disciplines *and* economic and sociopolitical systems. Thus, México is not alone in facing the daunting challenge of bird conservation.

Acknowledgments

Some of the concepts in this essay were presented by the author at the Neotropical Ornithological Society Meeting in Monterey, Nuevo León, México (1999), the Society for Conservation Biology Meeting (1999) and as part of the keynote address "The Sierra de Manantlán Biosphere Reserve: global links in corn, birds, sugar and trash" at the III International Partners in Flight Conference held at Monterey, California, U.S.A. (2002). It is a compilation of ideas that have emerged during discussions at various CIPAMEX, NABCI (México and International), and Partners in Flight ornithological meetings and that have been adapted from the manuscript Santana C., E., E. Jardel P. and S. Graf M. "Aportes hacia la construcción de una estrategia nacional para la conservación de aves en México."

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Avian Research in the U.S. Forest Service

Beatrice Van Horne[2]

Introduction

Avian research in the Federal Government is in a crisis. Yes, there is a strong interest in avian research, as evidenced by the size and level of interest in this conference. But political parties increasingly see wildlife research as expendable. At the same time, the reaction to environment-friendly legislation of the 1970s and 1980s has been strong from both sides. Conservationists are holding our feet to the fire to show that we know the status of all our species in the National Forests, and are managing for those species. Meanwhile those on the other side are increasingly drawing upon a general skepticism about science and scientists to call into question the scientific basis for species and ecosystem protection while taking a broad swipe at research programs and funding.

One thing is certain. If we continue with research as usual, we can expect support for that research to decline in the face of new priorities that this nation is facing. My objective here is to explore the major trends that have put Forest Service research where it is, and suggest how government supported researchers can strengthen their influence under the current political and social climate.

Wildlife Research in the Forest Service

It may be helpful to look broadly at how the role of wildlife science has changed over time. Beginning in the 1890s, exploitative hunting was the dominant concern, bolstered under Theodore Roosevelt by trophy hunting. This was followed by a decline of hunting associated with land conversion to development and agriculture, and decreasing subsistence use. Finally, an increase in recreational hunting became evident in the 1970s. Non-exploitative use of wildlife was minimal until about the 1960s, when interest in backpacking, wildlife viewing, nature photography, and similar activities took off.

Concern with non-game species has increased during this time, and the implicit and explicit role of the Forest Service in managing these species has also changed. The idea that the national forest system should provide habitat for a diversity of species, not just game and fish, was introduced in the Forest Service Wildlife Manual in 1941. For many years, good forestry management was equated to good wildlife (i.e., game species) management. Even-aged forestry was associated with a decline in conservation value, but the Blue Mountain Study by Jack Thomas (1979) and public reaction to clearcuts raised interest in conservation. The listing of the Red-cockaded Woodpecker (*Picoides borealis*) in 1973 and emerging concern for the Northern Spotted Owl (*Strix occidentalis caurina*) moved this conservation interest solidly into the legal arena.

The balance of power between states and the federal government is often contentious, swinging like a pendulum. By the 1940s and 1950s there was good agreement that the states would manage wildlife and the Forest Service would manage habitat. But then, in the 1970s, Federal legislation, such as the ban on use of aircraft in sport hunting and the Marine Mammal and Endangered Species Acts, reasserted Federal interest. More recently, this has been amplified by the far-reaching Migratory Bird Treaty Act. Now again Congress is strongly encouraging states to increase their role in managing non-game species by requiring them to develop Comprehensive Wildlife Conservation Strategies in order to be eligible for funding through the State Wildlife Grant Program (FY02 Interior Appropriations Bill).

With wildlife uses and interest generally increasing, and the state-federal balance of power in flux, what has happened to habitat research? The role of habitat research in the Forest Service has generally increased. In the 1960s and 1970s the Wilderness Act, National Environmental Policy Act, Endangered Species Act, and National Forest Management Act all provided major impetus, as the National Forests now had a mandate to manage for wildlife. Indeed, the Planning Rule issued pursuant to the Management Act required the maintenance of "viable populations of all native and desirable non-native species well-distributed within the planning area." The 1980s were marked by a high volume of timber sales and increased demands on Forest Service

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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biologists to provide information to support forest planning (Catton and Mighetto 1998).

Since the late 1980s, partnerships and challenge cost share have played a key role. This has engendered the rise of the marketing approach to science, in which specific research programs that have marketing appeal, such as "Partners in Flight," "Taking Wing" (wetland birds), "Making Tracks" (wild turkey), "Elk Country," "Full Curl" (wild sheep), "Dancers in the Forest" (grouse), "Answer the Call" (quail), "Bring Back Natives" (indigenous fish), "Animal Inn" (dead wood dependents), and others, are publicized. These partnerships foster funding through non-governmental organizations and other private sources, and have allowed for reduced federal funding for scientific research on wildlife of concern. Partnerships can influence research priorities and thereby make research less responsive to management needs.

Most recently, the awareness of issues of temporal and spatial scale, particularly the need to scale up, has increased. This was spurred by a move from single-species based research and management to a multi-species, ecosystem basis. In the 1960s and 1970s, we thought in terms of 40-200 acre clearcuts and 1-5 or 50-yr increments. Now we worry about ecosystems, 100-yr disturbances, 500-yr fire cycles, and, perhaps in our most enlightened moments, about maintaining genetic variation across evolutionarily-significant populations.

So, the role of habitat research has generally increased, while our attention to the role of scale has exploded since 1980 or so, spurred by the development of Geographic Information Systems (GIS), a trend toward regional planning efforts, and recognition of the need to plan at large landscape levels during the Forest Planning process.

I think it is useful to take a look at the sociology of the Forest Service during this period. The early, rugged individualist Forest Rangers were replaced by teams that sought to engineer habitat for game species, beginning with the Civilian Conservation Corps in the 1930s. After World War II, returning military staffed many forestry positions and were generally associated with an engineering approach and even-aged timber management. As these people retire, we have a diversity of groups made up of veterans, research biologists (mostly hired after 1970), environmental engineers, and rugged individualists. At the same time, ethnic and gender diversity has increased. This diversity has reinvigorated the Forest Service and presented some new challenges. There are difficulties in communication between research scientists and engineering and management-oriented individuals that stem from differences in their basic assumptions about the goals of management and research.

Research scientists may also be challenged in working with rugged individualists. One recent example arose when a few people caused a huge ruckus by deciding to violate scientific protocol in an effort to introduce some blind testing of lynx hair to a DNA lab. Some people assumed this was an effort to find evidence of lynx where they weren't, and, hence, to lock up the forests. Why did it take such a small match to light this conflagration? Apparently, people are at least paying attention to some wildlife research, and finding it to be important.

On the other hand, scientists are no longer assumed to be "experts." It is increasingly recognized that scientific research is subject to criticism, and that any weakness can be exploited to invalidate unwanted results. This change has been recently addressed by the Data Quality Act, which allows the public to challenge the scientific basis of research results that are used to make management decisions. Researchers are now working in the spotlight, with their sampling designs, protocols, and statistical analyses are under the microscope as never before.

So, we have a mixing of groups and points of view going on inside the Forest Service. At the same time, interest in Conservation and non-consumptive use of wildlife is increasing, evidenced partly by the laws protecting endangered species and rule providing habitat for viable populations of all species. Too often, monitoring and management of wildlife are insufficient to meet legal mandates. The net result is that the Forest Service ends up in court and can suffer costly delays in project implementation. The role of science and research, as well as the importance of scales of inference in time and space, is increasingly recognized. The task has overwhelmed resources, and decentralization of research has decreased our ability to coordinate over the large scale that we now know is important, while the collapsing of budget line items within Forest Service Research and Development has reduced funding accountability.

Sometimes conflicts among groups with different interests can lead to paralysis or gridlock. But there is no gridlock for bird populations. So, I hope I have convinced you that we have a problem, and we have to break out of it. The solution does not lie with doing more of the same, only better: the problem is far too big for that.

A Stronger Future for Avian Research

What should we do? First, with the very small cadre of scientists we now have, choosing the most effective and high priority research problem is critical. Our strength is in long-term research that is integrated across basic science and management disciplines. At the same time, research results must produce outcomes that clearly influence decision-making in management. In this context, designing long-term research that will also produce intermediate products of direct interest to managers in meeting their immediate, most pressing needs is the best way to assure their support. For example, a study describing trends in bird populations and their habitats might be designed so that within 1-3 years it produces good solid bird-habitat information, by year 5 overall trend information, and by year 8 trends by habitat, made possible by increasing cumulative sample size. Research results must be communicated in a way that is useful to management and understood by the public, whether this is through user-friendly models, direct contact, input to the development of forest plans and management guidelines, or readable syntheses of research results.

Second, we need to recast the way in which we, as research scientists, approach our research. We often carefully delineate the locale of inference, but this locale is not always matched to challenges faced by managers and decision-makers. Research not clearly linked to management problems or actions can lead to an impression that the choice of species, problems, and locations is haphazard or irrelevant.

One partial solution to some of these dilemmas is to couple intensive research on avian population declines with broad-scale monitoring, thereby expanding the scope of inference. Research is more useful to management when the processes it elucidates are interpreted in the context of changes to the species, similar species, or related groups of interest across time and space. GIS has opened up a whole new world of spatially explicit variables that influence wildlife populations. Attempts to use such broad-based approaches to extrapolate the findings of local studies more widely must be coupled with an understanding of the processes driving the patterns in order to make predictions beyond the time and place in which data were collected. Increasingly, attempts at such extrapolation will be attacked in court unless they are based on underlying mechanisms.

How can we improve the monitoring efforts that the National Forests are being legally directed to undertake and include in their Forest Plans? Research can help in determining which species are most important to monitor. Research can inform design, protocols, and verification, and maximize the useful information gained for each dollar spent. For example, what intensity of sampling do we need to detect a population decline of 10 percent? What is the best monitoring design to evaluate the results of management treatments? There are numerous examples of management treatments that are assumed to have a particular effect on wildlife; we should be testing such assumptions. This integration of monitoring and research would allow research to inform the monitoring design so that, for instance, it will be able to detect trends of some pre-determined magnitude with a specified level of statistical confidence. Monitoring could, in turn, provide a context for more intensive research. By designing monitoring with regard to management treatments, we can begin to investigate some management effects.

What should scientists do when monitoring demonstrates that a bird species is in decline? Amassing habitat correlations is not sufficiently informative, although it may be a useful step. For example, correlations between Red-cockaded Woodpeckers and their habitat would not have been sufficient in themselves to identify the nesting requirements that were critical to population recovery. A Habitat Suitability Index model or an envirogram (Andrewartha and Birch 1984) may be a good place to start, as it is an effort to represent what is, or could be, limiting populations.

Real progress is made when scientists are able to develop and investigate a hypothesis for the cause of a decline. The art is in knowing when there is enough information to develop useful hypotheses. Time and effort can be wasted on intensive studies that are initiated prematurely. Gathering reproduction and survival data may be helpful for understanding causes of decline in endangered, remnant species, such as spotted owls, but could be of limited use for more widespread species that might also be in decline. One should always remember that trends are often spatially explicit and quite likely habitat-specific. With monitoring information, we can evaluate the scale of the decline in time and space. Information from Breeding Bird Surveys and even Christmas Bird Counts is often used for this. There are serious biases in these data but these may be adequately compensated by the sheer volume of data. It may be useful to check whether similar species, that might be dependant on the same habitat features, are also declining.

Research has several roles in the Forest Service, but monitoring has often been avoided. I think our ability to fulfill other roles will be compromised unless we help with the design and analyses of monitoring efforts that have been mandated by the courts as a prime way to satisfy management responsibilities to wildlife.

I believe involvement in scientifically rigorous monitoring will be exciting for researchers. Monitoring may be one of the most valuable and useful technology

transfer tools available to assist with meeting desired future conditions and objectives. It is imperative, however, that monitoring designs have sufficient power to detect trends to warrant these efforts. Clearly, standardization of protocols, including prescriptions for measuring common covariates, will allow us to scale up from localized areas and Forests. By making data widely available and linked to GIS, we can facilitate this scaling-up process. The need for cooperation with agencies and other organizations is self-evident. It would be helpful to think carefully about how we structure the monitoring relative to various treatments and gradients-haphazard information defies our best efforts to extract important relationships. Finally, these monitoring efforts should be used as a springboard for more intensive studies of survival, reproduction, community structure, and the processes that influence them when such focus is needed.

I conclude by suggesting a few strategies for research in this new environment. Scientists should always consider their interface with monitoring efforts. Have a working Habitat Suitability Index model, envirogram, or other model that makes the processes that could regulate populations explicit. Avoid reliance on correlation alone. Think about process, but place this process-oriented work in a context by scaling up in space, and time by doing long-term work. And, finally, good science that uses tight design, controls, and careful statistical analyses is more important than ever. A single case of sloppy science can bring excellent research into question.

Acknowledgments

G. Contreras, S. Foster, C. J. Ralph, and J. Wiens provided useful input to this manuscript.

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Finding Our Wings: The Payoff of a Decade of Determination[1]

Naomi Edelson[2]

The International Association of Fish and Wildlife Agencies (IAFWA) was founded in 1902 as an association of state and provincial wildlife agencies. We had our 100-year anniversary in September 2002. Audubon also started almost 100 years ago. A lot has happened in those 100 years. I am pleased to say we are at another very critical and historic moment.

The Reno *Gazette*, in a recent editorial, wrote that preserving wildlife depends on three critical issues: 1) forming partnerships at all levels from the Federal to the personal; 2) involving local people in a meaningful fashion; and 3) providing sufficient money. That is exactly what has just happened in our Partners in Flight (PIF) world, so I want to start my presentation by saying *thank you* for all your hard work and persistence.

Think back to more than 10 years ago, to 1990. That was a big year. The States, through IAFWA, determined that nongame wildlife was their biggest challenge and, therefore, their biggest priority, as it has remained through the decade. This led to the initiation of a major congressional push to obtain substantial Federal money to States for nongame wildlife conservation. It also led to the active participation and leadership of the States in PIF, including the funding of the PIF Regional Coordinators.

Dan Beard, Chief Operating Officer of Audubon at the time said (after telling me that I had been harassing him for years), "That's the point: to get your agenda to become someone else's agenda." I think that is what we have done in PIF. We have done some remarkable work together, getting our agenda to be a state agenda, a Federal agenda, a non-governmental organization (NGO) agenda, and even a Congressional agenda.

We had over a decade of initiating, organizing, growing coalitions, gathering information, and putting it all into planning. The PIF plans are mostly done, including assessments and recommendations for hundreds of land bird species. Moreover, our efforts went way beyond land birds, stimulating many other groups of often-neglected wildlife. The U.S. shorebird plan is done. The waterbird plan is done. There are herpetology plans being formulated, as well as a national bat plan. This is a tremendous leap for wildlife diversity efforts, and much of it to our credit.

As we worked on these plans, we also grew the leadership among the major players in each of these entities.

On the NGO front, we have had leadership from many of the smaller and local bird-related organizations, notably the bird observatories. Now Audubon is back in the bird business in a big way through their Important Bird Areas program (IBA), in part because of all of this bird conservation activity. I, along with many others here, just came from Audubon's 2nd Annual Important Bird Areas Conference, held in Big Sur, CA.

This is our activist constituency. This is one way we may finally get those many birders organized and focused on a campaign good for birds at every scale. That is the role of the NGOs for birds. The IBA program efforts to work with the PIF and other bird plans will pay great dividends for us all. I strongly encourage you to become familiar with the IBA representatives working for Audubon and others.

Under Federal leadership, we now have full-time national coordinators for PIF, shorebirds, and waterbirds. In addition, the U.S. Fish and Wildlife Service has a PIF coordinator in each of its regional offices. Overall budgets for such bird work have increased for some of these agencies too. Recently, new Memoranda of Understanding are being developed under the new Executive Order which mandates that each federal agency will cooperate to take care of migratory birds.

Under State leadership, as I already pointed out, we have had significant movement translating into new funding, which I will talk much more about, staff, projects, and overall genuine awareness for the significance and need. The table is set. However, what would be the point of planning if not for implementation? And you cannot do implementation without money.

While you in this room have been doing the planning, some of us who care very much about this work have been politicking to secure such funding. Now we have a convergence: a decade later all the roads have come back around to the same spot. Just as you have these

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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PIF plans done, we have some real money to take action on them.

Due to the support of over 3000 wildlife-related groups under the Teaming with Wildlife coalition, for the first time ever, in the last 2 years, sizeable Federal money is flowing back to the states for essentially nongame wildlife conservation. It is under the same premise as PIF, to "keep common species common" or "an ounce of prevention is worth a pound of cure."

Let me show you the money. In fiscal year 2001, due to the efforts of this Teaming with Wildlife coalition, as part of a larger coalition working for passage of the Conservation and Reinvestment Act (CARA), we obtained $50 million for state wildlife conservation. These funds were allocated to the fish and wildlife agencies in all 50 states, the District of Columbia, Commonwealth of Puerto Rico, and U.S. territories. In fiscal year 2002, we secured $80 million, and in fiscal year 2003, we are aiming for another increase of up to as much as $150 million. This is now called the *State Wildlife Grants* program.

We have many examples of how the state wildlife agencies are using these funds for bird conservation and all wildlife on our web site at www.teaming.com. I think you will be very pleased with the number and quality of bird-related projects.

Our overall, and original, goal remains: to secure $350 million a year for state wildlife efforts on a long-term basis. In the meantime, as we work to ensure passage of CARA or something similar, we also are working at increasing these shorter-term appropriations for State Wildlife Grants under the Department of Interior's budget.

The planning is done, the money finally available, but the work is not really done. We need to close the deal. *You* need to make yourself heard. You've done something great with these plans; you now need to ensure that the implementation of the plans is a priority for spending this new money. In addition, that the money continues to continue—that it keeps on coming on.

You need to make yourself heard. There are two key ways to do that: 1) get (back) involved with your state wildlife agency; and 2) ask Congress for the money.

We have a simple message: urge members of Congress to support $150 million in State Wildlife Grants in the Department of Interior appropriations.

If there is one thing we should have learned from our duck friends in all of these years: be part of the movement that gets the money, then you can be part of spending of the money.

This is a tremendous asset we have created, and one that cannot be squandered if you want these plans on the ground. After many, many years of making songbird or land bird or really nongame bird conservation a priority, we can now say our collective efforts are beginning to pay off, literally. This is the payoff after a decade of determination.

I thank the state fish and wildlife agencies for the work they do every day on the front lines of conservation on behalf of birds and all the other wildlife. I also thank C. J. Ralph for his continuous support of and involvement in PIF, and, in particular, of my efforts to do the same, including giving this presentation.

Seasonal Bird Traffic Between Grand Teton National Park and Western Mexico[1]

Martin L. Cody[2]

Abstract

This paper presents data on variations in the breeding densities of birds in Grand Teton National Park, Wyoming, and evaluates these variations among years, habitats, and as functions of the migratory status of the breeding birds. Breeding opportunities certainly vary with the extremely variable weather conditions in the park year-to-year, and part of the variation in breeding density must be attributable to unpredictable on-site resources. A minority of the breeding birds is resident, but many species are long-distance migrants, and others make more limited winter movements of various distances. Most but not all of the migrants overwinter in habitats that are very dissimilar to those in which they breed. In some migrants the habitat range appears greater in wintering than in breeding habitats, and in others not. Some migrants winter syntopically with close relatives and others occupy winter habitats that lack resident relatives. I bring some perspective to these variations using winter and early spring observations of the same species (though not necessarily members of the same Teton populations) in western Mexico. In some instances in which Mexican wintering habitat similar to northern breeding habitat is available, wintering birds may be relegated to different habitats because of prior occupancy by resident species, often related species such as congenerics or even conspecifics.

Overwintering habitats are almost certainly at least as variable in survival opportunities as are the breeding habitats for reproduction. They also vary year-to-year in weather conditions that affect food supplies, and are co-occupied by resident species, some of which are close relatives to the winter visitors and have similar ecologies. The vagaries of overwinter survivorship and the transitions of the birds between breeding and wintering grounds constitute a broad and poorly understood category of off-site factors for conservationists and resource managers whose chief source of information is the breeding populations. A much closer integration of research on breeding and wintering populations will be required before useful conservation strategies for migrant bird populations can be devised. This integration, through organizations like Partners in Flight, must become a research priority in the future.

Introduction

Resource managers in parks and reserves at northern latitudes are faced with the daunting task of conserving populations of migratory birds that are within their jurisdictions only part of the year. The status of the breeding birds may be evaluated through monitoring programs, which can assess relative abundance or density of breeding birds as functions of habitat on-site, document changes in breeding abundance or density between years, and detect trends in relative abundance or breeding density over the longer term. However, interpreting changes in breeding density is difficult at best, as usually both off-site and on-site factors will be involved.

A brief evaluation of these factors illustrates the difficulties and the unknowns. At the breeding site, recent weather conditions may affect breeding densities in the current year. For example, precipitation from winter through spring as well as spring temperatures both affect different breeding resources in different ways, generally both species- and habitat-specific. Breeding densities also may be a function of recruitment and breeding success in the previous year, and therefore of the on-site conditions during earlier periods. The overwinter survival of resident birds may vary according to winter conditions on site, whereas the survival of migrants in the off-season depends on wintering conditions elsewhere. For breeding birds at middle latitudes in the United States, wintering sites are distributed as far south as northern South America, and encompass a wide range of non-breeding habitats. Wintering conditions for the migrants, and thence their over-winter survival, are likely to vary in species-, habitat-, and latitude-specific ways. The vagaries of the migration itself, the cues, timing, stopover resources, and so forth, comprise additional variables affecting a safe passage. And further, habitat perceived as offering good breeding opportunities to spring migrants might

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California**.

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intercept birds that would otherwise continue north to breed in or near their natal habitats. Thus the range of factors contributing variation to breeding densities is indeed diverse.

Consideration of the broader aspects of nearctic-neotropical bird populations not only helps to identify gaps in our present knowledge, but also highlights a potential to gain a better understanding of the larger system through wider geographical and cooperative studies. While there are formidable challenges inherent in such studies, there are also causes for optimism. The large and enthusiastic attendance at this Partners in Flight conference attests to the broad perception that the challenges are appealing and perhaps tractable, and an extensive literature includes many excellent overviews of migration systems and confirms the widespread interest (e.g. Keast and Morton 1980, Berthold, 1988, Hagan and Johnson 1992, Finch and Stangel 1993, DeGraaf and Rappole 1995, Martin and Finch 1995, Rappole 1995, Marzluff and Sallabanks 1998, Bauer 2001, Faaborg 2003). The new technique of stable isotopes (Kelly et al. 2002, Rubenstein et al. 2002) promises to yield a more rapid understanding of some aspects of migration patterns than banding studies have produced, and interest in the "stopover ecology" of migrant birds is expanding (e.g. Hutto 1998, Wang et al. 1998, Warnock and Bishop 1998).

This paper makes no attempt to review or synthesize the growing literature, but presents a personal view of migrants that breed in Wyoming and winter south as far as northern South America. The data are generally sketchy, often incomplete, and obviously constrained in time and space; their use is intended to be more illustrative of themes and potential research avenues than supportive of specific facts or theories, and note that truly definitive data are elusive even in the best of cases. I discuss results of monitoring summer bird populations in Grand Teton National Park, Wyoming, and patterns of year-to-year variation in breeding densities measured at fixed and mapped sites. I then take a long stride to where and how these same birds may spend the non-breeding season in western Mexico, where they are often found in contrasting habitats and with different constellations of coexisting species. The northern and southern endpoints are those for which I have some familiarity, but presumably my data could be paralleled broadly by those of many other ornithologists, each with personal favorite summering and wintering birding locales.

Breeding Birds in Jackson Hole, Wyoming

Climate, Weather, and Habitats

Grand Teton National Park (GTNP) encompasses the larger part of Jackson Hole, a north-south rift valley between 1800-2000m elevation at around 44° N latitude, 111° W longitude, and flanked on the west by the Teton Range (elevation <2000 to >4000 m). The landscape is spectacular (Love and Reed 1968, Knight 1994), and supports a wide range of habitats from Great Basin sagebrush (*Artemisia* spp.) desert on the valley floor through wetlands and marshy willow (*Salix* spp.) scrub to broad-leafed woodlands (cottonwoods, aspen-*Populus* spp.), coniferous forest, and alpine tundra. In the mid-1990's, the National Park Service supported a proposal to instigate a series of breeding bird monitoring sites that span the complete habitat range, some 30 sites in all. At these sites, standardized census protocols yield breeding bird densities spot-mapped in sites mostly around 6 ha in size (Cody 1996, 1999; Cody and Cain 1997). The monitoring sites differ from one another in vegetation structure, as illustrated in *Figure 1*, though clearly this quantification of habitat provides at least a crude indication of the resources available to breeding birds. At several sites we now have around a decade of continuous coverage, but two have a more extended coverage, and were first censused in the 1960's (Cody 1974). In all, around 150 bird species breed or have bred at the monitoring sites.

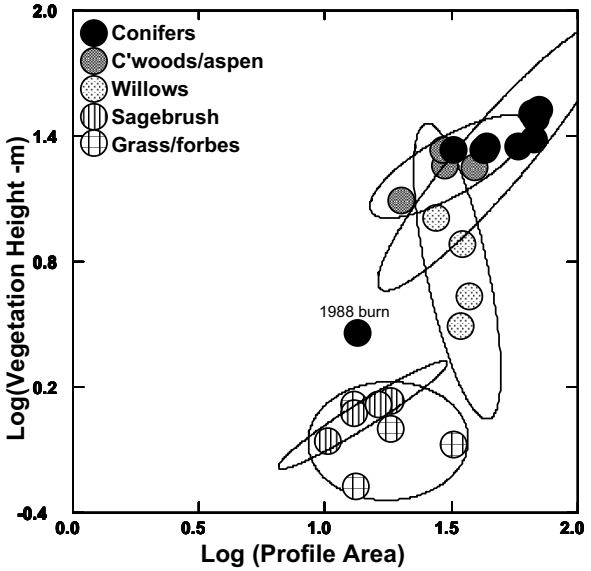

Figure 1—Monitoring sites for breeding bird densities in Grand Teton National Park, Wyoming, classified by vegetation structure. The ordinate reflects vegetation height, the abscissa the total amount of vegetation under the foliage profile, or total vegetation density. Waterfowl, aerial foragers, and tundra survey sites are not represented on the graph.

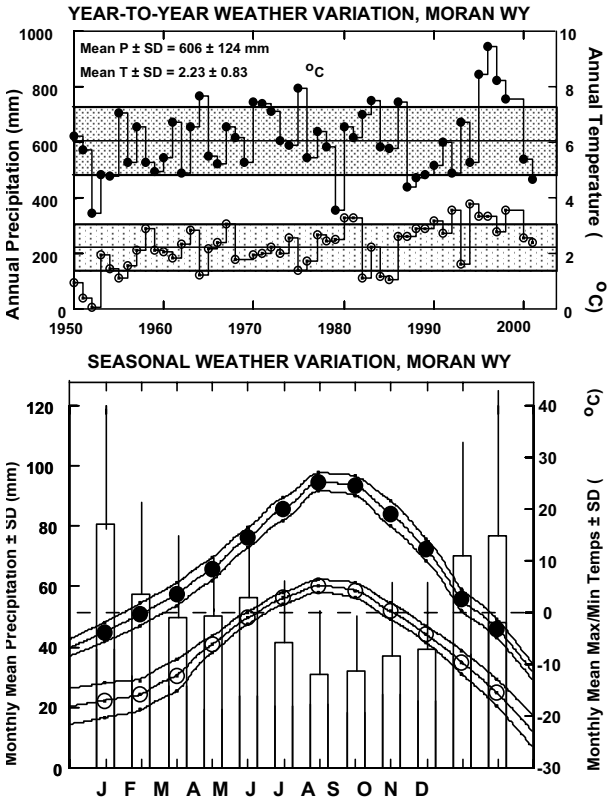

Figure 2—Year-to year (upper) and seasonal (lower) weather variations at Moran, Grand Teton National Park, Wyoming, over a 50-year period. Note both the inter-year variation and the extreme seasonality of the site. Upper graph: solid symbols, precipitation; open symbols, temperature; stippled regions: ±1SD of the mean. Lower graph: hatched histogram, monthly precipitation; solid symbols, mean maximum monthly temperature; open symbols, mean minimum monthly temperature; each with ±1SD as indicated.

The climate in Jackson Hole is typical of its mid-continental location and higher elevation (*fig. 2*). There is considerable year-to-year variation (*fig. 2*, *upper*), with around one-third of the annual temperature and precipitation means lying beyond the 50-year standard deviation band. There is no strong ENSO ("El Niño") signal in the climate here; the four ENSO winters of the 1990's that brought average winter rainfalls of 1330 mm to Topanga, in southern California (3.3 times the non-ENSO average), are barely detectable in GTNP, where ENSO winters are about 10 percent drier and 2° C warmer. The last 50 years also show a significant warming trend in mean temperature maxima of spring and summer months. Season temperature variations are extreme (*fig. 2*, *lower*), and the lowest precipitation occurs in the warmest months. Note that mean monthly temperature maxima are below 0° C for three winter months, and that mean monthly temperature minima are likewise above zero for three summer months only. The severe climate makes GTNP habitats particularly conducive to seasonal use by birds, and the great majority are migratory species. Further, returning migrant species face considerable uncertainty in local conditions, in terms of both the timing of the turn of the seasons and the absolute temperature and precipitation values they encounter.

Variations in Breeding Bird Densities

In most years passerine birds are established on-site in GTNP and breeding is underway by late May or early June, and breeding densities are high in many habitats (see e.g. Johnsgard 1986 for general distributional information). Some species are rather cosmopolitan in habitat use, as exemplified by Chipping Sparrow (*Spizella passerina*). This species winters chiefly in Sonoran Desert habitats of SW North America. It breeds in most of the GTNP monitoring sites (*fig. 3*, *upper left*; densities averaged over years), with a preference for drier habitats open at ground levels, and peaking in density in lodgepole pine (*Pinus contorta*) forest. Breeding densities, averaged over habitat, vary among years as well (*fig. 3*, *upper right*). Density variations are synchronized over years among some habitats, yet differ among others; a strong correspondence exists in density variation between some paired sites, but less correspondence between others (*fig. 3, lower*). Both on-site and off-site variation apparently contribute to these patterns.

About 17 passerine species breed each year at GTNP in a Wet Willows habitat (site #10). Variation in breeding density for four species of emberizine sparrows and five species of paruline warblers, over a discontinuous 35-year period, suggest that both on-site and off-site factors influence density in any given year (*fig. 4*). Inter-year variations in precipitation on-site are further influenced by beaver (*Castor canadensis*) activities, which raise or lower the water table. Wetter conditions (requiring hip-wader work) tend to favor species such as Virginia Rail (*Rallus limicola*), Marsh Wren (*Cistothorus palustris*), Northern Waterthrush (*Seiurus noveboracensis*), and Song Sparrow (*Melospiza melodia*), and disfavor species that are ground-foragers in drier sites such as Swainson's Thrush (*Catharus ustulatus*), White-crowned Sparrow (*Zonotrichia leucophrys*) and Fox Sparrow (*Passerella iliaca*). But the importance of off-site factors is suggested by the precipitous decline of Wilson's Warbler (*Wilsonia pusilla*) between 1991 and 1992 and its steady recovery since then, in apparent independence of factors operating at or within the site. This bird utilizes insect resources similar to those used by Yellow Warbler (*Dendroica petechia*) and Common Yellowthroat (*Geothlypis trichas*), though it forages higher in the vegetation (Cody 1999). Both of these latter species increased in density between 1991

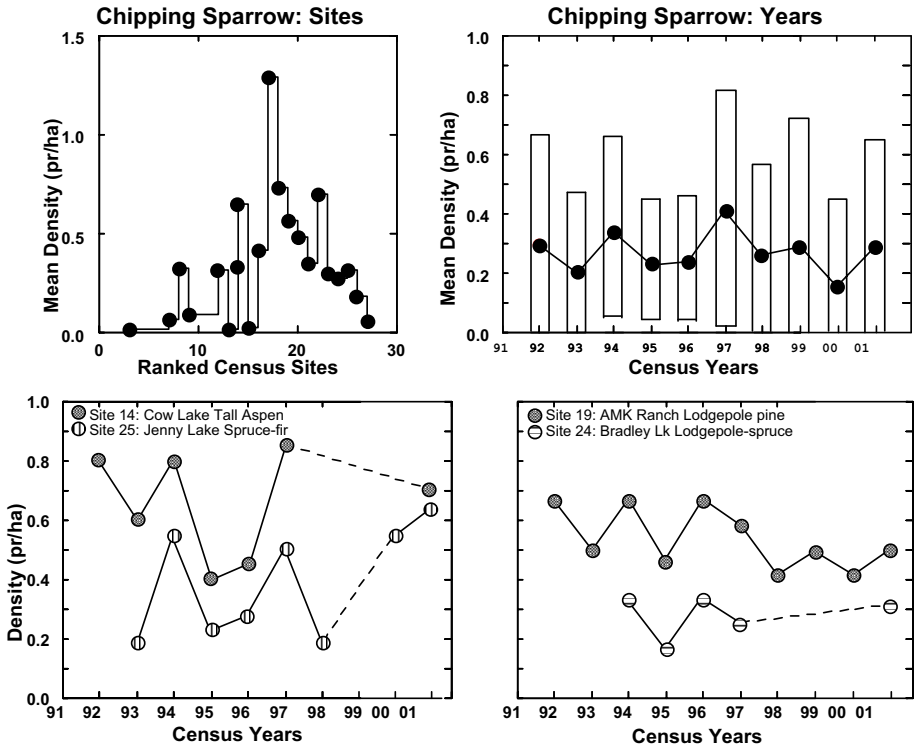

Figure 3—Variation in breeding density of Chipping Sparrow in Grand Teton National Park. Breeding densities vary over habitat (upper left) and among years (upper right; n.b. years 1999-2001 are averaged over a slightly reduced subset of monitoring sites). Variation in density is shown at four monitoring sites in the two lower parts of the figure.

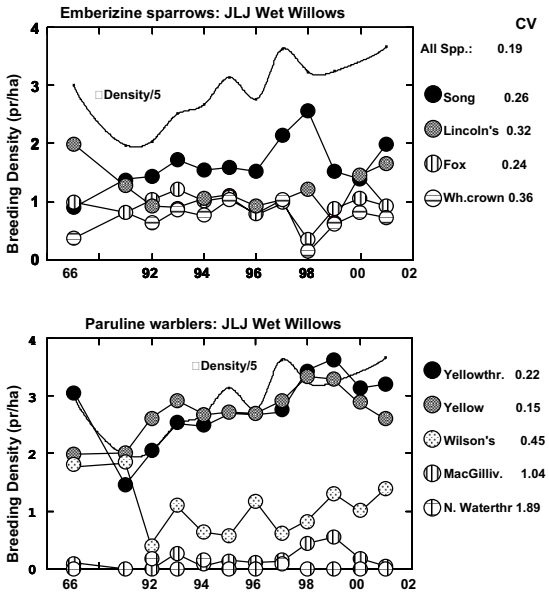

Figure 4—Variations in breeding densities of emberizine sparrows (above) and paruline warblers (below) at a Wet Willows monitoring site. Note the discontinuity between 1966 and later censuses. Total breeding bird density at the site is represented by the smoothed curve, with total density values divided by 5 to utilize to the same scale on the ordinate. The coefficient of variation (CV) is shown at the right; uppermost CV value is that for the total breeding density (all species) at the site.

and 1992, as did the overall breeding bird density at the site. Given the similarity of diet and foraging ecology between Wilson's Warbler and these other two warbler species that maintained steady or increasing populations at the census site, off-site factors seem the more reasonable cause of its breeding density variations.

Of the Wet Willows birds discussed, only Song Sparrow remains to winter locally. However, in a Lodgepole Pine forest (site #19), which harbors an average of 22 breeding passerine species, about half of the breeding community is resident or winters locally. Density variations in several resident species and migrant foliage insectivores and thrushes in the lodgepole forest also suggest the operation of both on-site and off-site factors (*fig. 5*). The resident species (*fig. 5, upper*) vary in density over the years in a notably synchronous way, presumably density variations result from variations in on-site factors to which all three residents respond in a similar fashion. The same is not true for the migrants (*fig. 5, lower two graphs*), in which density variations are generally unsynchronized over years. The Yellow-rumped Warbler (*Dendroica coronata*) winters farther north than nearly all other warblers, and no obvious on-site effects account for its striking peak in breeding density in 1999. However, this species was at 63 percent higher densities in 1999 at two other GTNP monitoring sites relative to densities in 1998 and 2000,

which suggests that the cause was not extremely localized. Note also that the two congeneric thrushes, Swainson's Thrush and Hermit Thrush (*C. guttatus*), tend to vary in density among years in the opposite way (Spearman r = -0.35). This observation has at least three interpretations: density varies due to on-site competition for Catharus resources, varies with on-site factors that affect the two species in opposite ways, or varies with factors on their respective wintering grounds that happen to be negatively correlated.

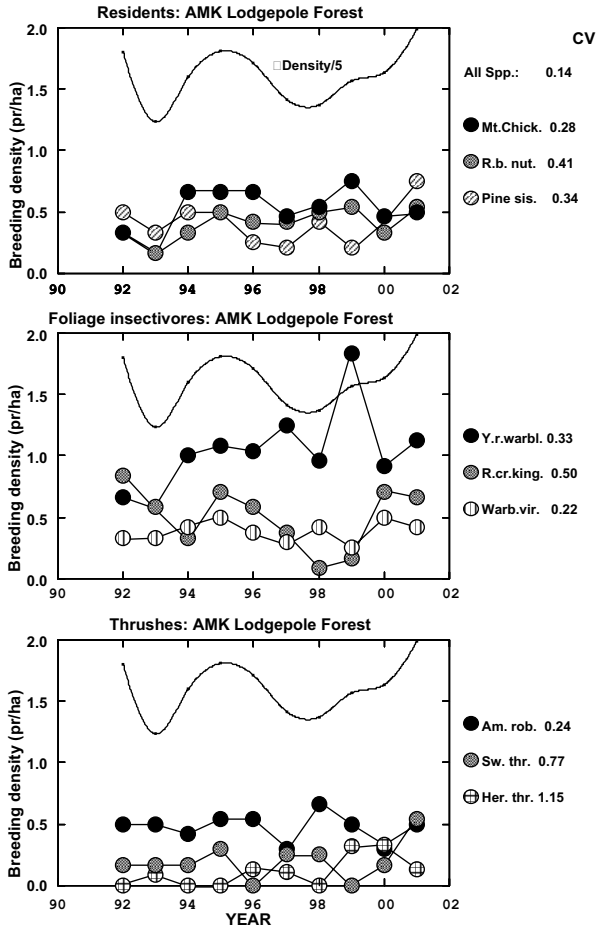

Figure 5—Variation in breeding densities of species in a Lodgepole Pine monitoring site in Grand Teton National Park. Abbreviations denote Mountain Chickadee (*Parus gambeli*), Red-breasted Nuthatch (*Sitta canadensis*), Pine Siskin (*Carduelis pinus*), Ruby-crowned Kinglet (*Regulus calendula*) and Warbling Vireo (*Vireo gilvus*). See caption for *fig. 4*, and text for discussion.

Variations in Wintering Areas for GTNP Breeding Birds

Most of the bird species that are found together in summer breeding habitats in GTNP are widely dispersed over southerly latitudes in the winter, and overwinter in a wide range of habitats, from desert to rainforest. Such information comes from limited personal observations in Mexico and Nicaragua, and from general sources (e.g. field guides) and the published literature for wintering birds in other Central American and South American areas. An indication of this variety of wintering strategies within taxonomic groups is shown for thrushes, sparrows, and warblers (*fig. 6*). Each of these three broad taxa has one or two species that winter in or close to GTNP, but the remainder are spread far and wide. Note, however, that the thick-billed sparrows, which make use of seeds rather than fruit or insects in winter habitats, have more northerly winter distributions in general. Two patterns are especially noteworthy in the figure. First, within each broad taxon the latitudinal range of a given species is much narrower than the range of the whole species group, and second, characteristic wintering habitats are very different among species, even though they may, and often do, breed together in the same GTNP sites. Differences among closely related species are particularly conspicuous, as among the *Catharus* thrushes, the grassland and scrub sparrows, and the *Dendroica* warblers. Thus, species that breed together in GTNP habitats, such as Wet Willows or Lodgepole Pine, winter over a wide range of latitudes in a diverse array of habitat types. Presumably, their relative overwintering success is determined correspondingly by a wide range of factors that are largely independent of each other.

Is it the case that species undertaking longer migrations and wintering further south show greater variation in breeding densities in GTNP? If greater uncertainty in overwinter survival and thence spring breeding density were attendant on longer migrations, such a relation might be expected. *Figures 4* and *5* include the coefficient of variation (CV) of each species depicted, and in *Figure 7* these CV values are plotted against categories reflecting the varying extent of the winter migrations, from on-site (residents) at one extreme to species that reach South America at the other. Though the relation is not statistically significant and the data are limited, there is the suggestion that the lowest CV's of breeding density, rather than the highest, are associated with the long distance migrants. Certainly there is no support for the hypothesis that resident bird populations remain more stable in density over the years, though that might seem the more likely or expected relationship. I believe a more logical argument is that there should be no overall difference in surviving winter as a resident or as a long-distance migrant. Selection surely has modified overwintering strategies such that survival in the non-breeding season is maximized, and must operate within species via cost-benefit trade-offs in the contest for off-season resources that will not result in gross survivorship inequities among species. I suggest that, amongst a plethora of viable overwintering strategies, major variations in survival are not expected, and not likely to correspond systematically to one or another particular strategy. Thus, *a posteriori*, it is expected that breeding CV's will not

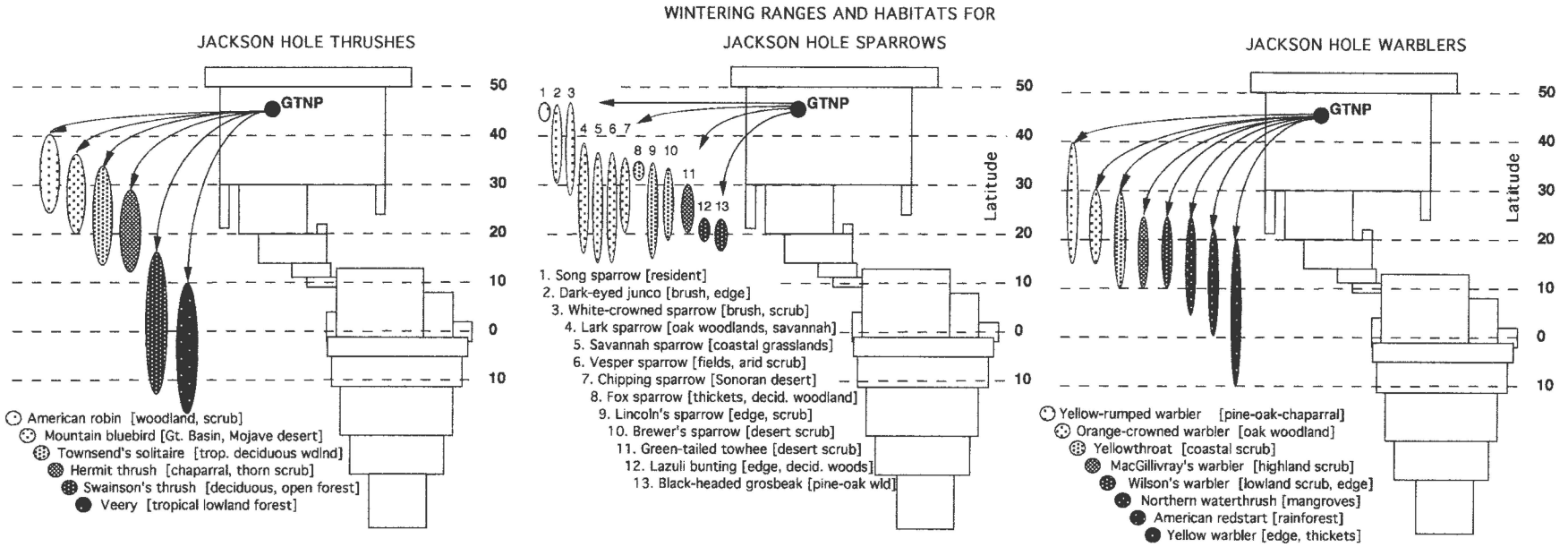

Figure 6—The range of approximate latitudes and of habitats used by wintering birds that breed in Grand Teton National Park, Wyoming. The figures display the wide variation in overwintering strategies found in these birds, which include residents to local, short- and long-distance migrants, and the use of winter habitats from desert to rainforest. Scientific names are given in the text, except for Veery (*Catharus fuscescens*), Dark-eyed Junco (*Junco hyemalis*), Savannah Sparrow (*Passerculus sandwichensis*), Vesper Sparrow (*Poocetes gramineus*), Lazuli Bunting (*Passerina amoena*), and Black-headed Grosbeak (*Pheuticus melanocephalus*).

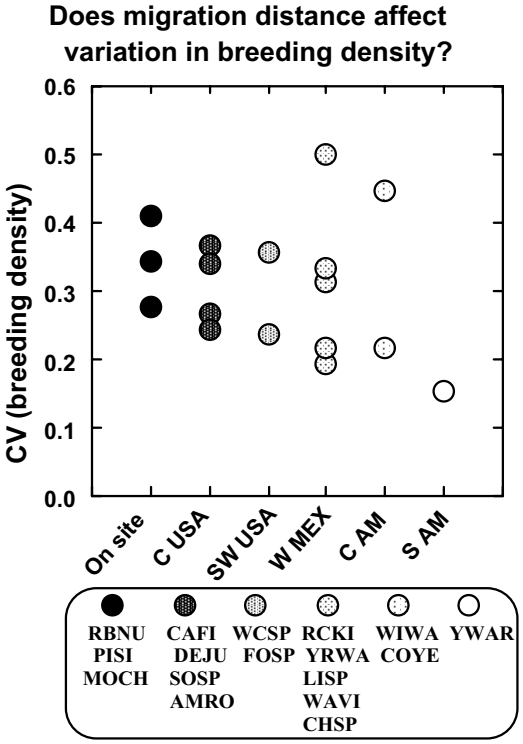

Figure 7—Coefficient of variation (CV) is plotted as a dependent variable with categories of distance to wintering sites on the abscissa. The species are those represented in Figs. 4 and 5, denoted by AOU codes, below. The relation is not statistically significant, but suggests, contrary to intuition, that long-distance migrants are not more variable in breeding density than are resident birds.

vary with migration distance or overwintering habitats, although it certainly is conceivable that overwintering strategies that entail more risk and cost might be offset by greater production in the breeding season.

Wintering Birds in Western Mexico

Winter Bird Habitats in West Mexico

Leapfrog migrations, in which the more polewards breeding populations overfly populations breeding to their south and winter at the lowest latitudes, are probably routine. Supportive data come from several sources: from species with well-defined (recognizable) subspecies (e.g. Fox Sparrow, Bell 1998), from banding studies (e.g. on Gray Catbird [*Dumatella carolinensis*], Cody 2003), and from recent stable isotope studies (e.g. Kelly et al. 2002 for Wilson's Warbler). Thus, it seems reasonable to conclude that species at mid-latitude sites in their breeding ranges will winter at mid-latitude sites in their winter ranges. I use this to justify associating species of breeding birds in GTNP with wintering populations in West Mexico, although the precise wintering grounds of the GTNP populations are not known (but this ignorance is not really critical to the points I wish to make). It is to be expected, given the recent enhancement of both interest and technology (*op. cit*.), that over the next decade or so the wintering areas of specific northerly breeding populations eventually will become known with much greater precision.

Over a long series of late winter and early spring visits to sites in western Mexico, I have seen many of the GTNP breeding bird species, recorded their winter habitats, and noted the species with which they are associated. Some of my observations undoubtedly refer to migrant birds in transit, but the habitat preferences of birds in transit, relative to those of breeding or resident birds, are relevant too. Far more comprehensive studies of wintering birds in this region have been conducted, e.g. by Hutto (1992); my observations, while anecdotal, are hopefully representative of the wintering ecology of GTNP breeders.

A view of the structural characteristics of the West Mexican habitats and their geographic locations is given in *Figure 8* (which includes a few sites in SE Arizona). The lower desert and thorn scrub habitats are much more open and sparsely vegetated than are the breeding habitats in the Tetons, but there is some concordance between tropical deciduous woodland and aspen/cottonwoods, and between the higher elevation Mexican pine forests and structurally similar GTNP conifers.

Emberizine Sparrows

Many emberizid sparrows breeding at northern latitudes winter no farther south than the Sonoran Desert and its scrubby fringes. Emberizines wintering on islands in the Sea of Cortés may escape the competitive influences of relatives that are locally present year-round, as most islands have only Black-throated Sparrows (*Amphispiza bilineata*) as residents. Incidence functions (proportions of islands occupied over island size classes) for seven of the commoner species, all GTNP breeders, vary widely among species (*fig. 9*, upper; from Cody and Velarde 2002). Incidence is highest in the Green-tailed Towhee (*Pipilo chlorurus*); notably Brown Towhees (*P. fuscus*), which are common mainland residents, are absent from nearly all islands). The figure shows that congeneric Chipping and Brewer's Sparrows (*Spizella passerina* and *S. breweri*), both common Tetons breeding birds, have very different island incidences. Wintering birds appear to use the islands in an "ideal free" fashion, in that they occur in higher species numbers on larger islands and in constant proportion to the number of island residents (same slope of Species-Area curve; *fig. 9*, *lower*).

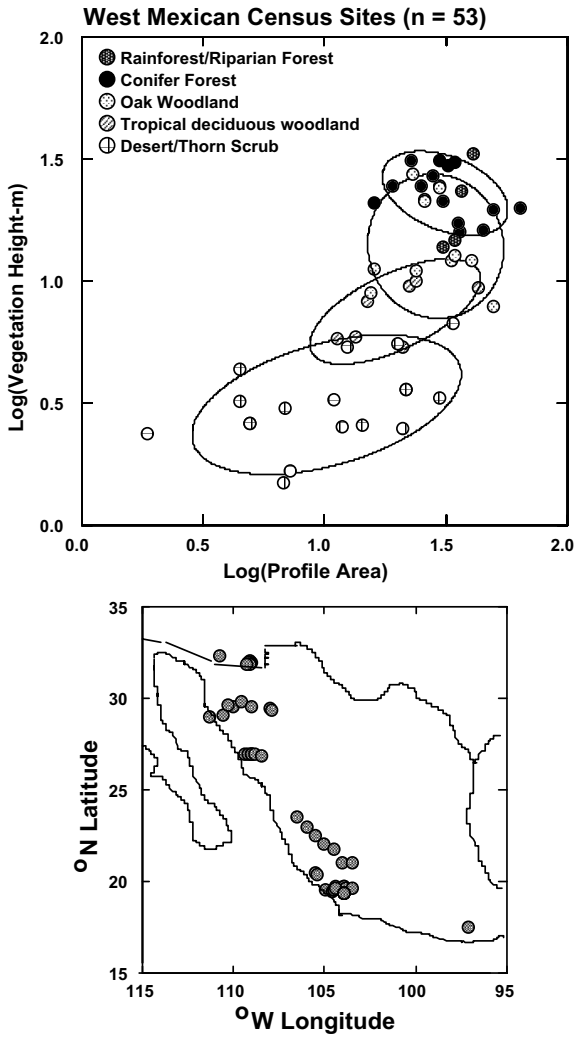

Figure 8—Locations of sites in West Mexico where observations on overwintering species that breed in Grand Teton National Park have been accumulated. Sites are depicted by vegetation structure and grouped into habitat categories (above; cf. *fig. 1*), and set by geographic location (below).

Some GTNP breeding species also breed in western Mexico. Chipping Sparrow breeds in pine-oak and pine woodlands in the Sierra Madre Occidental, in habitats that are the closest structural equivalents of its GTNP breeding habitats (*fig. 10*, *upper right);* no wintering Chipping Sparrows were encountered on the West Mexican transects. Lincoln's Sparrow (*Melospiza lincolnii*) and Brewer's Sparrow are common breeding species in GTNP, and Lark Sparrow (*Chondestes grammacus*) is an uncommon breeding species there. These three sparrows winter in western Mexico, but only Lincoln's Sparrow winters in habitats similar in structure to some of those in GTNP in which it breeds (*fig. 10, lower left*). The other two species are found in winter in low thorn scrub and desert habitats that are much different from their breeding grounds. Note that "similarities" in vegetation structure are assessed with respect to vegetation height and density only; there may well be other aspects of habitat that are more pertinent to certain, even many, bird species, than those summarized by the habitat variables that I measured. There are many breeding emberizines in western Mexico, besides the Chipping Sparrow of the woodlands and Black-throated Sparrow of the deserts already mentioned (*fig. 10*, *upper right*). The residents include species of the large genus *Aimophila*, some five species of which are shown in breeding habitats in *fig. 10* (*lower right*); these include Stripe-headed Sparrow (*A. ruficauda*), Rufous-crowned Sparrow (*A. ruficeps*), Rusty Sparrow (*A. rufescens*), Rufous-winged Sparrow (*A. carpalis*), and Black-chested Sparrow (*A. humeralis*). The presence of these breeding species might well influence the habitat options for wintering emberizines.

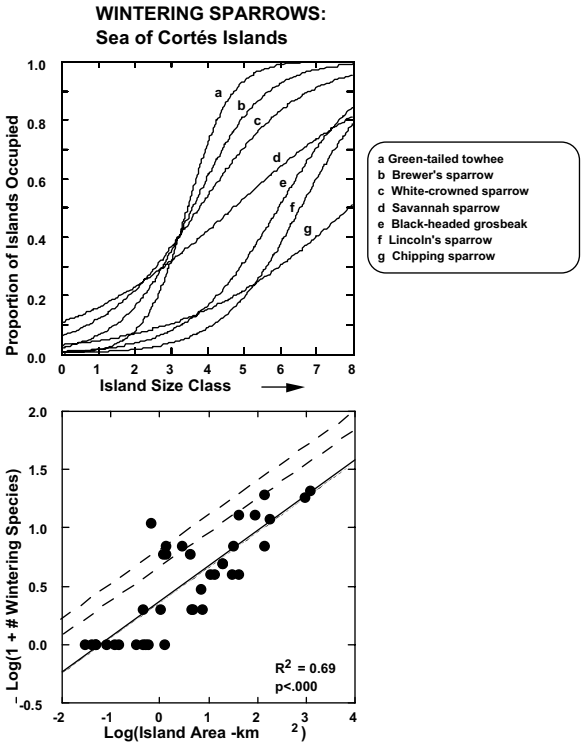

Figure 9—Many of the emberizine sparrows that breed in Grand Teton National Park winter in desert and near-desert habitats, and occur on islands in the Sea of Cortés. They differ in their incidences over island size (upper), but islands are occupied by numbers of wintering species in proportion to the numbers of resident species on the island, suggesting an "ideal free" distribution of the wintering birds. From Cody and Velarde, 2002.

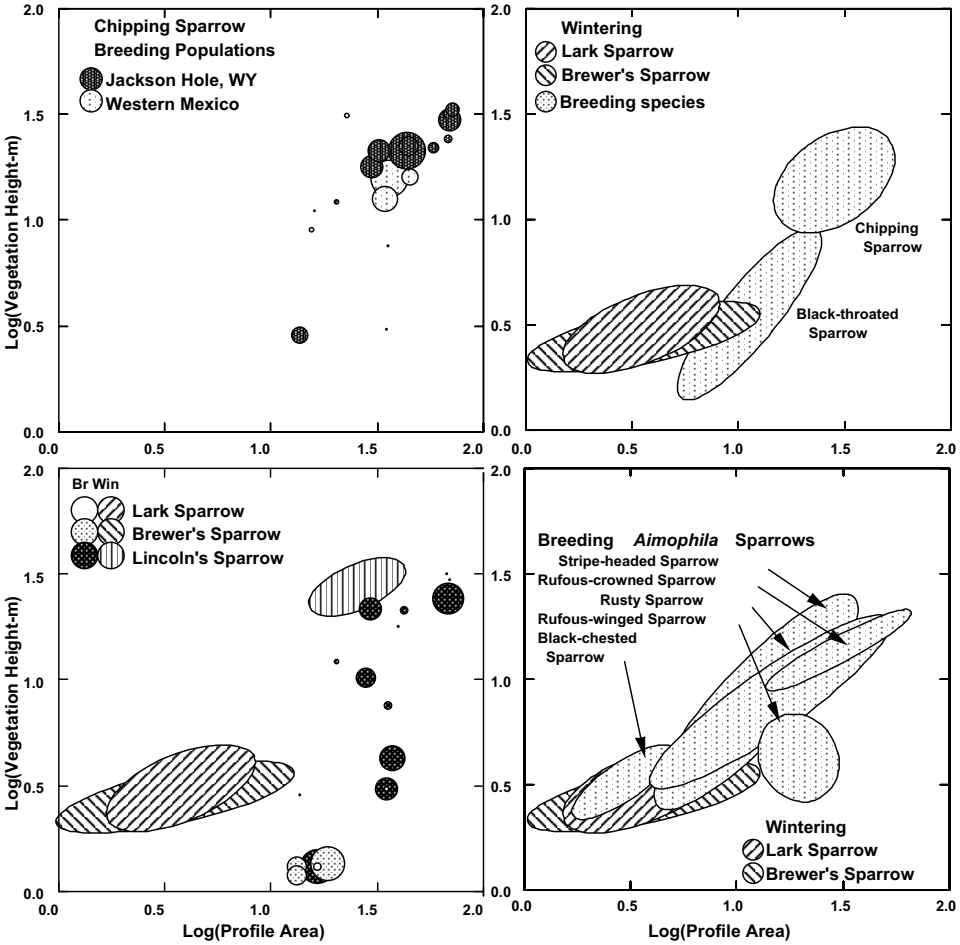

Figure 10—Chipping Sparrow breeds in similar habitats in GTNP and in western Mexico (upper left). Lark, Brewer's, and Lincoln's Sparrows winter in western Mexico, in habitats relatively dissimilar (first two species) or similar (last species) to their breeding habitats (lower left). The wintering sparrows encounter a wide range of resident species in western Mexico, the breeding ranges of which are shown (stippled, upper and lower right). Generally the wintering sparrows winter in lower and more open habitats than those used by the breeding birds.

Turdine Thrushes

Another common GTNP breeding species that, like the Chipping Sparrow, also breeds in western Mexico is American Robin (*Turdus migratorius*), where it is common in woodlands and forest in the upper Sierra. GTNP robins almost certainly winter within the U.S., many likely close to their GTNP breeding habitats, and thus they would not encounter their western Mexican conspecifics. Two GTNP breeding thrushes that do occur this far south are Hermit and Swainson's Thrushes, where they winter in pine- and pine-oak woodlands similar to their breeding habitats. The latter can be found at somewhat lower elevations in deciduous woodland, a difference that parallels the differences between the two species in GTNP where Hermit Thrush, but not Swainson's Thrush, is restricted to conifers. Here again there are resident breeding species, including two congenerics of the wintering birds, Russet and Orange-billed Nightingale- thrushes (*Catharus occidentalis* and *C. aurantiirostris*, respectively). These and other residents, including three *Turdus* species (White-throated Robin [*T. assimilis*], Rufous-backed Robin [*T. rufopalliatus*] along with American Robin), the Eastern Bluebird (*Sialia sialis*), Brown-backed Solitaire (*Myadestes obscurus*), and the Aztec Thrush (*Zoothera pinicola*), all breed in habitats similar to those in which the wintering thrushes occur (*fig. 11*, *right, upper and lower*). These local residents must constitute a survivorship challenge to the migrants in tough years. Note that migrant GTNP Mountain Bluebirds (*Sialia currucoides*) winter in open desert habitat, typically farther north in the Mojave, and migrant Townsend's Solitaires (*Myadestes townsendi*) are encountered chiefly in tropical deciduous woodland; both are too rare in my surveys to be shown in the figure. Both migrants therefore avoid their congenerics in the pine-oak and pine forests at higher elevations.

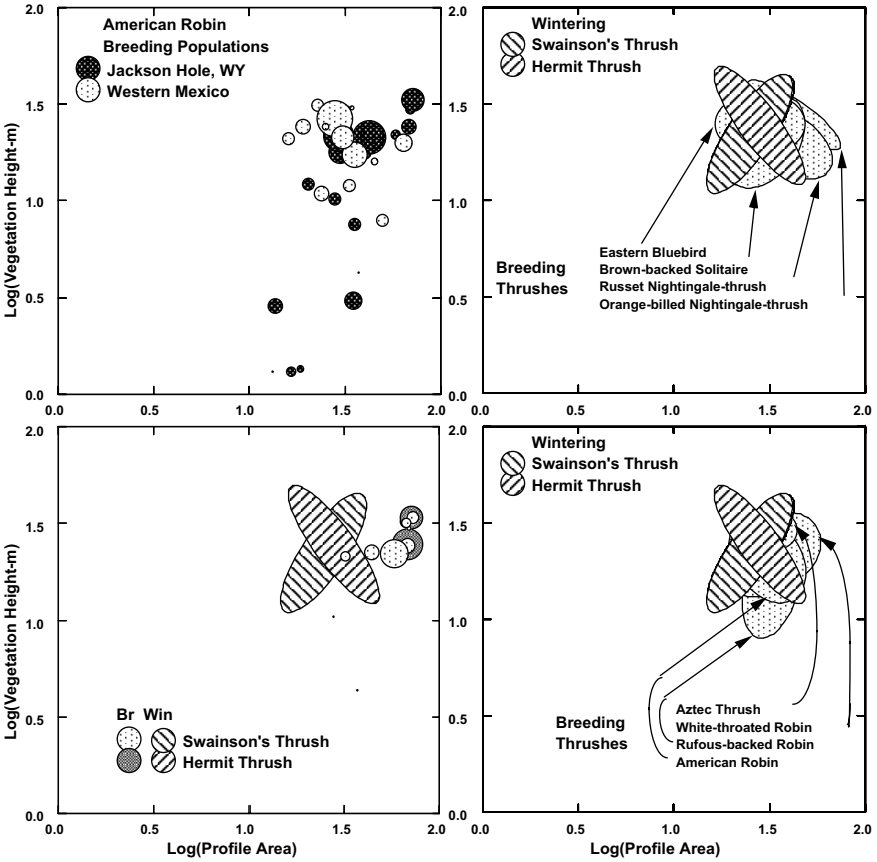

Figure 11—American Robin (upper left) breeds in similar habitats in western Mexico do Grand Teton National Park birds, which winter further north. Hermit and Swainson's Thrush winter in Mexican habitats most similar to their breeding habitats (lower left), even though these habitats support breeding and resident populations of numerous other thrushes, including two conspecific nightingale-thrushes (upper right) and others (lower right).

Paruline Warblers

Lastly I discuss the paruline warblers, which are common both as GTNP breeders and as wintering species in western Mexico. Two species, Yellow-rumped Warbler and MacGillivray's Warbler (*Oporornis tolmei*), winter in habitats relatively similar to their breeding habitats (*fig. 12*, *upper*), but in winter they occupy a much wider habitat range, being found in lower and more open vegetation. Two other species, Orange-crowned Warbler (*Vermivora celata*) and Wilson's Warbler, breed characteristically in tall willows and low aspens in GTNP (*fig. 12*, *lower*), but in winter, by contrast, are found in much taller vegetation, ranging from deciduous woodland to oaks and pine-oak.

The wintering warblers are faced with a diverse array of resident warblers in western Mexico, where my surveys recorded 11 species of migrants and 16 species of residents or locally breeding species (*Figure 13*). In *Dendroica* warblers (*fig. 13*, *upper left*), four migrant species (Yellow-rumped Warbler, Hermit Warbler [*D. occidentalis*], Townsend's Warbler [*D. townsendi*] and Black-throated Gray Warbler [*D. nigrescens*]) encounter resident Grace's Warbler (*D. graciae*) in the pines and pine-oak woodland. Note that the migrants are largely separated by geographic range in the breeding season (three are members of the same "superspecies"), and secondarily by habitat (with e.g. Black-throated Gray Warbler largely an oak woodland, rather than conifer, species in its breeding range). Thus they would seem to have the potential for far more congeneric competition in winter than they do at their breeding sites. In *Vermivora* warblers, three migrants and two breeding species occur over the Mexican habitats. The residents segregate by habitat, with Crescent-chested Warbler (*V. superciliosa*) typical of oak woods and Lucy's Warbler (*V. luciae*) breeding in tall thorn scrub and open deciduous woodland. The migrants tend to occur in more open habitats, with differences amongst them in habitat use that mirror the differences in their breeding habitats: Virginia's Warbler (*V. virginiae*) in lower scrubby habitats, Orange-crowned warbler (*V. celata*) in lower, more open, woodland and Nashville Warbler (*V. ruficapilla*) in taller, denser woodlands.

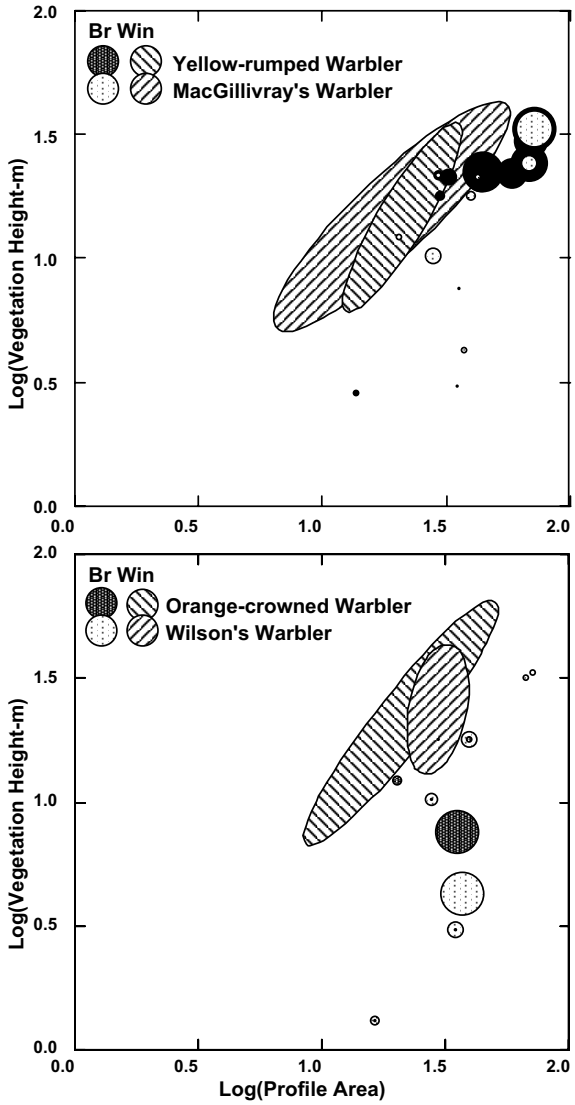

Figure 12—The winter habitats of common Grand Teton National Park breeding warblers in western Mexico may be similar (upper two species) or quite different (lower two species) from their breeding habitats.

Four other migrant species are depicted in the lower parts of *fig. 13*, where the habitat usage of additional breeding species is shown. The Central American endemic *Basileuterus* breed in the dense understory vegetation of the higher woodlands and forests; three species are represented here (Golden-crowned Warbler [*B. culicivorus*], Golden-browed Warbler [*B. belli*], and Rufous-capped Warbler [*B. rufifrons*]), in habitats co-occupied by wintering MacGillivray's and Wilson's Warblers. Of particular interest is the American Redstart (*Setophaga ruticilla*), which I found wintering exclusively in the coastal rainforest patches in western Mexico. Its closest ecological counterparts among the breeding birds are the *Myioborus* redstarts (a chiefly South American genus), Slate-throated (*M. miniatus*) and Painted (*M. pictus*). However, these residents are exclusively pine-oak and pine forest species, and have no contact with the wintering American Redstart.

Weather and West Mexican Winters

It is possible that variations in winter conditions in western Mexico are responsible for some of the variation in breeding bird densities of GTNP migrants. ENSO events, which have little impact on the Jackson Hole weather, apparently have decreasing effects to the south along the Pacific Ocean coast. However, it appears that western Mexico is unusually dry in these years; major cities from Sinaloa and La Paz (Baja California) south to Acapulco, with one exception in one year, recorded well below average rainfall in the winter months January-March of the ENSO years 1988, 1991, 1992, 1995, and 1998. Presumably drier winters in a generally arid region could impair the survival of wintering birds. Looking back at *Figure 3*, Chipping Sparrow breeding densities dipped in 1993, 1995, and 1998, all years immediately following ENSO winters. The Wilson's Warbler crash in the Wet Willows (*fig. 4*) followed two consecutive ENSO winters, 1991-92 and 1992-93. These associations suggest that variation in breeding densities may be dominated by phenomena occurring far from the breeding habitats.

Coda

The observations and figures discussed above present only a cursory overview of where migrants occur and which breeding or resident relatives they might encounter. It does not elucidate the many other ways in which migrants and residents may differ in their ecologies at tropical and subtropical latitudes (e.g. in foraging height, behavior, spatial disposition, sociality, diet, etc.), on which a good deal of information has been forthcoming in recent years. The emerging picture, supported by many of the references I have cited but still hazy, is that contrary to earlier views migrant birds fill rather precise ecological roles on their wintering grounds. These roles appear in some cases to be at least as circumscribed as those they fill on their breeding grounds. Some species are philopatric to the same wintering sites, some remain localized while others may be itinerant; some species integrate into mixed-species flocks, while others forage independently in edge, gap, or tree-top territories. Indeed, if breeding birds at high latitudes capitalize on seasonal flushes of temporarily abundant resources, there is a potential for even more fine-tuning of foraging ecologies, relative to resources and the constellation of consumers that vie for them, in wintering than in breeding grounds.

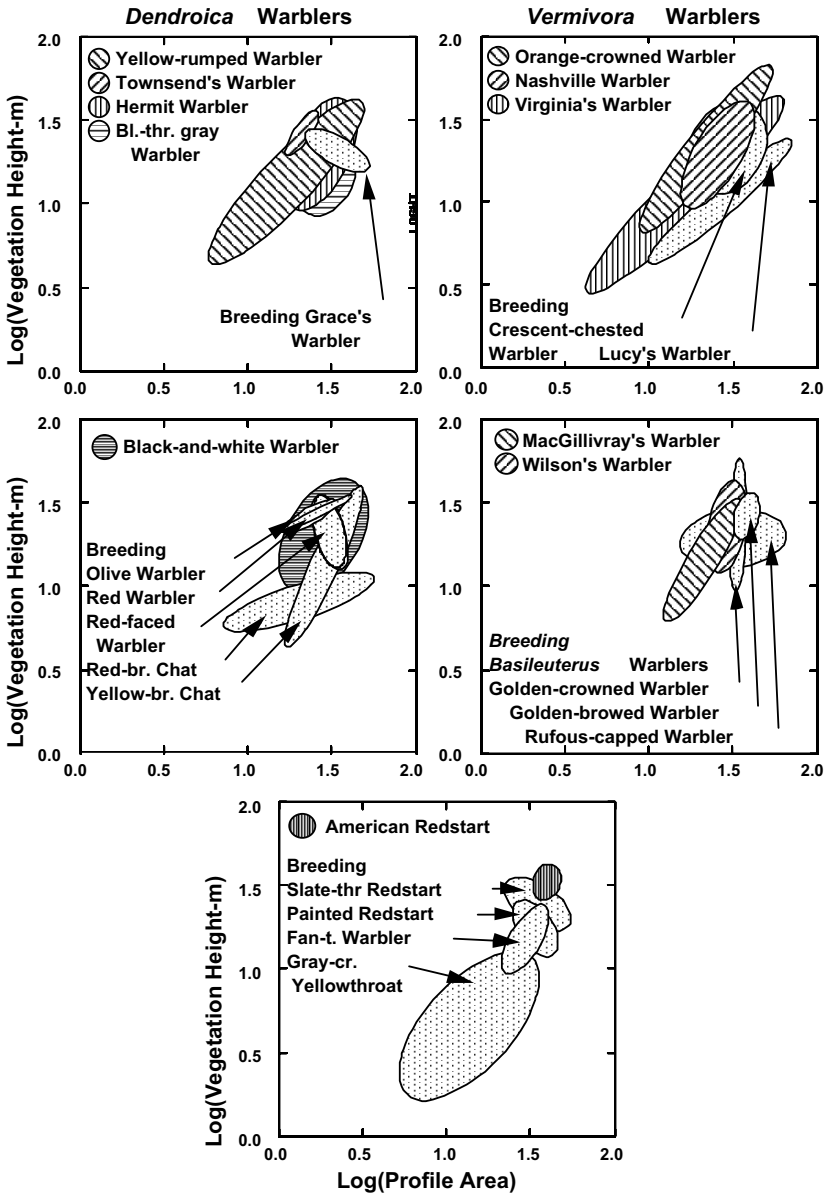

Figure 13—Wintering warblers in western Mexico encounter a wide range or breeding or resident species there. Migrant *Dendroica* warblers tend to occupy similar pine and pine-oak habitats as the resident Grace's Warbler (upper left), but migrant *Vermivora* warblers tend to occur in more open habitats than the two resident species (upper right). The winter habitat use of four other migrants are shown, including American Redstart (lower), which is marginal in Grand Teton National Park, and Black-and-White Warbler (*Mniotilta varia*), a species of eastern hardwood forests. Scientific names of species not mentioned in the text include Olive Warbler (*Peucedramus taeniatus*), Red Warbler (*Ergaticus ruber*), Red-faced Warbler (*Cardellina rubrifrons*), Fan-tailed Warbler (*Euthlypis lacrimosa*), Gray-crowned Yellowthroat (*Geothlypis poliocephala*), Red-breasted Chat (*Granatellus venustus*) and Yellow-breasted Chat (*Icteria virens*). See text for discussion.

Clearly our understanding of the details of migrant bird ecology is at best imperfect and the generation of a holistic perspective that incorporates both breeding and wintering aspects is not yet close at hand. Facile yet true, even the most accurate and comprehensive of monitoring efforts of breeding populations will be extremely limited in their explanatory power if the birds spend half the year elsewhere facing completely different challenges—more than half in the case of birds on the Neotropical wintering grounds! And even the "northern" half of the equation seems in jeopardy, with limited material input, and apparently limited interest, from governmental and regulatory agencies in precise, definitive, and coordinated monitoring programs. Technology is certainly a boon, but cannot begin to replace an essential commitment to competent, well-funded and -managed basic field research. It does not cost much to keep able and eager young researchers

in the field watching birds, but we seem particularly slow in developing programs that harness this talent. Surely studies that closely integrate the ecologies of breeding with non-breeding populations will prove to be a tremendously attractive and rewarding arena for future research.

Acknowledgments

My summer work in Grand Teton National Park has been facilitated by the Resource Management Office of the Park, especially S. Cain, and by the University of Wyoming/National Park Research Center, especially its current director Hank Harlow. The monitoring project at the Park has benefited from many able field assistants, chief among which in its earlier days was G. Shrott; currently S. Wolff is the project's most energetic proponent. L. Robinson graciously provided his weather data from the Moran Dam NCDC station. I am grateful to D. Hutto and R. Sallabanks who provided useful and thoughtful, though perhaps overly generous, reviews of the manuscript and pointed out many errors and obscurities. The participation of my family (Daryl Ann, Rosie, and Tim) has greatly enhanced the pleasures of the research, even beyond the Teton birds and scenery.

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The American Ornithologists' Union and Bird Conservation: Recommitment to the Revolution[1,2]

John W. Fitzpatrick[3]

Introduction

Exactly one hundred years ago, with North America in full-fledged environmental crisis, prominent members of the American Ornithologists' Union (AOU) participated in major political and social upheaval. A century of unrestrained exploitation had reached catastrophic proportions, with Passenger Pigeons and Eskimo Curlews representing only the tip of an iceberg. Birds as diverse as parakeet, egrets, ducks, terns, and plovers were plummeting. AOU leaders, led by one of the union's founders and first editor of *The Auk* (J.A. Allen), had argued publicly and lobbied privately alongside civic leaders to establish the continent's first wildlife protection laws and to monitor their consequences. Based on these efforts, the conservationist President Theodore Roosevelt would create over fifty national wildlife refuges by Executive Order and sign dozens of bills containing conservation statutes before leaving office. Today, we take for granted both the birth of the conservation movement and the crucial roles of government and scientists within it. A hundred years ago this was the stuff of revolution, and the AOU was intimately involved.

Does the revolution continue? Yes, of course it does. Infrastructure, laws, resources, and even professional scientific societies dedicated to conservation of biological diversity continue to grow stronger by the year. The question is, does the AOU still play a role? I suggest that we do, albeit with fervor that has ebbed considerably since the heady, early years of the conservation movement. Today it is time to renew our commitment and amplify our role. As a scientific body rooted in the very origins of this revolution (Barrow 1998), the AOU rarely has had as much opportunity as it now does to carry the banner and take part in the battle. Chief among our allies are two remarkable consortia that emerged in the 1990s, Partners in Flight (PIF) and the North American Bird Conservation Initiative (NABCI).

The premise of PIF seems so obvious that one wonders why it took until 1990 to be fully articulated: genuine, large-scale, long-term conservation of American birds and their habitats will be accomplished only via *explicit coordination* among a large and diverse constituency of organizations and individuals. At national meetings in Estes Park, CO (Finch and Stangel 1993, Martin and Finch 1995), Cape May, NJ (Bonny et al. 2000), and Asilomar, CA (Ralph and Rich this volume) and at countless smaller ones in between, the methods and goals of PIF have remained steadfast over its first decade: find consensus, prioritize action plans, and mobilize new resources among public agencies, private NGOs, academic professionals, and natural-product industries in order to leverage expertise and capacity in a collective effort to protect bird populations.

A catchy rallying cry, "keep common birds common," differentiated PIF's approach early on from the narrower focus on threatened and endangered species more typical of government-engaged conservation initiatives. I take the liberty of offering the following as a more robust mission statement for PIF and its sister initiatives:

> *Ensure persistence of all American bird populations in their natural numbers, natural habitats, and natural geographic ranges, through coordinated efforts by scientists, government, industry, and private citizens.*

"Birds Are Just Like Ducks"

PIF focused originally on Neotropical migrant land birds, many of which were perceived to be in rapid decline as the end of the 20th Century drew near. For good reasons the mission soon expanded to encompass all land birds not otherwise managed under game bird laws or waterfowl management plans of the United States and Canada. A brilliant summary phrase, first uttered by Gary Myers, Executive Director of the Tennessee Wildlife Resources Agency, became a PIF mantra: "Birds are just like ducks!" If waterfowl populations across North America could be stabilized via science-based management plans coordinated across government agencies and the private sector, why not apply the same approach to land bird populations? Indeed, key to the demonstrated success of today's North American Waterfowl Management Plan (NAWMP) are two elements: (1) a *science-based plan* incorporating annual monitoring and population esti-

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

[2]Reprinted by permission of the American Ornithologists' Union and The Auk.

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mates, rigorous statistical modeling, explicit priority-setting for habitat conservation, and regionally based partnerships (called Joint Ventures) representing efficient delivery systems for conservation action; and, (2) *lots of money*, which flows from sources both inside and outside of government (e.g. duck stamps, hunting licenses, Pitman-Roberts tax revenues, private contributions to NGOs such as Ducks Unlimited). As Gary Myers and others observed 10 years ago, accomplishing the mission of PIF will require these same two elements: good planning and significant, new resources.

Prioritization and Planning

PIF organizers addressed some important realities immediately. Surely the most difficult paradox in conservation (faced by every organization attempting to base conservation action on sound scientific principles across large geographic scales) is the need for globally scaled priorities but locally based delivery systems. To help resolve this paradox, the International Association of Fish and Wildlife Agencies developed proposals to fund four PIF Regional Coordinators and one National Coordinator. The U.S. Fish and Wildlife Service stepped up and delivered, using its own funds and also Pitman-Roberts funds allocated through consensus of state wildlife agency directors. The U.S. Forest Service, Department of Defense, and dozens of state wildlife agencies have also contributed significantly to funding PIF initiatives, as have private organizations such as American Bird Conservancy, The Nature Conservancy, Rocky Mountain Bird Observatory, and Cornell Lab of Ornithology.

Regional coordinators engaged researchers, NGOs, and wildlife offices in state-by-state and provincial working groups to develop a system for prioritizing North American bird species at global and regional scales, so that action plans could be directed preferentially to those species and habitats facing the most immediate threats (Beissinger et al. 2000, Carter et al. 2000). At the same time, coordinators began assembling data and searching for consensus to develop more than fifty individual bird-conservation plans treating all physiographic regions and U.S. states (Pashley et al. 2000). Canadian scientists and conservation leaders helped develop the PIF-U.S. planning process, and today are preparing similar plans for Canadian ecoregions. Mexican scientists recently began the process of species assessment for the entire Mexican avifauna, and soon will commence ecoregional planning along the lines of the U.S. and Canadian models. A continental synthesis of bird conservation strategies for the U.S. and Canada (*North American Landbird Conservation Plan*) is in its final drafting as this commentary goes to press. The next version will incorporate Mexico.

The community of academic ornithologists participated in the early stages of the PIF process, particularly in the Research Working Group, but its involvement waned as conceptual debate gave way to the hard work of organizing and attending meetings, assembling literature, committing to ranking criteria, and writing conservation plans. We have the PIF Regional and National Coordinators to thank that the huge initial job is now largely complete. In many respects the more interesting work—implementing, evaluating, refining, and revising the plans with on-the-ground work—is just beginning. In every ecosystem and at every landscape scale, opportunity exists again for research ornithologists to become involved.

"All Birds, All Habitats" and Birth of NABCI

PIF helped catalyze a union of several bird conservation initiatives during the late 1990s under a banner officially spawned by creation of the trilateral Commission for Environmental Cooperation (CEC) under the North American Free Trade Agreement. The North American Bird Conservation Initiative (NABCI) brings together long-standing initiatives such as the NAWMP and PIF with more recent ones such as the North American Waterbird Plan, the U.S. Shorebird Conservation Plan, and the Important Bird Areas programs of Audubon, BirdLife International, and American Bird Conservancy. Under NABCI, all of North America including Mexico (but, unfortunately, still excluding the Caribbean; see below) is divided into "Bird Conservation Regions" based the ecoregional classification systems of Omernik (1987, 1995) and Wiken (1986).

An important, still fluid relationship exists between NABCI's Bird Conservation Regions (N = 38 in the United States and Canada, plus about 30 more in Mexico) and the longer-standing Joint Ventures managed under the NAWMP. The latter represent explicit delivery systems, directing resources toward on-the-ground projects that improve long-term management of waterfowl habitat (remember, the *W* in *NAWMP* stands for *waterfowl*). Under the NABCI framework, however, "all birds, all habitats" expresses the modern goal for implementation. Joint Ventures are being modified, and new ones are being developed, to embrace the broader goals of all-habitat conservation.

A measure of success in all this planning and synthesizing is that upland, non-game species identified as high-priority by PIF are now playing significant roles in the awarding of grants under NAWMP and under grants from the new Neotropical Migratory Bird Conservation Act. Obviously, this vital step in the revolution—integration of the infrastructure for investing in waterfowl, shorebird, and landbird conservation—will stall if its financing

remains zero-sum. As was the case exactly a hundred years ago, new resources must be added to the effort if the revolution is to succeed. In this context, it is worth acknowledging—and assisting—efforts by NGOs (especially Ornithological Council, Wildlife Management Institute, The Nature Conservancy) to generate legislation that would dedicate significant new federal funding for wildlife conservation.

Measurable Goals for 2012

A maturing infrastructure is emerging for accomplishing large-scale, long-term conservation across the continent (by conservation, I refer only to measurable and permanent habitat protection *on the ground*). How will we know if this new revolution in American bird conservation is proceeding on track? Of particular relevance to the AOU, how will be know if scientists are playing as large a part in the revolution as they could and should? I suggest that a few measurable targets and timelines are appropriate, and offer the following as specific mileposts we can help attain, both individually and as a professional society. Ten years from now, late in the year 2012, I propose that we measure how many of the following goals have been achieved in the effort to conserve birds of the Americas and their habitats.

1. *Fewer gaps in understanding of population trends*. From tundra to rainforest, a large number of species undergo population expansions, declines, or fluctuations about which we understand far too little to suggest long-term management guidelines. Filling these gaps will require enormous investment both in monitoring programs (see below) and in creative, intensive studies of single species (e.g., Olive-sided Flycatcher [*Contopus cooperi*] significantly declining in every part of its range) or ecological assemblages (e.g., tundra-breeding shorebirds or grassland sparrows, both exhibiting large-scale declines). But also important is the synthesis of existing data and theory to advance the conceptual basis upon which we make judgments about the likely future trajectory of populations. This is one arena where the members of the AOU are uniquely qualified to increase their contributions.

2. *Redundant, question-driven monitoring of all bird species.* Effective conservation requires habitat management, which, in turn, requires accurate information about both status and population ecology of component species. Although several powerful bird-monitoring programs have produced valuable data since the 1960s, vast gaps still exist. Largely uncovered by any comprehensive monitoring schemes are boreal and arctic Canada (principal breeding grounds for hundreds of species), Mexico (wintering grounds for hundreds of species and breeding grounds for dozens of habitat-restricted endemics), and the Caribbean (proportionally, the most critically threatened avifauna in the Western Hemisphere; Stotz et al. 1996). Even within the coterminous United States, habitat-specialists with patchy distributions remain poorly tracked, numerous biases exist in survey methods (e.g., Sauer et al. 1994), and monitoring projects continue to grapple with statistical issues such as variable detection probability (e.g. Nichols et al. 2000). As pointed out by many monitoring experts over the past decade (e.g. Ralph et al. 1995), it is essential that we expand our arsenal of census approaches, so that results for individual species can be compared and pooled among projects, and we leave no species uncounted.

3. *Effective methods for monitoring difficult-to-detect species.* Particularly challenging for estimating population trends accurately are those species with habits, population densities, or ecological requirements rendering them difficult to detect by any conventional census method. Most notorious are marsh dwellers (Ribic et al. 1999), nocturnal species, and certain breeding raptors. Many of these species appear to be declining, but existing census techniques are inadequate to conclude even this with confidence, let alone to employ as long-term measures of management success. New technologies such as remote acoustic monitoring will be especially important in this context.

4. *Scientific auditing of monitoring projects and conservation plans produces adaptive responses in both.* A paradox for conservation is that knowledge is always incomplete, yet the scale of ongoing human impact on ecosystems demands action without delay. Resolution of this paradox depends absolutely on adherence to scientific methods in our conservation practices. Specifically, we probe, test, experiment upon, and challenge the assumptions and framework upon which we base our plans and our actions, and we do so without embarrassment. Conservation plans and management practices can be modified continually to reflect current knowledge, as long as all parties approach the challenge with this adaptive framework. Recently, for example, The Nature Conservancy formally instituted this adaptive research cycle throughout the organization as its *modus operandi* for accomplishing large-scale conservation. Its challenge, and that facing *all* conservation agencies and NGOs, is to approach land management as a scientific experiment, investing the talent and resources required to measure accurately the consequences of management alternatives. The vital role of research ornithologists in meeting this challenge is clear: opportunities abound today for conducting field experiments that test the assumptions of conservation plans and directly dictate new management

decisions. Testing the assumptions of conservation plans can be accomplished even while addressing some of the most basic conceptual issues in ecology (e.g. Winter and Faaborg 1999, Winter et al. 2001).

5. *Habitat management in place to stabilize all high-priority species in Canada, the United States, Mexico, and the Caribbean*. The rubber must meet the road. Simply having plans in place does not accomplish conservation. Ten years from now the vision statements represented by PIF and NABCI planning documents should have led to measurable action and results on the ground, or they were colossal wastes of time. Let us commit even more specifically: by 2012 every bird species ranked today as having high conservation priority should be under habitat management that intends to stabilize or increase its overall numbers. Uncertainty as to best management options for so many species is no reason for inaction. Rather, as discussed above, areas of uncertainty represent needs and opportunities for research as we implement best-guess management scenarios. Ten years is not a long time. Although the process of implementing bird conservation plans indeed has begun, it needs to be ramped up a hundredfold to meet the target proposed here. Moreover, as long recognized by PIF planners, conservation plans and implementation efforts under the NABCI banner need to expand to encompass the Caribbean region, home to some of the most endangered bird species in the hemisphere.

6. *Substantial new funding supports all-bird conservation*. Federal, state, and private infrastructures for funding conservation initiatives today are insufficient to meet the challenges of the all-bird approach, especially as it expands to incorporate Mexico and the Caribbean. Using the highly successful waterfowl model as inspiration, we must invigorate the efforts to dedicate new funds for upland, waterbird, shorebird, and tropical birds and their habitats. As the world's dominant economy, and by far its largest consumer of energy and resources, the United States must lead the way in creating a funding infrastructure that leaves out no bird or habitat. As discussed below, the AOU must redouble its own commitment to amplifying funds for conservation action. Countless avenues exist for doing so without sacrificing our basic research mission.

7. *NGOs shepherd bird conservation*. Mission-focused not-for-profits (including scientific organizations such as the AOU) must supply the ultimate guidance system for American bird conservation. Well-intentioned and well staffed as many public agencies are, their procedures and infrastructure often inhibit genuine adaptive management. Collaborating NGOs can make all the difference in setting long-term objectives, engaging in self-criticism, adjusting management strategies in mid-course, measuring results, and willingly dividing the labor required to achieve long-term conservation. NGOs also can draw on the resources of private industry on behalf of ecosystem protection (e.g., The Nature Conservancy and Disney in Florida) and conservation science (e.g., Audubon and Ford Motor Co.), whereas industry and government often find themselves adversarial over the very same issues. The 10-year challenge for NGOs: coordinate better among ourselves to take full advantage of our respective strengths, our access to industry, and our dedication to mission. PIF and NABCI remain crucial to this coordination.

8. *Bird conservation objectives stewarded by dedicated coordinators*. The most important jobs get accomplished because specialists are hired to do them. Today we have a comprehensive set of bird conservation plans to implement, test, criticize, and improve upon specifically because skilled individuals were hired to compile and write them. As these plans permeate the conservation infrastructure for the all-important implementation phase, it is equally vital that regional specialists be hired to track research and management accomplishments, keep the plans fresh and updated, coordinate research objectives, catalyze interactions among partners and funding sources, and generally keep the pressure on. Coordination among so many issues and entities will not come about for free. Recently, the U.S. Fish and Wildlife Service took a pivotal step by hiring a full-time PIF National Coordinator (Terry Rich). Funding for PIF Regional Coordinators and additional bird conservation staff facilitated by NABCI remains an uncertain scramble, however, and the AOU would make a significant contribution to American bird conservation by helping to solve this problem.

9. *Citizens engaged in numbers befitting a revolution*. Well-designed surveys confirm explosive growth of bird watching across North America over the past two decades (e.g. Cordell and Herbert 2002). Irrespective of debates over the true number of participants (estimates suggest up to 70 million adults in the United States alone), it is clear that many millions, perhaps tens of millions, of amateur birders regularly enjoy identifying wild birds in wild places. These numbers befit a revolution, yet direct involvement by these amateurs in the challenges outlined here remains at scales in the thousands rather than millions. The huge pool of committed amateurs has enormous potential to assist in monitoring bird populations and measuring their responses to land-management alternatives. A growing body of literature attests to the capacity of citizens even to help answer fundamental scientific questions, including ones of profound importance to conservation (e.g., Hames et al. 2002). To

this end, a new internet-based project jointly sponsored by the Cornell Lab of Ornithology and Audubon (http://ebird.org) permits individuals to contribute to a permanent data archive by logging bird observations through time from any site in North America (Fitzpatrick et al. 2002). Ten years from now the amateur bird-watcher should play a far more important role in conservation science than is the case today.

10. *The AOU actively assisting in American bird conservation*. Just as our forerunners found a hundred years ago, passion and commitment to birds place members of the AOU in a unique position in the conservation revolution. Birds are among nature's most accessible indicators of habitat change, and as teaching tools they are more effective at changing human behavior than is any other group of animals or plants. As the scientific society authoritatively studying birds of the Americas, we owe it to the subjects of our research to foster their long-term survival by recommitting to the revolution. The recently invigorated AOU Conservation Committee has begun producing scholarly reports on knotty issues at the intersection of conservation and science (e.g., Beissinger et al. 2000, Walters et al. 2000; current issues: cormorant control, Red-cockaded Woodpecker [*Picoides borealis*] recovery status, captive-rearing and wild-release of endangered species). In addition, we are examining our annual expenditures and dues structure with an eye toward improving our capacity to contribute to bird conservation directly with our own resources. We should amplify investment in the Ornithological Council if it proves to be an effective agent for increasing conservation legislation and appropriations in Washington, D.C. We should contribute effort and resources to promote coordination and scientific review of bird conservation plans. We should dedicate a percentage of our annual research awards budget to applied projects that test and improve these plans. To ensure long-term growth in our ability to finance conservation science, I suggest that the AOU launch a planned-giving campaign targeting this area explicitly (we have bequests largely to thank for our strong financial condition today).

Coast to coast and tundra to tropics, efforts to conserve American birds and their habitats benefit from an unprecedented amount of research by professional ornithologists. Coordination of these efforts through "all bird" conservation planning of NABCI, to implement what The Nature Conservancy calls "conservation by design," would be an achievement of timeless value. As individual AOU members, time and opportunity are right for each of us to align ourselves with a public or private conservation organization and pitch in. In myriad ways each of us can help grow the relationships among public agencies, conservation NGOs, land managers, and research scientists that will constitute the 21st-century phase of the revolution. Our individual roles will compound upon those we can play collectively through the AOU. Our holy grail—guaranteed persistence of all American birds in natural numbers and habitats—is indeed worthy of revolutionary fervor.

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Biological Objectives for Bird Populations[1]

Jonathan Bart,[2] Mark Koneff,[3] and Steve Wendt[4]

Introduction

This paper explores the development of population-based objectives for birds. The concept of population-based objectives for bird conservation lies at the core of planning in the North American Bird Conservation Initiative. Clear objectives are needed as a basis for partnership, and a basis for program evaluation in an adaptive context. In the case of waterfowl, species for which large demographic datasets provide a rich ground for analysis, there have been successes in formal, model-based scenarios for setting and tracking objectives. The approach used for waterfowl may allow uncontrollable environmental effects to be modeled, improving the evaluation of conservation actions. Setting such objectives for many landbirds seems difficult because data is often sparse and guidelines to avoid arbitrariness are few. A disciplined approach to setting objectives will be needed to achieve broad societal support for landbird conservation, and to provide a basis for the broad-scale conservation practices that most non-endangered landbird species need. We must set objectives for work on birds, but we will not want to expend the effort to set objectives for all birds in all areas - the current approach in identifying species for conservation priority will serve to provide a pool of candidate species for objective-setting.

Objectives for Managing Bird Populations

Many outcomes may be envisaged in a conservation plan for birds. They could include those usually anticipated for endangered species (establishing new populations, maintaining viable populations, accomplishing approved recovery plans) as well as efforts to keep common birds common. In some cases we may wish to reduce population numbers. The objectives can serve many functions such as marketing tools, as a basis for establishing other program objectives such as habitat objectives, or as agency performance indicators.

As is discussed in greater detail below for selected examples from work underway, bird conservation objectives should be achievable, communicable, understandable, consistent with other conservation plans, fit with the right scale for implementation, be measurable with current monitoring methodology, comparable among regions that share the species and across scales, quantitative, and robust to uncontrolled environmental variation. No system for bird conservation planning has all these desirable characteristics. Nevertheless, objective-setting should work towards these ideals.

The North American Bird Conservation Initiative envisages a hierarchy of objective-setting from the continental level down through a series of smaller scales. It sets a goal that "Populations and habitats of North America's birds [are]… protected, restored or enhanced through coordinated efforts at international, national, regional, state and local levels, guided by sound science and effective management."

This descent through scales to "step-down" continental population goals to regional population planning baselines greatly increases complexity. For example, model-based monitoring and comparison of predictions of models of population-environmental associations can be used to define local habitat targets and allow steps to implement conservation actions. However uncertainty is introduced throughout this process - Are the population models adequate? Will the habitat intervention have the predicted effect? Will local monitoring be adequate? Will environmental or social factors mask the intended effect? Is monitoring of treatment, response, regional habitat, regional populations, or range-wide populations accurate and precise? Are there threats to populations that we do not know about? Are there off-site effects that limit population growth? Can regional populations be linked reliably to the continental targets?

The three case studies provided below show how these problems are being tackled continentally for waterfowl and landbirds, and regionally in the Intermountain West Joint Venture for all bird species.

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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Biological Objectives and the North American Waterfowl Management Plan

One hallmark of the 1986 North American Waterfowl Management Plan (NAWMP; U.S. Department of the Interior and Environment Canada 1986) was an unprecedented international agreement on objectives for selected North American waterfowl populations. Duck population objectives were derived largely from average breeding population levels of the 1970s in geographic areas and for species that had well-established duck population monitoring. The decade of the 1970s was chosen to reflect general societal acceptance of waterfowl population levels. That period exhibited a range of environmental conditions in the prairie-parkland region, an important breeding area characterized by dynamic habitat conditions. Goose and swan objectives reflected more recent changes in the distribution and abundance of these species and were consistent with objectives developed through consultations mostly within waterfowl management flyways. Population objectives for waterfowl were intended to meet both consumptive and non-consumptive societal interests.

As noted in the 2003 Update to the NAWMP (in prep.), waterfowl population objectives serve three important functions related to communications, planning, and evaluation. First, population objectives establish the NAWMP's purpose as the maintenance of waterfowl populations, and identify habitat conservation as a primary means to this end. Explicit objectives for species conservation facilitate the communication of Plan priorities with policy-makers, conservation partners, and the public. Second, waterfowl population objectives provide a basis for cohesive regional conservation planning and evaluation, of value for habitat programs as well as for harvest management. Third, population objectives provide a benchmark for assessment of the status of North American waterfowl. To fulfill these functions, NAWMP population objectives must be quantitative and comparable to the results of operational monitoring programs.

The continental population objectives of the NAWMP provide a foundation for cohesive regional waterfowl conservation planning through the geographic structure of Habitat Joint Ventures and Bird Conservation Regions (BCRs). Several methods have been used to apportion the continental population objectives to regional levels. Each of these methods requires assumptions about seasonal waterfowl redistribution and the relationship between regional and continental populations. Continental objectives, once apportioned at the regional level, can become the basis for the development of regional conservation objectives.

Regional habitat conservation objectives derive from the species population objectives. Regional habitat objectives are ultimately derived from conceptual or empirical models that describe the effects of habitat and weather variability on waterfowl populations. To accommodate knowledge or data gaps, planning models are based upon assumptions that may be explicit or implicit. To make a plan, conservation specialists develop a suite of strategies or actions believed to be cost efficient in attaining regional habitat objectives, and thereby contribute to the population management targets. In developing conservation strategies, planners consider the present condition and distribution of regional habitats and make predictions about proposed conservation measures and the circumstances under which to apply specific treatments. Assumptions made throughout the planning process, when explicitly stated, can be viewed as management hypotheses, and monitoring and research activities can be developed to assess their validity and adjust conservation priorities as required (Anderson et al. 1996, Williams et al. 1999).

The utility of population objectives as measures of NAWMP performance is limited if the confounding effects of environmental variation are not taken into account. Moreover, it is not always possible to enumerate Plan habitat accomplishments, particularly in the case of environmental policy successes (Williams et al. 1999). Regardless of these limitations, significant, long-term declines in waterfowl populations from NAWMP objectives indicate a cause for concern and indicate the need for increased management attention. The development of objectives that are scaled to reflect the effects of natural environmental variation on population size is one proposed method to improve the utility of NAWMP continental population objectives as performance measures (Williams et al. 1999).

Similarly, population objectives apportioned at smaller geographic scales serve a valuable planning function but exhibit increasingly troublesome controllability problems as measures of management performance. This is because annual variation in regional population abundance of highly migratory species is in part a function of processes unrelated to the condition and availability of habitats within a region. At least two approaches can be envisioned that would improve the utility of smaller regional population objectives as performance metrics. First, scalable regional objectives of the kind applied at larger scales could be developed to control for population changes resulting from natural variations such as short-term weather patterns. Secondly, local management objectives could be stated in terms of specified vital rates instead of abundance, thus isolating the effect of that regional habitat within the annual population cycle. Objectives at local scales reflect underlying population dynamics models, and

these incorporate the targeted vital rates as well as other concerns such as density dependence. The challenge in focusing in to smaller geographic and temporal scales is in understanding the appropriate demographic and environmental parameters. The correct formulation of these scale-dependent population-environmental relationships is not only important to the establishment of useful population-based performance metrics, but also in the setting of regional habitat objectives and conservation strategies which are predictably related to population objectives.

The PIF Process for Setting Biological Objectives

The Partners in Flight (PIF) Continental Plan (in prep.) includes range-wide population targets for a selection of the 448 landbird species included in the Plan. Species were selected either because of perceived risk to their sustainability (Watch List Species), or because they exhibited high value for regional stewardship (Stewardship Species). Targets are not provided for species listed under the Endangered Species Act (in the United States, ESA) or the Species at Risk Act (in Canada, SAR) because legislated targets undergo greater scrutiny and have greater weight than the general targets established in PIF. The general objective in the PIF plan is to maintain current populations, or to return declining species' numbers at least to their level in the late 1960s. This period was selected because the targets it implies were believed to be achievable and realistic for most of the species, because PIF recognized that extensive losses and modifications of habitat since the European settlement of North America were not likely to be reversed to a significant extent, and because reliable trend data does not exist for most landbirds prior to the mid-1960s when the Breeding Bird Survey (BBS) was initiated. The population objectives were based on degree of population change since 1966, according to the BBS where applicable and any available supplementary information elsewhere. The targets are expressed as desired proportional increases in population size. Four possible objectives were defined:

1. *Increase population size by 100 percent*: This objective was established for all species that have declined ≥50 percent during 30 years. It was the goal for nearly a third of the 100 Watch List Species and for four Stewardship Species not on the Watch List.

2. *Increase population size by 50 percent*: This objective was established for all species that have declined 15-50 percent during 30 years. It was the goal for 23 Watch List Species and for 17 Stewardship Species not on the Watch List.

3. *Maintain population size*: This objective was established for species with stable or increasing populations. It was the goal for 37 Watch List Species and more than half the Stewardship Species not on the Watch List.

Estimates of current population size were used to derive desired population sizes. For example, the estimated current Brewer's sparrow population size is 16 million, and the goal was to double population size. The numerical target was thus set at 32 million birds. The authors emphasized, however, that the biological objective was defined by the categories above, not by the specific numerical targets some of which will probably change as better information is obtained on current population sizes. While these large-scale targets are expected to help motivate regional planning, complexities will develop in efforts to step down to the Province, State, and Bird Conservation Region levels, just as has occurred for waterfowl. In many cases it is expected that new priorities will emerge, together with a shifting of objectives towards habitat quality and quantity and locally-influenced vital rates of birds. The challenge will remain to maintain relevant links to the larger scale population objectives. Results of this work will be posted on the PIF web site, http://www.partnersinflight.org.

Biological Objectives in General Conservation Programs

The Intermountain West Joint Venture (IWJV) provides a current example of regional planning. It is developing habitat conservation targets based on consideration of larger scale population objectives for all bird groups. Each State in the IWJV is setting its own habitat targets, and a simultaneous effort is being made to link these to compatible regionwide targets. The process thus has both step-up and step-down elements. The initial goals will be based on birds but results will be circulated to other conservation planning groups in the hope that agreement can be reached on westwide "conservation goals", not just bird conservation goals. The smaller the scale of planning becomes the more this broadening of species coverage makes sense, as we have seen how population objectives for species often shift to overall environmental factors at smaller scales. The report describing the analysis for IWJV birds is expected to have the following sections.

1. Introduction: review of conservation plans prepared by the Joint Ventures, bird initiatives, the agencies, and others, with emphasis on plans that

include quantitative conservation targets; summary, identifying gaps by taxon and region.

2. How the west has changed: summary of major changes in the western environment since settlement by people of European descent; emphasis on changes that have reduced the quality of bird habitats but also including discussion of how changes have affected other animals and plants.

3. Expected future trends: summary of the expected major changes in the next several decades emphasizing changes that will reduce the carrying capacity of the environment for natural communities, especially birds (e.g., grazing, fire, water shortage, invasive species, development); estimates of how much degradation will occur if current trends continue.

4. Opportunities for conservation: identification of the major opportunities to reverse the negative trends identified in #2 and avoid the threats identified in #3 (e.g., the Farm Bill; private donations to The Nature Conservancy, Ducks Unlimited and other groups; the ESA; actions by regulatory agencies such as Environmental Protection Agency); assessment of how much progress can be made by using these opportunities.

5. The westwide conservation goals: quantitative conservation targets, consistent with, and based on, targets in conservation plans but adding additional targets where none has been established to produce westwide goals; discussion of how the targets were derived (e.g., emphasizing habitat or ecological processes); identification of how success will be measured emphasizing birds (e.g., density, fraction of birds paired, productivity).

6. The westwide conservation strategy: suggestions for how the goals can best be met including coordination, research needed, and roles for major participants.

Biological objectives will be formulated from these habitat conservation goals for selected species by (1) describing which habitat the species uses, (2) assessing how dependent each species is thought to be on this habitat, and (3) estimating how much the species' habitat will change if the conservation goals are achieved. For example, if breeding habitat for the species is expected to double, and unless there are clear indications that the species is limited by nonbreeding habitat, then the predicted population response - and the biological objective for the species - will be a doubling of population size. These predicted outcomes will be compared to the population objectives set by individual bird initiatives as one way to describe the expected accomplishments of the proposed conservation plan.

This approach to setting biological objectives differs from the high-level ones above in two fundamental ways. First, the large-scale plan objectives are based solely on birds (including their use by people); they thus present desired integrated outcomes for birds but lack details of the highly complex delivery processes evident at smaller spatial and temporal scales. The targets described here, in contrast, are meant to be fully achievable at the implementation scale and, therefore, to include other considerations such as needs of species other than birds, costs, opportunities, and a more detailed analysis of effects on people (e.g., the plan might call for locating habitat close to human settlements to increase the economic benefits these communities receive). The westwide conservation goals are thus fundamentally about more than just birds, though bird population targets are certainly being heavily used in setting the conservation goals. Second, the large-scale, species-based population objectives of continental plans are linked to measures of success of the regional plans but cannot be the sole determinant of that success. Thus, if the goal is to double the population size of a species, but this does not occur despite the regional conservation goals being met, then an investigation should be undertaken to determine why the expected increase did not occur. The investigation might reveal that habitat quality was not as high as expected, which might lead to additional restoration efforts. Alternatively, it might turn out that the species was limited by events in the wintering range of the species outside the IWJV area, in which case the discrepancy between predicted and observed population response would not be viewed as indicating a failure of the conservation program.

Comparison of the Approaches and Suggestions for Future Work

In the examination of work now underway several conclusions are possible:

1. At the highest geographic planning scale, objectives are being set quantitatively for species of birds. These objectives coincide well with international obligations for migratory birds treaties and the resulting federal bird protection mandates.

2. Rangewide objectives may not be set for all species. Instead, a selection of species with high priority for conservation may be made to make the planning effort more tractable.

3. At smaller geographic scales greater planning detail is required, leading to increased complexity

and shifted emphasis in objective setting. New priorities may emerge, species coverage may broaden, and models may be used to convert species conservation objectives to habitat objectives, to isolate controllable population parameters, or to control for external environmental factors.

4. The problem remains to maintain linkages among objectives at all scales, to meet the requirements of program development, partnership building, communication, marketing, evaluation, and to ensure that the desired conservation results are achieved.

5. Further work is needed in many areas, notably development of adequate monitoring programs, research into the root causes of bird population change, and development of ways to link the annual population cycle of highly migratory species to the effects of local interventions.

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Setting Numerical Population Objectives for Priority Landbird Species[1]

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Abstract

Following the example of the North American Waterfowl Management Plan, deriving numerical population estimates and conservation targets for priority landbird species is considered a desirable, if not necessary, element of the Partners in Flight planning process. Methodology for deriving such estimates remains in its infancy, however, and the use of numerical population targets remains controversial within the conservation and academic communities. By allowing a set of simple assumptions regarding species' detectability, relative abundance data from Breeding Bird Survey (BBS) routes may be extrapolated to derive first approximations of current, total species populations, both rangewide and within Bird Conservation Regions. Preliminary comparisons with independently derived abundance estimates (e.g., Breeding Bird Atlas) suggest that these population estimates are within acceptable limits of accuracy for many species. If restoring populations to early BBS levels (late 1960s) is desirable, trend data may be used to calculate the proportion of a species' population lost during this 35-year period, and an appropriate population target may be set. For example, in the Lower Great lakes/St. Lawrence Plain, BBS data indicate a current (1990-1999) population of about 14,000 Red-headed Woodpeckers (*Melanerpes erythrocephalus*) and a loss of >50 percent since 1966. A reasonable conservation objective, therefore, may be to double the Red-headed Woodpecker population in this region over some future time period. We encourage the use of numerical population estimates and conservation targets in implementing conservation objectives for priority landbird species, and we encourage further research that leads to refinement of our methodology and our estimates.

Key Words: Breeding Bird Survey, landbirds, population estimates, population objectives.

Introduction

Conservation actions are most effective and efficient when they are directed towards meeting explicit objectives or targets. In North America, conservation of birds and their habitats has benefited from numerical population targets developed by regional or species experts. For waterfowl and wetland habitats in particular, species-specific population targets were developed and published as part of the North American Waterfowl Management Plan (NAWMP 1986). Population targets were based on estimates from survey data from the 1970s, and these served as a baseline for restoring populations of declining species. These numerical targets, when scaled to waterfowl flyways and expressed in terms of habitat-acres or other limiting factors, have proven to be a very compelling tool for generating billions of dollars for wetland protection and restoration (NAWMP 2003). More recently, the U.S. Shorebird Conservation Plan has set numerical population targets for priority shorebird species, based on current survey data and also using early 1970s as a baseline (Brown et al. 2001). Other examples of numerical population targets exist in the numerous recovery plans for endangered species in the United States and Canada.

Conservation planning for the roughly 500 species of non-endangered landbirds in North America has been proceeding at the regional and national levels through the international initiative, Partners in Flight (Pashley et al. 2000). Although much discussion has taken place regarding the desirability and possible nature of population objectives for landbird species, we are just beginning to develop methods for deriving quantitative population targets for widespread and still-numerous species. Such numerical targets require the estimation of species' population size at several geographic scales, knowledge of recent historic population trends, and agreement on timeframes and baselines for setting desirable targets. In this paper we outline a pragmatic and repeatable approach to estimating landbird population sizes using indices from the North American Breeding Bird Survey (BBS, Robbins et al. 1989), the most comprehensive and continuous survey of landbird populations in most of the United States and southern Canada. We also discuss the many assumptions and issues that bear on the use of this approach. In addition, we propose a simple protocol for assigning numerical conservation targets for specific regions, based on current population estimates for high-priority species and knowledge of recent population trends. We present preliminary results of population estimation and objective

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California**.

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setting for two Bird Conservation Regions (BCRs) in which active bird-conservation initiatives are underway, the Atlantic Northern Forest (BCR 14) and Lower Great Lakes-St. Lawrence Plain (BCR 13). Finally, within these two regions, we compare our BBS-derived population estimates with independent estimates derived from alternative datasets. Additional details and results of our population estimation methods are found in the PIF North American Landbird Conservation Plan (Rich et al. 2004). Our goal here is to introduce a standardized methodology for incorporating numerical population objectives into landbird conservation plans and to stimulate further refinements of the population estimation approach.

Methods and Assumptions

Our primary method for estimating population size of widespread landbird species involves extrapolation using indices from the North American Breeding Bird Survey. Specifically, indices of relative abundance (birds per BBS route) were derived from every route surveyed during the 1990s. Relative abundance indices for each bird species were then averaged across all routes within each Bird Conservation Region. By making a series of assumptions regarding area sampled, habitats sampled, and detectability of individual bird species, we can extrapolate BBS' relative abundance to estimate total population size within geographic areas or for the entire continent.

Estimating Population Size from BBS Relative Abundance

A BBS route consists of a series of 50 point counts, distributed along a 39.4 km (24.5 mile) roadside tran-sect. The starting point and direction of each route are assigned randomly within 1-degree blocks of latitude and longitude in the United States and Canada (Robbins et al. 1989). Each route traverses a variety of habitat types; taken together, the routes in a region potentially provide a random sample of the broad landscape within that region as a whole. At each of the 50 BBS stops on a route, observers are instructed to count all birds seen or heard within a 3-minute period, out to a radial distance of 400 m (1/4 mile). The maximum area sampled by each route, without making any corrections for species' detectability (see below), is roughly 25.1 km^2 (*fig. 1*).

A formula for estimating regional population density from BBS counts has been presented by Bart (in press). This formula explicitly takes into account the proportion of individual birds that sing (or otherwise are detectable) during the 3-minute BBS stop, the probability that a singing bird will be detected by an observer, and the potential bias due to differences in roadside and region-wide distribution of habitats. An advantage of this formal approach is the ability to calculate error associated with population estimates, and values of 1.0 can be used for probability terms that cannot yet be estimated with empirical data. Bart (in press) provides examples of this approach for a suite of species in shrub-steppe habitats in the western United States.

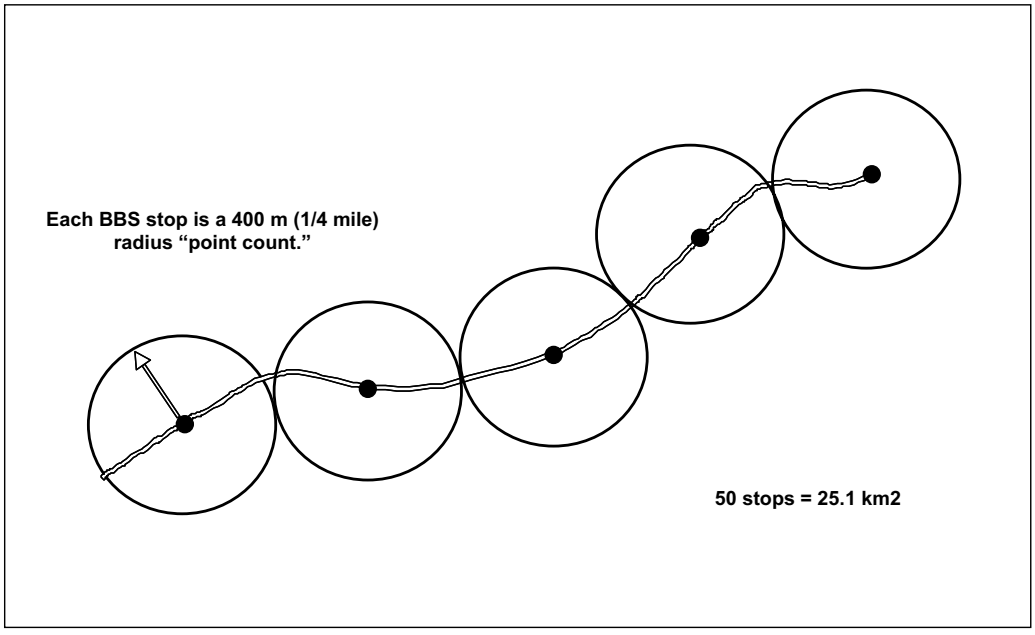

Figure 1— Schematic of a BBS route, illustrating how the 50 roadside points, each sampling out to a distance of 400 m, can sample a maximum of 25.1 km^2.

Assumptions: Habitats

For the purpose of our initial analyses, we assume that (1) BBS routes are randomly distributed across larger landscapes (e.g., BCRs), and (2) BBS routes sample habitats in proportion to their occurrence within the larger landscapes. Because BBS routes are assigned at randomly located starting points, and because BBS coverage is widespread across most of the United States and southern Canada, our first assumption is probably reasonable for most of the BBS coverage area. An exception occurs in boreal and arctic BCRs at the northern limit of BBS coverage, where roadless areas predominate and roads typically sample a geographically biased portion of the landscape.

The second assumption, namely that habitats along roadsides are an adequate sample of habitats throughout the region, is frequently discussed and is considered by some to be a serious flaw of the BBS. Although the capability now exists to test this assumption using GIS, this analysis has not yet been carried out for the entire survey area, or for many local regions. Those few studies that have examined potential roadside bias have presented mixed results. For example, Bart et al. (1995) found that the proportion of forest along BBS routes in Ohio (in a strip out to 280 m from roads) was not significantly different from the proportion in the overall landscape. In an inner strip within 140 m, however, the proportion of forest was significantly less (35 percent) than in the overall landscape, suggesting that for forest-breeding species detected primarily close to roads (see below), BBS would underestimate abundance. Keller and Scallan (1999) found similar results in Ohio and Maryland, with forest habitats under-sampled by 21 to 48 percent and agricultural and urban habitats over-represented along roads. Interestingly, forest-field edge habitats also were under-sampled along BBS routes, whereas early successional and wetland habitats did not differ between on-road and off-road landscapes. Most recently, Bart (in press) found that proportions of major forest, shrub-steppe, and grassland habitats along BBS routes did not differ from the surrounding landscape within U.S. Forest Service Region-4, a large area of the western United States. While we urge a continent-wide GIS analysis of roadside bias in the BBS, which could yield BCR-specific correction factors to plug into Bart's equation, for now we assume no roadside bias in our calculations. Further ramifications of this assumption will be discussed below.

Assumptions: Species Detectability

Our initial approach assumes that all breeding pairs of birds very close to an observer at BBS stops are detected, and that detectability is otherwise a function of distance from the observer. We assume that all species have a fixed, average maximum detection distance on BBS routes across their range, and that these distances can be translated into effective sample areas for each species. Because few published data exist on exact detection distances for a wide range of species, we chose to assign species to one of four detection classes as follows (*table 1*). A majority of birds on BBS routes in many regions are detected by songs or calls in forested or other densely vegetated habitats. A simple method of extrapolating avian density from counts of singing males using detection threshold distances was proposed by Emlen and DeJong (1981), who also provided average maximum detection distances for 11 species of common forest birds. These distances ranged from 72 m (Blue-gray Gnatcatcher [*Polioptila caerulea*]) to 186 m (Wood Thrush [*Hylocichla mustelina*]) and averaged 128 m for the 11 species. Emlen and DeJong (1981) further proposed that numbers of singing males be doubled to obtain a total population. Wolf et al. (1995) also found that most forest birds in northern Wisconsin could be heard to maximum distances of between 125 and 250 m. There was much individual variation, however, and some individuals could be heard at much greater distances. Wolf et al. (1995) also recorded the minimum distance at which individuals of a species could no longer be heard; this distance also averaged 128 m for the 12 species presented. Based on these empirical data, we chose to initially assign most forest birds and other weakly vocalizing species a detectability threshold of 125 m (close to the average in Emlen and DeJong's study). For these species, we assume that all breeding pairs are detected out to that distance, and the effective area sampled on a complete BBS route is therefore 2.5 km^2.

Table 1— *Categories of detection distances and equivalent BBS sampling area for landbirds.*

Maximum detection distance (m)	Effective BBS sample area/route (km^2)	Example species
80	1.0	Brown Creeper, Blue-gray Gnatcatcher, Golden-crowned Kinglet, Ruffed Grouse
125	2.5	Most forest-breeding warblers, Red-eyed Vireo, Downy Woodpecker, accipiters
200	6.3	Thrushes, waterthrushes, wood-pewees, meadowlarks, Bobolink, Song Sparrow
400	25.1	Whip-poor-will, Pileated Woopecker, Red-tailed Hawk, crows, vultures

A second group of species is detected visually or by loud calls over long distances; these include soaring raptors, crows and ravens, Upland Sandpipers (*Bartramia longicauda*), and a few other species with very loud vocalizations (e.g., Northern Bobwhite [*Colinus virginianus*], Pileated Woodpecker [*Dryocopus pileatus*]). For these species, we assume that all breeding pairs are detectable out to the full range of sampling at each BBS stop (i.e., 400 m). The effective sampling area is therefore the same as for the total BBS route, i.e., 25.1 km^2. A third group of species is considered to be intermediate and was assigned a detection distance of 200 m (effective sampling area = 6.3 km^2). These include species such as Bobolink (*Dolichonyx oryzivorus*) and kingbirds (*Tyrannus* spp.) that are detected by a combination of song and visual observations in open habitats.

After initially assigning most forest birds to the 125-m detection threshold category, we made two additional adjustments. First, for species with especially weak vocalizations, such as those with the closest detection thresholds in the above studies (e.g., Blue-gray Gnatcatcher), we created a fourth category with a detection distance of 80 m and an effective sample area for a BBS route of 1.0 km^2. We assigned a few other species that are particularly difficult to detect, such as grouse, into this category as well. Our second adjustment was to move several groups of forest birds with loud or far-carrying vocalizations into the 200-m threshold category. These included Ovenbird (*Seiurus aurocapillus*), most thrushes, pewees, tanagers, and some vireos. Our final estimate of detection-threshold categories was based on a combination of published data, our own personal experience on BBS routes, and consultation with other experienced observers. In the future it should be possible to use species-specific detection distances for a majority of species, rather than the categories used here.

In addition to correcting for detectability due to distance from the observer, we know that detectability also varies with time of day throughout a typical BBS route. Although surveys begin before sunrise, during the peak of vocal activity for many species, a full route takes several hours to complete and numbers of birds detected on later stops may be a small fraction of those detected on early stops. To correct for this variation, we examined the distribution of detections among the 50 BBS stops, for 369 species with at least 10 routes of stop-by-stop data across the entire continental BBS survey. Based on these distribution curves (*fig. 2*), we determined the peak detection probability for each species and then the ratio of peak detections to average detections across the 50 stops. This ratio was used to adjust average numbers of birds per route to peak numbers, as if peak detection lasted throughout the morning. Species-specific correction factors ranged from

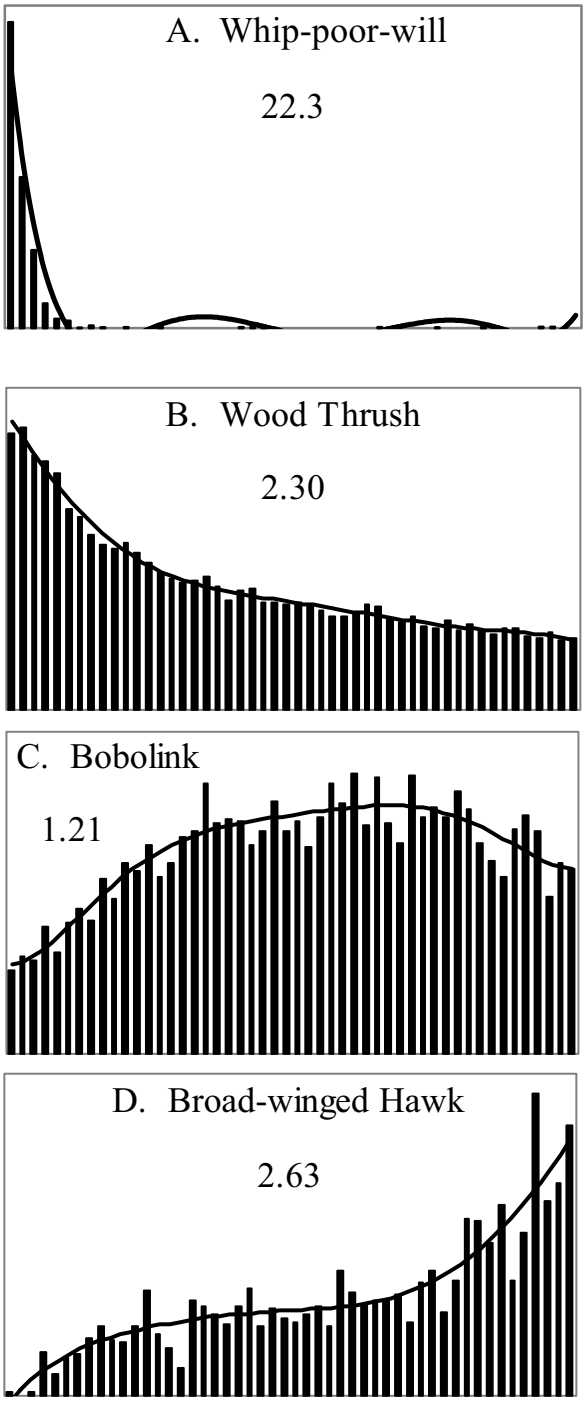

Figure 2— Distribution of detections across 50 BBS stops for four species with contrasting temporal patterns. Lines are 6th order polynomial regressions fit to the data. Numbers are time of day adjustments (max detection / avg detection) used in population estimates.

1.04 (House Finch [*Carpodacus mexicanus*]) to 22.3 (Whip-poor-will [*Caprimulgus vociferus*]) with a median of 1.34 across all landbird species examined (median of 1.32 for diurnal landbirds). Four different types of time-of-day distributions are illustrated in *figure 2*. Using these corrections, we can estimate populations

even for crepuscular or primarily nocturnal species (e.g., Great Horned Owl [*Bubo virginianus*], Common Nighthawk [*Chordeiles minor*]), as long as they are detected on several BBS routes on at least the first BBS stop. For the few species without adequate BBS data to calculate a time-of-day correction, we assigned a value based on another similar species with adequate data, or used the median value. Our time-of-day corrections will tend to be conservative for any species whose peak detection is outside of the BBS sample period, diurnally or seasonally.

Finally, we assume that individuals detected represent one member of a pair, and we therefore double all estimates to derive total number of breeding individuals. This 'pair correction' is most obvious for the many species that are primarily detected as territorial singing males. Even for species in which males and females may be equally detectable, however, our experience on BBS routes suggests that only one member of a presumed pair is usually detected at any given time. Possible exceptions include some corvids, in which both members of a pair are highly vocal, and swifts and swallows, in which both males and females typically forage together over open habitats. A pair correction of 2 (double) may also be high for species with a high proportion of singing but unpaired males. The 'correct' pair correction for all species lies somewhere between 1 and 2 and may be determined empirically with further study.

Comparisons with Breeding Bird Atlas Estimates

Few independent population estimates exist with which to make even crude comparisons with our BBS-derived estimates for common landbirds. One source of such data is the simple order-of-magnitude estimates of breeding populations gathered during Breeding Bird Atlas work in Ontario (Cadman et al. 1987) and in the Maritime Provinces (Erskine 1992). During the course of atlassing in these areas, observers were asked to estimate the total breeding population of each species within 100-km^2 squares. Although these estimates are very crude (e.g., 1, 2-10, 11-100, 101-1,000, 1,001-10,000 or 10,001-100,000 pairs in a square), precision is gained from the very large number of squares sampled. Because atlassers are not restricted to roads, to early mornings, nor to a single peak of the breeding season, atlas data differ from BBS in having a reduced bias against off-road habitats, seasonal changes in breeding activity, and nocturnal species rarely detected on diurnal routes. Atlases also differ by covering larger proportions of the landscape, providing a larger sample size of population estimates, coverage for less common species, and allowing extrapolation based on knowledge of the habitat by the observer.

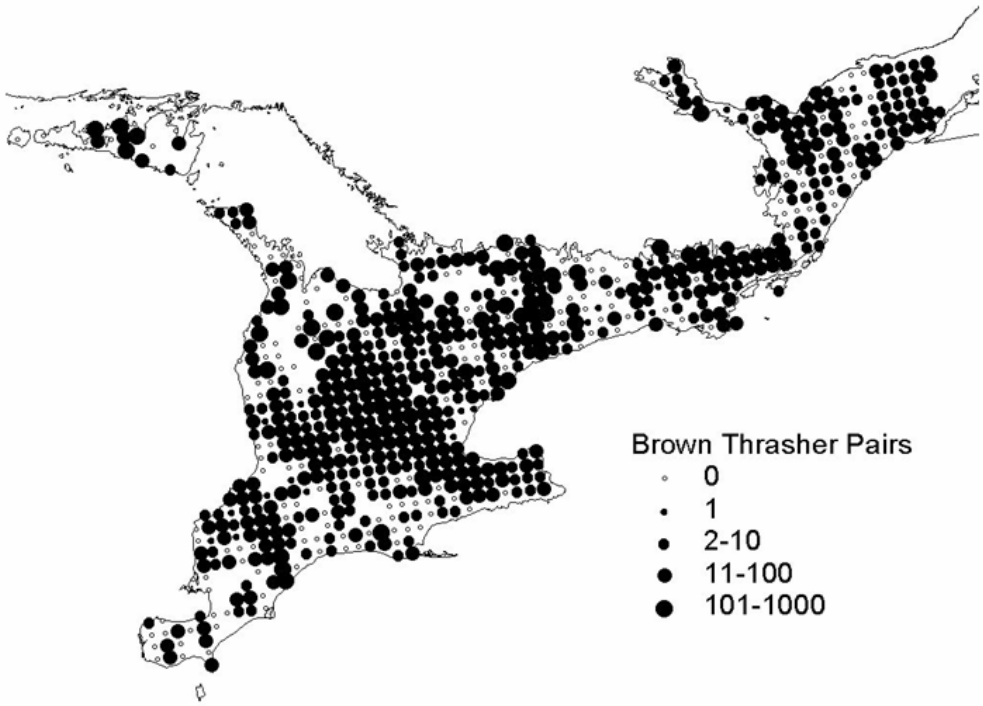

Figure 3— Brown Thrasher pair estimates in 10 x 10 km squares in the Ontario portion of BCR 13, from the Ontario Breeding Bird Atlas, 1981-1985.

To estimate a population in an area covered by breeding bird atlas, we follow Erskine (1992) in taking the midpoint of each categorical range (assuming a Poisson distribution of abundances within each category) as the estimate for the atlas square. These estimates are totaled for each species across all squares in which estimates were made, then extrapolated to account for unsampled squares. This method is illustrated using data for the Brown Thrasher (*Toxostoma rufum*) in the Ontario portion of Lower Great Lakes-St. Lawrence Bird Conservation Region (BCR 13). Brown Thrashers were found in 549 out of 744 censused atlas squares within this region, and estimates within squares ranged across several abundance categories (*fig. 3*). Extrapolating abundance from Poisson midpoints of these categories, and extrapolating to the full 840 squares in the region, we derive a population estimate for the region of 42,369 pairs. We compared atlas-derived population estimates for landbirds present in 25 or more atlas squares with population estimates based on the 28 BBS routes run from 1981-1985 within the same region. We then replicated this comparison using BBS and atlas data from the Maritime Provinces (part of BCR 14), which involved 1682 atlas squares and 39 BBS routes conducted from 1986-1990. In the Maritime comparison, we used estimates from Erskine (1992) only for species where they were based on data from atlassers, disregarding estimates from other sources.

Comparisons with Breeding Bird Census

Another source of density estimates for landbirds is the Breeding Bird Census (BBC), in which observers estimate breeding populations in small plots of fixed area and uniform habitat. We used the Canadian Breeding Bird (Mapping) Census Database (Kennedy et al. 1999) to obtain landbird densities in BCRs 13 and 14 for comparison with our BBS estimates. Because BBC plots are not randomly distributed across the landscape, we use total landbird density as our basis of comparison, rather than density of individual species. We also calculated BBC landbird density within each broad habitat type, and adjusted regional BBC averages according to the proportion of the regional landscape in each habitat type, based on satellite land cover data.

Results

Population Estimates

First approximations of breeding populations were derived for 167 species that were sampled by the BBS in the Lower Great Lakes-St. Lawrence Plain (BCR 13) and for 154 species in the Atlantic Northern Forest (BCR 14). These estimates ranged from roughly 100 breeding individuals for rare breeders such as Dickcissel (*Spiza americana*) and Le Conte's Sparrow (*Ammodramus leconteii*) in BCR 13, and for Peregrine Falcon (*Falco peregrinus*) in both regions, to 10 million American Robins (*Turdus migratorius*) in BCR 13 and 11 million Red-eyed Vireos (*Vireo olivaceus*) and 13 million robins in BCR 14. Breeding population size averaged 488,000 individuals across all landbird species in BCR 13 (398 birds per km^2), whereas populations averaged 792,000 individuals in BCR 14 (340 birds per km^2).

Of particular interest are population estimates for species considered of high conservation concern in these two regions. For BCR 13, we calculated populations for 20 species identified as high priorities by the landbird breakout group of the ongoing BCR 13 bird conservation initiative (see Hayes et al. this volume). Our estimates of regional populations for these species ranged from roughly 400 Short-eared Owls (*Asio flammeus*) to 1.9 million Bobolinks (*Table 2*). We also present average relative abundances on BBS routes in the region, as well as detection distance, effective sampling area, and time-of-day adjustment factors for each of these species. In BCR 14, our population estimates for 20 species with high PIF assessment scores (Panjabi et al. 2001) ranged from roughly 10,200 Whip-poor-wills to 2.1 million Veerys (*Catharus fuscescens*; *table 3*).

Comparison with Breeding Bird Atlas

We obtained independent estimates of breeding populations for 120 landbird species that had abundance data in at least 25 atlas squares and on at least one of 28 BBS routes in the Ontario portion of BCR 13. Correlation between these two sets of estimates was remarkably high (r = 0.95; *fig. 4a*). Two-thirds (66 percent) of species had estimates that differed by less than a factor of 2, and 99 percent were within an order of magnitude of each other. For example, in the Ontario/BCR 13 comparison, the atlas method estimated roughly 1.3 million pairs of American Robin versus 1.8 million pairs for the BBS method. Other close comparisons, representing a wide range of common and rare species, included European Starling (*Sturnus vulgaris*; 1.9 million vs. 2.2 million pairs), American Goldfinch (*Carduelis tristis*; 381,000 vs. 363,000), Hairy Woodpecker (*Picoides villosus*; 24,000 vs. 23,000), Great Horned Owl (5,700 vs. 6,300), and Henslow's Sparrow (*Ammodramus henslowii*; 147 vs. 160 pairs). Other individual comparisons that were not as close may suggest incorrect detectability thresholds, differences in habitat coverage between the two survey methods, or lack of precision for rare species.

Table 2— *Population estimates and numerical objectives for landbird species identified as priority by Hayes et al. (this volume) in Lower Great Lakes-St. Lawrence Plain, BCR 13.*

Species	BBS avg/ route	Max. detection distance	BBS sample area (km^2)	Time of day adjust	BCR population (individuals)	PT	BCR population objective	Numerical target (rounded)
Northern Harrier	0.302	400	25.1	1.29	6,200	3	1.1x pop	6,900
Black-billed Cuckoo	0.746	200	6.3	1.39	66,100	4	1.4 x pop	93,000
Short-eared Owl	0.004	200	6.3	1.60	400	5	2 x pop	800
Whip-poor-will	0.017	400	25.1	22.30	6,100	5	2 x pop	8,500
Red-headed Woodpecker	0.178	200	6.3	1.25	14,200	5	2 x pop	28,000
Eastern Wood-Pewee	3.477	200	6.3	1.12	249,200	4	1.4 x pop	350,000
Acadian Flycatcher	0.271	125	2.5	1.17	51,100	2	Current pop	51,000
Loggerhead Shrike	0.007	200	6.3	1.19	500	5	2 x pop	1,000
Sedge Wren	0.025	125	6.3	1.62	2,600	3	1.1 x pop	2,900
Wood Thrush	6.081	200	6.3	2.30	892,200	4	1.4 x pop	1,200,000
Brown Thrasher	1.499	200	6.3	1.12	107,800	5	2 x pop	215,000
Blue-winged Warbler	0.565	200	6.3	1.21	43,700	2	Current pop	44,000
Golden-winged Warbler	0.123	200	6.3	1.32	10,300	2	Current pop	10,000
Cerulean Warbler	0.100	125	2.5	1.35	21,800	2	Current pop	22,000
Hooded Warbler	0.357	200	2.5	1.20	68,800	2	Current pop	69,000
Field Sparrow	3.572	200	6.3	1.07	243,800	5	2 x pop	490,000
Henslow's Sparrow	0.025	200	6.3	1.66	2,700	5	2 x pop	5,600
Grasshopper Sparrow	0.476	200	6.3	1.47	44,700	5	2 x pop	89,000
Bobolink	24.863	200	6.3	1.21	1,927,000	4	1.4 x pop	2,700,000

Notes: Area of BCR13 is 201,292 km^2. Pair adjust = 2 for all species. For descriptions of detection distance categories, BBS effective sample areas for each species, pair adjustment, time-of-day adjustments and population trend (PT) scores, see Methods.

Table 3— *Population estimates and numerical objectives for landbird species with high PIF Assessment Scores in Atlantic Northern Forest, BCR 14.*

Species	BBS avg / route	Max. detection distance	BBS sample area (km^2)	Time of day adjust	BCR population (individuals)	PT	BCR population objective	Numerical target (rounded)
Broad-winged Hawk	0.190	125	2.5	2.63	143,100	2	Current pop	140,000
Ruffed Grouse	0.218	80	1.0	1.37	214,700	5	2 x pop	430,000
Whip-poor-will	0.016	400	25.1	22.3	10,200	4	1.4 x pop	14,000
Yellow-bellied Sapsucker	3.351	125	2.5	1.40	1,342,700	4	1.4 x pop	1,880,000
Black-backed Woodpecker	0.043	125	2.5	1.81	22,300	3	1.1 pop	25,000
Olive-sided Flycatcher	0.551	200	6.3	1.25	78,700	5	2 x pop	160,000
Veery	10.889	200	6.3	1.67	2,071,600	4	1.4 x pop	2,900,000
Wood Thrush	4.983	200	6.3	2.30	1,302,900	5	2 x pop	2,600,000
Chestnut-sided Warbler	7.622	200	6.3	1.23	1,070,000	4	1.4 x pop	1,500,000
Cape May Warbler	0.371	125	2.5	1.31	139,900	4	1.4 x pop	196,000
Black-throated Blue Warbler	1.988	125	2.5	1.12	639,400	2	Current pop	640,000
Blackburnian Warbler	2.324	125	2.5	1.28	852,700	1	Current pop	850,000
Bay-breasted Warbler	0.727	125	2.5	1.28	267,100	4	1.4 x pop	370,000
Canada Warbler	1.216	125	2.5	1.25	436,500	5	2 x pop	870,000
Scarlet Tanager	1.496	200	6.3	1.14	193,500	2	Current pop	190,000
Nelson's Sharp-tailed Sparrow	0.077	125	2.5	1.92	42,400	3	1.1 x pop	47,000
Rose-breasted Grosbeak	2.731	200	6.3	1.09	340,400	4	1.4 x pop	480,000
Bobolink	7.271	200	6.3	1.21	1,004,100	4	1.4 x pop	1,400,000
Rusty Blackbird	0.179	200	6.3	1.44	29,300	5	2 x pop	59,000

Notes: Area of BCR14 is 358,697 km^2. Pair adjust = 2 for all species. For descriptions of detection distance categories, BBS effective sample areas for each species, pair adjustment, time-of-day adjustments and population trend (PT) scores, see Methods.

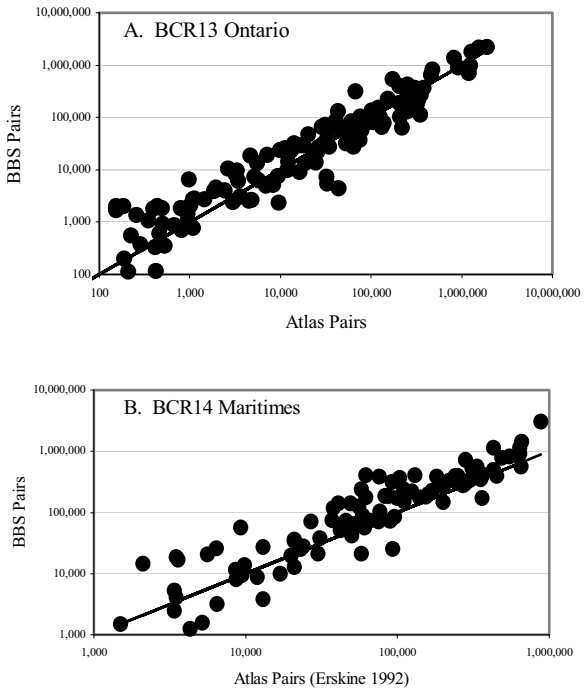

Figure 4— Comparison of BBS- and Atlas-derived population estimates: A. Ontario portion of BCR 13, 1981-1985; B. Maritime provinces (BCR 14), 1986-1990. Line shows equal BBS and Atlas values. Landbirds with atlas estimates from 25+ atlas squares and found on one or more BBS routes are included.

A similar comparison in the Maritime Provinces portion of BCR 14 also resulted in a high correlation (r = 0.91) between atlas- and BBS-derived estimates for 99 species (*fig. 4b*). For this comparison, we relied on Erskine's (1992) calculated estimates, which involved removing the highest 3 percent of abundance estimates for each species, and reducing the midpoint of the top abundance category. We estimate that this trimming procedure reduced atlas population estimates by more than 50 percent, on average, and resulted in conservative (lower) populations relative to our BBS-derived estimates. Still, atlas and BBS estimates were within a factor of 2 for 64 percent of species, and were within an order of magnitude for all species.

Comparison with Breeding Bird Census

Total population density for all landbird species was approximately three times higher when based on Breeding Bird Censuses, compared with BBS-derived density estimates, in both BCRs (*table 4*). Even when BBC densities were corrected for habitat availability in each BCR, BBC densities remained high relative to BBS-derived densities.

Deriving Numerical Population Objectives

To derive numerical population objectives in *tables 2* and *3*, we start with the premise that a reasonable conservation target is to reverse population declines observed over the past 30 to 40 years, as measured by BBS or equivalent survey. Rather than extrapolate annual rates of decline over 30 to 40 years, we chose to use broad classes of population decline as the basis for objectives, as in Rich et al. (2004). For this purpose we used population trend scores (PT) assigned to species in the PIF species assessment process (Carter et al. 2000, Panjabi et al. 2001). These scores of 1-5 are based on BBS population trends (or equivalent) over the entire timeframe of the survey, usually since 1966. A PT of '5' is assigned to species that have declined significantly by at least 50 percent over a 30-year period. For these species, our conservation objective is to double current populations over some future time period, and the numerical target is calculated as roughly twice the current population estimate. A PT score of '4' is assigned to species with less certain declines or significant declines of between 15 and 50 percent over 30 years. For these species we propose an objective of restoring populations based on a 30 percent decline (approximately the midpoint of the 15-50 percent range), which translates to a numerical target of about 1.4 times current population. PT scores of '3' are assigned to species with highly variable, uncertain, or unknown population trends. For these, we suggest a conservative objective of maintaining slightly higher populations in the future until we can acquire sufficient trend data to measure trend; i.e., 1.1 times current population estimates. Finally, for species with stable (PT = 2) or increasing (PT = 1) populations, our conservation objective is to maintain future populations at or above current levels.

Table 4— *Comparison of total landbird density from Breeding Bird Census (BBC) plots vs. estimates based on Breeding Bird Survey (BBS), for BCRs 13 and 14.*

BCR	BBC plots (N)	BBC landbird density (prs/km^2)	BBC density weighted by habitat in BCR (prs/km^2)	BBS landbird density (prs/km^2)	Ratio BBC/BBS
BCR 13	204	592	506	198	2.6
BCR 14	93	632	621	210	3.0

Note: Estimates are for Canadian portions of the BCRs.

Note that this categorical assignment of numerical objectives reduces the reliance on specific BBS trend estimates, which often have wide 95 percent confidence limits, especially in regions with small samples of BBS routes. Using this approach, we present conservation objectives and numerical population targets for several species identified as priorities in BCR 13 (*table 2*) and BCR 14 (*table 3*).

Discussion

We believe that our pragmatic approach, with clearly stated assumptions, can produce useful first approximations of total population size for North American landbirds. Our comparisons with independently derived population estimates suggest that extrapolations from BBS abundance data typically yield estimates well within the correct order of magnitude.

It is likely that our population estimates are conservative for most species because we did not include any correction for birds within maximum detection distance but still not detected during a 3-minute BBS count even at peak detection time of day, e.g., because they didn't vocalize or because observers missed them. Bart (in press) estimated that 30 to70 percent of shrub-steppe birds do not call during a 3-minute count, and a further 20 to 30 percent of birds singing within detection distance are missed by BBS observers. Our comparisons to BBC landbird densities also suggest our BBS-derived estimates are conservative, perhaps by a factor of 3, though it is possible that BBC densities are high if plots were biased to sites with more birds or if densities were overestimated in small BBC plots.

A habitat bias on BBS routes, if present in the region under consideration, would result in under- or over-estimated populations, so is best measured and incorporated into the estimate (Bart, in press). However, even where habitat bias has not been measured, this does not rule out use of BBS-derived estimates to set and track conservation targets, as long as progress towards objectives is measured using the same method. The same studies that documented a bias against forest sampling on roadside routes (Bart et al. 1995, Keller and Scallan 1999) did not find an equivalent bias in terms of the change in land cover over time.

While we are encouraged by the comparisons with other measures of population size, we acknowledge that our estimates are only crude first approximations that might be poor for some groups of birds, or in regions where BBS routes are sparse or strongly habitat-biased. We therefore encourage further research to refine the corrections we have applied so far and to test for and correct any habitat bias in BBS surveys in specific regions. Studies of species-specific detection distances, vocalization frequency, detection probabilities of males and females, and proportion of unpaired birds detected would all be extremely useful for refining population estimates. Our efforts thus far have focused on landbird species, which as a group are reasonably well sampled by BBS. These methods may also be appropriate for some species of waterfowl, shorebirds, and waterbirds typical of landscapes sampled by BBS; testing is needed to confirm this. Finally, our method does not address vast boreal/taiga and arctic regions of North America that are not sampled by BBS. Other methods will be needed to estimate populations of these far-northern breeding species (Rich et al. 2004, Appendix B). We invite additional comparisons and discussion, and we encourage testing of these methods on other species and in other regions.

Even if we accept the first approximation of landbird population estimates as reasonable, using these to set numerical conservation targets remains controversial. Fear exists among academic ornithologists and conservation practitioners that using inaccurate population estimates to set conservation targets may lead to misdirected conservation actions and loss of scientific credibility. Alternative forms of population objectives have been proposed and discussed, including using minimum block sizes of habitats for maintaining 'source' or 'viable' populations, using BBS relative abundance as a surrogate for population size (e.g., achieve a regional density of x birds per BBS route), and using raw trend estimates as objectives (e.g., stabilizing a 2 percent per year BBS decline). Our assumption in using explicit population estimates is that there is compelling value in knowing the magnitude of population change desired and in having easily understood objectives. Population estimates also allow comparisons to independently estimated sources of mortality and a grasp of the magnitude of habitat required to sustain bird populations across the landscape.

Other considerations in setting conservation targets relate to timeframes, historic baselines, and political and social acceptability of objectives. We selected 'early BBS' as a reasonable historic reference because it represents the extent of our knowledge of population trends for most species, and because it is a similar timeframe to that proposed for the restoration of waterfowl and shorebird populations. Just as important, it also allows a comparable measurement of success into the future, using the same BBS methodology. Numerous factors could make it desirable to alter this timeframe, however. For example, some populations and habitats were severely altered long before the beginning of the BBS, and it may be desirable to attempt restoration of these to some earlier baseline. Alternatively, some populations or habitats may have been artificially abundant in the 1960s (relative to pre-settlement conditions), such as some early successional habitats in eastern regions, or populations responding to spruce-budworm outbreaks, and proposing the return to these levels may be inappropriate. Full discussion of these and other factors is critical for setting effective and achievable conservation targets, but such a discussion is beyond the scope of our paper. Our proposed

method for setting numerical targets can be adapted to a variety of baselines or timeframes.

In conclusion, we believe that numerical population estimates and conservation targets for landbird species are useful and achievable. We propose a simple methodology for extrapolating from widely available BBS abundance data, while stating a series of assumptions and acknowledging the limitations of this approach. We encourage further research that aims to refine population estimates and better enables us to understand and use data from the BBS. We further encourage the use of additional survey data, point counts, checklist counts, and other measures of abundance to fill in gaps for species and regions poorly covered by BBS. Finally we encourage the use of population-based conservation targets in continental and regional plans as a compelling means of justifying and communicating levels of desired population and habitat change in specific regions.

Acknowledgments

We thank many individuals throughout the Partners in Flight network for inspiring discussions, formal and informal, on the topics of population estimation and objective setting. In particular, members of the PIF Species Assessment Technical Committee (C. Beardmore, G. Butcher, D. Demarest, E. Dunn, C. Hunter, A. Panjabi, D. Pashley and T. Rich) were instrumental in helping develop the methods and arguments presented in this paper. J. Bart contributed to early discussions and provided a draft of his methods for extrapolating BBS counts to population size. J. Sauer contributed insights into use of BBS data. In addition, we thank the many participants of meetings and workshops who encouraged us to continue our efforts. Our analyses and approach rely on data collected by many others; we thank all volunteers who participated in breeding-bird surveys and atlases, and the organizations that made those data available. This paper is a contribution of the Cornell Laboratory of Ornithology and Bird Studies Canada.

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Measuring the Success of Bird Conservation Plan Implementation[1]

Rolf R. Koford[2] and Jane A. Fitzgerald[3]

Introduction

Partners in Flight Bird Conservation Plans (BCPs) have been under development since 1995. Plans are now available for almost all of the physiographic areas and /or states in the continental United States (BCPs can be downloaded at www.partnersinflight.org). Although the format of and information in each plan varies to some degree depending upon the region and approach taken by its authors, every plan includes a list of bird species in greatest need of conservation attention in the planning unit, with those species then grouped into "suites" on the basis of shared general habitat affinities. The relationships of those species and species suites to the habitats and ecosystems they are dependent upon are discussed, and conservation actions thought to benefit the birds in each suite are recommended. Conservation agencies and organizations in each region are then encouraged to form partnerships able to implement habitat improvements "on the ground." The underlying assumption is that the habitat work will result in measurable, positive change in the populations of the priority species over time as a result of the improved conditions.

The methodology for detecting population change, however, should vary depending upon the scale of the project. Projects designed to increase populations at regional or continental scales must somehow be able to assess the combined impact of many local projects on populations of the species they target. Programs such as BBIRD (Conway and Martin (2000), Monitoring Avian Productivity and Survival, and the Breeding Bird Survey (BBS) are used to monitor population change and vital rates (Bonney et al. 2000). Population change resulting from local projects affecting even several thousand hectares may not be detected by large-scale regional monitoring efforts such as the BBS, either because the habitat change has not occurred within close proximity to a survey route, or because the increase in the number of individuals of a given species that occurred as a result of the project may not be significant enough to affect relative abundance at the regional scale. Thus it is also important to evaluate implemented BCPs or similar plans at the scale of those plans. A benefit of this smaller-scale evaluation is that population responses can be more closely associated with specific and quantified changes in habitat conditions than is the case with large-scale evaluations.

We organized the Asilomar conference symposium entitled "Measuring the success of bird conservation plan implementation" primarily to illustrate some ways that bird population responses to habitat improvements have been evaluated for projects affecting habitat at different spatial scales. Three papers addressed that topic.

Evaluating Implemented Plans

The first presentation was a premier example of a large-scale evaluation of duck population responses to habitat work implemented under the auspices of the North American Waterfowl Management Plan's Prairie Habitat Joint Venture in Canada. This example incorporated establishment of plan goals, predictive modeling, a decade of empirical study, and mechanisms for involvement of stakeholders. Although unable to contribute a paper to these proceedings, David Howerter and colleagues shared a few lessons learned in the ongoing biological evaluation of the North American Waterfowl Management Plan's Prairie Habitat Joint Venture. This evaluation was at a fairly large spatial (multiple provinces) and temporal (10 years) scale and focused on breeding ducks. While recognizing that other conservation plans would vary in scale and objectives, they thought that "certain overriding principles will likely be common to all successful evaluations." They reiterated the importance of having a strategy to evaluate the performance of planning models and management actions and that it is essential to have clearly defined goals developed with managers and other stakeholders' input. All parties should agree on how they expect conservation actions to affect progress in meeting the goals. As actions are taken, bird population response can be monitored and progress measured. Howerter et al. found simulation models of the system extremely valuable for working across large spatial scales, as it helped organize thoughts about the important responses and factors influencing these responses. Models also allow biologists to project a range of likely outcomes of various

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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management options. With well-developed models such as the Mallard Productivity Model used in this evaluation, sensitivity analyses will assist in identifying key uncertainties and assumptions (Johnson et al. 1987). These analyses can highlight the factors most likely to influence the accomplishment of plan goals.

Evaluations of population responses often involve considerable intervention in the system. In the case of evaluating how duck populations respond, it is important to have estimates of local breeding densities and nest success. Obtaining data for these estimates involves use of vehicles, nest searches, etc. Open communication among biologists, managers, and any stakeholders should identify and resolve conflicts resulting from the evaluation. Local managers may need help understanding the scale of the biological processes under study and of the information needs. It is useful for biologists to have a strategy for providing useful feedback to local habitat managers and regional planners.

A final point mentioned by Howerter et al. was that the processes of planning, implementation, and evaluation occur as a cycle that may be repeated annually or on longer time scales. These repetitions provide an opportunity to adapt to changing natural and social environments, and increase the likelihood of meeting goals of efficient management and increased understanding of the system.

The second paper, by Jacobs et al. (this volume), is included in these proceedings and the reader is referred there for more detail. It describes both a method for assessing population trends over time in ten grassland bird conservation areas in Missouri and Iowa, as well as one which allows conservationists and planners to evaluate more specifically which habitats and land use prescriptions are supporting target species in the greatest abundance. This example illustrates an evaluation at the BCP and Bird Conservation Area (BCA).

Another evaluation-related at the BCA level, is that of Winter et al. (2001), who tested some of the key assumptions of the grassland BCAs that have been proposed in BCPs. Winter and her colleagues examined the effect of size of patches of native prairie, such as might be core areas of BCAs, and the effect of having these patches bounded by neutral (e.g., small grains) or hostile (e.g., woody vegetation) land cover classes.

The third paper in our Asilomar session, presented by David Krueper, illustrated the response of vegetation and bird populations to the exclusion of cattle from riparian areas along the San Pedro River in southern Arizona. Point counts were conducted one year prior to the removal of cattle and five years after, and documented dramatic increases in riparian obligates, open cup nesters, Neotropical migrants, and insectivores.

Two posters at the Asilomar conference represent evaluation at the local site level. One, included in this section, is a paper by Krietinger and Uptain describing their sample design and results of a study evaluating bird responses to California's Central Valley Project Improvement Act Land Retirement Program. The other poster, by Fletcher and Koford, described changes in bird populations in response to habitat restoration (Fletcher and Koford 2003). Their approach can be summarized as follows: based on an assumption that bird densities in each habitat do not change over time, an evaluation can be done using bird data after the habitat change. Iowa is high on the list of states that have lost virtually all of their native prairie (Samson and Knopf 1994).

Fletcher and Koford estimated how bird communities have changed in the Eagle Lake Wetland Complex, an area with ongoing grassland and wetland restoration, by integrating Geographic Information Systems and recent bird surveys in different habitat types (restored grassland, restored wetland, row crop agriculture, hayfield, and pasture). Predominant land cover of restored areas prior to restoration (early 1980s) included: >80 percent row crop, ~6 percent pasture, <3 percent woodland, and ~1 percent hayfield. Most woodland habitat did not change with restoration; restoration efforts have primarily converted row crop agriculture and pastures into grassland and wetland habitat. Based on amount of land converted, and assuming unchanged bird densities in each habitat, most species have increased in the area, including many species of management concern. For example, the estimated change in the Bobolink (*Dolichonyx oryzivorus*) population was an increase of over 1,000 birds. A couple of species that prefer short or sparse vegetation, such as Killdeer (*Charadrius vociferus*), have apparently declined with grassland and wetland restoration. Fletcher and Koford (2002) also found that abundance in restored grasslands in the Eagle Lake Wetland Complex were similar, with very few exceptions, to abundances in ungrazed prairie remnants in northern Iowa.

The final paper in this section was not an evaluation of plan implementation but was included in the session at Asilomar because it dealt with issues involving planning and evaluation strategies. Daniel Twedt (this volume) provided an evaluation strategy for the Mississippi Alluvial Valley, focusing on a method to determine which species suites should be emphasized at a given site or landscape. Elements of the strategy were quantifying habitat, assessing effects of forest patch characteristics, analyzing demography, and testing population viability.

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An Objective Method to Determine an Area's Relative Significance for Avian Conservation[1]

Daniel J. Twedt[2]

Abstract

Land managers are often concerned with providing habitat that affords the "best habitat for songbirds." However, unless management simply is directed at rare species, it may not be clear which habitats or management options are best. A standard, quantifiable measure to compare the significance of different tracts of land or competing management techniques for avian conservation would benefit managers in decision making. I propose a standard measure that is based on the relative density of each species within a finite area and their respective regional Partners in Flight concern scores. I applied this method to >100 reforested sites in the Mississippi Alluvial Valley that ranged in age from 2 to 32 years. The objectively determined avian conservation significance for each of these reforested sites was correlated with stand age and with my subjective assessment of "habitat quality." I also used this method to compare the avian conservation significance of forested habitats before and after selective timber harvest. Sites with high significance for avian conservation provided habitat for species of conservation concern. I recommend application of this methodology to other sites, and areas under different management, to determine its usefulness at predicting avian conservation significance among habitats and at various avian densities.

Key words: avian habitat, conservation significance, objective assessment.

Introduction

Determining the relative significance of a tract of land for avian conservation is often subjective. If management is directed at a single species, differences in density or productivity of the target species can be compared among tracts and priorities of management action set accordingly. However, often managers are not concerned with a single species but desire to manage habitat that will support a community of species. Even so, managers recognize that different species have different habitat requirements and therefore exhibit different responses to habitat manipulations.

Faced with many options, how can managers objectively evaluate various properties as to their contribution to avian conservation? Similarly, how can the response of many species to competing management scenarios be objectively compared? For example, suppose management actions result in a 20 percent increase in the density of species 'X' but a concomitant 30 percent decrease in the density of species 'Y.' Is this "good" or "bad" for avian conservation? Although total bird numbers declined, if the species that increased in density is of greater management concern, this decline in bird numbers may actually benefit avian conservation!

Criteria that can be used to evaluate the condition of avian habitat and to guide management decisions include observed estimates of species density and Partners in Flight (PIF) concern scores (Carter et al. 2000). Although density may not be indicative of habitat quality (Van Horne 1983), when contrasting avian response to different habitats within similar landscapes or on the same area under different management, it is likely that relative avian densities will reflect the relative value of the habitats or management techniques. Furthermore, reliable estimates of demographic parameters for all avian species on a given tract of land will rarely, if ever, be concurrently available, and density (or at least relative density) is measurable for most species.

Concern Scores as Conservation Ratings

Partners in Flight regional concern scores (http://www.rmbo.org/pif/pifdb.html) vary from 7 to 35 (low score = low vulnerability) for a given species based on vulnerability of that species, both regionally and globally, and their need for management action. Thus, species in any geographic area can be ordered from high to low score. But what is the relative scale of the relationship

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California**.

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among avian concern scores? Should the relationship among these birds be linear, as indicated by their PIF concern scores or does their conservation rating vary relative to their PIF concern score?

If the relationship is linear, an increase of 5 "units of concern" would denote the same increase in conservation significance regardless of the actual concern score. That is, a species with a concern score of 15 would have 5 more units of concern than a species with a concern score of 10 and a species with a score of 30 would have 5 more units of concern than a species with a score of 25.

Within the lower range of concern scores (i.e., lower vulnerability), however, it is likely that the threats to these species are minimal. These species likely are abundant, widespread, and not declining. Generally, increasing the units of concern within this lower echelon of bird species should not engender dramatic changes in habitat management. Conversely, small increases in the units of concern for species with high concern scores (i.e., higher vulnerability) indicate further threats to already vulnerable bird populations. Thus, within the upper echelon of bird species, small increases in the units of concern should warrant a marked increase in management efforts.

Therefore, I suggest that the relationship among PIF concern scores when evaluating their application to conservation of habitats, is not linear but rather an exponential relationship. Within this relationship, each increase in unit of concern generates an increasingly inflated "concern rating" (*fig. 1*). Lower concern scores have corresponding "concern ratings" that are little different, whereas higher concern scores have corresponding "concern ratings" that are widely disparate.

Population Density

What is the optimal density for a given avian species? Obviously, not all species occur in all habitats. However, within appropriate habitats, does a linear increase in the density of a species connote a linear increase in its conservation significance? Even if a linear relationship holds for some range of densities, this is likely not the appropriate relationship at low or high densities. At low densities, at least a single breeding pair is essential for the population to replace itself. However, it is likely that several to many breeding pairs are needed to achieve a reasonable likelihood of sustaining the population (Reed et al. 1988). Thus, I've assumed that for avian conservation, the significance of a species' territory density increases rapidly until this threshold is achieved. Beyond this threshold, I've assumed that all optimal territories are occupied and further increases in densities likely contribute little to the conservation significance of the population. Assuming this asymptotic relationship, with a rapid increase in conservation significance until optimal density is achieved, I used a truncated logarithmic model to express the relationship between observed density and its adjusted density rating (*fig. 2*).

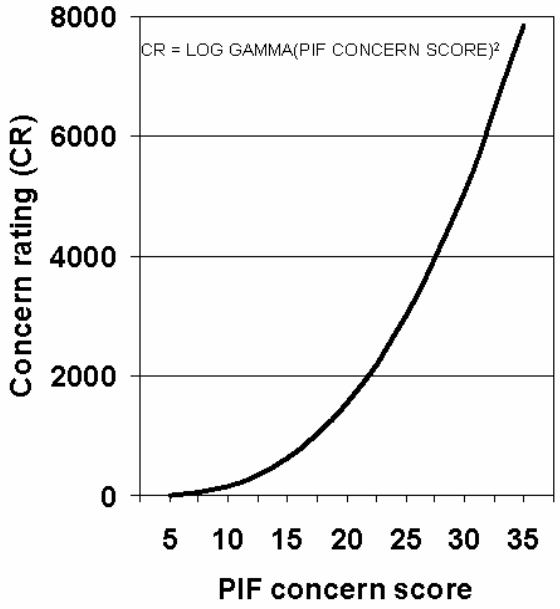

Figure 1—Relative concern ratings (CR), derived from the square of the logarithm of the gamma function [(x), SAS Institute Inc. 1985] of Partners in Flight concern scores used to calculate avian conservation significance (ACS) of avian habitat.

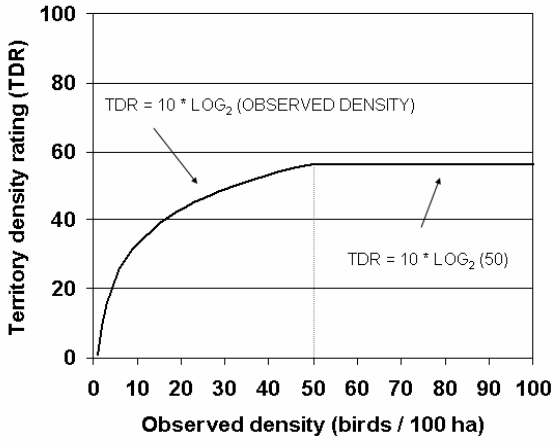

Figure 2— Territory density ratings (TDR) derived as 10 times the logarithm (base 2) of observed density (territories/100 ha) used to calculate avian conservation significance (ACS) of avian habitat. Peripheral or wide-ranging species that were detected, but at densities of <1 territory/100 ha, were assigned a territory density rating of 1.0. Densities were truncated at 50 territories/100 ha, thus species with >50 territories/100 ha were assigned a territory density rating of 56.4.

Calculating Conservation Significance

To calculate the "conservation significance" for each species, I used concern ratings (CR) that I determined from an "exponential type" relationship with PIF concern scores. Specifically, I used the square of the logarithm of the gamma function (SAS Institute Inc. 1985) of PIF concern scores (*fig. 1*).

I obtained territory density ratings (TDR) for each species from it logarithmic relationship with observed territory densities when expressed as birds per 100 ha. Specifically, I used 10 times the logarithm (base 2) of observed territory density when observed densities were ≤50 territories/100 ha. Territory density rating was truncated, and did not increase beyond that for observed densities of 50 territories/100 ha. I assigned a territory density rating of 1 to all species detected at densities of <1 territories/100 ha.

A measure of conservation significance for each species was obtained as the product of that species' concern rating and it's territory density rating divided by 1000. The avian conservation significance (ACS) of a tract of land was obtained as the sum of these measures of conservation significance over all species (Equation 1).

$$ASC \quad \sum_{i\ 1}^{n}\left(\left(CR_i * TDR_i\right)/1000\right)= \qquad \text{Equation 1}$$

for species i = 1 to n, where:

ACS = Avian Conservation Significance,

CR = Concern Rating derived from regional PIF concern scores as;

CR = LOG GAMMA(PIF CONCERN SCORE)^2 ,

TDR = Territory Density Rating derived from observed territory densities as;

TDR = 10 * LOG_2 (OBSERVED DENSITY), for observed densities of 1 to 50 territories / 100 ha.

Hypothetical Example

In a hypothetical comparison of two forest tracts, eight species, which held a combined total of 38 territories on each tract, were observed at densities that ranged from 0 to 12 (*table 1*). Using the truncated logarithmic model (*fig. 2*), I converted observed territory densities to territory density ratings (TDR, *table 1*). Similarly, using the exponential model (*fig. 1*), I converted PIF concern scores to concern ratings (CR, *table 1*). Using TDR and CR, I calculated a measure of conservation significance for each species and summed these values over all species (*table 1*). In this example, habitat unit A had a higher conservation significance (ACS = 298.6) than did habitat unit B (ACS = 245.3). Thus, the

Table 1— *Hypothetical data on avian species, their Partners in Flight concern score, their transformed concern rating (CR), their observed density (territories / 100 ha), their transformed territory density rating (TDR), and the avian conservation significance (ACS) from two units of habitat, each with identical total avian densities. Species are listed in taxonomic order.*

Common name	Scientific name	Concern score	CR	Observed density		TDR		ACS	
				Unit A	Unit B	Unit A	Unit B	Unit A	Unit B
Downy Woodpecker	*Picoides pubescens*	17	941	4	6	21.0	25.8	19.8	24.3
Acadian Flycatcher	*Empidonax virescens*	21	1792	10	4	34.2	21.0	61.3	37.6
White-eyed Vireo	*Vireo griseus*	23	2349	0	8	0	30.0	0	72.8
Carolina Wren	*Thrythorus ludovicianus*	17	941	12	12	35.8	35.8	34.7	34.7
Prothonotary Warbler	*Protonotaria citrea*	28	4168	8	2	30.0	10.0	129.2	45.8
Swainson's Warbler	*Limnothlypis swainsonii*	27	3753	2	0	10.0	0	41.3	0
Summer Tanager	*Piranga rubra*	18	1123	2	0	10.0	0	12.3	0
Indigo Bunting	*Passerina cyanea*	18	1123	0	6	0	25.8	0	30.1
Totals				38	38			298.6	245.3

conservation significance of habitat unit A is superior to that of B. This could suggest that management of unit A is better for birds than is management of unit B.

Comparison of Reforested Tracts

Using the above methodology, I calculated the avian conservation significance of 141 reforested bottomland tracts. These reforested sites were planted predominantly with oaks (*Quercus* spp.) and ranged in age from 2 to 34 years post-planting. Avian conservation significance of individual sites ranged from 100 to 1600, but average by year class, ranged from 300 to 1600 (*fig. 3*). A significant correlation (r^2 = 0.48) existed between age of reforestation and its significance for avian conservation, with an increase of just over 19 units of conservation significance per year (*fig. 3).* As these reforested tracts matured, at about 25 to 30 years post-planting, they resembled forested habitat rather than early-successional habitat. Once forested conditions were achieved, the relationship between age and avian conservation significance deteriorated as indicated by the wide range of avian conservation significance among tracts that were >25 years old (*fig. 3*). Indeed, the relationship between site age and avian conservation significance was markedly more pronounced (r^2 = 0.78) when I limited the comparison to sites that were <25 years old (*fig. 4*).

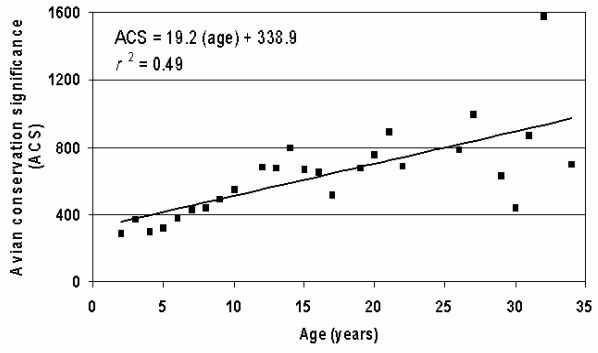

Figure 3— The relationship between age of reforested tracts in the Mississippi Alluvial Valley and their mean avian conservation significance (ACS).

The apparent increase in conservation significance for birds with the maturing of reforested sites conformed to expert opinion as to the conservation significance of mature hardwood forests compared with those in seral stages (Rumble and Gobeille 1998, Twedt et al. 1999, 2002). Degradation of this relationship as these stands mature indicates that factors other than age (e.g., internal forest structure) are influencing bird populations and thereby significance for avian conservation.

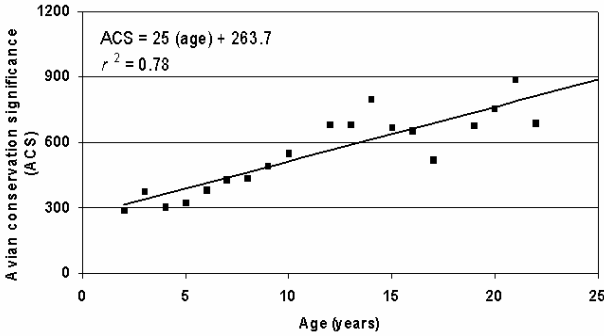

Figure 4— Relationship between age of reforested tracts in the Mississippi Alluvial Valley and their mean avian conservation significance (ACS) when restricted to tracts <25 years post-planting.

Habitat Management

Managers may wish to examine the habitat conditions within stands that have high conservation significance and undertake habitat manipulations within stands that have low conservation significance so as to emulate the conditions of the former. After habitat manipulations, conservation significance can be recalculated to assess changes in the quality of avian habitat.

As an example, I calculated avian conservation significance within second growth bottomland forests (*table 2*) based on 13 breeding bird censuses (Svensson et al. 1970) in unharvested forests and six breeding bird censuses in forests subjected to recent (within 4 years) selective timber harvest prescribed to improve wildlife habitat (Twedt et al. 1999). For each species, I calculated mean territory density over all breeding bird censuses, and used these to determine the conservation significance associated with each species. These were summed over all species to obtain the avian conservation significance of harvested stands (ACS = 2008) and unharvested stands (ACS = 1839). Although the difference in ACS between harvested and unharvested stands was small (<10 percent), it does suggest that prescribed habitat modifications achieved desired results. Note that the observed densities of birds in unharvested stands (841 territories/100 ha) was greater than that in harvested stands (813 territories/100 ha). Thus, the increase in conservation significance resulted from an increase in higher priority bird species rather than an increase in total numbers of birds.

Table 2— *Avian species, Partners in Flight concern score, transformed concern ratings (CR), observed densities (territories / 100 ha), transformed territory density rating (TDR), and avian conservation significance (ACS) calculated from 14 uncut (UNC) and 6 selectively, single tree and group selection, harvested (HAR) bottomland hardwood stands located in northeastern Louisiana from 1994 through 1997. Species are listed in taxonomic order.*

Common name	Scientific name	Concern score	CR	Observed density		TDR		ACS	
				HAR	UNC	HAR	UNC	HAR	UNC
Little Blue Heron	*Florida caerulea*	19	1325	1	1	1	1	1.3	1.3
Wood Duck	*Aix sponsa*	21	1792	2	1	10	1	17.9	1.8
Mississippi Kite	*Ictinia mississippiensis*	25	3001	2	1	10	1	30.0	3.0
Red-shouldered Hawk	*Buteo lineatus*	18	1123	2	1	10	1	11.2	1.1
Wild Turkey	*Meleagris gallopavo*	18	1123	0	1	0	1	0.0	1.1
Mourning Dove	*Zenaida macroura*	13	399	2	1	10	1	4.0	0.4
Yellow-billed Cuckoo	*Coccyzus americanus*	21	1792	23	29	45.2	48.6	81.0	87.1
Barred Owl	*Strix varia*	17	941	2	1	10	1	9.4	0.9
Ruby-throated Hummingbird	*Archilochus colubris*	22	2059	25	11	46.4	34.6	95.5	71.2
Red-headed Woodpecker	*Melanerpes erythrocephalus*	24	2663	19	3	42.5	15.8	113.2	42.1
Red-bellied Woodpecker	*Melanerpes carolinus*	20	1548	59	55	56.4	56.4	87.3	87.3
Downy Woodpecker	*Picoides pubescens*	17	9415	26	21	47	43.9	44.2	41.3
Hairy Woodpecker	*Picoides villosus*	15	635	4	1	20	1	12.7	0.6
Northern Flicker	*Colaptes auratus*	17	941	1	0	1	0	0.9	0.0
Pileated Woodpecker	*Dryocupus pileatus*	17	941	6	10	25.8	33.2	24.3	31.2
Eastern Wood-Pewee	*Contopus virens*	20	1548	20	7	43.2	28.1	66.9	43.5
Acadian Flycatcher	*Empidonax virescens*	21	1792	82	132	56.4	56.4	101.1	101.1
Great-crested Flycatcher	*Myiarchus crinitus*	19	1325	14	12	38.1	35.8	50.5	47.4
White-eyed Vireo	*Vireo griseus*	23	2349	57	37	56.4	52.1	132.5	122.4
Yellow-throated Vireo	*Vireo flavifrons*	21	1792	9	10	31.7	33.2	56.8	59.5
Red-eyed Vireo	*Vireo olivaceus*	17	9415	29	41	48.6	53.6	45.8	50.5
Blue Jay	*Cyanocitta cristata*	16	778	1	1	1	1	0.8	0.8
American Crow	*Corvus brachyrhynchos*	10	164	0	1	0	1	0.0	0.2
Carolina Chickadee	*Poecile carolinensis*	21	1792	22	43	44.6	54.3	79.9	97.3
Tufted Titmouse	*Baeolophus bicolor*	15	635	46	57	55.2	56.4	35.1	35.8
Carolina Wren	*Thrythorus ludovicianus*	17	941	68	70	56.4	56.4	53.1	53.1
Blue-gray Gnatcatcher	*Polioptila caerulea*	16	778	38	34	52.5	50.9	40.8	39.6
Wood Thrush	*Hylocichla mustelina*	25	3001	2	8	10	30	30.0	90.0
Northern Parula	*Parula americana*	24	2663	4	4	20	20	53.3	53.3
Yellow-throated Warbler	*Dendroica dominica*	21	1792	2	0	10	0	17.9	0.0
Cerulean Warbler	*Dendroica cerulea*	27	3753	1	1	1	1	3.8	3.8
Prothonotary Warbler	*Protonotaria citrea*	28	4168	25	42	46.4	53.9	193.4	224.7
Swainson's Warbler	*Limnothlypis swainsonii*	27	3753	2	5	10	23.2	37.5	87.1
Kentucky Warbler	*Oporornis formosus*	22	2059	6	14	25.8	38.1	53.1	78.4

Table 2. *(contd.)*

Common name	Scientific name	Concern score	CR	Observed density		TDR		ACS	
				HAR	UNC	HAR	UNC	HAR	UNC
Common Yellowthroat	*Geothlypis trichas*	18	1123	4	1	20	1	22.5	1.1
Hooded Warbler	*Wilsonia citrina*	21	1792	3	15	15.8	39.1	28.3	70.1
Yellow-breasted Chat	*Icteria virens*	21	1792	12	1	35.8	1	64.2	1.8
Summer Tanager	*Piranga rubra*	18	1123	19	19	42.5	42.5	47.7	47.7
Northern Cardinal	*Cardinalis cardinalis*	13	399	73	97	56.4	56.4	22.5	22.5
Indigo Bunting	*Passerina cyanea*	18	1123	51	9	56.4	31.7	63.3	35.6
Eastern Towhee	*Pipilo erythrophthalmus*	19	1325	6	5	25.8	23.2	34.2	30.7
Common Grackle	*Quiscalus quiscula*	16	778	3	2	15.8	10	12.3	7.8
Brown-headed Cowbird	*Molothrus ater*	16	778	25	34	46.4	50.9	36.1	39.6
Orchard Oriole	*Icterus spurius*	23	2349	15	2	39.1	10	91.8	23.5
Totals				813	841			2008.1	1839.3

Discussion

This method of comparing the significance of habitats for avian conservation is relatively simple and objective. Although I made comparisons using data from bottomland hardwood forests and PIF concern scores from the Mississippi Alluvial Valley, this methodology should be applicable to other habitats and other geographic regions. PIF concern scores vary among regions but are available for each physiographic area at http://www.rmbo.org/pif/pifdb.html.

Relative densities, however, must be obtained from the tracts that are to be compared. These data can be obtained from breeding bird censuses, strip transects (Emlen 1988), or point counts (Ralph et al. 1993).

In development of the methodology presented, I chose to use a gamma and a truncated base 2 logarithm scaling function for conversion of PIF concern scores and observed territory densities, respectively. These functions were chosen based on visual assessment of different scaling functions. However, other functions that produce similar transformations are equally valid and should result in similar relative values of conservation significance. The absolute magnitude of the resultant values will likely differ if other transformation functions are used. Even though the absolute magnitude of the resultant measures of conservation significance are influenced by these transformation functions, they can be scaled to restrict their range. For example, I arbitrarily chose to divide by 1000 (Equation 1) to limit the measure of conservation significance of each species to <250 (*table 2*).

Using the methods I've outlined to determine an area significance for avian conservation, managers can objectively evaluate and compare avian habitats based on estimates of avian territory density and published PIF concern scores. Comparison of results should provide for more informed decisions for management and conservation of habitats so as to provide the greatest benefit to birds.

Acknowledgments

I thank R. Wilson for discussions and comments that aided the development of this method. A. Mueller and D. Johnson provided additional comments on the draft manuscript.

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Grassland Bird Conservation Efforts in Missouri and Iowa: How Will We Measure Success?[1]

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Abstract

Missouri and Iowa have adopted the Bird Conservation Area (BCA) model of Partners in Flight and applied the BCA model to ten areas managed to benefit grassland birds. These ten BCAs have large core areas of continuous grassland centered on active lek sites of Greater Prairie-Chickens (*Tympanuchus cupido*). Management is focused on expanding the number of hectares of grasslands, opening vistas by tree and shrub removal, and mowing lek sites. Using annual roadside surveys, we are evaluating grassland bird responses to conservation activities on the ten BCAs by monitoring bird abundance within each BCA and a paired control area. We also are sampling bird abundances in several habitat types: grazed native prairie, hayed native prairie, grazed cool-season grasses/forbs, hayed cool-seasons grasses/forbs, warm-season Conservation Reserve Program (CRP) fields, and cool-season CRP fields. The roadside counts allowed comparison of population trends between landscapes managed for grassland birds and landscapes not managed for grassland birds. The assessment of abundances per habitat types will allow us to determine which cover types support greater abundances of high priority grassland bird species and allow us to make appropriate recommendations to public and private landowners.

Key words: Tympanuchus cupido, Ammodramus henslowii, Ammodramus savannarum, Spiza americana, grassland birds, Bird Conservation Area.

Introduction

In the last 35 years, grassland bird populations have declined more consistently and ubiquitously than any other avian suite of species associated with a certain habitat or landscape (Vickery et al. 2000). Recent analysis of the Breeding Bird Survey (BBS) reveals negative range-wide population trends for many grassland bird species between 1990 and 2000, including Henslow's Sparrow (*Ammodramus henslowii*), Grasshopper Sparrow (*Ammodramus savannarum*), Dickcissel (*Spiza americana*), and Eastern Meadowlark (*Sturnella magna*). States in the tallgrass prairie region have lost almost their entire native grassland habitat. For example, at the time of settlement by Europeans, 6,072,874 hectares (15,000,000 acres) of tallgrass prairie covered about one third of Missouri (Missouri Department of Conservation (1999). Today, fewer than 36,437 hectares (90,000 acres) of tallgrass prairie remain. Only 8,907 hectares (22,000 acres) are in public ownership (Missouri Department of Conservation 1999). Coincident with the loss of native grasslands was the rapid population decline of Greater Prairie-Chickens (*Tympanuchus cupido*) through market hunting in the 1800s and early 1900s (Callison 1981). Land use conversion (from native grasslands to cropland or nonnative grasslands) or natural succession (from grasslands to shrub or woodland vegetative cover types) as well as habitat fragmentation and habitat degradation have negatively affected distributions, abundances, and reproductive success of grassland birds.

The Greater Prairie-Chicken and the Henslow's Sparrow are two of the species of greatest conservation concern in every Partners in Flight (PIF) physiographic area where they occur. In Missouri, the Greater Prairie-Chicken recently was listed as state endangered and could be extirpated in the state by 2010 without a significant conservation effort on its behalf. A summary of the BBS from 1966 to 2000 revealed that Henslow's Sparrow has been declining range-wide by 7.7 percent annually, although it has been increasing in Missouri by 5.5 percent annually (Sauer 2001).

PIF has suggested a landscape and habitat model to help focus management efforts for grassland birds. The PIF Bird Conservation Area (BCA) model (Fitzgerald and Pashley 2000) attempted to meet the needs of all grassland birds at all relevant spatial scales. The BCA model was based on the biology and habitat requirements of Greater

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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Prairie-Chickens and other grassland birds (Fitzgerald and Pashley 2000), and evaluation studies of BCA model concepts (J. Herkert, unpubl. data). We are implementing the BCA model and will be evaluating and assessing the project until at least 2012.

In a coordinated effort between Missouri and Iowa, we have established BCAs in 10 study areas.

Project objectives overall are:

1. To increase habitat acreage for and population size of Greater Prairie-Chickens and other grassland bird species via land acquisition, easements, outreach, and incentive programs.

2. To implement the PIF grassland BCA model discussed in the Dissected Till Plains, Osage Plains, and other PIF physiographic area plans developed for tallgrass prairie regions of the midwestern United States (Fitzgerald and Pashley 2000).

3. To initially manage Pawnee Prairie/Dunn Ranch as the core of a healthy tallgrass prairie ecosystem, and to expand similar efforts to all 10 BCAs.

4. To create a partnership with landowners and foster an understanding of the importance of the need to conserve native grasslands and grassland birds.

5. To initiate a monitoring protocol to establish baseline and annual data collection, and monitor population change in relation to habitat quality and management.

Objectives of our paper are to:

1. Describe the organizational aspects of this project.

2. Present the short-term and long-term bird monitoring strategy.

3. Summarize briefly the first year's bird monitoring data collection effort.

Methods

Bird Conservation Area Model

The original PIF grassland BCA model called for an approximately 800-hectare (2,000-acre) core of quality grassland habitat within a 3200-hectare (8,000-acre) matrix, or a 1.5 km (1 mile) wide buffer zone. The matrix around the core area should contain an additional 800 hectares (2000 acres) of quality grassland habitat in blocks of 40 hectares (160 acres) or greater. Cropland in the matrix is considered "neutral," woody vegetation "hostile," with respect to their ability to facilitate the movement of predators of grassland birds. Core areas were centered upon Greater Prairie-Chicken leks and managed to provide adequate habitat structure for nesting, brood rearing, and roosting, which generally occur within a 1.5 km radius of a lek. Management to meet the needs of Greater Prairie-Chickens within core areas is hypothesized to be compatible with the needs of other high priority species such as Henslow's Sparrow, Dickcissel, and Grasshopper Sparrow. The matrix around the core areas should contain a minimum of tall woody vegetation, as well as the above mentioned 800 hectares (2,000 acres) of grassland so that the percentage of grassland in the matrix is 25 percent or greater and the percentage of grassland in the BCA as a whole is at least 40 percent.

Study Areas

In Missouri, the Grasslands Coalition formed in 1998. Nine Grasslands Coalition Focus Areas were designated. Bird Conservation Areas were superimposed over the Focus Areas based on active Greater Prairie-Chicken lek locations. Each Focus Area had a management team supported by many partners. The teams worked on public land and with willing landowners on private land to manage for BCA objectives. Federal and state agencies helped to target landowner incentives to areas that were within the focus areas. Management activities selected as appropriate for grassland birds in the focus areas were woody vegetation removal, fescue conversion to restored prairie with local ecotype seeds, prescribed burns on many thousands of acres of native prairie, and the establishment of low to moderate density rotational grazing.

As an example, the Dunn Ranch BCA in Harrison County, Missouri (Township 66N, Range 28W, Sections 29-33), encompassed four active Greater Prairie-Chicken leks, and the BCA design was modified to take this into account. The four overlapping core areas around the leks totaled 2,100 ha, with the matrix encompassing an additional 5,800 ha, for a total of 7,900 ha. Grassland (primarily pasture) and forest cover were approximately 80 percent and 6 percent, respectively, of the matrix of the Dunn Ranch BCA. This was well above 25 percent grass coverage targeted by the BCA model, and very near the recommended maximum of 5 percent forest coverage.

Conservation efforts in The Nature Conservancy's (TNC) Dunn Ranch Preserve area will involve mostly landowner incentive programs administered by the Natural Resources Conservation Service. Much of the land cover in the core zone was in grass, but had been heavily grazed and could benefit from a rest rotation. Some cropland will be converted to grassland. Prescribed fire, light grazing, and rotational grazing systems appear to be useful in producing the needed structure. Management costs and approaches vary dep-

ending on whether a given management unit is on public or on private lands within the BCA, as well as with the unpredictable responses of the vegetation to management. Without management, the newly acquired (1999) Dunn Ranch Preserve could quickly become unsuitable for Greater Prairie-Chickens and many other grassland species if rank weed growth occurs in the year after cattle were removed. Woody encroachment would likely follow within 5 to 10 years (K. Kinne TNC, R. Arndt Missouri Department of Conservation, pers. comm.).

Habitat on the Dunn Ranch will be managed by rotational grazing, haying, and prescribed fire. Habitat improvements on private lands in the core area will focus on the voluntary conversion of cropland to native grasses, reducing cattle stocking rates to mitigate the negative impacts of over-grazing, and removing tall woody vegetation in fence rows. Native prairie shrubs and vines will be left in small drainages and in fencerows when possible. Only invasive tree species will be targeted for removal. Cost-share has been offered to private landowners to encourage their cooperation.

Monitoring and Assessment Strategy

Assessing relative abundance by habitat type

We examined bird relative abundances in several habitat types—grazed native prairie, hayed native prairie, grazed cool-season grasses/forbs, hayed cool-season grasses/forbs, warm-season Conservation Reserve Program (CRP) fields, and cool-season CRP fields—to determine which support target species were in greatest abundance. Within each BCA, all habitats of the six designated treatment types were identified and mapped. Treatment types were mapped in the following four Missouri BCAs (*table 1*): Prairie State Park/Shawnee Trails, Taberville Prairie, Hi Lonesome, and Pawnee Prairie/Dunn Ranch (*table 1*).

Sixteen-hectare (40-acre) study plots were established in each available habitat type. Five BCAs were used during 2001: four in Missouri and one in Iowa. Within the four Missouri BCAs there were four clusters, each cluster with one replicate for each of the six habitat treatments. When more than one field of a single treatment type was available within a cluster, only one was selected randomly to survey. Occasionally, no treatment types were available within a cluster. The Iowa BCA did not have clusters.

Within each 16-ha plot, four points were located 100 m from each edge, or at the center of each quadrant of the plot. All birds were recorded over a 5-minute period. A notation was made for 0-3 minutes and 3-5 minutes. Bird observations were recorded either as 0 to 50 m or 50 to 100 m from the center point, or as flyovers.

Table 1— *The Grassland Coalition Focus Areas/Bird Conservation Areas*

Name	Acres	Hectares
Pawnee Prairie/Dunn Ranch	25,595	10,362
Green Ridge Township	15,502	6,276
Hi Lonesome	46,812	18,952
Taberville Prairie	13,433	5,438
El Dorado Prairies	10,449	4,230
Prairie State Park/ Shawnee Trails	20,199	8,178
Stoney Point/Horse Creek	24,423	9,888
Golden/Dorris Creek Prairie	20,250	8,198
Mystic	17,062	6,908
Kellerton, Iowa	7,040	2,850
Totals	**200,125**	**81,280**

After a point-count was conducted, vegetation was sampled at four randomly selected distances (between 5 and 95 m) and directions from the center point. A Robel pole was used to record and average four height-density readings at each of the four points (Robel 1970). Litter depth and bare soil were recorded along with each height-density reading, giving 16 litter-depth and bare-soil measurements per bird count point. Vegetation was monitored at all bird count points.

All point counts and vegetation monitoring were conducted twice during May and June. In Missouri, surveys started in the southernmost BCA and proceeded to the northernmost.

Data were analyzed by using PROC MIXED (Littell et al. 1996). The analysis accounted for the clustered plots and the four repeated samples within fields.

BCA and BCA pair monitoring

We evaluated grassland bird population responses to management in the ten BCAs by monitoring bird relative abundance within each BCA. Associated with each BCA was a paired control area of similar size and vegetative composition that was 8 to15 km away. The roadside counts allow comparison of population trends in managed and unmanaged landscapes. We used a modified BBS (Robbins 1986)-type roadside count to determine overall trends in BCAs managed for grassland ecosystems and grassland birds versus unmanaged paired areas. For each survey route, up to 50 stops were established along roads in all habitats in both the BCA and BCA Pairs. Three-minute counts were conducted at each stop, recording all individuals observed by sight or sound. A BCA and its pair were surveyed by the same observers when possible. Surveys were conducted between 25 May and 5 July. Surveys will be conducted annually for ten years. Surveys were con-

ducted in Kellerton, Iowa, using the same BBS methodology.

Results

Habitat Monitoring

Of the 70 fields available for survey in Missouri, 13 Native Prairie Grazed, 12 Native Prairie Hayed, 15 Cool Season Grazed, 13 Cool Season Hayed, 9 Warm Season CRP, and 8 Cool Season CRP fields were surveyed. Sixty-seven species of birds were recorded in the habitat fields in the four Missouri BCAs.

The primary results from an analysis of effects of site (BCAs) and habitat type were a significant interaction between these factors (*table 2*). Because of these interactions, examination of effects of habitat type would have to be done for each site. The variation in bird detections per point clearly was illustrated by Henslow's Sparrow (*fig. 1*), both within BCAs and among habitat treatments. The few detections of Northern Bobwhite in Hi Lonesome and especially Pawnee Prairie/Dunn Ranch BCAs (*fig. 2*) need further consideration. Brown-headed Cowbirds were present in most habitat types in all BCAs (*fig. 3*). Habitat data from Iowa were not analyzed in our paper; however, Iowa roadside counts are included in *figure 4,* indicating the total number of BCAs in which target bird species were detected.

Table 2— *Effects of the interaction between site and habitat type*

Species	df/df	F value	P > F
Bell's Vireo	13/168	7.52	<0.0001
Brown-headed Cowbird	13/167	1.93	0.0299
Bobolink	13/167	6.47	<0.0001
Dickcissel	13/168	2.82	0.0011
Eastern Meadowlark	13/168	2.36	0.0063
Field Sparrow	13/168	3.15	0.0003
Henslow's Sparrow	13/168	9.47	<0.0001
Northern Bobwhite	13/168	1.87	0.0366
Upland Sandpiper	13/168	4.14	<0.0001

BCA and BCA Pair Monitoring

On the 20 BBS-type roadside counts in the BCAs and BCA Pairs, 104 species of birds were recorded. The only target species to occur in all 20 areas were Dickcissel, Grasshopper Sparrow, and Eastern Meadowlark (*fig. 4*).

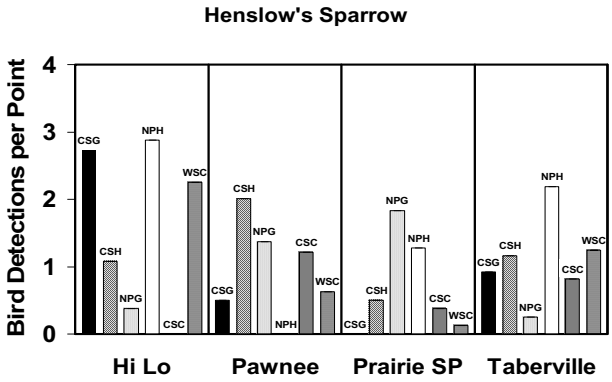

Figure 1— Henslow's Sparrow detections per point by habitat and BCA. Key to treatment labels: CSG = Cool Season Grazed, CSH = Cool Season Hayed, NPG = Native Prairie Grazed, NPH = Native Prairie Hayed, CSC = Cool Season Conservation Reservation Program (CRP), WSC = Warm Season CRP.

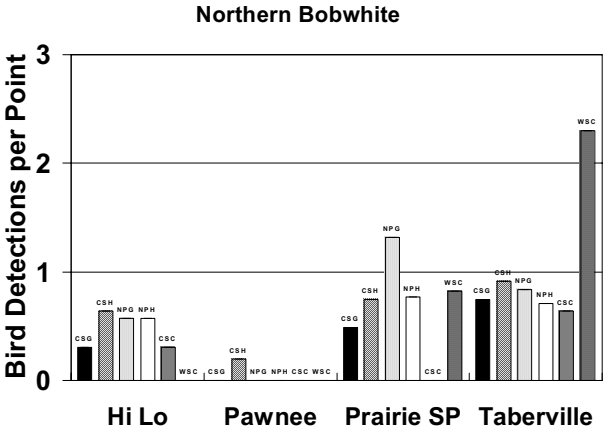

Figure 2— Northern Bobwhite per point by habitat and Bird Conservation Area. See *figure 1* for codes.

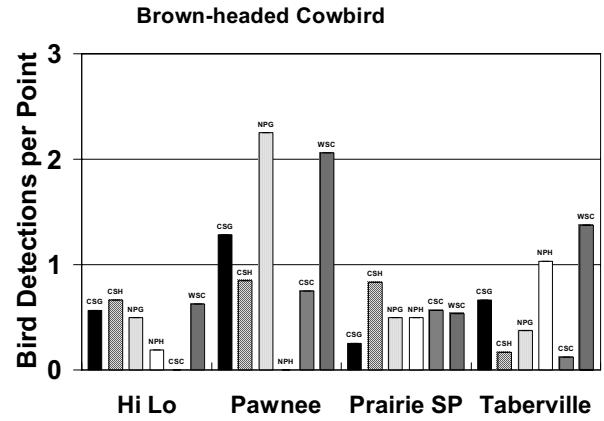

Figure 3— Brown-headed Cowbird per point by habitat and Bird Conservation Area. See *figure 1* for codes.

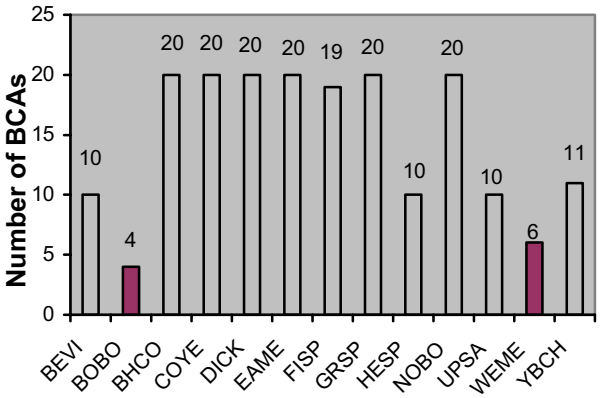

Figure 4— Number of Bird Conservation Areas in which target species were detected by roadside Breeding Bird Survey-type counts. BEVI = Bell's Vireo, BOBO = Bobolink, BHCO = Brown-headed Cowbird, COYE = Common Yellowthroat, DICK = Dickcissel, EAME = Eastern Meadowlark, FISP = Field Sparrow, GRSP = Grasshopper Sparrow, HESP = Henslow's Sparrow, NOBO = Northern Bobwhite, UPSA = Upland Sandpiper, WEME = Western Meadowlark, YBCH = Yellow-breasted Chat.

Discussion

In the first year of our study it appeared that we confirmed the highly variable nature of bird populations in grassland habitats (Winter et al. 2001) The variety of habitats used by most species and the variation of relative abundance between habitats in different BCA regions suggests a need to look at landscape level factors such as adjacent habitat types and overall land cover within each BCA in more detail.

An analysis of the Breeding Bird Survey for 1990 to 2000 indicated an annual decline of approximately 6.5 percent for Northern Bobwhite, explaining the low numbers all across Missouri. Few individuals were observed during point counts in the Dunn Ranch BCA; however, Northern Bobwhites were detected outside the 100 m point-count sampling radius on several occasions. Further study is needed to determine the effects of extensive removal of woody vegetation on this species.

The presence of Brown-headed Cowbirds in all habitat fields indicated that there likely was a high potential for brood parasitism in all habitats. It likely did not matter if the habitat was robust weedy vegetation or grazed pasture; cowbirds still would find nests to parasitize.

Acknowledgments

We would like to thank J. Bart, E. Kurzejeski, S. Sheriff, L. Mechlin, R. Clawson, R. Renken, M. Wallendorf, S. Hoerner, and E. Zenner for assistance in project and statistical design. Also, we would like to thank field technicians S. French, M. Hoffman, J. Snyder, and H. Winfrey for their attention to detail and dedication to the completion of field season assignments. We would like to thank the many volunteers who helped record the observations of the field technicians for both avian and vegetation data. Without volunteer help this project would have taken much more time.

Funding for this project was from the National Fish and Wildlife Foundation, U.S. Fish and Wildlife Service, and Missouri Department of Conservation.

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The Neotropical Migratory Bird Conservation Act: A Workshop to Discuss Improvements and a Brief Summary of First Year Results[1]

David Mehlman[2], Heather Johnson[3], and Bob Ford[4]

Introduction

The Neotropical Migratory Bird Conservation Act (NMBCA; Public Law 106-247), passed by the U.S. Congress in 2000, establishes a matching grants program to fund projects that promote the conservation of migratory birds in the United States, Latin America, and the Caribbean. During its deliberations, the U.S. Congress recognized that migratory birds provide significant and diverse benefits across the United States and the Western Hemisphere and that many migratory bird species populations have dramatically declined, often because of habitat loss or degradation. Congress also recognized that migratory bird conservation and management requires the commitment and effort of all countries along their migration routes, and that bird conservation initiatives can be strengthened and enhanced by increased coordination.

The Nature Conservancy's migratory bird program hosted a workshop on the Neotropical Migratory Bird Conservation Act during the Partners in Flight 3rd Annual Conference at Asilomar, California, March 21, 2002. About 80 people were in attendance, representing a diverse group of individual partners and organizations from Canada, the United States, Mexico, Dominican Republic, Trinidad and Tobago, Guatemala, and the Bahamas. The workshop was intended to provide potential applicants and beneficiaries of the Act with:

1. an introduction to and review of the Act;
2. an opportunity to ask questions and obtain clarifications; and
3. an opportunity to provide comments, feedback, and suggestions for improvement to the Act.

Congress charged the U.S. Fish and Wildlife Service with administration of the Act, and the Service is committed to a partnership effort for implementation. The purpose of this paper is to document the comments from a portion of the Act's constituents resulting from the workshop, and to provide a brief summary of proposals received during the first cycle of the Act funding.

The Act - Background

Expert witnesses, testifying before Congress in 1998, underscored the need for a "more comprehensive program to address the varied and significant threats facing the numerous species of migratory birds across their range." Furthermore, these witnesses noted that there is little, if any, coordination among existing programs, nor does any one program serve as a link among them. A broader, holistic approach would bolster existing conservation efforts, fill conservation gaps, and promote new initiative (House of Representatives Report 106-36). The purposes of the NMBCA lay the foundation for satisfying those needs. The Act's purposes are to:

- perpetuate healthy populations of neotropical migratory birds;
- assist in the conservation of these birds by supporting conservation initiatives in the United States, Latin America, and the Caribbean; and
- provide financial resources and foster international cooperation for those initiatives.

The NMBCA legislation currently authorizes an annual appropriation of US $5 million for each of fiscal years 2001 through 2005. At a minimum, 75% of this money must be expended on projects outside of the United States. All U.S. Government funds from the NMBCA must be matched at a ratio of at least 3:1. Project proposals need to demonstrate how a conservation partnership's activities will foster sustainable, effective, long-term programs to conserve neotropical migratory birds. The Act defines conservation as any method or procedure necessary to bring a species of neotropical migratory bird to the point at which there

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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are sufficient populations in the wild to ensure the long-term viability of the species, including:

- protection and management of populations;
- maintenance, management, protection, and restoration of habitats of these birds;
- research and monitoring;
- law enforcement; and
- community outreach and education.

Comments from the Attendees

The following comments represent a compilation of views expressed during the workshop and are generally in order of priority as expressed by those attending.

1. The current 3:1 match requirement imposes a significant barrier for partnerships, especially for small organizations without much capital. Attendees at the workshop believe the match is not only difficult to meet, but is probably not sustainable. The consensus recommendation is to establish a 1:1 match requirement.
2. In-kind match should be allowed in the United States, especially for native/aboriginal peoples that may have difficulty establishing the match.
3. Sustainable capacity to deliver bird conservation and strong partnerships should be a priority for funding.
4. Clear criteria for how projects are selected for funding need to be developed.
5. In the United States, proposals should have a strong relationship to implementation of the "biological foundation" provided by Partners in Flight, the U.S. Shorebird Conservation Plan, the North American Waterbird Plan, and the North American Waterfowl Management Plan.
6. Canada should be included in the Act, and projects from Canada should be made eligible for funding.
7. Additional time is needed for program information and criteria to be circulated in Latin America and the Caribbean before the proposal deadline.
8. Proposal solicitation, evaluation, and funds availability is badly timed for projects addressing work during the winter (non-breeding) season. By the time applicants are notified of the success of their proposal and funds are received, it is very difficult to organize a field season for the winter. Two funding cycles per year should be considered for NMBCA.
9. The availability of pre-proposal review by USFWS staff is useful and should be continued.
10. Workshops and similar outreach services should be developed to help applicants develop better proposals, particularly in Latin America and the Caribbean.

Preliminary Results

The deadline for proposal submission for the first round of proposals to be funded under NMBCA was May 13, 2002. Proposals were submitted from 33 countries across the Western Hemisphere and 31 states in the United States. Grant requests far exceeded the appropriation for the Act. In total, over $25,000,000 was requested of the Act, and the 292 submitted proposals generated over $95,000,000 in matching support. Available funding was provided to 32 proposals (11 percent) distributed across Latin America, the United States, and multi-country partnerships (*table 1*).

The large number and geographic extent of proposals, as well as the requested and matching funds generated by proposals, demonstrate the enormous need and constituent desire for a dedicated funding source for bird conservation. Furthermore, the overwhelming response illustrates the need for a broader, holistic approach to supporting existing conservation efforts, partnership development, and new initiatives. In consideration of the obstacles voiced by attendees at this workshop, the response to this year's appropriation may be only a small subset of potential partners that can positively impact bird conservation.

Table 1— *Summary statistics for proposals received by May 13, 2002, for funding during the first year of the Neotropical Migratory Bird Conservation Act.*

Location of project	Proposals received	Projects funded	Amount funded	Matching funds used
United States	71	5	$ 452,041	$ 1,417,590
Latin America/Caribbean (LAC)	200	22	1,856,830	9,202,682
Joint US/LAC	21	5	601,140	2,399,720
Total	292	32	2,910,011	13,020,172

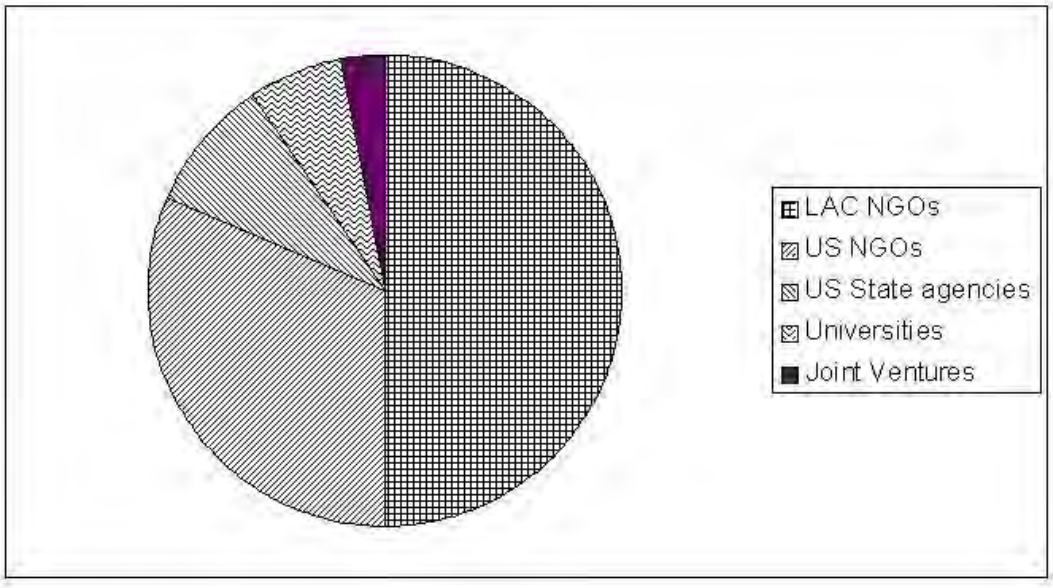

Figure 1— Distribution of number of projects funded by institution type.

Proposals were of extremely high quality and satisfied most of the Act's requirements. For example, of 292 proposals, only 20 (6.8 percent) were rejected as not meeting the requirements of the Act. Furthermore, the projects selected for funding represent an array of projects that will demonstrate both immediate and long-term bird conservation success (Douglas Ryan, U.S. Fish and Wildlife Service, pers comm.). Funded projects came from a variety of institutions (*fig. 1*), though the largest majority was from non-governmental organizations, both within and outside the US.

Conservation categories listed in the Act were fairly well represented, except for law enforcement. Most Latin proposals included several elements of implementation in the proposal. For example, one proposal may include elements of habitat restoration, monitoring, and building community capacity. Proposals in the United States and United States/Latin partnership proposals were more narrowly focused on a single category of the Act; in the United States, the highest number of proposals was for research and monitoring projects, although the highest dollar amount requested was for habitat acquisition and restoration projects.

Integrated Migratory Bird Planning in a Corps of Engineers' Irrigation Project, Bayou Meto, Arkansas[1]

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Abstract

The Bayou Meto Agricultural Irrigation Project, in the Mississippi Alluvial Valley, is currently being studied by the U.S. Army Corps of Engineers in eastern Arkansas. As part of the planning process the Arkansas Field Office of the U.S. Fish and Wildlife Service and the Arkansas Game and Fish Commission wrote a migratory bird management plan for the Bayou Meto project area. This plan addressed the needs of four bird groups: forest breeding birds, shorebirds, waterfowl, and wading and marsh birds. For the first three bird groups the plan applies the recommendations of the Mississippi Alluvial Valley Migratory Bird Initiative to the project area. The Mississippi Alluvial Valley Migratory Bird Initiative made quantified, landscape level recommendations for the habitat needs for these three bird groups. These habitat recommendations were "stepped down" to the Bayou Meto area. To conserve forest-breeding birds, we recommended reforestation of key tracts in the Big Ditch Forest Bird Conservation Area. This reforestation would also create habitat for wintering waterfowl. We recommended increasing shorebird habitat through a landowner incentive program to create mud flat habitat in dewatered aquiculture ponds during fall shorebird migration. Because the North American Waterbird Conservation Plan had not yet produced habitat recommendations useful for this area, we recommended surveys for wading and marsh birds. We need to know what species of secretive marsh birds are currently using the area before we can proceed to conservation recommendations. We also need to know the locations of wading bird breeding colonies to properly protect and manage them. This project shows how regional goals for priority bird species from various plans can be integrated during implementation at the local level.

Key words: irrigation, marsh birds, shorebirds, wading birds, waterfowl, wetlands.

Introduction

The U.S. Army Corps of Engineers, Vicksburg and Memphis Districts, is conducting a study of the agricultural irrigation and flood control needs in the Bayou Meto basin, Arkansas. This study could lead to a large water management project that would take water from the Arkansas River and distribute it to farms throughout the project area and construct levees or channel modifications to control flooding in the southern part of the basin. Migratory bird management is an important consideration in the design of this project. The Arkansas Game and Fish Commission's (AGFC) Bayou Meto Wildlife Management Area (BMWMA) is the most important wildlife habitat in the basin and has been managed primarily to provide habitat for waterfowl. This area also provides substantial habitat for other migratory birds including songbirds, shorebirds, and wading birds. We set habitat goals for migratory birds throughout the Bayou Meto basin.

Methods

Migratory birds can be divided into four groups: shorebirds, waterfowl, land birds, and other water birds (wading and marsh birds). The Mississippi Alluvial Valley Migratory Bird Initiative quantified the habitat needs of shorebirds, waterfowl, and songbirds in the MAV (Hunter et al. 1996, Mueller 1996, Twedt et al. 1999, Loesch et al. 2000, Mueller et al. 2000, Mueller et al. in press). Elliott and McKnight (2000) provided additional information on shorebirds, and the North American Waterbird Conservation Plan southeast working group is preparing a plan that will address the needs of wading and marsh birds. We "stepped down" the goals from these plans to derive habitat recommendations for migratory birds in the Bayou Meto basin and made recommendations for their implementation through the Corps of Engineers' project.

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California**.

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Study Area

The Bayou Meto basin is part of the Mississippi Alluvial Valley physiographic area. A 310,127 ha portion of the basin, including portions of Lonoke, Jefferson, Prairie, Arkansas, and Pulaski Counties (*fig. 1*), is the subject of this study. Historically bottomland hardwood forest dominated the basin (MacDonald et al. 1979). Wetter portions of the basin were, and for the most part still are, vegetated with bald cypress (*Toxodium distichum*), water tupelo (*Nyssa aquatica*), and overcup oak (*Quercus lyrata*). Drier, but still flood prone, portions of the basin had water oak (*Q. nigra*), willow oak (*Q. phellos*), Nuttall oak (*Q. Nuttallii*), green ash (*Fraxinus pensylvanica*), and other hardwood species. Most of the forest outside of the BMWMA has been cleared, and the basin is now dominated by agriculture. Rice, winter wheat, corn, and sorghum are the major crops.

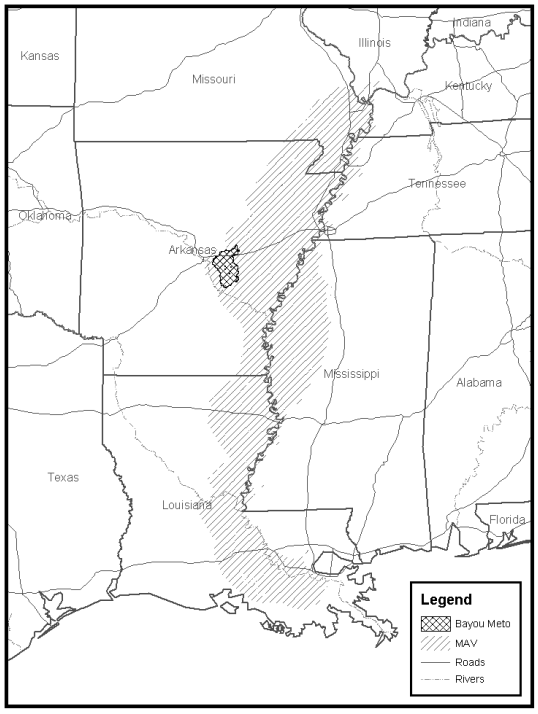

Figure 1— Location of Bayou Meto Study Area.

Results

Shorebirds

Few shorebirds breed (Killdeer [*Charadrius vociferus*], American Woodcock [*Scolopax minor*]) or winter (Least Sandpiper [*Calidris minutilla*), Killdeer, Lesser Yellowlegs [*Tringa flavipes*], Common Snipe [*Gallinago gallinago*]) in the Bayou Meto basin. The most common transient species are Pectoral Sandpiper (*Calidris melanotos*), American Golden-Plover (*Pluvialis dominica*), Solitary Sandpiper (*Tringa solitaria*; Short 1999), Western Sandpiper (*C. mauri*), and Greater Yellowlegs (*T. melanoleuca*). During spring migration the combination of frequent rain and bare agricultural fields usually provides adequate shorebird habitat. During fall migration (July-September) there is little rain and almost all fields are covered with crops. Consequently, conservation planning has focused on shorebird habitat needs during this period (Twedt et al. 1999).

The habitat goal for shorebirds in the MAV is 2,000 ha of mudflat (Twedt et al. 1999) available for feeding during fall migration. This has been further stepped down to a need for 520 ha in Arkansas (*table 1*). Currently 149 ha of fall mud flat habitat is being provided on national wildlife refuges in Arkansas (Bald Knob, Oakwood, Overflow, and Wapanocca), none of which are in the Bayou Meto basin. An unknown amount of mud flat habitat is provided on public lands incidental to other management actions. The remainder (371 ha) of the fall Arkansas shorebird habitat goal is unmet at this time.

Table 1— *Shorebird habitat goals in the Mississippi Alluvial Valley Bird Conservation Region.*

State	Hectares
Arkansas	520
Illinois	70
Kentucky	35
Louisiana	520
Mississippi	600
Missouri	70
Tennessee	185
Total	2,000

Fall shorebird habitat in the Bayou Meto basin is present in very limited amounts. Drying of streams and lakes creates low quality mud flats that quickly dry up or grow up in herbaceous vegetation. The normal management regime of fish hatcheries and aquicultural facilities creates high quality shorebird habitat when ponds are drained for cleaning and refurbishing. The ponds are high in nutrients and, consequently, have a high population of benthic invertebrates, the prime food source for shorebirds (Baldassarre and Fischer 1984, McCollough 1981, Schneider and Harrington 1981). Ponds are drained throughout the year so their occurrence during the southward shorebird migration period is accidental and not assured. Also during the typically hot fall migration period (July-September) the drained ponds rapidly dry up, destroying their mud flat characteristics.

The AGFC's Joe Hogan Fish Hatchery is in the Bayou Meto basin, and the University of Arkansas at Pine

Bluff (UAPB) owns 13 fish ponds (approximately 81 ha) near Lonoke. The management of these facilities could be modified to provide a small amount of fall shorebird habitat. The UAPB ponds need renovating at a cost of approximately $800/ha (pers. comm. Carole Ingle, UAPB). After renovation these ponds could be used by UAPB to research the management of agricultural irrigation reservoirs to provide fisheries habitat, with possible income to farmers from sport fishing, and also to provide fall shorebird habitat. Our current recommendations for the design of irrigation ponds to increase their value as fish and wildlife habitat include:

- Provide multilayered woody and herbaceous vegetation down to the water's edge on one or more sides.
- Create variable bottom topography – deep holes and shallow edges.
- Create islands inside the reservoir.
- Provide gradual bottom slopes.
- Construct variable side slopes, some gradual (<20H:1V) and some steep (>4H:1V).
- Construct islands and sinuous or irregular shorelines with peninsulas.

Each of these design features, and others, could be investigated by UAPB to determine their usefulness for creating fish and wildlife habitat in irrigation reservoirs. Once established, these design features and complimentary management techniques could be applied throughout eastern Arkansas, where the number of irrigation reservoirs is rapidly increasing.

The potential exists to provide a much greater amount of fall shorebird habitat on the privately owned aquiculture farms in the basin. The Bayou Meto basin has approximately 6,450 ha of catfish and baitfish farm ponds. A partnership-based financial incentive program could be formed to assure that each farm would drain one or more ponds during the fall shorebird migration period and maintain 1 to 4 inches of water in the pond(s) to provide prime mud flat feeding areas. Both the AGFC and the Fish and Wildlife Service have private lands biologists already on staff that could effectively deliver such a program.

Waterfowl

Arkansas is a major wintering area for waterfowl, especially dabblers, and achieving its waterfowl habitat goals (*table 2*) is critical to the North American waterfowl population (Loesch et al. 2000). The Mallard (*Anas platyrhynchos*) is the most abundant duck with Gadwall (*A. strepera*), Northern Shoveler (*A. clypeata*), American Wigeon (*A. americana*), Northern Pintail (*A. acuta*), and Green-winged Teal (*A. crecca*) also common wintering species.

The statewide waterfowl habitat goals have not been stepped down to the Bayou Meto basin, but goals have been established for individual parcels of public land, including BMWMA. Unmet habitat goals for wintering waterfowl in the Arkansas portion of the MAV remain for bottomland hardwood forest and moist soil (*table 2*). Within the BMWMA the goal is to maintain at least 7,462 ha of bottomland hardwood forest with water management capability and 354 ha of moist soil management. Currently, the management area has the ability to control water levels on only 6,390 ha of bottomland hardwoods, leaving a deficit of 1,072 ha. Managers also have the option of maintaining moist soil vegetation on 428 ha, although variations in water management capabilities and rainfall patterns result in only 257 ha being managed in any given year. This leaves a moist soil management deficit of 97 ha in the BMWMA. Any increase in bottomland hardwood forest or moist soil management in the BMWMA or elsewhere in the basin would contribute to the overall Arkansas goals. Moist soil management requires careful annual attention and the ability to regulate water levels.

Consequently, moist soil management will usually be applied only on public lands. On the other hand, bottomland hardwood reestablishment requires a large initial effort (planting and hydrology restoration as needed), but little annual effort. This makes bottomland hardwood restoration practical on both private and public lands.

In some years, water management on the BMWMA conflicts with adjacent farms. The inability to move

Table 2—*Duck habitat goals (ha) in the Arkansas portion of the Mississippi Alluvial Valley.*

	Private land	Private-managed		Private-unmanaged	
	Goal	Achieved	Goal	Achieved	Goal
Habitat		(All habitat types)			(Duck-use-days)
Bottomland Hardwoods[a]	35,026	32,743	84,018	81,000	45,194,800
Moist Soil	2,853	1,017			
Unharvested Crop	1,250	1,219			
Harvested Crop	0	980			

[a]Must have water management capability.

water quickly through the BMWMA sometimes causes flooding of adjacent cropland, preventing or delaying harvest or planting.

This situation could be resolved by improving the water management capability on the BMWMA or by reforesting the cropland. Ducks Unlimited, in cooperation with state and federal agencies, does the only other waterfowl management in the basin, consisting of agreements with private landowners to winter flood 292 ha of harvested cropland.

Forest Breeding Birds

Because the MAV was historically dominated by bottomland hardwood forest, the Mississippi Alluvial Valley Migratory Bird Initiative concentrated on forest breeding birds as the group of songbirds most in need of conservation action. Using the Partners in Flight priority system (Carter et al. 2000), 16 of the 20 species ranked as high overall concern use bottomland hardwood forest for breeding (*table 3*). The Mississippi Alluvial Valley Migratory Bird Initiative identified over 100 Forest Bird Conservation Areas (FBCA) throughout the Mississippi Alluvial Valley (Twedt et al. 1999) to meet the needs of forest breeding birds. Some of these FBCAs only require protection, but most of them require some level of reforestation to achieve the desired patch size.

Two FBCAs are in the Bayou Meto basin, the Big Ditch and Bayou Meto FBCAs (*fig. 2*). To the extent practical, each FBCA should be an unbroken stand of forest. This was established to reduce or eliminate the adverse effects of forest fragmentation on forest breeding bird success. To be assured of long term, secure populations, many forest breeding birds require "core" or interior forest, that is habitat some distance from the forest edge (Rosenfield et al. 1992). The Bayou Meto FBCA meets its forest goals. The Big Ditch FBCA meets the total forest area goal, but is lacking in core forest (*table 4*). Reforestation of key tracts in the Big Ditch FBCA would reduce fragmentation and enable the core forest goal to be met with a relatively small amount of reforestation. Bottomland hardwood forest restoration for forest breeding birds would also help meet that goal for waterfowl.

Table 3— *High Overall Priority Breeding Bird Species in the Mississippi Alluvial Valley Bird Conservation Region.*

Species	Partners in Flight priority score
Bachman's Warbler (*Vermivora bachmanii*)	35 – BLH[1]
Ivory-billed Woodpecker (*Campephilus principalis*)	35 – BLH
Prothonotary Warbler (*Protonotaria citrea*)	28 – BLH
Swainson's Warbler (*Limnothlypis swainsonii*)	27 – BLH
Cerulean Warbler (*Dendroica cerulea*)	27 – BLH
Swallow-tailed Kite (*Elanoides forficatus*)	26 – BLH
Wood Thrush (*Hylocichla mustelina*)	25 – BLH
Mississippi Kite (*Ictinia mississippiensis*)	25 – BLH
Northern Parula (*Parula americana*)	24 – BLH
Red-headed Woodpecker (*Melanerpes eruthrocephalus*)	24 – BLH
Painted Bunting (*Passerina ciris*)	23
Bell's Vireo (*Vireo bellii*)	23
Worm-eating Warbler (*Helmitheros vermivorus*)	23
Orchard Oriole (*Icterus spurius)*	23 – BLH
White-eyed Vireo (*Vireo griseus*)	23 – BLH
Yellow-billed Cuckoo (*Coccyzus americanus*)	22 – BLH
Kentucky Warbler (*Oporornis formosus*)	22 – BLH
Ruby-throated Hummingbird (*Archilochus colubris*)	22 – BLH
Hooded Merganser (*Lophodytes cucullatus*)	22 – BLH
Dickcissel (*Spiza ameriana*)	22

[1]BLH = Breeds in or requires bottomland hardwood forest as a component of breeding habitat.

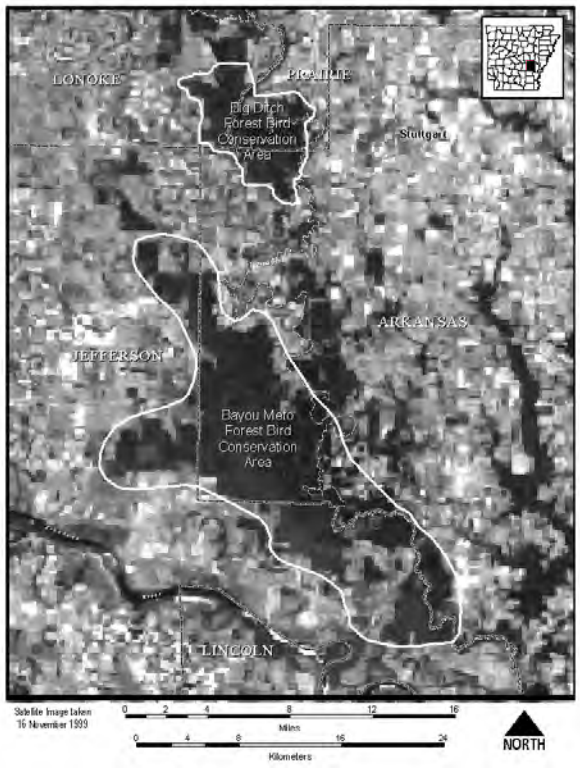

Figure 2— Forest Bird Conservation Areas in the Bayou Meto Study Area.

Reforestation under existing conservation programs has been limited in the Bayou Meto project area. Only one 22 ha tract has been reforested under the Wetland Reserve Program. Additional efforts will be required to accomplish the needed reforestation in the Big Ditch FBCA.

While establishing large, unbroken blocks of forest is the most important step in providing habitat for forest breeding birds, other measures are also beneficial. Reforesting marginal agricultural lands would increase migratory bird, including waterfowl, habitat while only slightly reducing agricultural production. The two-year floodplain is difficult to farm and is a logical area in which to focus reforestation efforts. The recently established Conservation Reserve Enhancement Program, a cooperative effort between the AGFC and the U.S. Natural Resources Conservation Service, is an excellent program that could reforest much of the two-year floodplain. Additional marginal farmlands should be reforested by the irrigation project.

Wading and Marsh Birds

The North American Waterbird Conservation Plan is in the early stages of setting wading bird (herons, egrets, and bitterns) and marsh bird (rails, wrens, and moorhen) population and habitat goals for the nation and the southeast. At this time they have not produced any goals that can be applied to Bayou Meto. Wading and marsh bird occurrence in the project area is poorly known. Three wading bird breeding colony sites have been identified (*table 5*). Several other locations appear to be suitable to support breeding colonies, especially the BMWMA, yet no additional colonies are known.

Surveys to locate all breeding colonies are required. The locations of feeding concentrations points and fall and winter roosts would also be valuable information. The occurrence and distribution of marsh birds in the basin is almost totally unknown. This basic information must be gathered before an effective management plan can be formulated. A wading and marsh bird management plan would address the conservation needs of each species and any depredation problems identified in the basin.

Table 4—*Forest area goals (ha) for the Big Ditch and Bayou Meto Forest Bird Conservation Areas.*

	Forest goal	Existing forest	Core forest goal	Existing core forest
Big Ditch	4,000	4,346	2,100	897
Bayou Meto	8,100	21,216	5,200	6,325

Table 5—*Wading bird colonies in the Bayou Meto project area*[1].

Species/Colony[2]	McSwain	Pine Tree	Preston Hamilton Reservoir
Great Blue Heron (*Ardea herodias*)	X		
Great Egret (*Ardea alba*)	X	X	X
Snowy Egret (*Egretta thula*)	X	X	X
Little Blue Heron (*Egretta caerulea*)	X	X	X
Cattle Egret (*Bubulcus ibis*)		X	
Green Heron (*Butroides virescens*)	X		
Black-crowned Night-Heron (*Nycticorax nycticorax*)	X		

[1]Based on information provided by Michael Kearby, Wildlife Services, Stuttgart, AR.
[2]Colony locations available on request.

Recommendations

These recommendations are made in the spirit of the 1989 "Cooperative Agreement Between the Department of the Interior and the Department of the Army Regarding Waterfowl Habitat Conservation Opportunities Associated with Corps of Engineers Civil Works Projects and Activities Consistent with the North American Waterfowl Management Plan." The habitat recommendations of the Mississippi Alluvial Valley Migratory Bird Initiative were established in cooperation with the North American Waterfowl Management Plan.

1. As part of the irrigation and flood control project, the Corps of Engineers should fund an incentive based, partnership program to ensure the presence of shorebird habitat on privately owned aquiculture facilities during the fall shorebird migration period. This program would be delivered by existing staff of the U.S. Fish and Wildlife Service and the Arkansas Game and Fish Commission.

2. The Corps of Engineers should also fund the University of Arkansas at Pine Bluff to establish a research program to investigate the design and management of irrigation reservoirs to provide sport fish, shorebird, and waterfowl habitat.

3. Until the University of Arkansas at Pine Bluff produces new recommendations, design and manage irrigation reservoirs as described in this document.

4. Do not construct irrigation reservoirs in wetlands or wooded upland habitat.

5. Resolve water management issues associated with Bayou Meto Wildlife Management Area by improving its water management capability or by reforesting adjacent cropland.

6. Reforest key tracts in the Big Ditch Forest Bird Conservation Area to achieve the core forest area goal required for forest breeding birds. This reforestation would also contribute to meeting waterfowl habitat goals.

7. Design project features to be compatible with the Conservation Reserve Enhancement Program.

8. Coordinate with the Service and Arkansas Game and Fish Commission to fund the establishment of 97 ha of moist soil management on newly purchased agricultural lands adjacent to existing public land in Bayou Meto WMA.

9. Survey the entire project area to locate and census wading-bird breeding colonies, roost sites, and feeding concentration points.

10. Conduct surveys to identify the locations and species of marsh birds present in the project area.

Acknowledgments

M. Hoy and M. Kearby of Wildlife Services provided information from their field experience on the occurrence of wading birds in the project area. C. Ingle of the University of Arkansas at Pine Bluff provided information on their ponds near Lonoke. J. Besely developed the project area map. J. Phillips and R. Wilson provided valuable reviews of this paper.

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Alternative Futures for Landscapes in the Upper San Pedro River Basin of Arizona and Sonora[1]

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Abstract

The Upper San Pedro River Basin in southeastern Arizona is well known for its avian diversity; however, water use by Sierra Vista, Fort Huachuca, and agriculture in the basin threatens to lower its water table. This, in turn, could alter vegetation in the basin in a way that would negatively impact habitat currently supporting nesting of the endangered Southwestern Willow Flycatcher (*Empidonax trailii extimus*) and foraging for a large number of resident and neotropical migratory birds during the breeding season and migration. We determined the range of potential Alternative Future growth patterns for the basin (Alternative Futures) and compared them for their relative impacts on a suite of environmental parameters including hydrology, biodiversity, and landscape vegetation pattern. The intent is to inform decision makers of which potential Alternative Future would have the greatest and least impacts on those parameters. This paper has been adapted from *Alternative Futures for Changing Landscapes: The Upper San Pedro River Basin in Arizona and Sonora* by Steinitz et al., published by Island Press, 2003 (800-828-1302).

Key words: Alternative Futures, ecosystem management, Fort Huachuca, hydrology, landscape planning, neotropical migratory birds, riparian, San Pedro River, Sonora, Southwestern Willow Flycatcher.

Introduction

The Upper San Pedro River Basin is one of North America's most diverse and well-known avian habitats (Arias et al. 1999). Over 400 avian species have been documented in the basin (Krueper 1999), and the riparian corridor along the river supports an estimated 1 to 4 million neotropical migratory birds annually during migration (Arias et al. 1999). The San Pedro is the last undammed perennial desert river in the Southwest, but its future existence is threatened by continued growth and agriculture in its watershed (Arias 2000, Kingsolver 2000, Varady et al. 2000).

In 1988, the United States Congress created the San Pedro Riparian National Conservation Area in recognition of this ecosystem's unique biological significance. However, the protection afforded by this action does not guarantee the river's long-term viability as habitat. Changes in land tenure, depth of the water table, and the volume of river surface flow, all can greatly impact riparian vegetation and the animal species that live in the region. Understanding the processes that relate land use and development to groundwater recharge, stream flow, vegetation, and habitat is of critical importance to the land management of the entire region.

This study explored how variations (Alternative Futures) in urban growth and change in the Upper San Pedro River Basin might influence the hydrology and biodiversity of the area over the next 20 years. Because of its international, regional, and local importance, and the intense controversy surrounding planning issues, the Basin has been well studied in recent years (Arias et al. 1999, BLM 1998, Krueper et al. 2003, Steinitz et al. 2003). This report seeks to contribute to the public debate in three ways: one, by considering the Sonora and Arizona portions of the river basin as a single area; two, by investigating the widest range of policy issues that have been raised by stakeholders in the past; and three, by adding spatial and temporal dimensions to anticipated changes and their impacts.

Urbanization and agriculture are the major environmental stresses affecting the San Pedro River Basin (Arias 2000, Varady et al. 2000). Direct impacts on hydrology and habitat are caused by activities such as grading, paving, plowing, grazing, irrigation and water use. Indirect effects

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference,** March 20-24, 2002, Asilomar Conference Grounds, California.

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include modified hydrology, fire suppression and vegetation change. Indirect effects may remain unnoticed by the casual observer, but their cumulative effects can be as detrimental to biodiversity as the direct impacts. Both direct and indirect impacts were assessed, with each impact assessment revealing one aspect of how an Alternative Future was predicted to change the landscape.

Study Area

The study area included the Upper San Pedro River Basin from its headwaters near Cananea, Sonora, northward 187.8 km to Redington, Arizona. Adjacent areas necessary for the maintenance of regional biodiversity also were included. In total, the analysis covers 10,660 km^2, centered on the northward-flowing San Pedro River. The Upper San Pedro River Basin is a transition area between the Sonoran and Chihuahuan deserts and is internationally recognized for its biodiversity. It supports the second highest land mammal diversity in the world (Arias et al. 1999), and it provides breeding habitat for more than 100 bird species (Krueper et al. 2003) and foraging or winter habitat for over 250 more (Krueper 1999). Elevations range from 900 to 2,900 meters, and annual rainfall averages 300 to 750 mm. Vegetation types include Chihuahuan and Sonoran desert scrub, semi-desert grassland, oak-woodland savanna, mesquite woodland, riparian forest, and coniferous forest. Because the watershed lies partly in Sonora and partly in Arizona, it is subject to widely different laws, regulations, and land-use practices.

Methods

To represent the dynamic processes at work in the study area, a computer based Geographic Information System (GIS) was used to organize spatially explicit and publicly available data for the region. The database was derived from available information on conditions in the study area during 1997 to 2000 (hereafter 2000), which defines the reference period against which impacts of future change were measured.

We used a development model to evaluate the attractiveness of available land for five kinds of development: commercial, urban, suburban, exurban (between suburban and rural), and rural housing. It then simulated the urbanization of the region under different future scenarios. These were linked to a suite of process models to describe and evaluate how certain aspects of the landscape were affected under each scenario. A hydrological model evaluated changes in head configuration, loss of groundwater storage, stream capture volume, and surface flows in the San Pedro River. A vegetation model responded to changes in the hydrologic regime, combined with changes in fire and grazing management practices. Predictions of new vegetation patterns then formed the basis for a three-part assessment of regional biodiversity: a landscape ecological pattern model, a Southwestern Willow Flycatcher habitat model (among other species in a larger study), and a vertebrate species richness model.

Because no single vision of the future can be certain, it is preferable to consider several Alternative Futures that encompass a spectrum of possibilities. Therefore, this study generated several variations of each Alternative Future (scenarios) and examined the resulting range of Alternative Futures that the region might experience. The models were used to assess the potential impact of each of the Alternative Futures and their scenarios relative to the 2000 baseline conditions. To help generate the scenarios in Arizona, we developed a questionnaire for local citizens based on three issues currently being considered that are central to public debate in the region: development, water use, and land management. The answers, interpreted into a set of assumptions and choices about policy, became the range of future scenarios. A similar set of questions regarding Sonora was submitted to the Mexican population of the basin. The input provided three basic future scenarios—*Planned, Constrained,* and *Open*—that were projected to 2020 via a development model. We then varied each main scenario two or three times to test outcome comparisons. None of the scenarios considered the impact of treated effluent and storm water recharge projects proposed by the city and Fort.

The *Planned* scenario was based on the interpretation of existing planning documents and land-use practices of the region. It assumed: (1) a population increase as currently forecast of 95,000 by 2020; (2) 80 percent of the population would be in urban homes, 15 percent in suburban, 5 percent in rural; (3) Fort Huachuca retained its current size, and growth in Sonora was moderate; (4) domestic per capita water consumption decreased 20 per cent from public and water company sources and 40 percent for individually owned sources; (5) irrigation within one mile of the river was prohibited and ranching within the basin's public lands was prohibited; (6) unprotected areas along the river between the National Conservation Area and Mexican border were purchased for conservation, and large natural patches (>5,000 acres) and connecting natural corridors were protected; (7) potential habitat for threatened and endangered species was protected; and (8) basin scale GAPS (from Arizona Gap Analysis) were not protected. Gap Analysis overlays maps of land cover and species occurrence onto maps of protected areas using GIS technology. The resulting maps show the relationship between areas of biological significance and the level of protection afforded these areas.

Three variations of the *Planned* scenario were tested:

Test 1 – *Planned* compared to *Planned-1* doubled the projected population growth in the Arizona portion of the basin.

Test 2 – *Planned* compared to *Planned-2* projected increased growth in Sonora, doubling the size of Cananea and its associated mining.

Test 3 – *Planned* compared to *Planned-3* compared the current plans with policies that concentrated development in the four current population centers: Sierra Vista, Benson, Tombstone, and Bisbee, and discouraged it in rural and exurban areas. Growth was directed mainly by the provision of infrastructure in advance of development.

The second scenario, *Constrained,* investigates lower-than-forecast population growth and tightly controlled development zones. It assumed: (1) a 50 percent smaller population than the currently forecast 78,500 by 2020; (2) 90 percent lived-in urban homes, 10 percent in rural; (3) Fort Huachuca remained open but was reduced significantly to approximately 1500 personnel; (4) domestic per capita water consumption decreased by 20 percent for all users; (5) elimination of all irrigated agriculture and ranching on state lands in the basin; (6) unprotected areas from the S.P.R.N.C.A to the Mexican border were purchased for conservation, Mexico managed an extension of the S.P.R.N.C.A., and large habitat patches (>5,000 acres) and connecting natural corridors were protected; (7) potential habitat for threatened and endangered species was protected; and (8) basin scale GAPs were protected.

Two variations of the *Constrained* scenario were tested against each other:

Test 4 – *Constrained* compared to *Constrained-1* assessed the effect of doubling the Fort's population while constraining off-post development.

Test 5 – *Constrained* compared to *Constrained-2* assessed the effects of closing Fort Huachuca and dividing its land between conservation and development. Since *Constrained-2* had the lowest population forecast, it was expected to have the least impact on hydrology and habitats. However, it increased attractiveness for development due to the newly available land on the Fort and, therefore, also continued to lower the water table. (Closure of the Fort would likely result in protection for large portions of the Fort's undeveloped land.)

The third scenario, *Open*, anticipated greater than forecast population growth and low-density development across the region. It assumed: (1) the population increased to 115,000 by 2020, 50 percent more than currently forecast; (2) 60 percent of the population lived in rural homes, 15 percent in urban, 15 percent in suburban, and 10 percent in exurban; (3) Fort Huachuca was closed and all its facilities and land were used for economic growth; growth in Sonora was moderate; (4) domestic per capita water consumption remained at 1995 levels; (5) an irrigation non-expansion area in the basin was created; existing irrigation continued, but proposed irrigation within one mile of the river was prohibited; (6) ranching in the basin continued at current levels, and leasing of state land for conservation was not allowed; (7) areas along the river south of the National Conservation Area to Mexico were purchased for conservation; and (8) potential habitat for endangered but not other species was protected, and no areas were protected for species diversity or GAPs based on Arizona GAP Analysis.

Two variations of the *Open* scenario were tested against each other:

Test 6 – *Open* compared to *Open-1* assessed the effects of closing most of Fort Huachuca when development controls were reduced and population growth in the area was higher than forecast. *Open-1* increased the attractiveness for development because of the newly available increase in land. Under the *Open-1* scenario, the minimum exurban lot size was increased to 16 ha.

Test 7 – *Open* compared to *Open-2* assessed the effects of the highest population growth when development controls were reduced. Populations for the Arizona portion and the Fort doubled, and Sonora experienced high growth as Cananea doubled in population. This produced the greatest level of groundwater depletion.

Results

Applying the process models to the scenarios for 2020 and comparing the results with the reference period (2000) yields impact assessments. The three *Open* scenarios were the most attractive to development. They provide the largest area of developable land from which to choose, resulting in lower land prices and housing costs. They also had the greatest negative impact on groundwater storage and recharge, substantially accelerated the drying of the San Pedro River, increased vegetation loss, and reduced all of the measures of potential wildlife habitat and visual quality. The *Open* scenarios resulted in a diffuse pattern of development, and the lowest level of environmental sustainability.

The three *Constrained* scenarios, which directed most future development into existing developed areas, substantially reduced attractiveness for developers. These scenarios could alter current development practices, but were dependent upon changes in the nature of the housing market. They had the lowest negative hydro-

logical impacts, reducing the rate of loss of groundwater. The *Constrained* scenarios also resulted in the least loss or greatest gains in habitat types, and in the least harmful impacts on visual quality. This could improve species diversity in the region, and benefit those species that depend on this habitat such as the Southwestern Willow Flycatcher.

The four *Planned* scenarios' impacts were between those of the *Open* and *Constrained* scenarios, but were closer to the latter. The *Planned* scenarios were attractive to developers, except where urban development is limited to land within current sewer service areas. They resulted in reduced loss of groundwater, but the water table continued to lower. *Planned* scenarios caused environmental and visual impacts that generally represented a slow decline in several important qualities of the region.

The impacts caused by variations in specific assumptions and policies within the scenarios were tested by comparison of selected scenarios. In all cases, the impact assessments were made from a regional perspective, but were also shown with locally varied impacts in maps accompanying the broader study (Steinitz et al. 2003).

Test 1 — *Planned* compared to *Planned-1.* Despite the policy assumption of reduced municipal and industrial water demand per capita, the increased population in *Planned-1* overwhelmed the assumed water savings. The loss of groundwater storage over 20 years increased from 22,600 acre-feet/year to 27,300 acre-feet/year, and the water captured from the river over 20 years increased from 27,600 m^3/day to 30,100 m^3 /day (*table 1*). There were reductions in large natural habitat patches (>5,000 acres) and Southwestern Willow Flycatcher habitat of 0.9 and 6.5 percent, respectively (*table 2*).

Test 2 — *Planned* compared to *Planned-2*. Because of increased groundwater pumping and water use in Sonora, the rate of lowering of the water table increased. Loss of groundwater storage after 20 years was 9,100 acre-feet/year more than for *Planned* (*table 1*). These impacts would be experienced in Arizona by irrigators as well as in Sonora by ranchers. However, the hydrological impacts due to Sonora were small relative to the potential for impacts from Arizona users due to water-use policy choices in that state. Changes in ecological characteristics were similar to the first test.

Test 3 — *Planned* compared to *Planned-3.* The policy to concentrate development in existing population centers had hydrological and other environmental advantages. Development zones improved attractiveness for urban and suburban development because of available infrastructure. They also reduced the attractiveness for rural development by reducing the amount of available land. The problem of compensation for development rights was not addressed. Regionally significant impacts included a small 0.7 percent increase in area for large habitat patches, but a sizeable 206 percent increase (3,100 to 6,400 ha) in Southwestern Willow Flycatcher habitat compared to *Planned* (*table 2*).

Test 4 — *Constrained* compared to *Constrained-1*. The hypothetical doubling of the Fort's population had adverse but minor impacts on groundwater. There was a 10 percent increase in loss of groundwater storage, but only a little more than 1 percent increase in capture from the river (*table 1*). The *Constrained* scenario showed a 71 percent increase in flycatcher habitat over the 2000 baseline, and doubling the Fort's population did not change this. There were small decreases in large habitat patches from the baseline of 0.6 percent and 2.3 percent

Table 1— *Changes in hydrology and vegetation under the ten scenarios.*

	Hydrology					Vegetation	
	Loss from groundwater storage over 20 yr (ac-ft/year)	**Change in agricultural pumping over 20 yr (m^3/day)**	**Change in municipal/ industrial pumping over 20 yr (m^3/day)**	**Capture from river over 20 yr (m^3/day)**	**Length of dry river (km)**	**Change in riparian vegetation (ha)**	**Change in grassland vegetation (ha)**
Baseline 2000	39,000	113,000	94,600	38,300	7.7	9,600	372,000
Planned	22,600	21,000	91,900	27,600	2.6	12,500	325,900
Planned-1	27,300	21,000	112,500	30,100	2.6	12,300	325,600
Planned-2	31,700	23,700	125,400	30,200	3.4	12,300	325,600
Planned-3	23,400	20,600	94,000	27,300	2.6	12,600	326,000
Constrained	16,600	2,300	93,200	20,900	2.6	13,100	326,000
Constrained-1	18,250	2,300	99,800	21,200	2.6	13,100	326,000
Constrained-2	14,100	2,300	85,600	21,100	2.6	13,100	326,000
Open	42,100	106,800	109,700	38,100	39.5	7,300	321,600
Open-1	43,600	106,800	113,800	37,500	38.0	7,250	321,600
Open-2	53,300	109,900	144,600	38,300	40.8	7,300	321,300

Table 2— *Changes in ecological characteristics under the ten scenarios.*

	Landscape ecology	Single species potential habitat		Species richness
	Change in area of large patches (ha)	Change in Southwestern Willow Flycatcher habitat (ha)	Change in potential habitat for all endangered species (ha)	Change in mean number vertebrate species detectable from one location over one year
Baseline 2000	688,000	9,600	136,300	167.7[1]
Planned	681,500	3,100	137,500	168.3
Planned-1	678,400	2,900	137,400	168.1
Planned-2	678,700	2,900	137,300	168.2
Planned-3	686,400	6,400	137,500	168.3
Constrained	683,800	16,400	137,800	168.6
Constrained-1	672,500	16,400	137,800	168.6
Constrained-2	672,500	16,400	137,800	168.6
Open	620,500	7,400	133,100	166.7
Open-1	586,500	7,600	133,000	166.6
Open-2	638,000	7,400	133,000	166.8

[1]Source: Arizona Gap Analysis Program.

respectively for the *Constrained* and *Constrained-1* scenarios. The Fort and city's proposed effluent treatment and storm water recharge projects were not included in calculating the *Constrained* Alternative Futures. The Fort has certified in formal consultation with the U.S. Fish and Wildlife Service that its groundwater withdrawal will be fully mitigated by 2011.

Test 5 — *Constrained* compared to *Constrained-2.* Since *Constrained-2* removed all agricultural pumping in the basin and had the lowest municipal pumping, it had the most favorable hydrological impacts (*table 1*). All *Constrained* scenarios resulted in similar increases in flycatcher habitat (*table 2*). The loss of large habitat patches was the same as *Constrained-1*. Even with the least hydrological impact, *Constrained-2* also continued to lower the water table. However, regional storm water and effluent recharge projects now proposed were not evaluated during the 1997 to 2000 study period.

Test 6 — *Open* compared to *Open-1.* Loss of groundwater storage for the *Open* scenario was 8 percent more than baseline, but *Open-1* was greater at 11.8 percent. The *Open* scenario captured 0.5 percent less water from the river than baseline, and *Open-1* decreased this further to 2 percent. *Open-1* showed the largest adverse impact on large habitat patches of all scenarios with a decrease of 14.8 percent over the baseline, compared to 9.8 percent for the *Open* scenario. The riparian habitat impacts were similar: *Open-1* showed a 24.5 percent decline in flycatcher habitat compared to 24 percent for *Open.* The decline in potential habitat for all endangered species was slightly more for *Open-1,* but all showed slightly less than 2.5 percent declines (*table 2*).

Test 7 — *Open* compared to *Open-2* assessed the impact of the largest population growth when development controls were reduced. The populations in the Arizona portion and Fort Huachuca doubled, and Sonora experienced high growth with the doubling of Cananea's population. As anticipated, *Open-2* produced the highest negative impacts on hydrology with a 36.6 percent increase in loss from groundwater storage due mainly to increased municipal and industrial water use. Capture of water from the river was the highest of all scenarios at 38,300 m^3/day, even though this was similar to the 2000 baseline. *Open-2* showed a 7.3 percent loss in large habitat patches compared to 9.8 percent for *Open. Open-2* showed a similar reduction in flycatcher habitat compared to *Open.*

Discussion

A full understanding of the maps and tables produced by the simulation of the ten scenarios into Alternative Futures for 2020 and the seven tests of policy sensitivity is necessary before detailed strategies can be chosen, as amplified in Steinitz et al. (2003). However, there are some informative generalizations that can be made from the results shown here. The evaluation of scenarios was based on considering the following as positive impacts: slowing the decline of groundwater storage, slowing the drying of the river, retaining or improving wildlife habitats, maintaining or improving

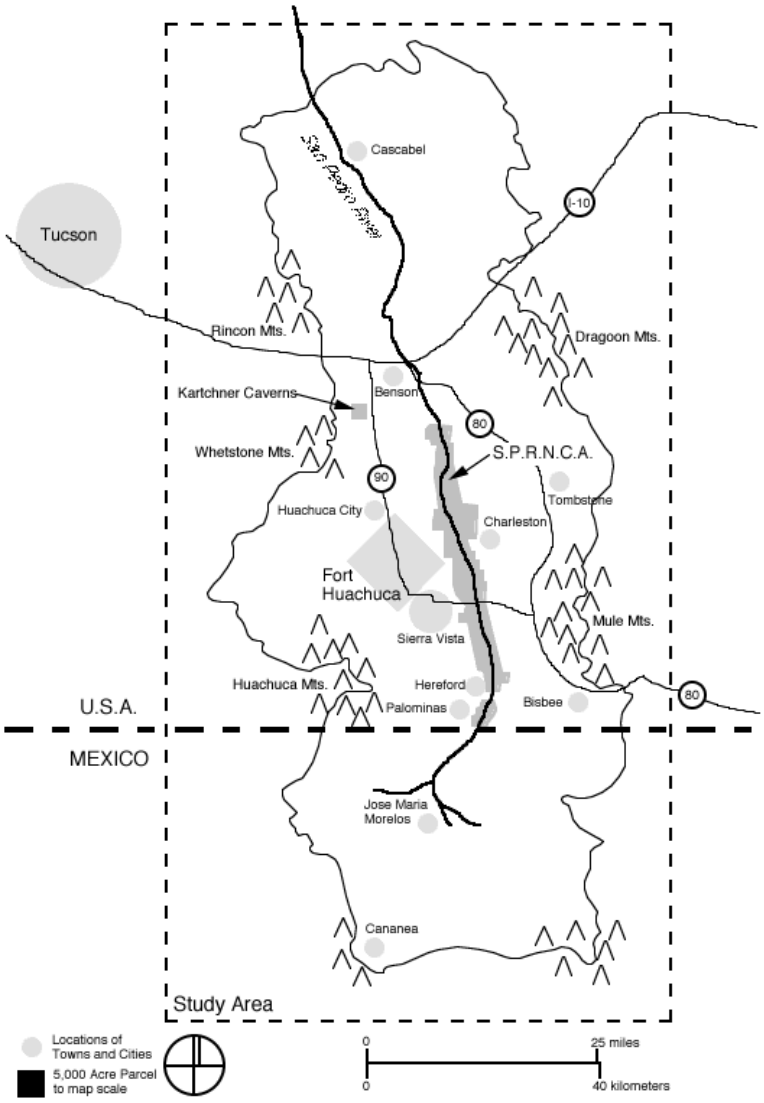

Figure 1— Study area showing Upper San Pedro River Basin.

species richness, improving attractiveness for developers, and maintaining the beauty of the landscape.

The most important findings involved the fundamental factor for life in an urbanizing desert: water. All of the scenario-generated Alternative Futures, even those that are most restrictive of population growth and water use, resulted in overall loss of groundwater storage and decreased stream flow in the San Pedro River. All scenarios resulted in a lowering of the water table near Sierra Vista and Cananea, with a severe drop in level around Sierra Vista of 10 to 15 m. However, the scenarios that most restrict irrigated agriculture resulted in water table gains to the north of St. David (on the river 10 km south of Benson, *fig. 1*). The San Pedro River continued to lose flow under the *Open* and *Planned* scenarios, and in the *Open* scenarios, the riparian habitat continued to decline. The region's recent governmental and non-governmental organization effort, the Upper San Pedro Partnership, is developing a regional water management plan that shows great promise in reversing the aquifer's decline. Not considered for the scenarios were USPP projects just now underway to infiltrate treated effluent and storm water into the water table. Follow-up efforts are needed to evaluate the impact of these projects.

There will be an increasingly fragmented pattern of habitat patches that will cause decline in the habitat quality of the region's landscape. This effect is particularly noticeable in alternatives that create development on and around the lower slopes of the mountains. Habitat for pronghorn (*Antilocapra americana sonoriensis*) declined in all the scenarios, as groundwater losses and changes in grazing and fire management caused the region's extensive grasslands to decline.

While the scenarios produced a generally negative set of impacts, there is considerable variation, especially between the extremes produced by the *Constrained* and *Open* scenarios. The *Open* scenarios resulted in an accelerated decline in all environmental impact measures. Although they included more developable land, they were not more attractive to developers due to a lack of infrastructure. The *Constrained* scenarios would see slower but continued lowering of the water table, a slowing of the processes of decline in the San Pedro River, and improved wildlife habitats. Because it had the lowest forecast population, *Constrained-2* had the lowest impact on hydrology and habitats as expected. The *Planned* scenarios produced futures that lie between the other two, but were closer to the *Constrained* scenarios in impacts. The *Planned* scenarios most closely resembled the current Cochise County Plan, and the most likely 2020 projections for Sonora. Comparing all the Alternative Futures revealed that policy decisions affecting irrigated agriculture in Arizona will cause the greatest impacts on the region's hydrology and ecology.

The second most significant policy is local governmental control of development. Population growth in Arizona, with its accompanying municipal and industrial water demands, will be the second largest consumer of water in the future. It is informative to compare the two scenarios that differ most in their impacts, *Constrained-2* and *Open-2*. *Open-2* is expected to have the highest harmful impact on the hydrology and environment of the region. It had the most rapid depletion of groundwater of any of the Alternative Futures. However, comparing the hydrological impacts of all *Open* scenarios in *table 2* revealed those for *Open-2* are not much worse than impacts of other *Open* scenarios. This led to the conclusion that encouraging population growth and relaxing development constraints are very powerful influences on potential negative environmental impacts.

Third in significance is growth policy in Sonora. The high growth assumed for Sonora in *Planned-2* and *Open-2* resulted in greater impacts than the lower growth scenarios. However, these differences were small when compared to the effects of agricultural and development policies in Arizona.

The effect of Fort Huachuca on the region was tested by selecting one of three policy choices in each scenario. It would either continue as at present, double in size of on-base population, or be closed. Closing most of the Fort was desirable for developers because of the subsequent increase in available land. But for suburban and exurban development, attractiveness decreased because larger lot sizes under that scenario used up the best available land faster. While local consequences in Sierra Vista may be large, when taken in the context of the entire Upper San Pedro River Basin, the variation associated with Fort Huachuca is small when compared with variations caused by agriculture and urbanization in the Arizona portion of the basin.

These findings were not unexpected. The projected future of the Upper San Pedro River Basin is one that will bring environmental crises closer to more people in the region. We do not propose solutions. Many people have views on the problems facing the region and on the policies that will influence change. The complex assessment of costs and benefits related to policy decisions is beyond the scope of this study. Responsibility for making the critical choices about the future of the region lies in Mexico and Sonora, and in the United States and Arizona, and with the present and future residents of the Upper San Pedro River Basin.

Critical choices will be made over the next twenty years that will determine whether or not the most attractive areas—both for conservation and development—will continue to be attractive. The land allocations made in the study represent our best projections about where development is likely to occur under the various scenarios, and what some of the most important environmental impacts might be. Patterns may change depending on people's preferences for housing, agriculture, and policy choices. If the people who live in the San Pedro Basin care deeply about preserving areas that will almost certainly be developed in the absence of protection, they must act now.

Acknowledgments

The authors gratefully acknowledge the cooperation of the regional planning agencies for the city of Sierra Vista and Cochise County, the multi-agency Semi-Arid Land-Surface-Atmosphere Program (SALSA) and Fort Huachuca, the Army's Construction Engineering Research and Development Lab, and the Environmental Protection Agency's Las Vegas Lab. The research was funded by a grant obtained by the U.S. Army Training and Doctrine Command's Environmental Division from the Department of Defense's Legacy Resources Management Program.

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Predicting Bird Response to Alternative Management Scenarios on a Ranch in Campeche, México[1]

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Abstract

We developed models to predict the potential response of wintering Neotropical migrant and resident bird species to alternative management scenarios, using data from point counts of birds along with habitat variables measured or estimated from remotely sensed data in a Geographic Information System. Expected numbers of occurrences at points were calculated for 100 species of birds, under current habitat conditions and under habitat conditions that would result from seven alternative management scenarios for Rancho Sandoval, a cattle ranch and private nature reserve in Campeche, México. Most bird species of conservation concern would benefit from management scenarios that increase the amount of forest, but the highest priority resident species would not. To balance the somewhat conflicting habitat needs of these species and the concerns of ranch managers, we recommend that forest area and connectivity be increased, and pastures be maintained but more efficiently managed to support cattle and the priority resident and migrant birds that require open habitats.

Introduction

North American bird conservation initiatives are increasingly oriented toward quantitative approaches. Bird and habitat data, collected at regional scales, are integrated in Geographic Information Systems (GIS), and used to model bird distribution or abundance as a function of landscape characteristics. The models are then used to predict bird response to possible land-use changes (Ruth et al. in press, Williams et al. 2002). Models can aid in identifying priority areas for conservation, guiding regional habitat conservation planning efforts. This framework also permits adaptive management of bird populations, in which models are used to predict the outcomes of management, and birds are monitored both to evaluate their response to management and, when alternative models exist, to choose among models to increase our understanding of how birds relate to landscapes (Lancia et al. 1996). An approach that links modeling with management and monitoring is especially applicable at more local scales such as National Forests or Wildlife Refuges, where there often are well-defined management units and objectives, and better data for development of predictive models. Developing and implementing management projects that explicitly use GIS, modeling, management, and monitoring is a primary task for bird conservation.

While most habitat conservation efforts have focused on the North American breeding grounds of migratory birds, similar quantitative approaches can be applied toward conservation of habitat on the wintering grounds. Predictive modeling of habitat associations of wintering Neotropical migrants and associated resident bird species can improve our understanding of winter habitat requirements and population dynamics, and provide a reasonable basis for bird management and conservation in the Neotropics. We developed models to predict the consequences to wintering migrant and resident birds of alternative land management scenarios on Rancho Sandoval, a 9,000-ha cattle ranch and private nature reserve in Campeche, México. Here, we provide a summary of our approach, and report example results for a few species and for groups of species of conservation concern. More details and results of the modeling effort are available from Wood (2000) and Wood et al. (1999).

Rancho Sandoval

Rancho Sandoval is located at approximately 18°22'N, 91°40'W, to the south of the Laguna de Términos. Cattle have been ranched on Rancho Sandoval at least since its acquisition by the Sandoval family in the early 1950s. At its peak of operation, the ranch supported more than 1,500 head of cattle on about 2,000 ha of pasture. The number of cattle was reduced to 500 over the past 10-15 years, and some pastures have been abandoned or less intensively managed, providing a diversity of habitats for birds and other wildlife. Currently areas of open pasture maintained by machete or mowing are interspersed through denser woody growth regenerated over a few months to 20 years.

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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Other habitats include forest dominated by evergreen or drought-deciduous trees, a band of mangroves along the Laguna and Río del Este, and savanna, a wet plain with scattered trees and forest islands.

Rancho Sandoval was designated a private nature reserve in 1993, with a goal of managing both for wildlife conservation and for cattle (to provide income for reserve operation). Research on site fidelity and survival of Neotropical migrant and resident birds began in 1992 in a collaborative project conducted by biologists from the U.S. Geological Survey Patuxent Wildlife Research Center and Pronatura Yucatán. In 1996, we began to develop a bird-focused conservation and management plan for Rancho Sandoval, with funding from the National Fish and Wildlife Foundation through a cooperative agreement with the U.S. Agency for International Development, under the Neotropical Migratory Bird Conservation Initiative.

Methods

Geographic Information System

To aid in development of the management plan, a GIS was developed for Rancho Sandoval. Aerial photos (scale 1:75,000) taken in 1994 were scanned and imported into ARC/INFO (Environmental Systems Research Institute, 380 New York Street, Redlands, CA 92373 USA.). The photos were ground-truthed, and a Global Positioning System receiver was used to obtain UTM coordinates for over 1,200 reference points, including landmarks, fence junctions, and vegetation patch boundaries. These reference points were used to geo-reference the scanned photos, and generate coverages of property boundaries, pasture fences, and aguadas (water holes). Vegetation patches were digitized from the photos, and classified as forest, pasture, or savanna. In 1994, there were 5,024 ha of savanna, 2,889 ha of forest, and 652 ha of pasture.

Alternative Management Scenarios for Rancho Sandoval

Although cattle occasionally graze in the savanna, the logistics of accessing and traversing this remote and perpetually inundated habitat render it virtually unmanageable. So, in considering how best to manage Rancho Sandoval in the future, we focused on the upland portions of the ranch. We developed seven scenarios for managing vegetation that represented alternatives to current management (*table 1*). We then evaluated the potential response of bird species on the ranch to each alternative management scenario, comparing predicted species occurrences to that under current (i.e., 1994) vegetation conditions. To be viable, an alternative management scenario had to maintain about 500 ha of pasture, the area needed to support 500 head of cattle, the herd size sufficient to ensure the economic stability of the ranch. However, other compatible economic activities could be implemented to reduce the number of cattle (and hectares in pasture).

We considered several strategies to increase forest area: allowing some pasture to revert to forest, consolidating existing forest patches (Scenarios 1, 2, 2a; *table 1*), or establishing forest corridors to increase patch connectivity (Scenarios 5 and 6). In the latter two scenarios, woody cover is managed as strips or blocks within the pasture matrix. This configuration would likely be easier to maintain than the current interspersion of open pasture and shrubby vegetation, and it could provide cover and additional forage for cattle during times of drought. We also considered the possible response of birds to the extreme scenarios of allowing all existing pasture to revert to

Table 1— *Alternative management scenarios for Rancho Sandoval used in analysis of consequences of management decisions on bird distributions.*

Management scenario	Description
94	Conditions as in 1994: a mosaic of open pasture (<30% woody cover), regenerating shrubs and patches of forest trees.
1	Some areas revert to forest; remaining pasture is maintained in 1994 conditions.
2	Some areas revert to forest as in scenario 1, but woody cover on remaining pasture is reduced to <30%.
2a	Some areas revert to forest as in 1 and 2, but all woody cover is removed from remaining pasture.
3	All forest is converted to pasture with 30% woody cover.
4	All pasture reverts to forest.
5	Some areas revert to forest. A corridor connects existing patches of forest. Woody cover is managed as strips of secondary vegetation in open pasture.
6	As in MS 5, but with two forest corridors and an alternative configuration of strips of woody vegetation.

forest (Scenario 4), or converting all forest to pasture with 30 percent woody cover (Scenario 3), a condition that could result if wildfires were allowed to burn unchecked.

Modeling Bird Distributions on Rancho Sandoval

To develop predictive models of bird distribution, we conducted a survey of birds on Rancho Sandoval during November-December 1997. In ARC/INFO, we generated a grid of points (n = 628), spaced at 200-m intervals over the manageable portion of the ranch (approximately 2,900 ha), and used it as the sampling frame for the survey. One hundred fifty-one points were selected from the grid, 30 in forest, stratified by distance from the forest edge (within and beyond 100 m), and the rest in pasture. At each point, all birds heard or seen during a 10-min period were counted within three intervals of distance (0-30 m, 30-100 m, >100 m) from the observer. This count was followed by an additional 5-min period during which whistled imitations of a Ferruginous Pygmy-Owl (*Glaucidium brasilianum*) were used to increase the probability of detecting birds present near the point (Lynch 1995).

We then assembled a set of habitat variables that could influence bird occurrence at the points, be managed, and be measured or estimated in the GIS. We classified each bird survey point as to its basic habitat type (forest or pasture); measured the distance from each point to the nearest forest edge, fence, and aguada; and used commands in the Grid module of ARC/INFO to estimate from the scanned aerial photos the percent woody cover around each point in pasture. We used logistic regression analysis to associate presence of each bird species with combinations of these habitat variables and selected the best model for each species using Akaike's Information Criterion (Burnham and Anderson 1992).

After developing and evaluating the models, we used them to predict occurrence for each bird species across all 628 points in the grid, for the habitat conditions of 1994 and under each alternative management scenario. GIS coverages were developed to reflect the changes in vegetation patch boundaries that would occur under each alternative management scenario (*table 1*), and the habitat variables were calculated for all grid points, for the 1994 conditions and for the alternative scenarios. We then calculated for each species a "total occurrence" for each management scenario, by summing over all points the predicted probabilities of occurrence based on the model. This number represents the number of grid points at which a species would be expected to occur under each management scenario. Standard errors of the total occurrences were estimated using the multivariate delta method (Kendall and Stuart 1977).

We were interested in the overall effect of alternative management scenarios on bird species of conservation concern. We considered several groups of birds, including migratory species of conservation concern (as defined by Partners in Flight prioritization; Carter et al. 2000) and priority resident birds (for constituent species, see Wood 2000). To simultaneously evaluate use of Rancho Sandoval by the species in a group, we summed the total occurrences of the constituent species to obtain total group occurrence. We viewed maximizing the summed total occurrences of these bird species of concern as the primary goal of habitat management and conservation activities on the ranch.

We used chi-square tests to test for differences among management scenarios in the predicted total occurrences for individual species and for the species groups, and we used z-tests to test for differences between predicted occurrences under 1994 conditions, which we considered the current habitat conditions, and under each alternative management scenario.

Results

Of the 161 bird species detected during the point counts, sufficient information existed to conduct analyses on 100 species, including 27 species of Neotropical migrants. Details of the models and the summed total occurrences under the management scenarios are presented in Wood et al. (1999) and Wood (2000), but the results for a few species are presented here as examples. The resident Ivory-billed Woodcreeper (*Xiphorhynchus flavigaster*) and migratory Wood Thrush (*Hylocichla mustelina*) were detected almost exclusively at points in the forest. The best models for both these species included a strong negative effect of the pasture habitat type (coefficients = -4.114 and -3.953, respectively), but the woodcreeper also showed a weak positive association with distance from forest edge (coefficient = 0.003, P = 0.02). The best model for the migrant Magnolia Warbler (*Dendroica magnolia*), like other species that commonly occur in forest, included a strong negative effect of the pasture habitat type (coefficient = -5.437), but also a weak positive association with woody cover in pasture (coefficient = 0.051, $P < 0.01$), reflecting its use also of pasture dominated by regenerating woody vegetation. Data for the resident Tropical Kingbird (*Tyrannus melancholicus*) best fit a model that incorporated a positive effect of the pasture habitat type (coefficient = 4.075) with a negative effect of woody cover (coefficient = -0.031), indicating that its probability of occurrence is highest in pasture with little woody cover.

Using these models and considering habitat conditions as they were in 1994, Ivory-billed Woodcreeper is predicted to occur at 193 points on the 628-point grid (*table 2*), Tropical Kingbird at 150 points, Wood Thrush at 196 points, and Magnolia Warbler at 579 points. If all forest was converted to pasture with <30 percent woody cover (Scenario 3), as could occur if

Table 2— *Number of grid points at which selected bird species are predicted to occur and, for groups of species of concern, summed total occurrences at grid points under habitat conditions as in 1994 and under three alternative management scenarios.*

	1994		Scenario 3		Scenario 4		Scenario 6	
Species	**n**	**SE**	**n**	**SE**	**n**	**SE**	**n**	**SE**
Ivory-billed Woodcreeper	193	34.6	3	2.9	349	53.5	236	38.9
Tropical Kingbird	150	21.8	478	39.8	68	26.3	139	22.8
Wood Thrush	196	33.0	8	7.4	249	42.2	209	35.2
Magnolia Warbler	579	14.3	261	45.8	655	15.7	584	14.7
Species of concern								
Migrants	2,762	98.2	1,890	123.6	3,264	141.0	2,879	107.5
Highest priority residents	705	57.8	1,257	128.3	710	77.8	724	62.8
High priority residents	1,101	82.4	854	105.6	1,420	138.7	1186	97.9

wildfires ravaged the ranch, the predicted number of points of occurrence would decline significantly for Ivory-billed Woodcreeper (to 3 points, *table 2*), Wood Thrush (to 8 points), and Magnolia Warbler (to 261 points), and increase significantly for Tropical Kingbird (to 478 points). Not surprisingly, under the other extreme, letting all pasture revert to forest (Scenario 4), species that regularly use forest are predicted to occur at many more points, though it would take a considerable number of years for that outcome to be achieved. Under Scenario 6, Ivory-billed Woodcreeper, Wood Thrush, and Magnolia Warbler would show slight but non-significant increases (*table 2*), while Tropical Kingbird would experience a slight decline.

Expected total occurrence summed for all migratory species of concern is 2,762 under the habitat conditions of 1994 (*table 2*). Under Scenario 3, expected occurrences would drop significantly (to 1,890; $Z = 30.5$, $P < 0.001$), and under Scenario 4, occurrences would significantly increase (to 3,264; $Z = 8.6$, $P = 0.004$), indicating the benefits of increased forest for this group. For resident bird species of concern, the highest priority species (those with narrow distributions, restricted habitats, and small populations; see Wood 2000 for further discussion) would benefit significantly from a reduction in forest cover (summed total occurrences 705 under 1994 conditions and 1,257 under Scenario 3; $Z = 15.4$, $P < 0.001$), but the species group of next highest priority (species with wide distributions but restricted habitats) would not. Instead, they would increase significantly under Scenario 4 (from 1,101 to 1,420; $Z = 3.9$, $P = 0.05$). Under the other scenarios, summed total occurrences for these species groups did not differ significantly from those expected under the habitat conditions of 1994. To balance the somewhat conflicting habitat needs of these species groups and the concerns of ranch managers, we recommended in the conservation and management plan for Rancho Sandoval that management approximating Scenario 6 be implemented. This approach would increase forest area and connectivity, while maintaining but more efficiently managing the pastures, supporting cattle and increasing (though not significantly) summed total occurrences for the groups of migratory and resident bird species of concern (*table 2*).

Discussion

We show how point count data can be used together with habitat data in a GIS to model possible costs and benefits to birds of alternative management scenarios. The structure presented here provides a reasonable approach to predicting bird response to alternative management or land-use scenarios, and a means to compare the scenarios in terms of expected total occurrence of bird species. Our models of bird distribution are based on count data from one year, and additional work should be done to validate and refine them.

Because we wished to make inferences to points beyond those sampled, we used a set of explanatory variables that could be measured remotely (i.e., in the GIS). These variables relate to the spatial configuration of habitats and habitat features, which many birds respond to, but species' distributions within habitats are likely also influenced by vegetation structure and other variables that can only be measured in the field. Although not presented in this paper, we field-sampled vegetation characteristics at bird survey points (but not at other grid points), and compared them at points where a species was present or not detected. Inclusion of these variables would likely improve the bird distribution models, but they can only be used to predict bird occurrence at points where values of the variables are available. However, in the conservation and management plan for Rancho Sandoval (Wood et al. 1999),

we used the information to make additional recommendations for managing habitats to benefit birds.

We evaluated predicted bird response to the alternative management scenarios by comparing expected occurrences for each scenario to those under the vegetation conditions in 1994. For most species and species groups, significant differences could be detected only for the extreme scenarios of converting all forest to pasture (Scenario 3) or allowing all pasture to regenerate to forest (Scenario 4). For some scenarios, the changes in the configuration of habitats were relatively minor and affected few of the grid points. In addition, although logistic regression models were significant for nearly all bird species, standard errors of the parameter estimates and the predicted number of occurrences were often large, reflecting imprecision in the data.

The examples that we present demonstrate that conflicts can arise in efforts to manage habitats for multiple species or species' groups. Deciding upon the objectives of management, and how to weight or prioritize species, can be difficult, and these decisions often are influenced by politics. For example, maximizing occurrence of bird species of concern is desirable for many sites, but nature reserves such as Rancho Sandoval may want also to emphasize species of interest to birdwatchers, to enhance the potential for eco-tourism. And, programs to manage and conserve wintering habitat for Neotropical migrants will more likely have local support if the needs of resident bird species are considered.

Models have limited scopes of applicability, and it is often useful to consider additional information (such as availability of additional nearby habitats) in defining which taxa should be local priorities for management. Resident species of concern that require open habitats may well have been using the extensive areas of savanna on Rancho Sandoval, which we were unable to survey. If so, their status on the ranch may be maintained or enhanced by protecting the savanna, rather than focusing entirely on managing for all birds within the confines of the upland portions of the property. This strategy could free up additional land for re-forestation, benefiting other resident and migrant birds, should economic substitutes for cattle ranching be found.

The foundation that this study provides, and the quick response of tropical vegetation to management (relative to temperate regions) make Rancho Sandoval an ideal locale at which to implement a program to manage habitats adaptively for birds and cattle. We recommend that such an effort adopt a hypothesis-driven approach to defining models, in which uncertainties in our understanding of bird habitat use in the tropics are incorporated directly into alternative model sets, and the alternative models are used to derive several sets of predictions of the consequences of management actions (Nichols 2000, Runge and Johnson 2002). Model uncertainty could be addressed, for example, through the addition of a set of models that only incorporate major habitats as a predictor of occurrence, to provide a parsimonious set of alternative models for comparison. Monitoring the response of birds to management would allow us to tailor management to benefit priority bird species and to update our view of which models best predicted the consequences of management, furthering our understanding of the system. Such a program could serve as a model for integrating bird habitat conservation with cattle ranching elsewhere in the Neotropics.

Acknowledgments

We thank A. Sandoval for his support and hospitality throughout the project. The staff of Rancho Sandoval, especially Jose Angel, provided considerable assistance and logistical support for the fieldwork. J. Fallon developed the GIS coverages for the alternative management scenarios, and I. Thomas assisted with other GIS tasks. B. Kendall and W. Thogmartin provided suggestions for improving the manuscript. The project was conducted while P. Wood was enrolled in the master's degree program at the State University of New York (SUNY) at Syracuse. The project was supported by a grant from the National Fish and Wildlife Foundation through a cooperative agreement with the U.S. Agency for International Development, under the Neotropical Migratory Bird Conservation Initiative. Additional support was provided by Fundación Sandoval Caldera, SUNY-Syracuse, and Friends of the Patuxent Wildlife Research Center.

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Integrated Bird Conservation along the Pacific Coast of North America: An Action Agenda[1]

Gregg Elliott[2], Bob Altman[3], Wendy Easton[4], Ricardo Estrella[5], Geoffrey Geupel[6], Mary Chase[6], Ellie Cohen[6], and Ann Chrisney[6]

Abstract

Scientists and managers representing the continental bird conservation plans explored the status of conservation planning and implementation for birds along the Pacific coast of North America. The theme of the session, "using common currencies to advance bird conservation," emphasized the components of bird conservation shared among the major initiatives, such as Bird Conservation Region coordinators, species, habitats, partnerships, funding opportunities, and Adaptive Conservation Planning. A primary goal of the session was to develop a conservation action agenda, agreed to by all participants. Types of action items identified include developing new modes of outreach to non-traditional partners, prioritizing funding needs, identifying new sources of funding, and integrating planning and partnerships among the four continental bird conservation plans.

Key words: all-bird, common currencies, conservation planning, integrated bird conservation.

Priorities for Bird Conservation: The Plans

On 21 March 2002, 18 presenters from six states and provinces of Mexico, the United States, and Canada (see *Appendix 1*) participated in a daylong series of presentations and discussions concerning the current status of continental conservation planning and implementation for birds along the Pacific coast of North America. A central focus of the discussions was integration of these efforts among bird conservation plans and regions. Participating scientists and managers represented all four of the continental bird conservation plans: the North American Waterfowl Management Plan (NAWMP), Partners in Flight (PIF), the U.S. Shorebird Conservation Plan (USSCP), and the North American Waterbird Conservation Plan (NAWCP), also known as "Waterbird Conservation for the Americas." These programs have joined forces under the umbrella of the North American Bird Conservation Initiative (NABCI) to support "all-bird" conservation. NABCI's mission is to facilitate the conservation of native North American birds by increasing the effectiveness of existing and new initiatives, enhancing coordination, and fostering greater cooperation among the nations and peoples of the continent (Pashley et al. 2000).

The theme of this session, "using common currencies to advance bird conservation," emphasized the components of bird conservation shared among the major initiatives, such as Bird Conservation Region (BCR) coordinators, species, habitats, partnerships, funding opportunities, management techniques, and Adaptive Conservation Planning (ACP). A primary goal of NABCI is to deliver the full spectrum of bird conservation through regionally based, biologically driven, landscape-oriented partnerships. In many cases, these partnerships take the form of NAWMP Joint Ventures (U.S. NABCI Committee 2000). Indeed, in late 2002 the Director of the U.S. Fish and Wildlife Service (USFWS) issued Order No. 146 to "ensure. . . development and support of Joint Ventures that are regionally based, biologically driven, landscape-oriented partnerships delivering the *full spectrum of bird conservation*," (emphasis added). The order goes on to state that "Joint Ventures should strive to develop the capacity to become the delivery agents for all migratory bird habitat conservation priorities in their geographic areas" (U.S. Department of Interior 2002).

One goal of this session was to develop an action agenda—a list of specific tasks agreed to by participants—to further the integration and achievement of bird conservation objectives as described in the regional bird conservation plans and other appropriate plans and strategies (for example those of the USFWS, The Nature Conservancy, and state agencies).

In providing summaries of their regional bird conservation plans, and thinking about common currencies,

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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[5]Centro de Investigaciones Biológicas del Noroeste, Mar Bermejo # 195, Col. Playa Palo Santa Rita, La Paz, Baja California Sur, 23090, MEXICO.
[6]PRBO Conservation Science, 4990 Shoreline Hwy, Stinson Beach, CA 94970.

presenters were asked to respond to the following questions:

1. What do you see as the best tools or mechanisms for implementing your conservation priorities?

2. What do you see as the best tools or mechanisms for measuring the success of your conservation actions?

3. If reasonably unlimited resources were available for conservation, what would you suggest as the most important one or two conservation activities that should be initiated now?

Presentations progressed geographically from south to north, beginning with Baja California and progressing through California, Oregon, Washington, British Columbia, and concluding with Alaska. Details of plans presented may be found at http://www.partnersinflight.org/. Other sources include http://www.nawmp.ca/eng/index_e.html and http://www.manomet.org/USSCP/. See also http://www.nacwcp.org/, or http://www.nabci.org/cec/.

Looking for Common Currencies: Panel Discussion

A panel of the presenters entertained questions from the audience. Discussion focused on how to bring the three newer conservation initiatives (PIF, USSCP, NAWCP) squarely into the realm of "implementation" with as much success as NAWMP. NAWMP Joint Venture representatives emphasized the need for measurable conservation targets (numbers of birds, hectares of habitat) from each of the non-waterfowl conservation initiatives. Many participants agreed that a current lack of funding for bird conservation in upland habitats is a significant roadblock to implementing conservation on a meaningful scale.

Using Common Currencies to Advance Bird Conservation

Practitioners presented a series of talks highlighting mechanisms for integration and achievement of bird conservation objectives (some of the papers from these talks are included in this volume). They focused on case studies of actual conservation projects.

What follows here is additional information on common currencies for bird conservation: a discussion of the role of BCRs, Adaptive Conservation Planning, and an action agenda for conservation integration. Policy developments at the national level and successful conservation partnerships at the international level point to future opportunities in the Pacific coast region.

The Role of Bird Conservation Region Coordinators

The first meeting of BCR coordinators held 14-16 August 2002 in Hood River, Oregon resulted in the following consensus concerning a BCR coordinator's job: it is as variable as the circumstances under which the coordinator operates.

Some BCR coordinators have dual roles as Joint Venture coordinators. Some have responsibility for a geographic area that spans several states, and some BCRs are encompassed entirely within one state. Thus, a BCR coordinator's job is to do whatever it takes to ensure that the trajectory of bird conservation emphasizes coordination among initiatives. Joint Ventures and other bird conservation groups are being encouraged to play an increasing role in the delivery of all-bird conservation. If a Joint Venture is already successfully delivering all-bird conservation (as, for example, in the Mississippi Valley), there may not be a need for a BCR coordinator. A substantive consensus emerging in the Pacific Region was that a significant role of BCR coordinators should be to track, maintain, and facilitate the use of information concerning new and existing sources of funding for all-bird conservation projects of all types (i.e. upland and wetland habitat protection, restoration, enhancement, monitoring, and research).

Adaptive Conservation Planning

One common currency widely recognized by conservationists is adaptive resource management, a process that emphasizes interaction between resource managers and scientists. Adaptive management involves treating management as a continual experiment in which the results of previous actions are monitored and used to modify future management (Holling 1978, Ringold et al. 1996).

Adaptive Conservation Planning (ACP) (*Fig. 1*) focuses on closing the scientific feedback loop, a critical but neglected component of adaptive management. ACP is a process designed to pool the results of many adaptively managed projects by collecting data on focal species, then developing an adaptive conservation plan (often called a bird conservation plan), which contains science-based conservation, management, monitoring and research recommendations for specific habitat types or ecoregions (Chase and Geupel this volume). The ACP process involves five steps: 1) compile and summarize existing knowledge, incorporating expert opinion, 2) identify system stressors and set conservation goals (this step entails substantial participation by land/ocean managers), 3) develop an adaptive conservation plan to achieve those conservation goals (this step focuses on data synthesis to generate management and research recommendations), 4) continue

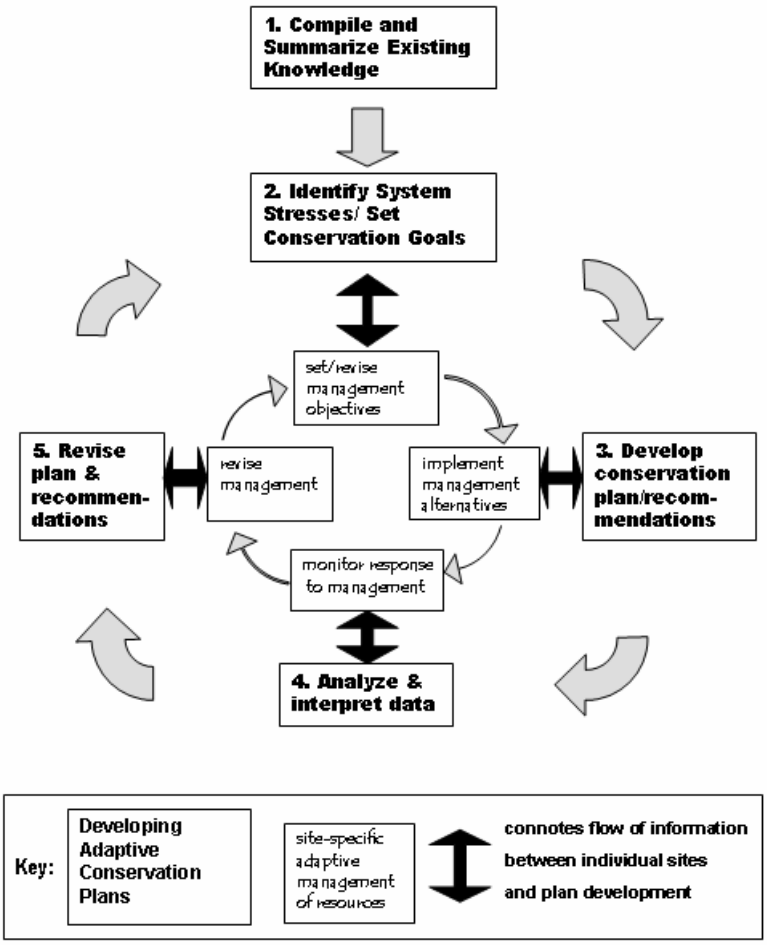

Figure 1— Flow of Adaptive Conservation Planning, showing development of adaptive conservation plans and linkages to site-specific adaptive management of resources.

to collect relevant data, and 5) revise the adaptive conservation plan on a regular basis.

Action Agenda for Conservation Integration

This session closed with a discussion to develop an action agenda for future collaboration. Participants identified the following as important objectives to be achieved over the next several years.

1. Increase collaboration between Mexico, the U.S., and Canada through development of joint proposals and projects that cross borders. Projects should address the needs of migrant species irrespective of political borders.

2. Integrate, through joint planning exercises, the geographic and habitat conservation priorities of all four continental bird conservation programs.

3. Identify Pacific coast all-bird projects/focus areas for the Trinational NABCI Committee to support as demonstration trinational conservation projects.

4. Work with the NABCI U.S. Committee to augment support and funding for the Neotropical Migratory Bird Conservation Act (NMBCA), viewed as the upland equivalent of the North American Wetlands Conservation Act, which provides funding for waterfowl and wetland conservation.

   (*Note:* Results from the first round of NMBCA grants in 2002 resulted in the funding of 32 proposals, at a mean match-to-grant ratio of 4.7 to 1. Many high quality projects went unfunded, and this overwhelming response to the first grant round showed an enormous demand for upland projects in the United States and Latin America.)

5. Increase financial support for people traveling internationally, particularly biologists and agency representatives from Latin American countries who may have limited sources of support for international travel. Increase financial support for much-needed equipment and facilities for biologists, particularly those in Latin American countries seeking to build a more robust bird monitoring infrastructure. For example, this could be accomplished if key sources

of federal or private funding allowed a greater percentage of project funds to cover the cost of new equipment (such as mist nets, computers, wet labs).

6. When working internationally, realize that the interests and priorities of research institutions can differ substantially from those of government agencies.

7. Identify and increase use of non-wetland/non-game conservation funding (in addition to NMBCA funding), for example, state wildlife grants (federal wildlife conservation funds available to state fish and wildlife agencies) or other state programs that target habitats or regions rather than wildlife directly (such as programs for coastal conservation).

8. Help to establish state matching programs for federal dollars.

9. Develop a list of top priority projects for all birds, with associated price tags, to demonstrate need and help with fundraising.

10. Recruit and/or identify non-game agency personnel and non-governmental organization representatives to participate in existing Joint Ventures (boards and technical committees).

11. Build partnerships with private landowners and seek the support of new funding sources in 2002 Farm Bill conservation programs. For example, there will be $50 million in new grassland conservation programs and a 15 percent earmark of Wildlife Habitat Improvement Program funds for species at risk.

12. Work with the Natural Resources Conservation Service to partner with and help train new employees who will be hired to conduct technical assistance (120 new employees in 2002 in California alone).

13. Conduct outreach to private landowners to facilitate realistic wildlife-friendly stewardship.

14. Ensure that bird conservation initiatives work together to develop incentives for landowners to improve stewardship for birds and other wildlife.

15. Work with the hunting community to further enhance traditionally managed habitats for all birds.

16. Use resources of the Land Trust Alliance and similar organizations, which provide business support and other resources and can assist in identifying local land trust partners.

17. Work with private forests and other industries as partners to identify economically viable wildlife conservation practices and projects.

18. Help other regions and Joint Ventures learn from successful programs, such as the Central Valley Habitat Joint Venture's relationship with agriculturalists (i.e., their partnership with the California Rice Growers).

19. Increase the staff available to all-bird conservation programs within the Pacific states and provinces of North America to achieve stepped-down conservation goals of PIF, USSCP, and NAWCP. Increases could take the form of dedicated state or federal agency staff time, the hiring of new BCR coordinators, or project-level staff based at private organizations.

Future Directions

Participants discussed the concept of developing a regional Pacific All-Bird Conservation Initiative (PABCI) to help achieve the objectives listed above. The mission of PABCI would be to conserve all birds and ecosystems throughout the Pacific Flyway by integrating the interests of the waterfowl, landbird, shorebird, and waterbird efforts locally, regionally and flyway-wide. They agreed to meet again in 2003 or 2004 (as of May 2003, no meeting had yet been scheduled) to further refine these goals, facilitate collaboration, and ensure true integration of bird conservation action.

The primary goal of an inaugural PABCI meeting would be to facilitate new partnerships or expanded roles for Joint Ventures by:

1. Developing one or more pilot all-bird conservation projects, which integrate data and data collection, conservation planning, prioritizing, and fundraising across continental bird conservation programs and across borders.

2. Assessing existing monitoring and research programs to increase cooperation, identify gaps, and develop a set of common priorities across bird conservation programs.

3. Developing strategies to foster real international communication and partnership through seminars, courses, research opportunities, and on-the-ground conservation projects.

4. Identifying agencies or NGOs to lead each of these actions and target potential sources of funding.

Acknowledgments

The authors wish to acknowledge the Common Currencies panelists listed in *Appendix 1* for their partici-

pation and contributions in developing the action agenda presented here.

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Appendix 1— *Common Currencies panelists.*

Province or State	Panelist
Baja, Mexico	Eduardo Palacios, Centro de Investigatión Científica y de Educación Superior de Ensenada (CICESE) (Waterbirds) Eric Mellinck, CICESE (Shorebirds) Ricardo Estrella, Centro de Investigaciones Biológicas del Noroeste (CIBNOR) (Landbirds)
California	Mark Pietre and Mike Eicholz, Ducks Unlimited; Bob Schaffer, Central Valley Habitat Joint Venture; and Catharine Hickey, Point Reyes Bird Observatory (Central Valley Habitat Joint Venture) Karl Malamud Roam, San Francisco Bay Joint Venture (SFBJV) Kyra Mills and Gregg Elliott, Point Reyes Bird Observatory; and Maura Naughton, U.S. Fish and Wildlife Service (Waterbirds) Catharine Hickey, Point Reyes Bird Observatory (Shorebirds) Geoffrey Geupel and Sandy Scoggin, Point Reyes Bird Observatory (Landbirds)
Oregon-Washington	Joe La Tourrette, Washington Joint Venture Coordinator (Pacific Coast Joint Venture) Joe Buchanan, Washington Department of Fish and Wildlife (Shorebirds) Bob Altman, American Bird Conservancy (Landbirds)
British Columbia	Andre Breault, Canadian Wildlife Service (Waterfowl) Rob Butler, Canadian Wildlife Service (Shorebirds) Wendy Easton, Canadian Wildlife Service (Landbirds)
Alaska	Brad Andres and Heather Johnson, U.S. Fish and Wildlife Service (Shorebirds) Steve Matsuoka and Colleen Handel, U.S. Geological Survey, and Brad Andres, U.S. Fish and Wildlife Service (Landbirds)

Priorities for Implementation of the Northern Pacific Coast Regional Shorebird Management Plan[1]

Joseph B. Buchanan[2]

Abstract

Marine and upland habitats in western Washington and Oregon provide essential conditions for many wintering and migratory shorebird species along the Pacific Flyway. Known or potential threats to shorebirds include loss or degradation of habitat, invasion of exotic vegetation and invertebrates, environmental pollution, and human disturbance. Initial priority activities should focus on protecting, restoring, and enhancing shorebird habitats. Monitoring will be required to evaluate shorebird responses to management efforts. Implementation of the Northern Pacific Coast shorebird plan's key elements likely will require parsimonious incorporation of shorebirds into other multi-species, habitat-based or ecosystem-level conservation efforts; the Pacific Coast Joint venture likely will play a crucial role in this regard. Success of the planning effort will be determined by evaluating population responses at local (short-term) or flyway (long-term) scales, by reducing and/or eliminating threats, and by purchase or protection of important shorebird areas, including degraded or abandoned roost sites. The overall effort will require a highly coordinated monitoring and management network within and among regions and flyways. Because some of the most important habitats used by shorebirds are of great economic value to humans, outreach activities must effectively convey a meaningful conservation message to the public.

Key words: conservation implementation, north Pacific coast, Oregon, priority activities, shorebirds, Washington.

Introduction

The need for conservation activities focused on shorebirds has become clear in recent years. A national plan (Brown et al. 2000) and multiple regional plans were completed in 2000. At about this same time, conservation plans had been completed or were under development for most other groups of birds in North America and elsewhere in the western hemisphere. At a special session of the international Partners in Flight conference, in Asilomar, California, participants in some of the bird conservation planning processes were asked by session facilitators to address three questions such that the breadth of issues and solutions might be identified (see Elliot et al., this volume). The questions posed were as follows:

1) If a reasonable amount of funding were assumed to be available, what would be the highest priority conservation activities that should be initiated now?

2) What would be the best tool or mechanism for implementing conservation priorities?

3) What would be the best tool or mechanism for measuring success of conservation actions?

This paper briefly summarizes responses to these questions. The response to the first question is very specific in that it identifies only the top three priority activities in the region. Responses to questions two and three refer to the top several priority activities in the region. For the purposes of this overview, the Northern Pacific Coast plan area is defined as those portions of Washington and Oregon west of the Cascade Mountain crest including the nearshore and offshore waters (Drut and Buchanan 2000).

Threats to Shorebirds and Their Habitats

There are several real or potential threats to shorebirds in the Northern Pacific Coast plan area (Drut and Buchanan 2000). The greatest of these threats include the loss or degradation of habitats. The priority activities described below relate to issues involving the loss or degradation of habitats.

Priority Activities

The priority activities in the Northern Pacific Coast plan area are to (1) effectively eliminate and otherwise control exotic species in essential shorebird habitats, (2) improve oil-spill-prevention strategies and spill-

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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response efficiency, and (3) restore degraded habitats. Other priority activities, including monitoring, are described elsewhere (Buchanan 2000, Drut and Buchanan 2000).

Invasive Species

Extensive areas of the non-native cordgrass, *Spartina alterniflora*, have now very nearly covered certain tide flat areas in Willapa Bay that supported high numbers of wintering and migrant shorebirds (Buchanan and Evenson 1997, Buchanan 2003). Invasion by *Spartina* results in elevation increases in salt marsh and a reduction in the total area of mudflats available for foraging by shorebirds. *Spartina* has spread beyond Willapa Bay to other estuaries (see Daehler and Strong 1996). It may within a few years become so widespread—in Willapa Bay or other estuaries—that reasonable management options become much more costly or are no longer feasible. Therefore, the highest priority should be to restore tide flat areas invaded by *Spartina* and then control the spread of *Spartina* in those areas.

Other exotic species also have become established in the plan area. The Asian clam (*Potamocorbula amurensis*), European green crab (*Carcinus maenas*), and other marine invertebrates have been introduced into the plan area through unintentional transport via packing materials and in ballast of marine vessels. These invertebrates are capable of dramatically altering invertebrate communities in estuaries, therefore potentially influencing shorebird prey populations (Grosholz et al. 2000, Grosholz and Ruiz 1995). Dense growths of purple loosestrife (*Lythrum salicaria*) and reed canary grass (*Phalaris arundinacea*) have invaded the shorelines of some freshwater wetland habitats and made them unsuitable for most shorebirds (see Buchanan 2000). Similarly, the establishment of European beach grass (*Ammophila arenaria*) has altered beach dune systems along much of the Washington and Oregon coast (Wiedemann and Pickart 1996), making some of these areas less suitable for the Snowy Plover (*Charadrius alexandrinus*). Methods should be developed to control or eliminate exotic vegetation and populations of harmful invertebrates that become established in estuaries or freshwater habitats.

Reduce Risk of Oil Spills

The second priority is to improve oil spill prevention strategies and to enhance spill response efficiency, particularly in areas of essential shorebird habitat. A huge volume of oil is transported throughout much of the Northern Pacific Coast plan area, including the outer coast, several of the larger bays, the lower Columbia River, and Puget Sound. In 1999, for example, 12,308 commercial vessels, including 1,748 oil tankers or tank barges, passed through the Strait of Juan de Fuca. Moreover, an estimated 15.1 billion gallons (57.15 billion liters) of oil transited Washington's Puget Sound in 2000 (Washington Department of Ecology 2000). The coastal and inland beaches and tidal flats that would potentially be polluted from oil spills collectively support the vast majority of wintering and migrant shorebirds in the region. Some of the sites that could be impacted are either regionally or internationally important sites (Drut and Buchanan 2000) according to the Western Hemisphere Shorebird Reserve Network criteria (Harrington and Perry 1995). Perhaps the most important activity to reduce the risk of oil spills would be to provide funding for more commissioned tugboats to escort (or be available to) tankers that use near shore waters.

Restore Degraded Habitats

The third priority activity is to conduct habitat management to restore suitable conditions at historical shorebird stopover and wintering sites. Many important shorebird sites have been degraded over the years such that shorebirds rarely, if ever, use the degraded areas. Some examples of needed restoration activities include reconstruction of roost sites (e.g., at Tillamook Bay, Oregon), removal of dikes to allow resumption of natural tidal actions (e.g., at Nisqually National Wildlife Refuge, Washington), and removal of tiling to allow for a more natural occurrence of flooded fields in agricultural landscapes (e.g., in the Willamette Valley, Oregon).

Implementing Conservation Priorities

Implementation of priority conservation activities will be a great challenge. Although discussion within the various bird conservation initiatives acknowledges the need for an opportunistic approach to implementing certain elements of the plan, it also is widely believed that a healthy partnership with existing Joint Ventures and a new focus on landscape- or ecosystem-level forms of "all bird" conservation planning will be the most effective delivery mechanism. This approach may be most successful for priority activities such as control of exotic species and restoration of degraded habitats. Pollution control/response and other activities will involve other partnerships.

In all of the priority activities described above, a significant level of coordination will be essential. This coordination should span the various bird conservation planning initiatives (landbirds, waterbirds, waterfowl, raptors, etc.) and should involve other efforts that focus on reserve planning (e.g., National Wildlife Refuges), ecosystem planning (e.g., The Nature Conservancy's eco-regional planning), and other resource

management programs (e.g., those that strive to maintain water quality). In many instances, planning must include multiple states and provinces, agencies and organizations, within and among flyways. Such comprehensive coordination and facilitation of implementation will require more active participation by the resource management agencies. Agencies will need to fund internal positions designed to assist with coordination, or provide funding for unaffiliated regional coordinators. Because some of the most important habitats used by shorebirds are of great economic value to humans, outreach activities must effectively convey a meaningful conservation message to the public.

Measuring Success

The procedures used to measure success of program implementation must obviously be designed to best evaluate the particular activities under consideration. Measuring the effectiveness of some of the activities described above can be accomplished by examining the response of shorebirds to the restoration or enhancement measures taken. This will require that funding is made available for monitoring. Response monitoring may involve documentation of numerical responses and also should use other procedures, where appropriate, such as nesting success and rates of lipid deposition (Williams et al. 1999), to evaluate the functional value of restored habitats. The success of other activities will be measured by determining whether threat factors have been reduced or eliminated and by the purchase or protection of important shorebird areas.

Acknowledgments

I thank M. Drut for his lead role in completing the Northern Pacific Coast plan. About 30 members of the regional working group provided ideas and thoughtful discussion that greatly contributed to plan development. M. Naughton reviewed the draft presentation and made helpful comments, and B. Altman made constructive comments that improved the final document.

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Terrestrial Birds and Conservation Priorities in Baja California Peninsula[1]

Ricardo Rodríguez-Estrella[2]

Abstract

The Baja California peninsula has been categorized as an Endemic Bird Area of the world and it is an important wintering area for a number of aquatic, wading and migratory landbird species. It is an important area for conservation of bird diversity in northwestern México. In spite of this importance, only few, scattered studies have been done on the ecology and biology of bird species, and almost no studies exist for priority relevant species such as endemics, threatened and other key species. The diversity of habitats and climates permits the great resident landbird species richness throughout the Peninsula, and also explains the presence of an important number of landbird migrant species. Approximately 140 resident and 65 migrant landbird species have been recorded for Baja California state (BCN) and 120 resident and 55 landbird migrant species for Baja California Sur state (BCS). Three terrestrial endemics have been recognized for BCN and four endemics for BCS. Sierra de la Laguna at the southern tip of the Peninsula contains an important number of endemic taxa at the subspecies level (N = 11). Most migrant species use oases of southern Baja as stopovers and Sierra de la Laguna as a final overwintering area. Twenty taxa are listed as threatened or endangered in BCN and two species extinct, the California Condor (*Gymnogyps californianus*) and the Guadalupe caracara (*Polyborus lutosus*). Ten raptors and 10 Passeriformes (seven from Guadalupe island) are in threatened categories. In BCS, 32 taxa are also listed. One extinct species, 11 raptors and 20 Passeriformes (14 from Sierra de la Laguna). The most important areas for landbird conservation in the Peninsula are the oak and pine-oak forests of Sierra de la Laguna, Sierra San Pedro Mártir and Sierra de Juárez; Valle de Los Cirios; Sierra de la Giganta; and Bahía Magdalena and the series of oases throughout the Peninsula. Critical areas for conservation are the scattered oases, particularly those of San Ignacio, Sierra de la Giganta, La Purísima, the Comondúes, San José del Cabo and Santiago. Threats for terrestrial birds are due to habitat fragmentation, the use of pesticides in agriculture areas and big development projects such as the Nautical Ladder that will have impacts at the regional level on the biodiversity. Proposals for research and conservation action priorities are given for the conservation of birds and their habitats throughout the Peninsula of Baja California.

Introduction

The Baja California peninsula is an important area for conservation of bird diversity in northwestern México (CCA 1999, Arizmendi and Marquez 2000). It has been classified as an Endemic Bird Area of the world (Stattersfield et al. 1998) and also has been considered as an important wintering area for a number of aquatic, wading and migratory landbird species (Massey and Palacios 1994, Rodríguez-Estrella 1997, Mellink this volume).

Studies documenting birds in Baja California Peninsula date from the end of the 1800. Baja is one of the better studied regions in northwestern México, but most studies were anecdotic and descriptive, scattered throughout the Peninsula, and have focused on taxonomy and distribution of species based on specimen collection and observations. Only a few of them discuss the origin and biogeography of the avifauna (Anthony 1893, Brewster 1902, Grinnell 1928, Bancroft 1930, Davis 1959, Stager 1960, Banks 1967, Cody 1983, Wilbur 1987, Erickson and Howell 2001). Only a few other studies have been done on the ecology of terrestrial bird species and on the habitat requirements of resident birds. Very little is known of migrant bird ecology and almost no information exists on the distributional patterns of species throughout the Peninsula.

Little is known of landbirds ecology in Baja California despite the wide array of habitats the peninsula contains. Oak and pine-oak forests, mediterranean scrub, tropical deciduous forest, xerophytic scrub vegetation (including the vegetation of temporal flood beds or arroyos), a series of oases containing relictual mesic conditions, and the adjacent islands in both the Pacific and Gulf of California coasts (Wiggins 1980, Cody 1983, Arriaga and Rodríguez-Estrella 1997).

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California**.

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There are only a few papers dealing with productivity, diet, and breeding biology of several bird species and almost no information on the habitat requirements, habitat use and habitat selection of resident birds, winter or migrant ecology (see Wilbur 1987; Rodríguez-Estrella et al. 1997, 1998, in press). Finally, almost no information exists on the distributional patterns of birds among important bird areas, hotspots and critical areas.

Characteristics of the Baja California Peninsula

The Baja California Peninsula contains 12 Priority Terrestrial Areas (Arriaga et al. 2000). These areas are contained into the Sierra de la Laguna, Sierra El Mechudo, Sierra de la Giganta, Planicies de Magdalena, El Vizcaíno-El Barril, Sierras La Libertad-La Asamblea, Valle de los Cirios, San Telmo-San Quintín, Punta Banda-Eréndira, Santa María-El Descanso, Sierra San Pedro Mártir and Sierra de Juárez (*fig. 1*).

The length of the peninsula is about 1300 km, and the width ranges 30-80 km. Coastal plains, deep canyons and rough mountains can be found throughout the Peninsula. Vegetation types include xerophitic scrub, pine-oak forests, Mediterranean scrub chaparral, tropical deciduous forest, coastal vegetation, mesic vegetation in oases with palms, reed grass, and *Typha*. The altitude ranges between 0 and 3100 m. Mean annual precipitation ranges from 100 mm in Vizcaino desert to more than 765 mm in Sierra de la Laguna.

Dominant plants are columnar giant cardon cacti (*Pachycereus* spp.), mesquite (*Prosopis* spp.), palo verde (*Cercidium microphyllum*), plum tree (*Cyrtocarpa edulis*), lomboy (*Jatropha spp*.), copal (*Bursera* spp.), dagger cactus (*Stenocereus gummosus*), Adam's tree (*Fouquieria diguetii*), Cirio (*Fouquieria columnaris*), ruellia (*Ruellia peninsularis*), and cholla (*Opuntia cholla*) in scrub vegetation. The mesic vegetation of oases is dominated by palms (*Washingtonia robusta*, *Phoenix dactylifera*), reed-grass (*Phragmites communis*), and clumps of cattails (*Typha domingensis*) associated with the water's edge or freshwater marshes. Pine-oak forests are dominated by pines (*Pinus* spp.), oaks (*Quercus* spp.), and manzanita (*Arbutus peninsularis*). Tropical deciduous forest is dominated by *Lysiloma divaricata*, *Albizzia occidentalis*, *Jatropha cinerea*, *Tecoma stans*, *Cassia emarginata* and *Pithecellobium undulatum*. Mediterranean scrub vegetation or chaparral contains *Archillea millefolium*, *Adenostoma fasciculatum*, *Adiantum jordanii*, *Aesculus parriyi*, *Baccharis sarathroides*, *Camissonia lewssi*, *Ephedra californica*, *Daucus pusillus*, *Mimulus aridus*, *Dryopteris arguta*, and *Hemizonia fasciculata*. Coastal vegetation is dominated by *Abronia maritima*, *Jouvea pilosa*, *Sporobolus virginicus* and *Maytenus phyllantoides* (Delgadillo 1992, Rodríguez-Estrella et al. 1999, León de la Luz et al. 2000).

Figure 1—The Baja California Peninsula priority and critical terrestrial areas (A), and the most relevant oases locations (B).

Urbanization, agriculture and ranching, tourism and mining are the main human activities in the area. Baja California has the lowest human density of all of México and most natural vegetation in middle and south Baja California is disturbed mostly by grazing. Threats for oases have been determined to be tourism, burning reed-grass and palm vegetation to eliminate dry vegetation so as to avoid fires, cutting stems of reed grass for rural home construction, human water use, and cattle, horses and burros feeding on reed grass

(Rodríguez-Estrella et al. 1999). Mesquite wood extraction was the main threat we detected in arroyo habitat. The use of pesticides presents a serious threat on most agriculture land. Common pesticides are DDT and PCBs (Merino et al. 2002).

Official Natural Protected Areas

Baja California Peninsula contains several protected areas (INE 2002). The most important in terms of size are those of Vizcaino desert Biosphere Reserve and Valle de Los Cirios National Park, both comprising more than 4,000,000 ha. Sierra de La Laguna Biosphere Reserve is the most important protected area in terms of number of endemic taxa (*fig. 1*). Sierra de La Laguna is an important relict area because it is the only area in south Baja California containing oak and pine-oak forests, and has been isolated since the Miocene (Rodríguez-Estrella 1988). Several birds, reptiles and small mammal species have been isolated since then and have high levels of endemism (Rodríguez-Estrella 1988, Cancino et al. 1994).

Bird Species Diversity

Baja California Peninsula is divided geopolitically in the Baja California (BCN) and Baja California Sur (BCS) states. Approximately 140 resident and 65 migrant species has been recorded for BCN. There are three endemics in BCN, the Guadalupe Junco (*Junco insularis*), Mountain chickadee (*Poecile gambeli*) in Sierra Juárez and Sierra San Pedro Mártir, and the Guadalupe Caracara (*Polyborus lutosus*) which is extinct (Ceballos and Marquez 2000). For BCS, 120 resident and 55 migrant species have been recorded. There are four terrestrial endemics in BCS, the Belding's Yellowthroat (*Geothlypis beldingi*; endemic to particular oases of Baja California Sur; Rodríguez-Estrella et al. 1999), Xantus' Hummingbird (*Hylocharis xantusii*; originally endemic to Sierra de la Laguna and subsequently colonizing most of the Peninsula, mainly in mesic vegetation, canyons, and islands habitats), Gray Thrasher (*Toxostoma cinereum*; endemic to scrub vegetation in BCS and part of BCN), and the Cape Pygmy-Owl (*Glaucidium hoskinsii*; endemic to Sierra de la Laguna following Howell and Webb 1995, Stattersfield et al. 1998). The San Lucas Robin taxonomic status is now considered a subspecies endemic to the mountain pine forests of Sierra de la Laguna by all modern authorities (*Turdus migratorius confinis* AOU 1998, Stattersfield et al. 1998) contrary to some authorities that considered this bird as an endemic species in the past (e.g. *Turdus confinis*). Sierra de la Laguna at the southern tip of the Peninsula contains the most endemic taxa at the subspecies level (N = 11), as a result of its particular geological and evolutionary history (Rodríguez-Estrella 1988).

Most migrant species use oases of southern Baja as stopovers (Rodríguez-Estrella et al. 1997), and Sierra de la Laguna as a final overwintering area (Rodríguez-Estrella, unpubl. data[1]) (*fig. 1*).

Status of Birds

There are 20 taxa listed as threatened or endangered and extinct species in BCN (NOM 2001). Two species are extinct, the California Condor (*Gymnogyps californianus*, extinct in the wild but recently reintroduced) and the Guadalupe Caracara (*Polyborus lutosus*). Ten raptors and 10 Passeriformes are threatened. Seven of the Passeriformes are from Guadalupe island.

In BCS, 32 taxa are listed: the Groove-billed Ani (*Crotophaga sulcirostris pallidula*) is extirpated since early 1900 from the Cape region (Grinnell 1928), and 11 raptors and 20 Passeriformes (14 from Sierra de la Laguna) are officially listed (NOM 2001).

Important Areas for Bird Conservation

We can propose that the most important areas for bird conservation in Baja California Peninsula are the oak and oak-pine forests of Sierra de la Laguna and Sierra San Pedro Mártir and Sierra de Juárez; Valle de Los Cirios; Sierra de la Giganta; and Bahía Magdalena (because the only breeding Bald Eagle population in Baja California is present here) and the series of oases throughout the Peninsula (*Fig. 1*). Most endemic and priority species, and a high species richness have been recorded in those areas.

Critical areas for conservation are the scattered oases, particularly those of San Ignacio, Sierra de la Giganta, La Purísima, the Comondúes, San José del Cabo and Santiago (Rodríguez-Estrella et al. in press) used as stopovers by a significant number of migrant bird species. An important number of oases are critically threatened (Rodríguez-Estrella et al. 1999). Oases contain the highest species richness and diversity of all habitats. Also, the highest bird abundances have been recorded at oases. Oases seem to be attractive habitats for birds, both residents and migrants (see Rodríguez-Estrella et al. 1997a). Oases represent small gaps of rich habitats inserted in the adjacent arid regions of Baja California that contain xerophythic scrub vegetation.

Also, field crops and golf courses are intensively used by resident and migrant birds in Baja California

Peninsula (Rodríguez-Estrella 1997; Rodríguez-Estrella, A. Cota, and R. Bolaños, unpubl. data[2]).

Threats to Birds

The main threats for birds in Baja California are increasing urbanization and tourism development, and agriculture, grazing and mining activity with resulting habitat loss. The development of the Nautical Ladder Route (Escalera Náutica; http://www.bajaquest.com/escaleranautica/) will certainly represent a change at the regional scale and a major threat for biodiversity conservation. The plan includes the development of buildings, roads and small airports in many areas of Baja that will increase the traffic and permit people to easily arrive to areas inaccessible before. Thus, it is expected human activity will increase threats to birds mainly because of habitat changes and disturbance. On the other hand, agriculture and the use of organochlorines and organophosphates pesticides (e.g. DDT, DDE, PCBs, Malathion) are among the most serious threats to bird populations and functional ecosystems.

Proposals and Perspectives for Research and Conservation

I propose the next research could be conducted in Baja California Peninsula to correctly establish management plans for the conservation of landbird diversity:

- Research on changes in landbird distributional patterns due to habitat transformation by human activity (as field crops, urbanization, golf courses) is urgently needed. Habitat changes will influence the presence and abundance of many bird species, some of them will benefit from these changes while others will be negatively affected. It is important to establish the native species that are currently being affected with the still moderate habitat changes.

- Research on habitat use and habitat selection of endemics, rare and other key species in critical areas is urgently needed because these species are crucial in biodiversity conservation strategies.

- Research on changes of functional systems with the introduction of non native species. Alien species (e.g. predators) are known to produce functional systems changes and could reduce population size of other species until extinction.

- Research on the effects of habitat changes on colonization rates of highly successful invasive species. Also, to evaluate the effects of these species on the bird community structure and its dynamics. For example, the European Starling (*Sturnus vulgaris*) is an aggressive and highly competitive species for cavity nesting birds as woodpeckers and small owls in the desert (Kerpez and Smith 1990, Ingold 1994). The Bronzed Cowbird (*Molothrus ater*) can parasitize nests of small passerines. Both species have increased their distribution in the Baja California Peninsula and are now breeding throughout the peninsula (Wilbur 1987, Rodríguez-Estrella et al. 1997b).

- Research on the effects of habitat changes of oases on migrant birds as they use them as stopovers and are key habitats during the migration process.

- Research on sub-lethal effects of toxic chemicals used in agriculture (i.e. organochlorine contaminants) on bird individuals and at the population level. It is well known that some toxic chemicals, in particular organochlorines, have the ability to interfere with the development of the reproductive, endocrine, immune and nervous systems of embryos. It has been reported in many studies the decline of bird populations due to the increase in the use of chemical pesticides (Safford and Jones 1997).

- To determine the natural and man-made variables influencing the presence of key bird species at the regional scale through spatial analysis.

There are several ways landbird conservation priorities in Baja California Peninsula could be implemented. First, it is needed to convince governmental authorities about the need to protect particular areas for landbird conservation showing a documented analysis of social and economic benefits using alternative activities as for example ecotourism. Environmental education can play an important role for this purpose. Second, it is needed to find ways for local people to continue the use of natural resources without making strong impacts, particularly in fragile and critical systems such as oases; or secure funds to pay for the non-use of these particular resources in the long-term. Third, use legal mechanisms to prohibit the use of persistent pesticides (i.e. organochlorines) in agriculture lands, and enhance the use of alternative non-toxic, non-persistent, pest controls. Fourth, involve golf course investors in conservation activities through agreements for developing habitat improvements for birds as is happening in many places in the United States (Gillihan 2000). Finally, it is clearly urgent to establish a plan for ecological restoration and detoxification of critical areas.

[1]unpublished data on file at CIBNOR, La Paz, Baja California Sur, México.
[2]unpublished data on file at CIBNOR, La Paz, Baja California Sur, México.

The indicators of the success of the conservation actions could be: 1. maintenance of habitat suitability in the long-term; 2. increase population viability of species of concern; 3. maintenance of functional and healthy biological systems; 4. increase the concern of the human population and their support for conservation activities. An important mechanism to assure the success of conservation actions will be surely the establishment of specific legal laws for conservation or protection of critical habitats and hotspots in Baja California Peninsula.

Priorities for landbird conservation actions should be established. I propose that the most priority conservation actions in Baja that should be immediately initiated are:

1. protect and preserve oases;
2. eliminate the use of pesticides in agriculture lands; and
3. protect bird migratory routes throughout Baja peninsula.

Acknowledgments

I thank the Partners in Flight 2002 meeting organizers for the invitation to attend the meeting and for financial support. B. Granados and L. Rivera for help with the presentation. T. Rich, E. Palacios and E. Mellink for helpful comments to a first draft. Consejo Nacional de Ciencia y Tecnología (México), SEMARNAT-CONACYT, 2002-318, and Centro de Investigaciones Biológicas del Noroeste gave financial support during the writing of this paper.

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Building a Habitat Conversion Model for San Francisco Bay Wetlands: A Multi-Species Approach for Integrating GIS and Field Data[1]

Diana Stralberg[2], Nils Warnock[2], Nadav Nur[2], Hildie Spautz[2], and Gary W. Page[2]

Abstract

More than 80 percent of San Francisco Bay's original tidal wetlands have been altered or displaced, reducing available habitat for a range of tidal marsh-dependent species, including the Federally listed California Clapper Rail (*Rallus longirostris obsoletus*) and three endemic Song Sparrow (*Melospiza melodia*) subspecies. In the South Bay, many tidal marshes were converted to commercial salt ponds, which have since become among the most important Pacific coast sites for shorebirds, waterfowl and other waterbirds. Recently, however, over 6,000 ha of commercial salt ponds were sold to wildlife management agencies for creation and restoration of tidal marsh systems, which will result in a significant change in the Bay's wetland landscape. This situation creates a need to evaluate the interrelated and potentially conflicting habitat needs of a wide range of species, in order to inform priorities for wetland restoration and management. Using a combination of standardized bird survey protocols, GIS habitat mapping, statistical modeling and simulation, PRBO is developing the first iteration of a "habitat conversion model." The goal of this project is to identify the key relationships between habitat features and bird distributions, develop models to predict bird community changes that accompany habitat conversion and disseminate results to other scientists and land managers.

Key words: habitat restoration, salt ponds, San Francisco Bay, tidal marsh, waterbirds.

Introduction

Since the mid-19th century, > 80 percent of original tidal marsh as well as large amounts of mudflats, seasonal wetlands, and upland habitats in the San Francisco Bay have been lost due to human development (Goals Project 1999). In the southern San Francisco Bay (South Bay), almost 15,000 ha of historic tidal marsh were converted to commercial salt evaporation ponds, primarily from the 1930s through the 1950s (Goals Project 1999, Josselyn 1983; *fig. 1*).

Historically, natural salt pannes were an integral component of the tidal marshes in San Francisco Bay (Goals Project 1999), and along with seasonal wetlands, presumably provided important wintering and breeding habitat for waterbirds. Thus, for many species, commercial salt evaporation ponds have filled a habitat void left by displaced natural salt pannes and loss of tidal mudflats. Today the San Francisco Bay salt pond complex is one of the most important Pacific coast sites for waterbirds, hosting millions of wintering and breeding birds annually (Accurso 1992, Page et al. 1999, Takekawa et al. 1988 and 2001, Warnock et al. 2002). However, the dramatic displacement of natural wetlands has reduced available habitat for a range of tidal marsh-dependent bird species, including three endemic Song Sparrow subspecies (*Melospiza melodia pusillula, M. m. samuelis, M. m. maxillaris*) (Marshall and Dedrick 1994), the Salt Marsh Common Yellowthroat (*Geothlypis trichas sinuosa*), and the Federally listed California Clapper Rail (*Rallus longirostris obsoletus*) (Albertson and Evens 2001), as well as plants and other animals.

The San Francisco Bay Habitat Goals Report (Goals Project 1999) and Save the Bay (2002) have recommended a threefold increase in South Bay tidal marsh habitat (from 3,500 to 10-11,000 ha) to improve the quality, extent and connectivity of natural wetland systems and protect populations of threatened marsh-dependent species. Thus, as commercial salt production becomes less economical and regulatory pressures lead to more tidal marsh restoration and mitigation, salt evaporation ponds are being sold to wildlife management agencies and non-governmental organizations (NGOs) for tidal marsh restoration and creation projects. In March of 2003, Cargill Salt, which operates the South Bay salt ponds, sold nearly 6,500 ha of salt ponds in the South Bay to the State of California and the federal government. The cost of restoring and managing these salt pond areas has been estimated to range from $314 million to more than $1 billion, with initial annual costs of $6.5 million to $14 million (Siegel and Bachand 2002).

The addition of extensive areas of new tidal marsh will benefit a host of tidal marsh-dependent species. For some, it may make the difference between population extirpation and survival or recovery. However, there is a danger that the hundreds of thousands of birds and

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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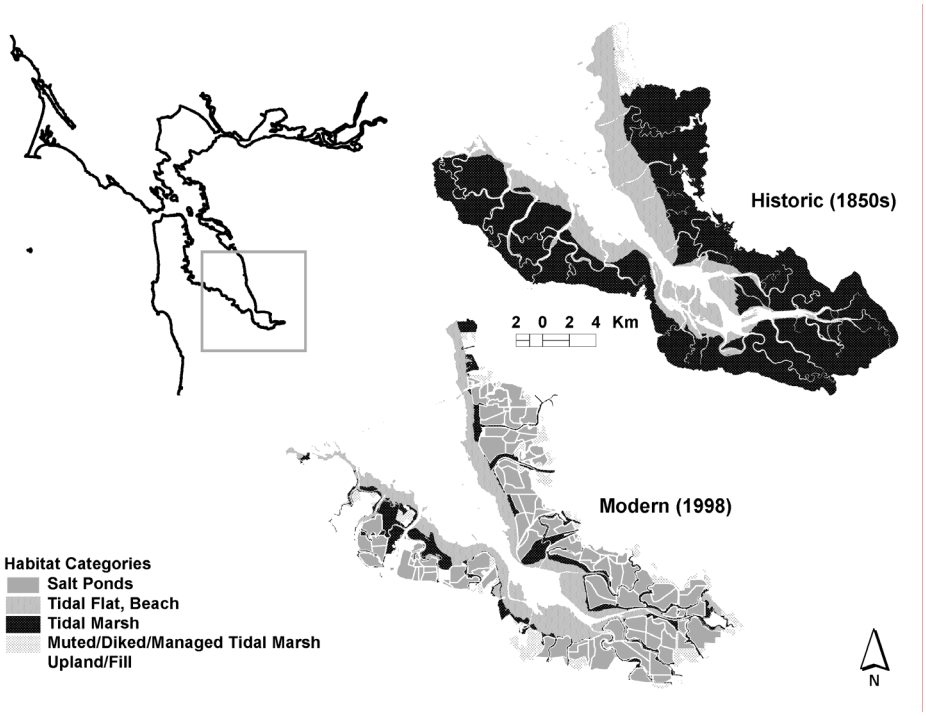


Figure 1— Change in south San Francisco bayland habitats, 1850 to present. Map source: San Francisco Estuary Institute EcoAtlas, v.1.50b4.

other wildlife that are now dependent on salt ponds will be negatively affected by this habitat conversion. Tidal marsh restoration and preservation of some existing commercial salt ponds are necessary to maintain or enhance current bird populations in the San Francisco Bay (Goals Project 1999). In addition, the creation of ponded areas within tidal marshes may improve habitat diversity and help maintain existing populations of waterbirds (Siegel and Bachand 2002). However, the size, location and physical attributes of salt ponds preferred by waterbirds, and the value to birds of natural salt ponds, channels and other features within variable tidal marsh habitat, are not well known. We have identified the need to quantify this variation and relate it to the differential use of tidal marsh by birds.

The goal of this project is to identify the key relationships between habitat features and bird distributions in tidal marshes and salt ponds, and develop models to predict bird community changes that accompany habitat conversion. Results of these models will then be made available to management agencies, the scientific community, conservation NGOs and partnerships such as the San Francisco Bay Joint Venture and California Partners in Flight.

Objectives

Using a combination of standardized bird survey protocols, GIS habitat mapping, statistical modeling and simulation techniques, PRBO Conservation Science is working toward the development of a first generation *habitat conversion model* (HCM). Our goal is to develop a model that can be used to estimate the quantitative and qualitative effects of bayland habitat conversion on bird populations, initially with respect to tidal marsh and salt pond habitat, but eventually expanding to include tidal flats, bayland-adjacent uplands and non-tidal wetlands. Although bird numbers and distributions are driven by a variety of complex and difficult-to-quantify factors (Wiens 1992), we hope to characterize the sensitivity of avian communities to anticipated habitat changes within the South Bay. Even order-of-magnitude estimates and predictions of presence/absence throughout the South Bay may be helpful in planning and implementing large-scale habitat restoration projects.

Our objectives are:

1. To identify costs and benefits to birds of habitat conversion, as a result of salt pond loss and tidal marsh gain;
2. To develop a quantitative basis for guiding:
   - Design of restoration projects to maximize habitat potential (site level) and
   - Optimal ratio and configuration of tidal marshes and salt ponds (landscape level); and
3. To monitor and evaluate the cumulative effects of restoration on birds.

Model development will be an iterative process, allowing us to quickly disseminate preliminary results and predictions to managers. Following model evaluation and solicitation of peer review, we hope to be better able to incorporate the spatial and temporal dynamics of restoration, as well as demography and energetics of avian populations. We envision three phases, each building on and improving upon the previous phase:

- Phase 1 – static model predicting bird responses to restoration at pond/marsh level
- Phase 2 – spatially-explicit dynamic model incorporating change in restoration sites over time
- Phase 3 – mechanistic model incorporating demography and energetics of selected species

Phase 1 Methods

General steps for constructing a Phase 1 Habitat Conversion Model (HCM) can be summarized as follows: (1) conduct field surveys; (2) develop site- and landscape-level GIS maps; (3) identify model currency; (4) compare marsh and pond bird densities and diversity; (5) identify bird responses to habitat and landscape variation among ponds and among and within marshes; (6) develop integrated model; (7) predict bird loss/gain for specific tidal marsh restoration scenarios; and (8) suggest optimal restoration configurations.

Field Surveys

From fall 1999 to spring 2001, we conducted monthly high- and low-tide surveys of selected accessible salt evaporation ponds and tidal marshes in the South Bay (*fig. 2*). Several marshes were highly modified and in some cases consisted of a linear strip surrounding a tidal channel (e.g., Ravenswood Slough). Although the historic extent of natural salt ponds is not well known, most study marshes lacked a natural configuration of ponds and salt pannes, with many ponded areas forming along roads and levees.

Salt pond and tidal marsh survey methods were standardized with respect to South Bay tidal conditions and survey period. Salt pond surveys were accompanied by water salinity samples (see Warnock et al. 2002 for complete description). Each bird observation was coded by behavior (e.g., foraging, roosting, flushing) and microhabitat category (e.g., salt pan, channel, man-made structure or vegetation within marshes; and island, mud, man-made structure or open water within salt ponds). Because visibility within the marsh was variable, we noted the distance of each bird to the observer and mapped the estimated visibility for each site.

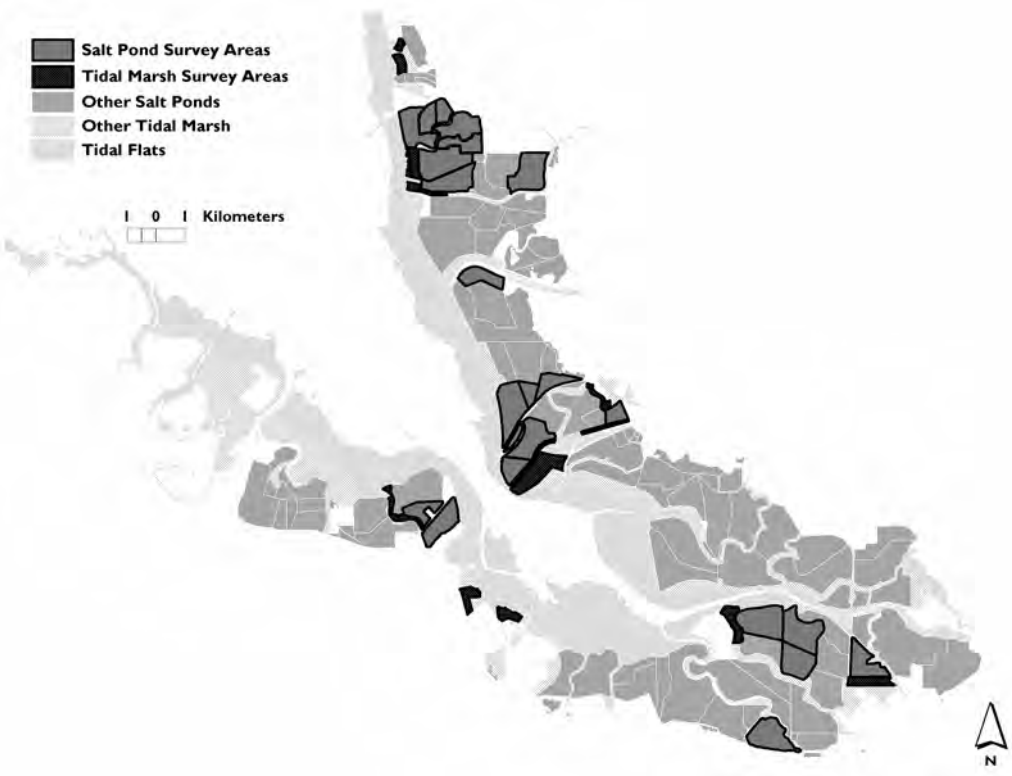


Figure 2— South San Francisco Bay tidal marsh and salt pond study sites (1999-2001). Map source: San Francisco Estuary Institute EcoAtlas, v.1.50b4.

We also conducted point-count surveys (Ralph et al. 1993) at 102 point-count stations in 14 tidal marshes. Point-count surveys are better suited for estimation of passerine densities, and may be used to quantify within-marsh variation in some species. Because they were conducted year 'round, they should allow us to estimate breeding, as well as winter density and diversity of tidal marsh birds. In addition to the data we collected, we sought ancillary breeding season data for the Federally-listed Clapper Rail and Western Snowy Plover (*Charadrius alexandrinus nivosus*), which are important target species for restoration and management.

GIS Mapping

Our initial comparison of tidal marsh and salt pond bird use has included a GIS-based analysis of site-level habitat characteristics, pond/marsh habitat configuration, and surrounding landscape characteristics.

For site-level comparisons of marsh study sites, we used large-scale (1:4800), high-resolution (0.5' pixels) color-infrared photos (flown at high tide in August 2001) to map channels and natural salt ponds within our tidal marsh study sites. We used ArcView's Image Analysis extension (ESRI 2000) to classify each photo into three basic landcover types: marsh vegetation, open water (ponds and channels) and upland (including levees). We then used ArcInfo 8.1 (ESRI 2001) to manually digitize ponds and channels, classify the channels by width category and classify the ponds as either tidal (connected to bay via channels) or ephemeral (not connected, only flooded at extreme tides).

For landscape metrics, we used a composite landuse GIS layer, comprised of data from the San Francisco Estuary Institute's EcoAtlas (1998), the U.S. Geological Survey's Midcontinent Ecological Science Center (USGS MESC 1985), and the National Oceanographic and Atmospheric Administration's Coastal Change and Analysis Program (NOAA C-CAP 1993). Within a 1-km radius of each site (pond and marsh), we used ArcView's Spatial Analyst extension (ESRI 1999) to calculate the percent marsh, salt pond, tidal flat, urban development and other upland land uses (*fig. 3*). We also calculated marsh/pond size, shape and isolation (distance to nearest pond/marsh), as well as distance to the open bay.

Model Currency

Given the wide range of potential management objectives, we did not attempt to prioritize or assign value to particular species or groups, but instead provide value-neutral predictions for a variety of species and guilds. Our approach is to combine the examination of densities of wetland-associated focal species (Lambeck 1997) and species groups, as well as overall species richness and diversity. Preliminary focal species and groups include:

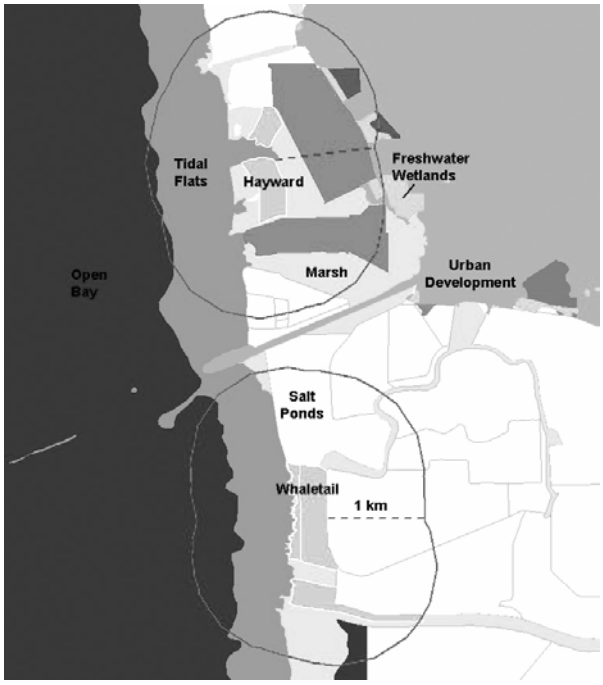


Figure 3— Sample calculation of landscape metrics for Whaletail Marsh and Hayward Regional Shoreline. Map source: San Francisco Estuary Institute EcoAtlas, v.1.50b4.

Wintering Species Groups:

- Large shorebirds (Black-bellied Plover [*Pluvialis squatarola*] and larger)
- Small shorebirds
- Diving ducks
- Dabbling ducks and coots
- Eared Grebe (*Podiceps nigricollis*)
- Other grebes, pelicans and cormorants (fish-eaters)
- Gulls and terns
- Herons and egrets
- Landbirds
- Rails

Breeding Species:

- Song Sparrow
- Common Yellowthroat
- Clapper Rail

- American Avocet (*Recurvirostra americana*)
- Black-necked Stilt (*Himantopus mexicanus*)
- Snowy Plover.

Preliminary Marsh-Pond Waterbird Comparisons

During 2 years of surveys, we recorded 75 species of waterbirds at salt pond sites, with shorebirds being the most dominant group, followed by dabbling ducks and diving ducks (Warnock et al. 2002). Seventy-three non-passerine species were recorded at tidal marsh sites. Averaging across all winter surveys (Nov. to Feb.), we examined the differences between salt pond and tidal marsh densities of selected shorebird, waterfowl and seabird species, finding significant between-habitat differences (two-tailed T-tests, P <0.05) for most species (*figs. 4-6*). While most waterbird species were more abundant in salt ponds than in tidal marsh, it is important to note that these comparisons do not include data from peak fall and spring migration periods (to be included in future analyses). Nor do they include tidal-marsh-dependent songbirds and rails, which are essentially absent from salt ponds.

Given the high variation in densities among salt pond and tidal marsh sites, however, we recognize that it is important to quantify the effects of this variation on bird communities in order to construct meaningful predictive models.

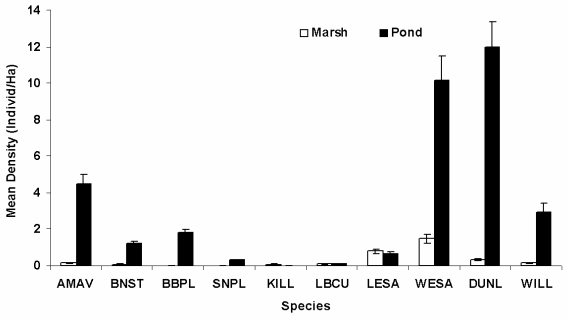


Figure 4— Mean (+/- SE) winter (Nov-Feb) densities for shorebird species, tidal marshes (N = 104 surveys) vs. salt ponds (N = 210 surveys). Mean pond densities significantly higher than mean marsh densities for all species examined except KILL, LBCU and LESA (two-tailed T-tests, P <0.05). AMAV = American Avocet; BNST = Black-necked Stilt; BBPL = Black-bellied Plover (*Pluvialis squatarola*); SNPL = Snowy Plover; KILL = Killdeer (*Charadrius vociferous*); LBCU = Long-billed Curlew (*Numenius americanus*); LESA = Least Sandpiper (*C. minutilla*); WESA = Western Sandpiper (*C. mauri*); DUNL = Dunlin (*C. alpina*); WILL = Willet (*Catoptrophorus semipalmatus*).

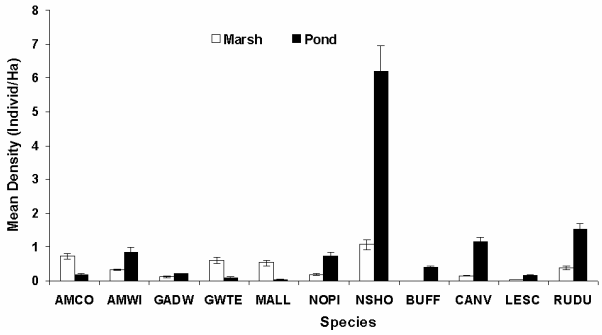


Figure 5— Mean (+/- SE) winter (Nov-Feb) densities for waterfowl species, tidal marshes (N = 104 surveys) vs. salt ponds (N = 210 surveys). Mean pond densities significantly higher than mean marsh densities for AMWI, NOPI, NSHO, BUFF, CANV, LESC and RUDU; mean marsh densities significantly higher for AMCO, GWTE and MALL (two-tailed T-tests, P <0.05). AMCO = American Coot (*Fulica Americana*); AMWI = American Wigeon (*Anas americana*); GWTE = Green-winged Teal (*A. crecca*); MALL = Mallard (*A. platyhynchos*); NOPI = Northern Pintail (*A. acuta*); NSHO = Northern Shoveler (*A. clypeata*); BUFF = Bufflehead (*Bucehala clangula*); CANV = Canvasback (*Aythya valisineria*); LESC = Lesser Scaup (*A. affinis*); RUDU = Ruddy Duck (*Oxyura jamaicensis*).

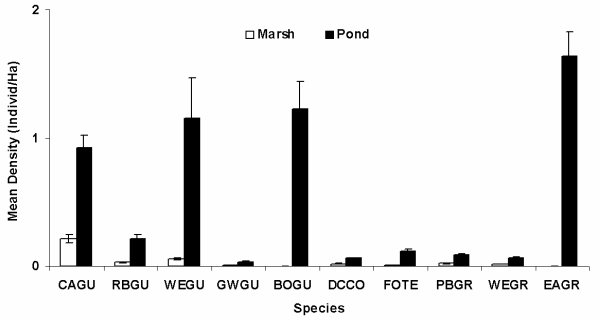


Figure 6— Mean (+/- SE) winter (Nov-Feb) densities for selected seabird species, tidal marshes (N = 104 surveys) vs. salt ponds (N = 210 surveys). Mean pond densities significantly higher than mean marsh densities for all species examined (two-tailed T-tests, P <0.05). CAGU = California Gull (*Larus californicus*); RBGU = Ring-billed Gull (*L. delawarensis*); WEGU = Western Gull (*L. occidentalis*); GWGU = Glaucous-winged Gull (*L. glaucescens*); BOGU = Bonaparte's Gull (*L. philadelphia*); DCCO = Double-crested Cormorant (*Phalacrocorax auritus*); FOTE = Forster's Tern (*Sterna forsteri*); WEGR = Western Grebe (*Aechmophorus occidentalis*); PBGR = Pied-billed Grebe (*Podilymbus podiceps*); EAGR = Eared Grebe.

Bird Responses to Variation Among Ponds and Marshes

Our first objective in developing a habitat conversion model was to characterize variation in abundance and diversity of birds in the two habitat types in relation to site- and landscape-level features. Standardized bird densities and species diversity metrics were compared across ponds and marshes, accounting for differences

in pond depth and salinity, as well as marsh vegetation, channelization and pond characteristics. We also analyzed microhabitat use within tidal marshes, attempting to quantify the relative importance of channel vs. pond vs. marsh plain. These analyses are presently ongoing; preliminary results are presented here.

Salt ponds – preliminary results

Shorebirds and dabbling ducks were the most abundant groups of birds using the salt ponds. Shorebirds, in particular, responded to the tide cycle, with higher numbers using the ponds at high tide and lower numbers at low tide, and pond salinity was important for almost all groups examined (Warnock et al. 2002). Waterbird abundance and species richness were significantly affected by the salinity of ponds in a non-linear fashion with lower numbers of species predicted on the highest salinity ponds (*fig. 7*). For most groups examined, tide height at the Bay significantly affected bird numbers in the salt ponds with ponds at high tides having higher numbers of birds than the same ponds on low tides. Considerable numbers of birds fed in the salt ponds on high and low tides, although this varied greatly by species. Exposed moist soil around the perimeter of ponds was observed to be important for foraging, while islands in the ponds were important for roosting birds.

Tidal marsh – preliminary results

For tidal marsh species, we found significant associations between various landscape parameters and species richness summed over all surveys. For example, shorebird species richness was positively associated with the proportion of tidal mudflat habitat contained within 1 km of tidal marsh survey areas (*fig. 8*), but negatively associated with tidal marsh size (*fig. 9*), perhaps because the smaller marshes tended to be linear segments along major sloughs, whose mudflat edges attract large numbers of shorebirds (Spautz, pers. obs.). For site-level habitat characteristics, however, we found that individual species' responses differed among species and in some cases were inconsistent with the overall patterns demonstrated by species richness. We found that responses to channel and pond characteristics, as well as tide conditions, varied greatly among species (*table 1*).

Integrated Model Development

We plan to use existing field and GIS data sets to conduct a series of statistical analyses identifying important site- and landscape-level habitat parameters for wetland-associated bird species and guilds. Analyses will be conducted by species/guild, season (winter and breeding season) and general habitat type (salt pond and marsh). Statistical methods will primarily

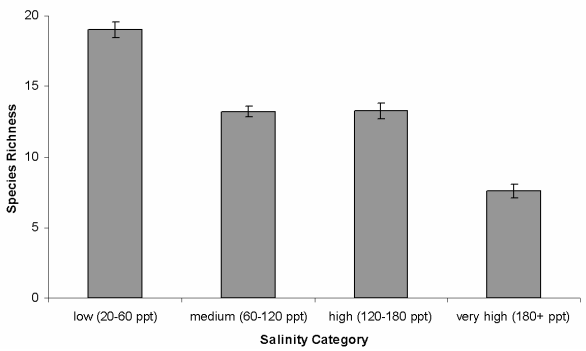


Figure 7— Species richness by salt pond salinity category (ppt) in south San Francisco Bay salt ponds, 1999 and 2000. Error bars represent standard errors of the mean for each salinity category.

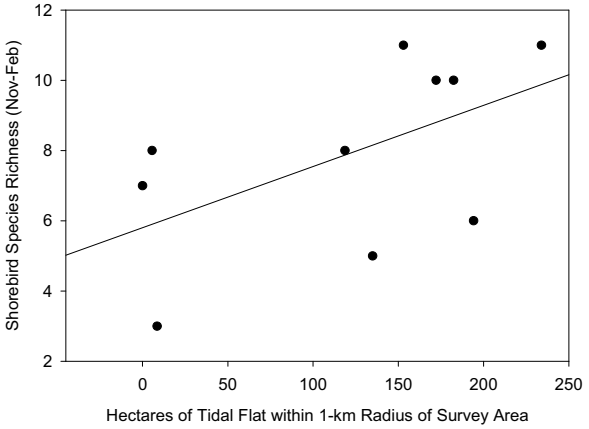


Figure 8— Winter (Nov. to Feb.) shorebird species richness vs. tidal flat area within 1 kilometer of tidal marsh study sites in South San Francisco Bay, 1999-2001.

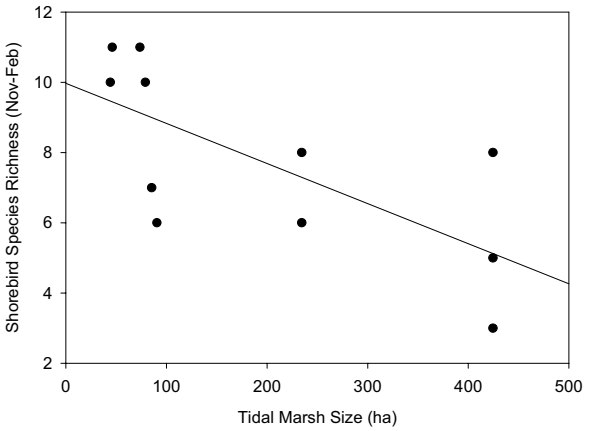


Figure 9— Winter (Nov. to Feb.) shorebird species richness vs. size of tidal marsh study sites in South San Francisco Bay, 1999-2001.

Table 1— *Significant month, tide, and habitat associations for winter (Nov. to Feb.) densities of selected species surveyed in South San Francisco Bay tidal marshes. Significant terms in ANOVA models denoted by * (P < 0.05) or *** (P < 0.001). Direction of effect denoted by + or -.*

	Northern Shoveler	Northern Pintail	American Avocet	Willet	Snowy Egret
Month			(*)		
Tide					(*)
Channel Density		- (*)			+ (*)
Pond Density	+ (***)				- (*)

consist of regression analysis with generalized linear models (GLM), and may also include multivariate techniques such as canonical correspondence analysis (CCA), classification and regression tree (CART) models, and spatial autocorrelation analysis. Results of statistical analyses will be combined with ancillary data sources, prior knowledge and information from relevant wetland ecology literature to develop an integrated (static) model predicting salt pond loss and tidal marsh gain (in terms of birds) for a range of restoration scenarios. The next objective is to use our integrated model to compare and quantify differences in the predicted distribution and abundance (including species richness) of bird populations under various management and restoration scenarios. Our model prediction efforts will be conducted at two scales of analysis: the site (pond/ marsh) level and the regional landscape (South Bay) level. In the next phase of model development, we will seek out independent datasets to validate our integrated model, preferably from existing restoration projects.

Predicting Restoration Outcomes

Site level predictions

First we will select representative characteristics of several actual ponds proposed for restoration and, for each pond, develop a range of feasible tidal marsh outcomes. Assuming current land use conditions, we will present three or more alternative predicted outcomes, depending on ultimate tidal marsh conditions. We will make the simplifying assumption that tidal marsh habitat parameters can be designed and controlled, and that such a restoration marsh will function in the same way as an existing tidal marsh with the same parameters.

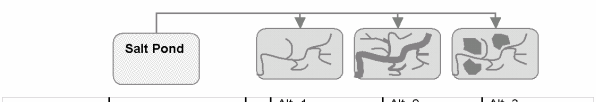
Model results for a range of restoration scenarios will be presented in tabular and graphical form (*fig. 10*), with model parameters specified. Restoration scenarios will be assumed to proceed from salt pond to marsh. Thus results will be expressed in terms of salt pond losses and tidal marsh gains for each hypothetical pond-to-marsh restoration. We will present results for multiple species and groups and refrain from assigning priorities to the species and groups modeled. The results for each species, however, will be evaluated in the context of its conservation status, population trends and the relative geographic importance of San Francisco Bay. To the extent possible, we will use the attributes of existing marshes as hypothetical restoration endpoints.

Landscape level predictions

The next step will be to look at restoration outcomes at the landscape or regional level, setting the stage for prioritization of prospective tidal marsh restoration sites. The product of this analysis will be spatially explicit, and presented in map format. We will develop a series of maps of South Bay ponds and marshes, representing the following conditions:

- Value of study salt ponds and marshes for selected species/groups
- Predicted salt pond loss and tidal marsh gain (current salt ponds only) for a range of restoration scenarios, varying by:
- number and configuration of ponds restored to tidal marsh
- type of tidal marsh restoration (based on site level predictions)
- At this stage, we will make the simplifying assumption that any pond can be restored to any tidal marsh condition, with respect to channel and pond configuration. We will not consider admittedly important issues such as elevation and level of subsidence, available sediment and seed source, and hydrologic constraints such as tidal exchange volume, effects of levees and freshwater inputs (see Siegel and Bachand 2002).

The next step will be to develop an algorithm for selecting optimal configurations of tidal marshes and salt ponds that satisfy a given conservation objective. A key part of this exercise is to identify the appropriate currency for a cost-benefit analysis. In addition, there is a need to derive spatially explicit optimal solutions. Potential methods include linear programming



			Alt. 1	Alt. 2	Alt. 3
	Salt Pond Loss		Tidal Marsh Gain		
Waterfowl					
Winter	W		X	Y	Z
Spring	.		.	.	.
Breeding	.		.	.	.
Shorebirds					
Winter	.		.	.	.
Spring	.		.	.	.
Breeding	.		.	.	.
Seabirds					
Winter	.		.	.	.
Spring	.		.	.	.
Breeding	.		.	.	.
Landbirds					
Winter	.		.	.	.
Spring	.		.	.	.
Breeding	.		.	.	.

Figure 10— Sample format for site-level tabular results of habitat conversion model predictions for three different restoration scenarios.

techniques (Hof and Bevers 2002, Nevo and Garcia 1996) as well as numerical simulation models, such as the Spatially-Explicit Species Index (DeAngelis et al. 1998) and Spatially-Explicit Simulated Annealing (Ball 2000). A simplified representation of a hypothetical optimization result is shown in *figure 11*.

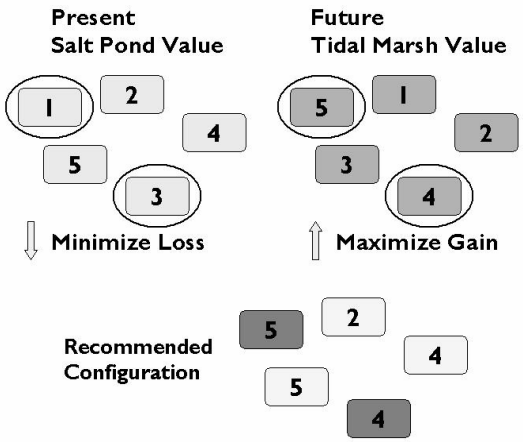


Figure 11— Simplified optimization scenario for salt pond to tidal marsh conversion. Squares represent hypothetical existing salt ponds and potential future tidal marshes with given predicted values for birds (1-5). The circled ponds and marshes represent those that would be identified as the best candidates for restoration. The recommended configuration below would provide the best overall value for birds, minimizing salt pond loss while simultaneously maximizing tidal marsh gain.

Future directions

For the first iteration, our modeling units will be discrete ponds and marshes, with habitat parameters such as sloughs and ponds aggregated at the marsh or pond level. However, future versions may include predictions of intra-site variations in bird use, to the extent that our data capture specific habitat preferences of individual species. For example, it may be useful for modeling purposes to develop a layer of grid cells or hexagonal units for which important habitat, landscape and spatial proximity parameters could be determined using GIS data and aerial photos. Although additional field data may be needed, we hope to develop a spatially-explicit model and extrapolate bird distributions to a broader area.

Using GIS data to simulate real or hypothetical marsh/pond landscapes, we will eventually evaluate the relative value of various management scenarios for wetland birds, based on existing relationships detected from our field data to date. Using comprehensive habitat data for the South Bay (interpreted from satellite imagery), we plan to simulate landscape changes over time and model waterbird responses to those changes. A combination of aerial photo interpretations and field-collected data may be used to assign habitat classifications to 30-m satellite imagery (e.g., LANDSAT TM) pixels using geostatistical scaling (Sanderson et al. 1997) or other relevant techniques. Alternately, high-resolution (1-m) satellite imagery (e.g., IKONOS) may be used to derive a finer-scale representation of South Bay habitats.

The final phase will be to develop a dynamic model of San Francisco Bay bird populations that incorporates key demographic, energetic and spatial parameters, as well as the underlying physical processes of restoration (see Nur and Sydeman 1999).

Conclusions

San Francisco Bay habitats are changing quickly. Thus we realize the immediate need to evaluate the impacts of these changes on birds and other species. Our approach is intended to quickly provide useful information to land managers and other interested parties. The proposed Habitat Conversion Model may provide a valuable opportunity to integrate GIS, field data and spatial analysis to guide and optimize the restoration process and monitor the cumulative impacts of restoration on birds. The success of this effort will depend on the formation of effective partnerships with land managers and researchers from other disciplines.

Acknowledgments

This work was made possible by grants from the Gabilan Foundation, the California Coastal Conservancy, the Tides Foundation, Rintels Charitable Trust, the Bernard Osher Foundation, the Richard Grand Foundation, the Mary A. Crocker Trust and ESRI. The following organizations gave access to tidal marsh and salt pond

study sites: the Don Edwards San Francisco Bay National Wildlife Refuge, Cargill Salt, East Bay Regional Parks, Sunnyvale Baylands and East Palo Alto Baylands. Our collaborators include the San Francisco Bay Bird Observatory, the San Francisco Estuary Institute, the U.S. Fish and Wildlife Service and the USGS Biological Research Division (J. Takekawa). We are also grateful for assistance with the collection of field data by J. Wood, J. Hammond, M. Ruhlen, C. Rintoul, S. Abbott, J. DeStabler, S. Macias, C. Millett, E. Brusati, Y. Chan, M. DiAngelo and M. Anderson. A. Campomizzi and C. McCreedy provided invaluable GIS assistance. This is contribution number 1085 of PRBO Conservation Science.

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The Use of Avian Focal Species for Conservation Planning in California[1]

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Abstract

Conservationists often try to facilitate the complex task of protecting biological diversity by choosing a subset of species from a larger community to help them plan their conservation objectives. Biological knowledge about these species then is used to plan reserve systems or to guide habitat restoration and management efforts, with the assumption that the implementation of these recommendations will maintain overall biodiversity. Partners in Flight (PIF) is developing Bird Conservation Plans to set conservation priorities and specific objectives for bird populations and habitats throughout the United States. Many of these plans use focal species in some way. Here we briefly review the issues surrounding the use of focal species in conservation planning, and present the focal species strategies being developed and implemented by Partners in Flight in California. California PIF created focal species lists by identifying focal habitats, and then selecting those species associated with important habitat elements or ecosystem attributes, as well as those species with special conservation needs. Thus, a suite of species was chosen whose requirements define different spatial attributes, habitat characteristics, and management regimes representative of a healthy system. This process resulted in a diverse list of focal species for each habitat that includes both common and uncommon or rare species. Because focal species lists are based on numerous hypotheses and assumptions, these should be made as explicitly as possible and tested in ongoing monitoring studies as part of an adaptive management program.

Key words: adaptive management, bird conservation plans, monitoring, surrogate species, umbrella species.

Introduction

Protecting biological diversity is an extremely complex process, and conservationists often lack even the most basic data on which to base management and planning decisions. Conservation planners often try to facilitate this process by choosing a subset of species from a larger community to help them formulate their conservation objectives. Biological knowledge about these species then is used to plan reserve systems or to guide habitat restoration and management efforts, with the assumption that the implementation of these recommendations will maintain overall biodiversity. Here, we use the general term "focal species" to describe any species chosen for special attention in a multi-species planning effort. Although the use of focal species has been criticized on both theoretical and empirical grounds, many conservation biologists believe that their use can be valuable if the assumptions underlying their choice are stated explicitly and subjected to scientific testing (Caro and O'Doherty 1999, Lindenmayer et al. 2002, Poiani et al. 2001, Soulé 1995).

In the past, focal species often have been selected on the basis of their threatened or endangered status, largely because these species are given the strongest legal protection. However, the species that are at the greatest risk are not necessarily the most effective focal species (Franklin 1994). Partners in Flight (PIF) is developing Bird Conservation Plans (BCPs) to set conservation priorities and specific objectives for bird populations and habitats throughout the United States. Many of these plans use focal species in some way. Here we briefly review the issues surrounding the use of focal species in conservation planning, and present the focal species strategies being developed and implemented by Partners in Flight in California, as well as in Oregon and Washington.

The Uses of Focal Species in Conservation Planning

Focal species may be used to guide several components of conservation planning: (1) the selection and design of habitat reserves, (2) habitat restoration and management, and (3) population monitoring, both of population trends over time and effects of management actions. Planning a reserve system involves selecting which sites should be preserved and determining what their configuration

[1] A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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should be, for example, for size, shape, and connectivity. Thus, the distribution and ecological needs of one or more focal species may be useful in site selection and reserve configuration, both of which are major foci of conservation planning (Margules and Pressey 2000). However, to ensure the persistence of biodiversity, conservation planners must also identify effective forms of habitat restoration and active habitat management to maintain desired conditions, both in habitat reserves and in working landscapes. One way to accomplish this is to design restoration and management to benefit one or more focal species. Monitoring is an essential companion to the other components of conservation planning, especially when management takes place in an adaptive manner. Adaptive management involves treating management as a continual experiment in which the results of previous actions are monitored and used to modify future management (Holling 1978, Ringold et al. 1996). Thus, focal species also can be monitored to test the effectiveness of management activities (Gibbs et al. 1999).

Clearly, a number of different classes of focal species are needed to address such a variety of conservation goals. In *table 1* we define several classes of focal species that are used or have been proposed for use in conservation planning. Caro and O'Doherty (1999) provide a more in-depth review of focal species types and their characteristics.

Table 1— *Classes of focal species[1] that are used or have been proposed for use in conservation planning.*

Focal species class	Definition
Flagship	Species that attract the attention of the public and generate popular support for the conservation of their ecosystems (Caro and O'Doherty 1999).
Keystone	Species whose presence is especially crucial in maintaining the organization and diversity of their ecological communities (Mills et al. 1993).
Special status	Species that have been given special status as endangered, threatened, or "of special concern" by local or national governments.
Indicator	Organisms whose characteristics are used as an index of attributes too difficult, inconvenient, or expensive to measure for other species or environmental conditions of interest (Landres et al. 1988)[2].
Umbrella	Species requiring large areas of habitat, which if given sufficient protection, will provide for the needs of a larger suite of species occupying the same habitat (Noss 1990)[3].

[1]Here we use focal species as a general term to describe individual species chosen for special attention in a multi-species conservation effort. The term surrogate species also has been used for this purpose (but see Armstrong 2002).
[2]Indicator species can be further divided into health indicators, population indicators, and biodiversity indicators (Caro and O'Doherty 1999).
[3]Some authors use umbrella species in a more general manner to include any species whose protection provides for the needs of a larger suite of co-occurring species (e.g., Launer and Murphy 1994).

The Pros and Cons of Focal Species

The use of focal species has a number of advantages. First, planning and managing for the habitat requirements of every species present in a planning unit is often impractical, if not impossible. Second, knowledge of the needs of individual species can help direct ecosystem or landscape level planning (Simberloff 1998, Wilcove 1994). Third, the legal protection assigned to species in the United States (rather than to higher levels of biodiversity, such as habitats, ecosystems, or landscapes) sets up a funding and incentive structure that is species-specific (Noss 1990). Fourth, some species are simply much more amenable to monitoring and research than others, a consideration that is crucial given real-life time, logistical, and funding constraints.

However, there are a number of problems associated with some uses of focal species (Landres et al. 1988, Lindenmayer et al. 2002). Here we discuss three problematic uses of focal species. First, the use of indicator species (as defined in *table 1*) to assess population trends of other species has been criticized on the grounds that individual species have unique ecological requirements (Taper et al. 1995). Indeed, empirical studies have shown that population responses to habitat change often cannot be extrapolated from one species to another, even within the same guild (Landres et al. 1988), or from one population to another of the same species (O'Conner 1991).

Second, the use of focal species to delineate habitat reserves also may be questionable if focal species do not reliably co-occur with a large proportion of other species in the area of interest (Andelman and Fagan 2000). This assumption is often difficult to test rigorously given our incomplete knowledge of species distributions. For example, Andelman and Fagan (2000) tested the effectiveness of several focal species approaches using species distribution databases from three geographical areas, and found that most approaches performed poorly. However, these databases contained incidence records only for species with special legal status. Therefore, the authors were unable to test the effectiveness of schemes that include "non-listed" as well as "listed" focal species and could not evaluate the effect that protecting focal species would have on other "non-listed" species.

Third, using species as indicators of habitat quality is only valid if research shows that the density or demographic parameters of focal species are reliably linked to specific habitat, population, or community attributes. Population density alone is known to be an unreliable indicator of habitat quality, even for a single species (Van Horne 1983). Clearly, focal species should be chosen based on explicitly defined criteria, and empirical research and monitoring are needed to validate the assumption that other species are receiving protection as a result of the protection of a focal species (Landres et al. 1988, Noss 1990). As this has become more widely recognized, more empirical tests of focal species approaches have appeared in the literature, with mixed results (e.g., Andelman and Fagan 2000, Chase et al. 2000, Kremen 1992, Poiani et al. 2001). Therefore, we agree with Lindenmayer et al. (2002) that a focal species approach should not be the only conservation strategy adopted in a given region and that the effectiveness of all restoration programs should be rigorously tested.

It is especially tempting to suggest that threatened and endangered species are good focal species. These species may be especially sensitive to changes in habitat attributes of concern, but they may not meet the other criteria for effective focal species. For example, the presence of a threatened species, such as the California Gnatcatcher (*Polioptila californica*), often does not indicate the presence of a more diverse or distinctive ecological community (Chase et al. 2000) or the presence of other sensitive taxa (Rubinoff 2001). Managing for the habitat requirements of an endangered species may not benefit other species present, and may even be detrimental to some species or habitats of conservation concern (Launer and Murphy 1994). Also, endangered species that occur at low densities or have regulatory status pose more sampling problems, which render monitoring less reliable and more expensive (Landres et al. 1988, O'Conner 1992, Strong 1990). Even when an endangered species appears to be a good umbrella for co-occurring species, it can be risky to focus conservation emphasis on a single species. If the species can be shown to be more flexible in its breeding requirements that was thought (Abate 1992), or to be genetically indistinguishable from other, less-threatened populations (Zink et al. 2000), the justification for protection of its habitat may be undermined.

Focal Species in PIF Conservation Planning

The national PIF Bird Conservation Strategy consists of four steps that result in the development and implementation of Bird Conservation Plans (Pashley et al. 2000). These are: (1) identify species and habitats most in need of conservation; (2) establish population and habitat conservation objectives; (3) identify actions to meet objectives and implement plans; and (4) monitor progress and refine the plans. Within this general framework, planners in different geographic regions have used different approaches to accomplish these goals. California PIF has stressed the management and restoration aspect of conservation planning in its Bird Conservation Plans, because public and private land managers are eager for more information to support their decision-making. California PIF uses a habitat-based adaptive management approach (*fig. 1*), acknowledging the gaps in our current knowledge, and emphasizing the need to test the hypotheses and assumptions involved in conservation planning and to revise the Conservation Plans regularly. In this way, California PIF provides decision-makers and conservation initiatives with biological assumptions (models) in a timely manner, and these can be tested with effective monitoring (Gibbs et al. 1999). Therefore, California's Bird Conservation Plans acknowledge the uncertainties involved in selecting focal species, and focal species lists are expected to be revised as the assumptions and hypotheses inherent in such lists are tested.

The identification of species and habitats most in need of conservation (Step 1) can be accomplished in a number of different ways. Many plan writers have chosen focal species by using the national Partners in Flight assessment score database to identify species most in need of conservation (Carter et al. 2000). California PIF and Oregon-Washington PIF created focal species lists by identifying those species associated with important habitat elements or ecosystem attributes, as well as those species with special conservation needs. This approach explicitly places greater emphasis on ecosystems in the planning

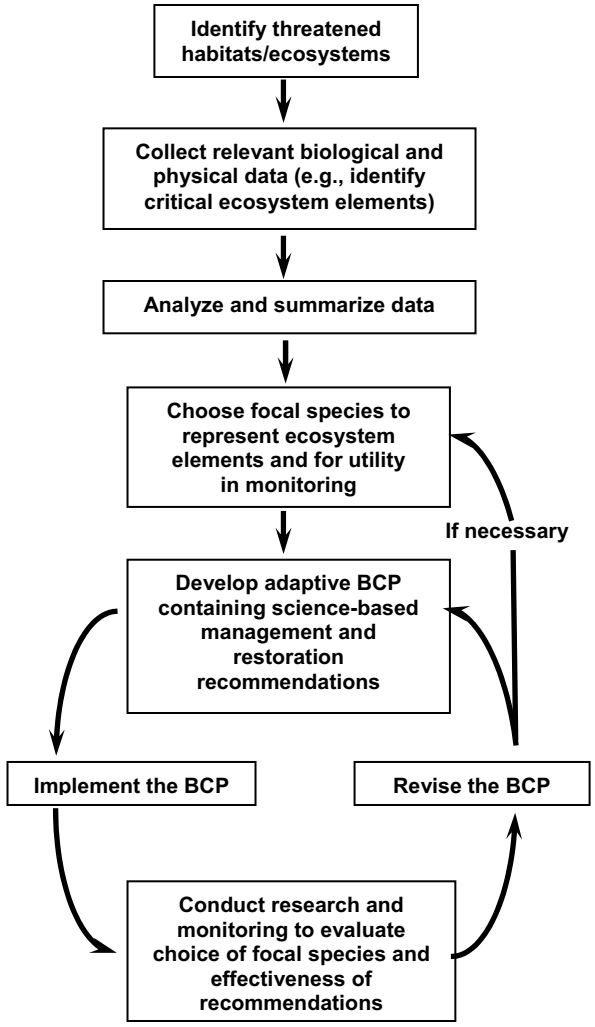

Figure 1— Adaptive conservation planning approach used by California Partners in Flight to develop Bird Conservation Plans (BCP) for five major habitats.

process, and is related to the "coarse-filter" approach of Wilcove (1993) and the multiple umbrella-species concept elaborated by Lambeck (1997). In general, this type of focal species approach attempts to meet the needs of as many species as possible by identifying those species in a region that are most demanding of resources and then targeting them for management. The specific method proposed by Lambeck (1997) focuses on landscape characteristics, and involves choosing a suite of focal species whose spatial, compositional, and functional requirements encompass those of all other species in a given landscape. For example, the bird that requires the largest area to survive in a certain habitat would determine the minimum suitable area for that habitat type. Likewise, the requirements of non-migratory birds that disperse short distances to establish new territories would define the attributes of connecting habitat. This approach was broadened by California PIF to include focal species that represent habitat characteristics across multiple scales (e.g., microhabitat requirements as well as landscape-scale habitat requirements). Thus, a suite of species can be chosen whose requirements define different spatial attributes, habitat characteristics, and management regimes representative of a healthy system. This process often results in a diverse list of focal species that may include both common and uncommon or rare species. It is important to note that the best indicators often may be common species.

Once an initial list of focal species is compiled, the current state of knowledge of their ecological requirements can be used to guide the establishment of conservation objectives (Step 2) and the identification and implementation of conservation actions (Step 3). Because the success of implementation must be evaluated (Step 4), the focal species list should be directly linked to the defined conservation objectives and should include species that make good indicators for monitoring the results of management actions. Good indicator species are those that are more sensitive to environmental change than others, and respond quickly and consistently to environmental stresses or enhancements (Landres et al. 1988, Caro and O'Doherty 1999). The most useful indicators are those which also have populations large enough to be easily monitored and to provide sufficient samples sizes for statistical analysis across sites and/or regions.

Another pragmatic reason for including relatively common, "unlisted" focal species in conservation planning is that some landowners and managers may be more interested in undertaking restoration or management activities for these species. Many private landowners are reluctant to take conservation actions that may attract an endangered or threatened species—and associated regulatory attention—to their property. In contrast, landowners often are enthusiastic about voluntarily creating habitat on their land for 'unlisted birds'. Both private and public land managers also are attracted to projects that will show results in the short-term. For example, managers who design riparian restoration projects to include the diversity of shrub and tree species needed by both common and threatened bird species can expect to attract multiple species of riparian birds within a few years. In contrast, managers planting only the vegetation needed by the state-endangered Western Yellow-billed Cuckoo (*Coccyzus americanus*) may need to wait decades to see results.

California's Choice of Focal Species

California's focal species strategy incorporates the use of focal species into an adaptive management feedback loop (*fig. 1*). Seven major habitat types in California were identified for conservation planning (riparian, grasslands, coastal shrublands, oak woodlands, coniferous forests, desert, and shrub steppe) based on results of a species and habitat prioritization scheme developed by the USFS (Davidson 1995, Manley and Davidson 1993). The initial focal species lists were compiled based on expert consensus at California PIF meetings focusing on each habitat type. Focal species were chosen so that, as a group, their breeding (and in some cases, wintering) requirements represented the full range of critical ecosystem/habitat elements. Individual species were chosen so that they also met as many as possible of the following criteria:

- Use the focal habitat as a primary breeding (and in a few cases, wintering) habitat in most bioregions of California.
- Warrant special management status or have experienced reduction in breeding range or population declines.
- Are invasive or may have negative impacts on native species.
- Represent a taxonomic group other than land birds (passerines and near-passerines). e.g. Wood Duck (*Aix sponsa*)', Spotted Sandpiper (*Actitis macularia*).
- Are useful for monitoring effects of management actions:
    - Abundant breeders in focal habitat throughout CA (i.e., provide adequate sample sizes for analysis).
    - Amenable to monitoring (e.g., nests can be easily monitored, high detection rates).
    - Thought to demonstrate quick, strong or consistent responses to habitat attributes, management, or restoration.

Thus, the number of focal species chosen depended on the characteristics of the focal habitat as well as the availability of biological information. While no single number can be put forward as ideal, we advocate a larger, more inclusive list rather than a restrictive list. Due to limitations of time, resources, and available information, it was not possible to immediately write detailed species accounts for every proposed focal species in some of California's Bird Conservation Plans. For these plans (Oak Woodland, Grassland, Coastal Scrub and Chaparral, and Coniferous Forest), species accounts were written for a subset of the focal species (sometimes referred to as "primary focal species"). However, this terminology is somewhat misleading because it was not necessarily intended that the "primary" focal species should be given higher conservation priority than the "secondary" species.

Bird Conservation Plans for the five focal habitats in California, including their associated focal species lists and conservation-oriented species accounts, are available at: http://www.prbo.org/calpif/plans.html. Two others (shrub steppe and desert) are currently being drafted. Oregon and Washington's habitat-based Bird Conservation Plans are available at http://community.gorge.net/natres/pif/cons_page1_.html. Below we provide examples from several of these plans to illustrate how focal species were chosen.

Examples from Bird Conservation Plans

Riparian Bird Conservation Plan (BCP)

The Riparian BCP (RHJV 2000) provides a good example of how focal species can be used in adaptive conservation planning and management (Geupel and Elliott 2001). A consensus emerged within California PIF that the first planning efforts should focus on riparian habitat, due to its high bird diversity, major historical loss of area, and serious ongoing conservation threats (Davidson 1995, Gaines 1977, Katibah 1984, RHJV 2000). A review of existing scientific information on riparian ecosystems in California was conducted and newly collected data were analyzed. These findings demonstrated that both habitat structure and seral stage were critical ecosystem elements for riparian birds. Therefore, a suite of focal species was chosen that together represented a range of riparian habitat components and also met many of the criteria for focal species listed above (*table 2*).

Species accounts were written containing detailed information about each species, along with a summary of key information. Account authors and other conservation and land management experts collaborated to synthesize these results into a summary of concerns, habitat requirements, conservation objectives, and recommended actions for riparian habitats. For example, available data indicated that seven of the ten focal species that have suffered the greatest range reductions and/or population declines tend to depend upon early successional riparian habitats with dense understory cover. Therefore, restoration recommendations were

developed that emphasized the need to restore and manage riparian forests to promote structural diversity and volume of understory (RHJV 2000). Monitoring methods also were recommended to guide the assessment of avian responses to riparian restoration projects. Thus, as the conservation plan is implemented, the effectiveness of the plan's recommendations and choice of focal species are being evaluated and this new information is being used to revise the plan. As part of this process, additional focal species candidates have been identified (see below).

Table 2-- *California Partners in Flight riparian focal species and the criteria used in their selection (reproduced from RHJV 2000).*

Focal species	Primary riparian breeder	Special status	Reduction in breeding range	Abundant breeder in CA	Nest site location
Swainson's Hawk (*Buteo Swainsoni*)	X	X	X		Canopy
Yellow-billed Cuckoo (*Coccyzus americanus*)	X	X	X		Midstory to canopy
Willow Flycatcher (*Empidonax traillii*)	X	X	X		Understory
Bell's Vireo (*Vireo bellii*)	X	X	X		Understory
Warbling Vireo (*Vireo gilvus*)	X		X	X	Canopy
Bank Swallow (*Riparia riparia*)	X	X	X		Sandy banks
Swainson's Thrush (*Catharus ustulatus*)	X		X	X	Understory
Yellow Warbler (*Dendroica petechia*)	X	X	X	X	Midstory
Common Yellowthroat (*Geothlypis trichas*)	X	X[1]	X	X	Understory
Wilson's Warbler (*Wilsonia pusilla*)	X			X	Understory
Yellow-breasted Chat (*Icteria virens*)	X	X	X		Understory
Song Sparrow *Melospiza melodia*	X		X	X	Understory
Black-headed Grosbeak (*Pheucticus melanocephalus*)	X			X	Midstory
Blue Grosbeak (*Guiraca caerulea*)	X		X		Understory

[1]Only the subspecies endemic to San Francisco Bay area (*G. t. sinuosa)* has special status.

Oak Woodland Bird Conservation Plan

Although California's oak woodlands are threatened by accelerating loss to urbanization and intensive agriculture, lack of regeneration of young trees, and the sudden oak death epidemic, they have not experienced nearly as drastic a reduction in area as riparian habitats (CPIF 2000). Thus, the focal species list for the Oak Woodland BCP differs from that of the riparian plan in that none of the species have special status designations. A suite of species was chosen that have a range of life history characteristics (*table 3*) and require a variety of habitat elements in oak woodlands (*table 4*). This list illustrates that the full range of species found in oak woodland includes not only those that consume acorns and nest in oak cavities, but also those that depend on understory components such as shrubs, grasses, and brush piles. Including the latter species in the list emphasizes the need to manage for the more subtle ecological characteristics of oak woodlands that might otherwise be overlooked. The Oak Woodland BCP also demonstrates the importance of including focal species from a variety of taxonomic groups as needed to represent the full range of important components of a habitat.

Coastal Scrub and Chaparral Bird Conservation Plan

Shrubland habitats in California tend to occur in coastal areas where habitat loss and fragmentation due to human development are major threats to bird communities. Together with fire, these are the most important processes affecting California's shrublands. Therefore, birds believed to be most sensitive to these processes were chosen as focal species for these habitats. For example, several species on the list, such as Sage Sparrow (*Amphispiza belli*) and Rufous-crowned Sparrow (*Aimophila ruficeps*), have been shown to be negatively affected by habitat fragmentation (Bolger et al. 1997). The list also includes species, such as California Gnatcatcher (*Polioptila californica*) and Gray Vireo (*Vireo vicinior*), that are influenced in different ways by fire frequency (CPIF 2000).

Because this plan covers a wide range of coastal, shrub-dominated habitats, the focal species list represents the full geographic and ecological spectrum of coastal scrub and chaparral communities. For example, the list includes Nuttall's White-crowned Sparrows (*Zonotrichia leucophrys nuttalli*), which are characteristic of northern coastal scrub; Greater Roadrunners (*Geococcyx californianus*), which represent drier, more open shrubland habitats; Wrentits (*Chamaea fasciata*), which are characteristic of denser, moister shrublands; and Cactus Wrens (*Campylorhynchus brunneicapillus*),

Table 3— *Oak woodland focal species in California, with information on their use of acorns, nesting substrate, general foraging habitat in oak woodlands, and whether the species is endemic to California (reproduced from CPIF 2000).*

Species	Consumes acorns?	Caches acorns?	Nest[1]	Foraging habitat in oak woodlands	California endemic?
Wood Duck *(Aix sponsa)*	Yes		2° Cavity	Wooded Streams	
Red-shouldered Hawk *(Buteo lineatus)*			Platform	Woodlands	
Wild Turkey *(Meleagris gallopavo)* (I[2])	Yes		Ground	Woodlands	
Band-tailed Pigeon *(Columba fasciata)*	Yes		Platform	Woodlands	
California Quail *(Callipepla californica)*	Yes		Ground	Woodland-shrub	
Northern Pygmy Owl *(Glaucidium gnoma)*			2° Cavity	Woodlands	
Acorn Woodpecker *(Melanerpes formicivorus)*	Yes	Tree, many	1° Cavity	Woodlands	
Lewis Woodpecker *(Melanerpes lewis)*	Yes		1° Cavity	Woodlands	
Nuttall's Woodpecker *(Picoides nuttallii)*	Yes		1° Cavity	Woodlands	Yes[3]
Ash-throated Flycatcher *(Myiarchus cinerascens)*			2° Cavity	Open Woodlands	
Western Scrub-Jay *(Aphelocoma californica)*	Yes	Ground, many	Cup	Woodland-Scrub	
Yellow-billed Magpie *(Pica nuttalli)*	Yes	Ground, few	Cup	Woodlands	Yes
Oak Titmouse *(Baeolophus inornatus)*	Yes	Tree, few	2° Cavity	Woodlands	Yes[3]
White-breasted Nuthatch *(Sitta carolinensis)*	Yes	Tree, few	2° Cavity	Woodlands	
Bewick's Wren *(Thryomanes bewickii)*			2° Cavity	Woodland-Scrub	
Blue-gray Gnatcatcher *(Polioptila caerulea)*			Cup	Woodlands	
Western Bluebird *(Sialia mexicana)*			2° Cavity	Open Woodlands	
California Thrasher *(Toxostoma redivivum)*			Cup	Woodland-Scrub	Yes[3]
European Starling *(Sturnus vulgaris)* (I)			2° Cavity	Agriculture edge	
Hutton's Vireo *(Vireo huttoni)*			Cup	Woodlands	
California Towhee *(Pipilo crissalis)*			Cup	Woodland-Scrub	Yes[4]
Lark Sparrow *(Chondestes grammacus)*			Ground	Grass - Woodland	

[1]Cavity-nesting species differ as to whether they excavate their own cavities (1° cavity nester) or they take over disused nests or naturally occurring cavities (2° cavity nester).
[2](I) denotes an introduced, nonnative species.
[3]Also occurs in Baja California, Mexico.
[4]Also occurs in Baja California, Mexico, and extreme southern Oregon.

Table 4— *Essential habitat elements for focal species, based on California Wildlife Habitat Relationships System V. 7.0 (reproduced from CPIF 2000)1.*

Focal species	Acorns	Cavities	Trees	Shrub	Grass/ herb	Snags	Brush piles	Water/ riparian
Wood Duck *(Aix sponsa)*		X						X
California Quail *(Callipepla californica)*			X	X	X		X	X
Red-shouldered Hawk *(Buteo lineatus)*			X	X				X
Northern Pygmy Owl *(Glaucidium gnoma)*		X	X			X		
Band-tailed Pigeon *(Columba fasciata)*	X		X					
Acorn Woodpecker *(Melanerpes formicivorus)*	X	X	X			X		X
Lewis's Woodpecker *(Melanerpes lewis)*	X	X	X					
Nuttall's Woodpecker *(Picoides nuttallii)*		X	X			X		
Ash-throated Flycatcher *(Myiarchus cinerascens)*		X	X	X				
Western Scrub-jay *(Aphelocoma californica)*	X		X	X				
Yellow-billed Magpie *(Pica nuttalli*	X		X					X
Oak Titmouse *(Baeolophus inornatus)*		X	X			X		
White-breasted Nuthatch *(Sitta carolinensis)*	X		X			X		
Bewick's Wren *(Thryomanes bewickii)*		X	X	X				
Blue-gray Gnatcatcher *(Polioptila caerulea)*			X	X				
California Thrasher *(Toxostoma redivivum)*				X				
Western Bluebird *(Sialia mexicana)*		X	X		X	X		X
Hutton's Vireo *(Vireo huttoni)*			X	X				X
Lark Sparrow *(Chondestes grammacus)*					X			
California Towhee *(Pipilo crissalis)*				X				X

[1] Includes selected elements classified by CWHR as "essential" or "secondarily essential".

which are found in coastal scrub habitats with a cactus component. Even within southern California coastal sage scrub, plant, bird, and small mammal species composition shows a clear gradient from coastal (mesic) to inland (xeric) communities (Chase et al. 2000). Chase et al. (2000) found that Cactus Wrens and Wrentits are significantly associated with the coastal-type species assemblage while Sage Sparrows and Greater Roadrunners are associated with the inland-type species assemblage. Thus, the focal species list for coastal scrub habitats includes representatives from both ends of this spectrum of species composition.

WA/OR Bird Conservation Plans

Oregon-Washington PIF used a similar approach to develop Bird Conservation Plans for five habitats /ecoregions (westside coniferous forest, westside lowlands and valleys, Columbia Plateau, northern Rocky Mountains, and east-slope Cascades). In each plan, habitat conditions and habitat attributes of importance to birds were defined and focal species were chosen to represent each attribute. For example, habitat conditions for westside coniferous forests were chosen based on successional stages. For each habitat condition, attributes such as forest type, structural components, landscape parameters, and microhabitat features were identified, and focal species associated with each attribute were chosen (*table 5*). Finally, biological objectives and conservation options were described for each focal species and associated habitat attribute (http://community.gorge.net/natres/pif/westside_plan.html).

Evaluation and Revision of Focal Species Lists

After Bird Conservation Plans have been developed, their recommendations typically are implemented by a wide range of partner organizations. To further the adaptive conservation planning process, California PIF encourages all partners to monitor population parameters of focal species in order to evaluate the response of birds to the conservation actions recommended in the plans. Both intensive demographic monitoring and population trend monitoring programs should be put in place to evaluate whether focal species and other species within the habitat are benefiting from the prescribed conservation actions. California PIF encourages all partners to contribute information that can guide ongoing revisions of the BCPs. For example, California PIF maintains a statewide geographic database of landbird species distributions, breeding status, and monitoring sites (to view and submit data, visit http://www.prbo.org/calpif/maps.html). In the future it may be possible to use this information to evaluate and revise conservation plans, and to test the effectiveness of focal species approaches.

In addition, the assumptions and hypotheses used to choose focal species should be evaluated through monitoring and research (Lindenmayer et al. 2002). New studies may change our understanding of the important processes influencing birds in each habitat, or how species respond to those processes. To evaluate the focal species lists, it also will be important to verify whether the observed responses of species to habitat change in one area or habitat are similar to those in other areas (Landres et al. 1988). Finally, focal species lists may change as conservation strategies are evaluated and revised through time. For example, the "all bird" approach to bird conservation in North America has broadened the scope of many conservation efforts that once were divided among taxonomic groups.

California's choice of riparian focal species currently is being evaluated as part of the process of revising the Riparian BCP. The focal species list is being reexamined to evaluate whether it actually represents all the important habitat elements in California's riparian ecosystems. It has been recognized that the original landbird focus of the plan resulted in no species being chosen that is dependent on gravel bar habitat, an important early-successional element of riparian ecosystems. Therefore, the addition of the Spotted Sandpiper (*Actitis macularia*) has been proposed to represent this habitat attribute.

Additional riparian focal species candidates also may be identified by analyses of monitoring data. For example, recent analyses of the life history and habitat associations of Spotted Towhees (*Pipilo maculates*) suggest that they may be valuable as indicators for monitoring the effectiveness of habitat restoration and management in the Central Valley. Spotted Towhees, like many other open-cup nesting species in riparian habitats, experience high nest predation rates (mean nest survivorship = 0.23, range 0.20 – 0.50, n = 309 nests; Point Reyes Bird Observatory unpublished data). However, because they are common in Central Valley riparian habitats (present at 56 percent of point-count stations, n = 1005 stations, 3 surveys per year, 1995-1998; Point Reyes Bird Observatory unpublished data) it is possible to monitor a larger sample of nests than is practical for other riparian birds. Also, their abundance was found to be positively correlated with bird species richness in riparian habitats, which suggests that they are responding to habitat conditions that also influence many other riparian species. Finally, Spotted Towhees also appear to show relatively strong relationships between abundance and habitat attributes (e.g., shrub cover and species richness, tree cover and species richness) that may be affected by management and restoration activities.

Table 5— *Forest conditions and associated habitat attributes and focal species for landbird conservation in coniferous forests of western Oregon and Washington (reproduced from the Westside Coniferous Forest Landbird Conservation Plan, Oregon-Washington Partners In Flight,* http://community.gorge.net/natres/pif */westside_page1.html).*

Forest condition	Habitat attribute	Focal species
Old-growth forest	Large snags	Vaux's Swift *(Chaetura vauxi)*
	Large trees	Brown Creeper *(Certhia Americana)*
	Conifer cones	Red Crossbill (*Loxia curvirostra)*
Mature forest: multi-layered	Large snags	Pileated Woodpecker (*Dryocopus pileatus)*
	Large trees	Brown Creeper *(Certhia Americana)*
	Conifer cones	Red Crossbill (*Loxia curvirostra)*
	Closed canopy	Hermit Warbler (*Dendroica occidentalis)*
	Deciduous canopy trees	Pacific-slope Flycatcher (*Empidonax difficilis)*
	Mid-story tree layers	Varied Thrush *(Ixoreus naevius*)
	Open mid-story	Hammond's Flycatcher (*Empidonax hammondii)*
	Deciduous understory	Wilson's Warbler (*Wilsonia pusilla)*
	Forest floor complexity	Winter Wren (*Troglodytes troglodytes)*
Young forest: understory reinitiating	Closed canopy	Hermit Warbler (*Dendroica occidentalis)*
	Deciduous canopy trees	Pacific-slope Flycatcher (*Empidonax difficilis)*
	Open mid-story	Hammond's Flycatcher (*Empidonax hammondii)*
	Deciduous canopy trees	Black-throated Gray Warbler (*Dendroica nigrescens)*
	Deciduous understory	Wilson's Warbler (*Wilsonia pusilla)*
	Forest floor complexity	Winter Wren (*Troglodytes troglodytes*
Pole forest: stem exclusion	Deciduous canopy trees	Black-throated Gray Warbler (*Dendroica nigrescens)*
	Deciduous subcanopy/understory	Hutton's Vireo *(Vireo huttoni)*
Early-seral forest: stand initiation	Residual canopy trees	Olive-sided Flycatcher (*Contopus borealis)*
	Snags	Western Bluebird *(Sialia mexicana)*
	Deciduous vegetation	Orange-crowned Warbler *(Vermivora celata)*
	Nectar-producing plants	Rufous Hummingbird *(Selasphorus rufus*)
Forest inclusions/	Mineral springs	Band-tailed Pigeon *(Columba fasciata)*
unique habitats	Alpine	American Pipit (*Anthus rubescens)*
	Waterfalls	Black Swift (*Cypseloides niger)*
	High elevation wet meadows	Lincoln's Sparrow (*Melospiza lincolnii)*

In some cases, new research may support the original focal species choices. In one example, recent research has shown that the abundance of two Oak Woodland focal species is associated with the density of human development in oak woodlands. Stralberg and Williams (2002) found that Lark Sparrows (*Chondestes grammacus*) were less abundant and Western Scrub-jays (*Aphelocoma californica*) more abundant where levels of human development in the oak woodland landscape are high.

Indeed, one purpose of choosing focal species and developing management recommendations, even when available information is limited, is to encourage and focus the development of new research and monitoring projects and thus obtain information needed for better conservation planning. Only through ongoing monitoring of restoration and management projects will we be able to test the basic assumption of the focal species approach taken by California, Oregon and Washington: that managing for the needs of a suite of carefully chosen focal species will ultimately improve conditions for the larger community of species that shares the same habitat.

Conclusion

In conclusion, we suggest that focal species lists used in Partners in Flight and other conservation planning exercises should include species that represent various habitat elements and processes in the ecosystem and species that are easily and efficiently monitored. It is crucial to note that the focal species that are the best indicators may well be common species that have not been identified as a 'priority' by ranking schemes or 'in decline' by monitoring programs. Ideally, the avian focal species identified by Partners in Flight would be considered alongside focal species from broader bird taxa (e.g. waterfowl and shorebirds) as well as other wildlife (fish, mammals and invertebrates) as conservation actions are weighed and evaluated. Although the focal species approach described here may provide a good starting point for conservation planning, we should not complacently assume that all other species in the habitat consequently will be conserved. Because focal species lists are based on numerous hypotheses and assumptions, these should be made as explicitly as possible and tested in ongoing monitoring studies as part of an adaptive management program.

Acknowledgments

Many California Partners in Flight collaborators have contributed to the development and implementation of the focal species approach described here. We thank especially B. Allen, B. Altman, B. Barnes, G. Ballard, C. Beardmore, J. Buchanan, L. Comrack, D. Craig, G. Elliot, T. Gardali, S. Heath, A. Holmes, D. Humple, C. McCreedy, N. Nur, D. Pashley, J. Robinson, S. Small, and S. Zack. Partner and collaborating organizations include the American Bird Conservancy, Bureau of Land Management, California Department of Fish and Game, California Oak Foundation, Central Valley Habitat Joint Venture, The Nature Conservancy, Natural Resource Conservation Service, Riparian Habitat Joint Venture, US Fish and Wildlife Service, and Wildlife Conservation Society. Generous financial support to PRBO for adaptive conservation planning in California has been provided by the National Fish and Wildlife Foundation, David and Lucile Packard Foundation, Resources Law Group, USDA Forest Service, and Bureau of Reclamation. This is PRBO contribution number 1045.

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Conservation Priorities for Landbirds of the Pacific Coast of Oregon and Washington[1]

Bob Altman[2]

Abstract

Conservation of landbirds in western Oregon and Washington is being guided by two Bird Conservation Plans, a Coniferous Forest plan and a Lowlands and Valley plan. In coniferous forests, all seral stages are recognized as important to maintain avian communities, although late-successional habitats are a priority because of their reduced presence across the landscape. Conservation priorities focus on forest management and providing habitat conditions and special habitat attributes for focal species at site and landscape scales. The best approach for implementing landbird conservation will be incorporating bird conservation objectives into policy and planning of forest management agencies and private companies. The best tools for measuring the success of conservation efforts include habitat monitoring of desired conditions and population monitoring of resident birds. Priority habitats in the lowlands and valleys include grassland, oak, and riparian. Conservation priorities emphasize protection and restoration activities, and enhancing populations for many declining species. Securing protection status for important areas and conducting restoration activities is likely to be the best approach for the declining and heavily impacted grassland, oak, and riparian habitats. The best tools for measuring the success of conservation efforts include tracking the amount and condition of land secured for conservation, and tracking populations of declining and sensitive species. With limited resources, the two most important conservation activities to implement now for landbirds in western Oregon and Washington are protection and management of high priority lowland sites, and institutionalizing landbird conservation into forest management policy and planning.

Key words: coniferous forests, conservation priorities, declining species, landbirds, Pacific Coast, western Oregon and Washington.

Introduction

In the Southern Pacific Rainforest Physiographic Region (mostly western Oregon and Washington except for the west-slope of the Cascade Mountains), a review of Breeding Bird Survey (BBS) data over the last approximately 35 years indicated that 38 species had significantly declining long-term (1966 to 2000) population trends, but only 19 species had significantly increasing trends (Sauer et al. 2001) (*table 1*). Further examination of the data indicated that there was high confidence in the reliability of the data for 24 of the 38 declining species (63 percent), but only six of the 19 increasing species (32 percent). Thus, our most confident assessment of landbird population trends based on BBS data in western Oregon and Washington indicated that there were four times as many species with significant declining trends than with significant increasing trends.

Further, many of the species with significantly increasing trends were generalist species that are already common or abundant, and hence are of little conservation concern. Some examples include Rock Dove, Steller's Jay, House Sparrow, and Red-winged Blackbird (*table 1*). Two exceptions were Osprey and Bald Eagle, which are rebounding from low populations. Some of the other species with significantly increasing trends were species formerly peripheral to this area that are expanding their range, such as Brown Pelican, Black Phoebe, and Red-shouldered Hawk.

Among significantly declining species, a variety of ecological niches were represented, but the most noteworthy patterns were the relatively large number of aerial insectivores (i.e., swifts, swallows, flycatchers, nighthawk), late-successional coniferous forest species (e.g., Blue Grouse, Pine Siskin, Golden-crowned Kinglet, Chestnut-backed Chickadee, Olive-sided Flycatcher, and Vaux's Swift), and grassland-oak species (e.g., American Kestrel, Lazuli Bunting, Western Wood-pewee, Bushtit, Western Bluebird, Chipping Sparrow, and Western Meadowlark) (*table 1*). These patterns likely reflected the conservation issues of habitat loss due to harvesting of late-successional forest and human development in the lowland grassland-oak habitats.

Scope

The Pacific Coast of Oregon and Washington as defined in this paper includes all lands west of the crest of

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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Table 1— *Species with significant population trends (p < 0.10) based on Breeding Bird Survey data from the Southern Pacific Rainforest Physiographic Region, 1966-2000 (Sauer et al. 2001).*

Declining species	
Cinnamon Teal *(Anas cyanoptera)*	Golden Eagle *(Aquila chrysaetos)*
American Kestrel *(Falco sparverius)*	Ring-necked Pheasant* *(Phasianus colchicus)*
Ruffed Grouse *(Bonasa umbellus)*	Blue Grouse *(Dendragapus obscurus)*
Mourning Dove* *(Zenaida macroura)*	Common Nighthawk *(Chordeiles minor)*
Vaux's Swift *(Chaetura vauxi)*	Rufous Hummingbird* *(Selasphorus rufus)*
Belted Kingfisher *(Ceryle alcyon)*	Northern Flicker* *(Colaptus auratus)*
Olive-sided Flycatcher* *(Contopus cooperi)*	Western Wood-pewee* *(Contopus sordidulus)*
Willow Flycatcher* *(Empidonax trallii)*	Pacific-slope Flycatcher* *(Empidonax difficilis)*
Cliff Swallow* *(Petrochelidon pyrrhonota)*	Barn Swallow* *(Hirundo rustica)*
Chestnut-backed Chickadee* *(Poecile rufescens)*	Bushtit* *(Psaltriparus minimus)*
Golden-crowned Kinglet* *(Regulus satrapa)*	Western Bluebird* *(Sialia mexicana)*
Swainson's Thrush* *(Catharus ustulatus)*	Orange-crowned Warbler* *(Vermivora celata)*
MacGillivary's Warbler* *(Oporornis tolmiei)*	Chipping Sparrow *(Spizella passerina)*
Lark Sparrow *(Chondestes grammacus)*	Song Sparrow* *(Melospiza melodia)*
White-crowned Sparrow* *(Zonotrichia leucophrys)*	Dark-eyed Junco *(Junco hyemalis)*
Lazuli Bunting *(Passerina amoena)*	Western Meadowlark* *(Sturnella neglecta)*
Brown-headed Cowbird *(Molothrus ater)*	Bullock's Oriole* *(Icterus bullockii)*
Pine Siskin* *(Carduelis pinus)*	American Goldfinch* *(Carduelis tristis)*
Increasing species	
Brown Pelican *(Pelecanus occidentalis)*	Black Phoebe *(Sayornis nigricans)*
Black-crowned Night Heron *(Nycticorax nycticorax)*	Steller's Jay* *(Cyanocitta stelleri)*
Osprey (*Pandion haliaetus*)	Common Raven* *(Corvus corax)*
Bald Eagle (*Haliaeetus leucocephalus*)	Common Yellowthroat* *(Geothlypis trichas)*
Sharp-shinned Hawk (*Accipter striatus*)	California Towhee *(Pipilo crissalis)*
Red-shouldered Hawk (*Buteo lineatus*)	Black-headed Grosbeak *(Pheucticus melanocephalus)*
Wild Turkey (*Meleagris gallopavo*)	Red-winged Blackbird *(Agelaius phoeniceus)*
Caspian Tern (*Sterna caspia*)	Evening Grosbeak *(Coccothraustes vespertinus)*
Rock Dove (*Columba livia*)	House Sparrow *(Passer domesticus)*
Northern Pygmy-owl (*Glaucidium gnoma*)	

* = a high degree of confidence or reliability in the trend (Sauer et al. 2001)

the Cascade Mountains. This area is entirely encompassed within the Oregon and Washington portion of the Northern Pacific Rainforest Bird Conservation Region. PIF-based landbird conservation efforts in this area are being directed by two Oregon-Washington PIF Bird Conservation Plans: *Conservation Strategy for Landbirds in Coniferous Forests of Western Oregon and Washington* (Altman 1999) and *Conservation Strategy for Landbirds in Lowlands and Valleys of Western Oregon and Washington* (Altman 2000). The former plan covers the west-slope of the Cascade Mountains and three coastal mountain ranges: Olympic Mountains, Oregon Coast Range, and the Klamath-Siskiyou Mountains. The latter plan includes primarily the Puget Lowlands and Willamette Valley, but also the San Juan Islands, Umpqua Valley, Rogue Valley, and non-coniferous forest coastal lowland and riparian habitats.

Purpose

This paper describes coarse-level high priorities for landbird conservation in the Pacific Coastal region of Oregon and Washington, and provides relevant recommendations to implement and track the progress of actions designed to address those priorities. Establishing conservation priorities is not a trivial task, and is always an issue of scale. The purpose of this paper is to identify some of the highest and most immediate priorities at the regional scale to provide direction for land managers and conservationists and encourage conservation actions within the context of the "big picture." We recognize that local opportunities, strategies, and priorities may be justifiably different, but suggest that landbird conservation is likely to be most successful in the long-term when activities support large landscape and regional goals and priorities to the extent possible.

Determination of regional priorities required assimilation and evaluation of common themes in Pacific Coast bird

conservation. What is presented here is my interpretation of numerous conversations among many colleagues over the last 10 years of planning and implementing landbird conservation in western Oregon and Washington. Any list of priorities is, of course, debatable, and the intent here is not to provide the ultimate list, but to suggest that there is a broad constituency that indicates certain conservation actions are of the greatest importance from a regional perspective. This prioritization also was intended to assist in answering the following three questions posed to all presenters in the Asilomar PIF Conference, Pacific Coast session. The questions were posed to provide consistency when discussing the means of achieving priorities in the context of the North American Bird Conservation Initiative (NABCI) and all-bird all-habitat conservation (Elliott et al. this volume):

1. What do you see as the best tools or mechanisms for implementing your conservation priorities?

2. What do you see as the best tools or mechanisms for measuring the success of your conservation actions?

3. If reasonably unlimited resources were available for conservation, what would you suggest as the most important one or two conservation activities that should be initiated now?

Coniferous Forests

Conservation Issues

Coniferous forests of western Oregon and Washington are among the most intensively managed forests in the world. These forests have been substantially altered by forest management practices associated primarily with timber harvest (Franklin 1989). This included emphasizing shorter rotation periods, clearcutting and even-aged management, chemical applications to enhance growth and control pests, and thinning to reduce competition from deciduous trees and less vigorous conifers.

The consequences of these and other intensive forest management activities on landbirds is complex and dependent on numerous environmental and ecological factors. In general, the four areas of concern for landbirds that relate to intensive forest management include shortening of the grass-forb-shrub stage (i.e., less time in this stage due to growth enhancement), reductions in structural diversity, loss of snags, and reductions in late-successional forest (Meslow and Wight 1975).

Current forest management, particularly on federal lands, has shifted towards ecosystem management in which maintaining ecological values and functions is integrated with sustainable commodity production (Franklin 1989). In particular, there is more of an emphasis on retention or creation of structural complexity in harvest units and attempts to retain features thought to be important to late-successional forest species.

Most management activities in coniferous forests of western Oregon and Washington have been directed at listed species (e.g., Spotted Owl [*Strix occidentalis*] and Marbled Murrelet [*Brachyramphus marmoratus*]), emphasized stand-level activities, or indicated conservation under the general term of "neotropical migrants." Thus, the major conservation gaps are consideration of non-listed but declining or otherwise ecologically significant species, knowledge and application of landscape factors to conservation implementation, and specific direction for management for a suite of priority or focal landbird species. These are the factors that were emphasized in the landbird conservation plans.

Priorities

The conservation priority for coniferous forests is forest management that provides habitat conditions and attributes for focal and/or declining species at site and landscape scales (*table 2*). All forest seral stages are important to maintain the complete coniferous forest avian community, although late-successional habitats are a priority because of their reduced presence across the forested landscape, and their importance to declining populations of late-successional species.

Because the primary conservation issue is habitat alteration from forest management, the highest priority is institutionalizing landbird objectives and conservation emphasis into forest management policy and planning. Until landbird conservation is institutionalized, conservation efforts for landbirds will be sporadic, local, and potentially out of context from a regional perspective. Institutionalizing landbird conservation is mostly dependent on people to campaign for a stronger emphasis on wildlife, especially birds, in forest management policy and planning and in forest practice regulations.

Implementation

To ensure implementation of landbird conservation priorities on public lands, it will be important to incorporate landbird conservation objectives during any proposed forest management activities. Another important opportunity is during the process of updating U.S. Forest Service, U.S. Bureau of Land Management, and State Forestry land use plans at local and regional levels. These plans are updated periodically, and it will be essential to have a strong presence during these efforts with clearly articulated, scientifically sound,

Table 2— *Forest conditions and associated habitat attributes and focal species for landbird conservation in coniferous forests of western Oregon and Washington (Altman 1999 modified for Version 2.0, in prep.).*

Forest condition	Habitat attribute	Focal species
Old-growth/Mature forest	Large snags	Pileated Woodpecker *(Dryocopus pileatus)*
(Multi-layered)	Large trees	Brown Creeper (*Certhia Americana)*
	Deciduous canopy trees	Pacific-slope Flycatcher
	Mid-story tree layers	Varied Thrush (*Ixoreus naevius*)
	Conifer cones	Red Crossbill (*Loxia curvirostra*)
Mature/Young forest	Closed canopy	Hermit Warbler *(Dendroica occidentalis)*
(Multi-layered/Understory	Open mid-story	Hammond's Flycatcher (*Empidonax hammondii*)
reinitiating)	Deciduous understory	Wilson's Warbler (*Wilsonia pusilla*)
	Forest floor complexity	Winter Wren (*Troglodytes troglodytes*)
Young/Pole forest	Deciduous canopy trees	Black-throated Gray Warbler *(Dendroica nigrescens)*
(Understory reinitiating/	Deciduous understory	Hutton's Vireo (*Vireo huttoni*)
stem exclusion)		
Early-seral forest	Residual canopy trees	Olive-sided Flycatcher
(Stand initiation)	Snags	Western Bluebird
	Deciduous vegetation	Orange-crowned Warbler
	Interspersion of shrubs	Mountain Quail (*Oreortyx pictus*)
	Nectar-producing plants	Rufous Hummingbird
	Nectar producing plants	Rufous Hummingbird

and practical objectives for landbirds. The planning process mechanism can be laborious and time consuming, but offers the best opportunity to affect bird conservation over large landscapes.

Another essential opportunity to implement landbird conservation priorities will be working with private forest products companies. There are many opportunities to conduct management for landbirds within the context of commercial forest land management, especially in early and mid-seral stages. These opportunities include retention or creation of structural features and providing specific vegetative composition as described in the landbird conservation plan (also see *table 2*). A variety of approaches may need to be used to effectively implement landbird conservation priorities. These will range from negotiated volunteer or incentive programs to forest management regulations (Buchanan this volume). In all of these approaches, it will be important to work with forest products companies through direct personal communication with appropriate staff, and present realistic expectations that reflect the benefits of both conservation and economics.

Tracking Progress

The best tools for measuring the success of conservation efforts in coniferous forests include monitoring of desired habitat conditions and bird species population monitoring, especially resident birds. Migratory birds are impacted by conditions at numerous places outside Oregon and Washington, thus are less desirable as indicators of progress than resident birds.

Lowlands and Valleys

Conservation Issues

The two predominant conservation issues in the lowlands and valleys of western Oregon and Washington are habitat loss and degradation due directly or indirectly to an expanding human population, and extensive private land ownership (Altman 2000). Urban and residential sprawl has eliminated and/or degraded most of the quality native habitats, and landscape-scale management and restoration activities are problematic due to the dominance of private land ownership.

Another principal factor contributing to the loss and degradation of quality habitats for landbirds is the alteration of natural ecological processes such as fire and flooding. Fire suppression in the grassland-oak mosaic has resulted in encroachment of conifers, particularly Douglas-fir. This has changed the composition of the vegetation community because oak trees are suppressed by, and have poor recruitment, due to the presence of these conifers (Thilenius 1968). Flood control has reduced the areal extent of riparian habitats, altered hydrological regimes, and altered community composition by allowing a forest community to develop in areas formerly dominated by early successional willow floodplain shrub habitat.

The highly urban and residential nature of lowland and valley habitats also has resulted in hostile landscapes

for landbirds, even where habitat is suitable. Several non-native bird species (e.g., European Starling [*Sturnus vulgaris*], House Sparrow), and high densities of domestic cats have negatively impacted native landbird species. Additionally, extensive agricultural development has provided suitable habitat for an invasive brood parasite, the Brown-headed Cowbird.

Priorities

The two greatest conservation priorities are protection and restoration activities to address high levels of both habitat loss and degradation for priority habitats. In the lowlands and valleys, priority habitats include the grassland-oak mosaic and riparian habitats because of their reduced presence and degree of degradation across the landscape, and their significance to populations of declining species, especially those associated with grassland-oak habitats (see *table 1*).

The greatest priority is protection of the highest priority lowland sites. Because of the expanding human population and the concomitant loss of habitat associated with development, there is a sense of urgency to secure conservation status for high priority sites, because these sites may be lost if not protected. This will require considerable funds, but it is generally a one-time cost for each site.

The second priority is restoration of degraded sites. Most of what hasn't been lost is highly fragmented and degraded. Restoration is a rapidly evolving science that requires varying levels of active management and adaptive management principles. Additionally, restoration will be an on-going process in many situations that requires regular management either through anthropogenic use of natural processes (e.g., flooding, fire) or use of mechanical applications (e.g., mowing, planting). Thus, costs must be considered over a long period of time.

In the case of both protection and restoration, identification and prioritization of sites is essential in lieu of limited financial resources and an expanding human population. There have been several significant efforts to identify and prioritize sites including PIF plans, The Nature Conservancy Ecoregional Plans, Important Bird Area programs of the American Bird Conservancy and National Audubon Society, and Pacific Coast Joint Venture (PCJV) Willamette Valley and Puget Trough Implementation Plans. The highest priority sites for protection and restoration can be identified where prioritized areas among these plans overlap.

Implementation

Securing conservation status for important sites and conducting restoration and management activities is likely to be the best approach for the declining and heavily impacted grassland-oak and riparian habitats. This might include acquisition, easements, or other means of securing conservation values. Because so much degradation also has occurred, another important activity will be management that restores or improves function and process to the habitat.

An emerging tool for conservation of lowland habitats for landbirds, especially in terms of protection and securing conservation status for important habitats, is the PCJV. Under the vision of NABCI, Joint Ventures are being encouraged to expand their mission and sphere of influence beyond wetlands and waterfowl to play an integral role in the implementation of all-bird, all-habitat conservation. As integrated bird conservation evolves under NABCI, and opportunities for landbird conservation are enhanced through new funding programs, the experience of PCJV partners in habitat protection can be important.

A variety of other tools exist through State Programs (e.g., State Wildlife Grants) and Federal Agencies (e.g., USFWS Private Landowner Programs). Perhaps the most important opportunity for conservation on the private lands that dominate the lowlands and valleys is through programs of the Natural Resources Conservation Service (NRCS). They assist in implementing the Farm Bill through programs such as the Wildlife Habitat Incentive Program and the Conservation Reserve Enhancement Program. Thus, they have the ability to affect large areas if the bird conservation objectives of PIF are institutionalized into their programs.

Tracking Progress

Tracking progress primarily will be a numbers game. The best tools for measuring success in the lowlands and valleys will be tracking the amount of land secured for conservation, and monitoring populations of focal and declining species. There also will need to be assessments of the quality and location (e.g., connectedness) of habitat secured for conservation, and the viability of landbird populations to ensure that efforts are providing "real" conservation value.

Acknowledgments

The ideas presented in this paper are the author's interpretation of 10 years of dialogue among numerous colleagues working on bird conservation in western Oregon and Washington. J. Buchanan and R. Sallabanks provided comments on an earlier draft.

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Current Status of Research on the Shorebirds, Marsh Birds, and Waders of the Peninsula of Baja California[1]

Eric Mellink[2,3]

Overall Setting

Regarding the information on its birds, the peninsula of Baja California has a luxury status, compared to other regions of México. In this sense, it is useful to compare it with its nearest states: Sonora and Sinaloa. While the peninsula measures 143,790 km^2, Sonora is 184,937 km^2. Sinaloa (58,092 km^2), although much smaller, has a wide arrange of habitats going from tropical forests to semiarid thornscrub, from sea-level mangroves to oak and pine forests.

Information-wise, whereas Baja California has three books devoted to its birds, Sonora has only two, and Sinaloa none. Moreover, the books about Baja California birds preceded those for Sonora by a long time: respectively, Grinnell (1928) vs. van Rossem (1945); Wilbur (1987) vs. Russell and Monson (1998); and Howell and Erickson (2001), unmatched yet. Also, whereas nearly 800 bibliographic sources deal with birds of Baja California, less than 550 focus on those of Sonora (*table 1*). Over 60 published sources on the birds of Baja California pertain to shorebirds (s), marsh birds (m) and waders (w) (or s/m/w), but only five such articles exist for Sinaloa (not including Sonora).

Current Research

Although the ornithofauna of Baja California has been surveyed more than that of nearby states, little local research goes on. Only six Mexican academia-based teams have studied s/m/w in the peninsula in the last decade (Lead by Roberto Carmona, Horacio de la Cueva, Osvel Hinojosa, Eduardo Palacios, Gorgonio Ruiz-Campos / Marcelo Rodriguez / Salvador González, and myself). All but one of these groups have one researcher, and except for one, the time devoted to s/m/w is shared with studies on other animals, from fish to mammals, and teaching. From the private arena, only biologists from "Exportadora de Sal," the salt mining company at Guerrero Negro, conduct surveys of waterbirds anywhere in the Peninsula.

Three foreign groups have researched waterbirds along the coasts of Baja California in recent times. Brian A. Harrington, of the Manomet Bird Observatory and R. I. G. Morrison, of the Canadian Wildlife Service, independently conducted shorebird aerial surveys in northwestern México, in the early 1990s, the former only the delta of the Río Colorado (in addition to the east coast of the Gulf of California), the later, covering the entire peninsula. Several researchers from Point Reyes Bird Observatory have conducted marsh and shorebird censuses in San Quintín and Punta Banda, in the northwestern peninsula. Although staff from the U.S. Fish and Wildlife Service in Alaska have worked in San Quintín for several years, their main study subjects have been Black Brants (*Branta bernicla*). Unlike what happens in the United States and Canada, Mexican environmental government agencies do not engage in research (except monitoring to establish fishing quotas), and non-governmental organizations (NGOs) are just beginning to enter this field, most often associated with research/education institutions.

In contrast with the low level of Mexican institutional research, independent observers (highly qualified "bird watchers" as well as trained ornithologists, on leisure time) have provided much information on Baja California´s birds (not just s/m/w). Their contributions are found in several formal articles, in Wilbur (1987; in which 34 such independent observers are acknowledged), and in Howell and Erickson 2001. Based on independent observers, Ensenada had its first Christmas Bird Count in January 2001. Contributions to the recently established Baja California section in *North American Birds* will evidence the relevance of this group of people.

Use of Knowledge

The information gathered to date seems to have had little impact on public policy. Aerial surveys of shorebirds in the 1990s provided the data to nominate two Baja California sites for the Western Hemisphere Shorebird Reserve Network (the delta of the Río Colorado and the Guerrero Negro lagoons), but exhaustive

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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Table 1-- *Approximate number of articles dealing with the ornithofauna of the Peninsula of Baja California and the state of Sonora, México (excluding AOU checklists, additions to them, article reviews and field guides).*

	Baja California		Sonora	
	"Old"	**"Recent"**	**"Old"**	**"Recent"**
Articles	422 (pre 1928)	303 (1928-1986) >60 (1987-1997)	448 (pre 1945)	86 (1945-1997)

bird data analysis was not a part of the designation process of any of the natural protected areas in Baja California, although in some cases birds were included in the arguments (the Guadalupe Storm-petrel, *Oceanodroma macrodactyla*, for example, or "seabirds" on Gulf of California islands). Other exercises of determining biologically important areas, organized by both government and NGOs, have relied heavily on opinion, rather than on "hard" data.

There are five taxa of s/m/w from Baja California on the Mexican list of species at risk (not including those species included as of "special protection" because of their game status): *Ardea herodias sanctilucae, Charadrius montanus, Egretta rufescens, Rallus longirostris levipes,* and *Rallus longirostris yumanensis*. These were included not based on solid research, but rather because of opinion or on their legal status in the United States. To my knowledge, no active management action has been taken for any of these species in the peninsula of Baja California, nor any management plans designed for them. (Indeed, active management doesn't exist for almost any species or guild in México, although a few management plans have been written.) The recent appointment of a non-governmental national shorebird conservation plan coordinator might well be the beginning of active management for sensitive species or guilds.

Research Needs

The fact that the knowledge gathered so far has been of little impact in decision-making, does not mean that no further research should be carried out. In fact, knowledge is badly needed if we are to be able to influence policy by argumentation (and I believe the system is ripening for this). Knowledge needs can be divided in what would be neat to know, and what we need to know to help in the conservation of s/m/w in Baja California. At this time, I believe, we should focus on the later. Each one involved with s/m/w birds in Baja California would have a different perspective of what particular research is most needed, depending on personal experience and perspectives, and particular regions and guilds of study. Despite this, I feel that it is valuable to post my own opinion on this matter. My list is (order of appearance is not order of priority):

1. Nesting species and permanent residents
   - 1.1 Taxonomy of selected species of marshbirds and waders.
   - 1.2 Surveys of unstudied regions.
   - 1.3 Conservation status and conservation threats of species that seem to be in trouble. Objective evaluation of those listed officially as at risk.
   - 1.4 Ecology of species that appear to be in trouble.
2. Migratory species using Baja California during the non-breeding season.
   - 2.1 Microhabitat selection by migrating shorebird, including analysis of prey base.
   - 2.2 Age/sex differences in resource (habitat, microhabitat, and food) use by migrating shorebirds.
   - 2.3 Links between sites along migratory corridors.
   - 2.4 Much more on distribution and numbers, especially on long term dynamics at several different sites (+ ENSO effects, etc.).
   - 2.5 Threats to migratory species in the peninsula of Baja California.

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Seabird Research and Monitoring Needs in Northwestern México[1]

Eduardo Palacios[2] and Lucía Alfaro[3]

Abstract

Seabird research in northwestern México has increased in the last 20 years, however many areas remain unexplored and seabird colony inventories are badly needed. Coastal wetlands and adjacent islands from southern Sonora through Nayarit host large colonies of pelecaniforme and other seabirds, but surveys of these areas have been limited and localized. Seabird colonies on islands in the Gulf of California and off the west coast of the Baja California peninsula have been well documented but only for surface nesting species. Population abundance estimates for sub-surface nesting species are almost non-existent although recent projects are beginning to address this issue. Monitoring in México is basically limited to 10 species: Brown Pelicans (*Pelecanus occidentalis*), Double-crested Cormorants (*Phalacrocorax auritus*), Blue-footed (*Sula nebouxi*) and Brown boobies (*S. leucogaster*), Heermann´s Gull (*Larus heermmanni*), Royal (*Sterna maxima*), Elegant (*S. elegans*), Gull-billed (*S. nilotica*) and Least Tern (*S. antillarum*), and Xantus´s Murrelet (*Synthliboramphus hypoleucus*) in a few colonies. It is essential to develop a network of institutions and researchers to do monitoring and research. Here, we provide an overview of seabird research and monitoring status and needs in northwestern México and conservation actions that are being done for the conservation of seabirds in this region.

Key words: conservation, islands, monitoring, northwestern México, research needs, seabirds.

Introduction

Seabird conservation is mostly a matter of island conservation (D. W. Anderson, pers. comm.). About 4 percent of the marine area and almost all the islands in northwestern México, including those holding major seabird colonies, are federally protected under different categories of natural protected areas, such as Biosphere Reserve, National Park, and Area for Protection of Flora and Fauna. In addition, there is a proposal to protect the Pacific islands off Baja California (B. Tershy, pers. comm.).

Management plans to these areas involve scientific research and monitoring as the key instruments for the management of the whole protected area. Based on the concept of adaptive management, applied research and monitoring will be the base for the evaluation and permanent adaptation of management practices implemented in the reserve. Associated actions include the creation of databases linked to Geographical Information Systems. Hence, the importance of establishing research priorities applied to management and to start an inter-institutional, long-term seabird-monitoring program in different regions.

Seabird monitoring is the accumulation of time series data on any aspect of seabird distribution, abundance, demography, or behavior of seabirds (S. Hatch, pers. comm.). Its importance has been largely overlooked both by researchers and managers, and therefore, if funded, monitoring programs are usually underfunded. Monitoring is important in determining the welfare of seabird populations that may be affected by human activities or use of marine resources. But equally important is the role of seabirds as indicators of environmental change. There is ample evidence that seabirds respond manifestly to oceanographic variations such as El Niño-Southern Oscillation and lesser oceanic and atmospheric events (e.g. Ainley et al. 1986; Sydeman et al. 2001), thus enhancing the relevance of seabird monitoring in an era when global change is a growing concern. In addition, fishery managers are realizing that seabirds can serve as cost-effective samplers of fish stocks (e.g., Anderson et al. 1980; Cairns 1987, 1992; Sunada et al. 1981). In ecology, observational data obtained passively can be important for community experiments requiring great numbers of relevant simultaneous variables, often on a great scale, and long time periods to render the information more significant. Thus, seabird monitoring may be important for testing of various hypothesis

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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regarding environmental or human causes of population dynamics.

The objective of this paper is to review seabird research and monitoring needs in northwestern México (*fig. 1*). We emphasize the need for long-term breeding seabird monitoring programs in different regions or protected areas to provide management agencies the necessary information for better-informed decision-making.

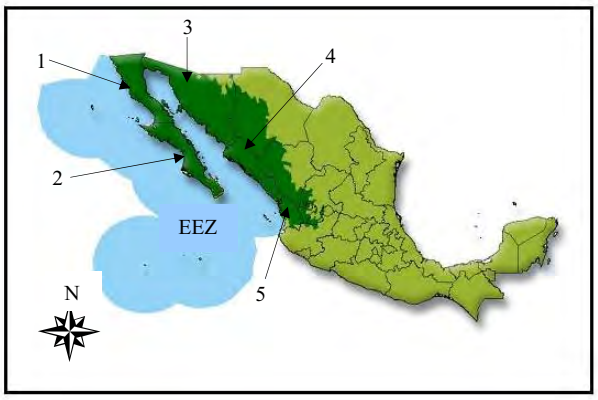

Figure 1— The region of northwestern México. It includes the peninsula of Baja California that comprises the states of Baja California (1) and Baja California Sur (2), the mainland states of Sonora (3), Sinaloa (4), and Nayarit (5), and the Economic Exclusive Zone (EEZ), including the Gulf of California and its associated islands.

Overview

The region of northwestern México includes the peninsula of Baja California, the states of Sonora, Sinaloa, and Nayarit, the Gulf of California, the Economic Exclusive Zone (200 nautical miles, expanded by Isla Guadalupe in the north and by Isla Clarión in the south), and its associated islands (*fig. 1*). This region comprises an important area for seabirds. Specific information on seabirds distribution and conservation needs in northwestern México has been published in three major summaries: Anderson (1983), Everett and Anderson (1991), and Velarde and Anderson (1994). As important, however, are also two books that cover the region: Wilbur (1987) and Howell and Webb (1995), as well as numerous recently published species accounts (e.g., Carter et al. 1995; Erickson and Howell 2001; Massey and Palacios 1994; Mellink 2001; Molina and Garrett 2001; Palacios and Mellink 1996, 2000; Pitman 1986; Rebón-Gallardo 2000, and others). The major ornithological journal on seabirds from the region has been *Western Birds* (Western Field Ornithologists).

Some particularly noteworthy remarks regarding the importance of the region to seabirds include the following examples: A large percentage of the world populations of Black (70 percent) and Least (90 percent) storm-petrels, Blue-footed Booby (40 percent), Heermann´s (90 to 95 percent) and Yellow-footed (100 percent) gulls, Elegant Tern (95 percent), and Craveri´s Murrelet (*S. craveri*) (90 percent) breed in the region. All these taxa, plus Black-vented Shearwater (*Puffinus opisthomelas*), and Xantus´s Murrelet are endemic or quasi-endemic to the region (Howell 2001). The region also hosts the world´s largest Brown Pelican and Brown Booby colonies (D. W. Anderson, 1983). At least 40 species of seabirds breed on the islands and coastal wetlands in northwestern México (Everett and Anderson 1991, Howell and Webb 1995).

Methods

In 1998, consigned by the Pacific Seabird Group, we initiated a survey and compilation of past and present effort to monitor Pacific seabirds in México. Through literature review and applying a questionnaire to key seabird researchers in the region we focused on past and present efforts to monitor Pacific seabirds — which species have been monitored, where, what parameters have been measured, and who has done the work? We plan to continue this survey in the future because updated on an annual or more frequent basis, this information will permit a continuing evaluation of where we have been in seabird monitoring, where we would like to go, and what we need to do to get there. Here, we considered a total of 70 seabird projects conducted since 1970 that included some sort of monitoring. In addition, we reviewed a list of more than 200 published and unpublished reports that include potential data on seabirds of northwestern México.

Results

Seabird colonies on islands in the Gulf of California and off western Baja California peninsula have been well documented but only for surface nesting species. Population abundance estimates for sub-surface nesting species such as storm petrels and murrelets are very few although recent projects (such as the U.S. Geological Survey [USGS] and Island Conservation and Ecology Group [ICEG] surveys, see below) are addressing this gap of knowledge. Monitoring in México is very modest and systematic seabird monitoring is limited to ten species in few colonies: Brown Pelicans, Double-crested Cormorants, Blue-footed and Brown boobies, Heermann´s Gull, Royal, and Elegant, Gull-billed and Least Tern, and Xantus Murrelet.

In the last 30 years, more than 100 researchers (77 Mexicans and 33 Americans) have been and/or are

conducting Pacific seabirds research in México. Based on the responses to the survey and on the literature documentation, 55 species of seabirds have been monitored in México, but the extent of the monitoring effort is still to be determined.

We reviewed 70 seabird projects conducted since 1970 and major surveys or research projects prior to this date. The periods of these monitoring efforts are not continuous but depend on funding, permits, weather, researchers, students' or technicians' availability. Only 13 of these projects were conducted for three or more years; the remaining were single visits to survey a given location, although other papers or people have additional observations for the same locations for other years. From this accumulation of data, a time-series can be built. Of the 13 projects lasting longer than two years, most (70 percent) have monitoring periods around 6 years or less; only three have run for more than 20 years. The temporal frequency of the projects has been mostly 2 or more times per year of study. The main parameters measured during these projects were population size, reproductive success and phenology, foraging studies, and disturbance monitoring. The main research techniques used to collect the information have been shore surveys, boat surveys, in-colony surveys, aerial surveys (photographic), observations outside of a colony, prey collection, and banding.

The most important concentrations of potential contributors to a database on the seabirds of northwestern México occur in California, USA (28), Baja California Sur (17), Baja California (15), and México City (15).

Current Seabird Monitoring Programs

To our knowledge, the ten major current seabird monitoring programs in the region are the following:

1. Since at least 1964, B. Villa-Ramírez and E. Velarde and students (Universidad Nacional Autónoma de México [UNAM]) have been and are currently protecting and monitoring breeding seabird populations on Isla Rasa, northern Gulf of California.

2. Since 1971, D. W. Anderson and students (University of California-Davis [UC-Davis]) and J. O. Keith (Western Environment and Ecology, Inc.) have been and are currently monitoring seabirds in the Midriff islands of the Gulf of California, and other islands in the Gulf of California and off western Baja California, especially California Brown Pelicans and cormorants.

3. Since 1977, F. Gress and D. W. Anderson (UC-Davis) have been and are currently, along with E. Palacios, monitoring California Brown Pelicans and cormorants in the northwestern Baja California islands.

4. Since at least 1980, H. Drummond and students (UNAM) have been and are currently investigating seabird behavior in Isla Isabel, Nayarit.

5. Since 1985, E. Palacios (Centro de Investigatión Científica y de Educación Superior de Ensenada [CICESE]) and E. Amador (Centro de Investigationes Biológicas del Noroeste [CIBNOR]) have been and are currently monitoring seabirds breeding in the Baja California coastal wetlands.

6. Between 1987 and 1999, F. Rebón-Gallardo and students (UNAM) monitored seabird populations on Islas Marietas, Nayarit.

7. Since 1991, E. Mellink and students (CICESE) have been and are currently monitoring breeding seabirds mostly in the northern Gulf of California and some other islands in the whole region, including Sinaloa.

8. Since 1994, B. Tershy, D. Croll, B. Keith, J.A. Sánchez, S. Wolf, and others (ICEG) have been monitoring seabirds and removing exotic mammals in 10 of the islands of the region. Additional removal projects are currently in progress and an island conservation database is available over the internet via the world wide web (http://islandconservation.org).

9. Since 1996 K. C. Molina and K. Garrett started monitoring Gull-billed Terns colonies and other waterbirds breeding in the Cerro Prieto geothermal ponds, Baja California.

10. Since at least 2000, H. Carter and others (USGS) have been and are currently studying Xantus Murrelet populations on islands off the west coast of Baja California, especially on Islas Los Coronados.

Discussion

Major changes in northwestern México seabird populations have occurred without being quantified. Some examples include the demise of the seabird colonies on Islas San Martin and Todos Santos (Palacios and Mellink 2000), the extinction of the Guadalupe Storm-petrel (*Oceanodroma macrodactyla*) from Isla Guadalupe (Jehl and Everett 1985), the recent colonization of Islas Guadalupe, Clarión and San Benedicto by the Laysan Albatross (*Diomedea immutabilis*) (Howell and Webb 1992). It is important to document the timing and location of declines and/or increases of seabird populations to better understand the underlying causes.

Although seabird research in northwestern México has increased during the last 20 years, many areas remain unexplored, and seabird-colony catalogs are badly needed for the region. In western North America, seabird colony

catalogues and monitoring programs exist for all of Alaska, Washington, Oregon, California, and Hawaii. The next logical step is México. Also, completion of a colony catalogue for western México will complete the series all the way to Central America.

The lack of baseline data makes it impossible to quantify changes in numbers in most seabird species over time. Numerical baseline data are sketchy because early ornithologists reported species' presence and breeding information but seldom numbers (Massey and Palacios 1994). We need to plan and promote seabird monitoring on an international basis and to strive for cooperation of seabird specialists throughout the region. Ideally, a few widespread species should be monitored throughout their ranges in the Pacific, which requires an internationally coordinated effort.

Monitoring needs that we consider high priority include an inventory of past and present monitoring effort in northwestern México (what species? where? what parameters have been measured, and so forth). Then, we can proceed to selection of species, locations, and parameters to be monitored.

Seabird monitoring is most effective when it incorporates planned comparisons. For example, paired observations on surface feeders and divers are often revealing (especially if we have temperature and turbidity to correlate with), as are studies targeting different trophic levels (piscivores vs. planktivores) or species with contrasting foraging areas (inshore vs. oceanic feeders in relationship with temperature and/or turbidity). Monitoring of seabird breeding parameters at colonies needs to be done with simultaneous independent measures of prey abundance.

Research and information needs that we consider of high priority for seabird conservation can be grouped into the following categories: populations and their dynamics, human impacts, ecological role in ecosystems, habitat ecology, and habitat planning. Most of these items were also identified as high priority in the Colonial Waterbird Conservation Plan.

Populations and their dynamics. This category should include a catalog and mapping of seabird colonies in the region as well as information on the population status of sensitive species (estimated current and past population sizes to establish recovery goals); the subspecific status of sensitive species; and the wintering ecology of seabirds (mortality factors, at-sea distribution, conservation problems in wintering grounds). This will allow us to estimate trends among breeding and nonbreeding populations (trend analyses) and evaluate the most urgent conservation needs.

Human Impacts include the effect of human disturbance on seabird colonies and direct effects of egging and by-catch in long-line and gill-nets.

Ecological role in ecosystems. These studies would include determining which species were most appropriate as bioindicators for which questions; and competition with human fisheries (pelagic and coastal fisheries, especially in coastal wetlands).

Habitat ecology research needs include: research on ocean regime shifts, warming, ENSO (El Niño Southern Oscillation), and so forth; changes in fish communities and influence on seabirds; seabird interaction with aquaculture facilities, including methods to minimize impact to birds; and the role of birds as predators.

Habitat planning at local/regional level: identification of essential roosting and nesting habitat required for sustaining seabird populations in a given region of conservation concern (scales from a natural protected area to the northwestern region of México).

Conservation problems and threats faced by seabirds in the region have been discussed elsewhere (see Anderson 1980, Anderson and Keith 1980, Anderson et al. 1989, Everett and Anderson 1991, Howell and Webb 1995, Jehl 1984, Velarde and Anderson 1993, and others), but briefly these include offshore pollution, commercial exploitation of prey on which seabirds feed, incidental take, human disturbance, habitat reduction, and introduced predators at colony sites.

Island and seabird conservation in the region is complex, and all developed conservation planning needs to consider the following aspects: (1) Local, state, and federal governments must ensure the protection of these ecosystems by enforcing the environmental law, using data from academia for informed decision-making, and supporting applied research to conservation such as monitoring of indicator species and fisheries resources; (2) conservation of natural habitat must continue being an important approach, but should be followed by completion and implementation of management plans; and (3) cooperative programs between Canadian, United States', and Mexican wildlife agencies should expand, but solutions to the problems must be site-specific and operational.

Acknowledgments

This work was partially supported by the USGS through the Pacific Seabird Group (thanks to Scott Hatch). Consejo Nacional de Ciencia y Tecnologia (CONACyT) (Repatriation Program) and CICESE in Baja California Sur provided support to E. P. while working on this paper.

Financial support for E. P. to attend the International Partners in Flight (PIF) Conference in Monterey, California in March 2002 was provided by PIF California through the Point Reyes Bird Observatory. We thank R. Rodríguez for insisting on the submission of this paper. Our collaboration with E. Amador-Silva, D. W. Anderson, F. Gress, J. O. Keith, and E. Mellink has taught us most of what we wrote here. To all of them, our deepest gratitude.

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Seabird Conservation Planning in the Pacific Region[1]

Kyra L. Mills[2], Maura Naughton[3], and Gregg Elliott[4]

Abstract

The North Pacific is a highly productive marine area, sustaining millions of resident and migratory marine birds. These birds are faced with a variety of threats, both on land, where they breed and roost, and at sea, where they forage for food. Several seabird conservation plans are currently underway in this region. The U. S. Fish and Wildlife Service (USFWS) Pacific Region Seabird Conservation Plan is a strategic planning effort (currently underway), to review seabird conservation efforts in the Pacific Region and identify USFWS priorities for management, monitoring, research, and outreach in California, Oregon, Washington, Hawaii, and the U.S. Pacific islands. The California Current System Marine Bird Adaptive Conservation Plan (CCS Plan) is a multi-species adaptive conservation plan for marine birds inhabiting the California Current System from southern British Columbia to Baja California. The focus of this plan is on-going scientific study, monitoring, data analysis, publication and outreach. For the British Columbia region, the Canadian Wildlife Service has developed an adaptive seabird conservation plan. Coordination between these three plans, within the context of the broader scale North American Waterbird Conservation Plan (NAWCP), is essential.

Key words: California Current System, conservation planning, Pacific Ocean, seabirds, tropical Pacific.

Introduction

Marine birds in the Pacific Region currently face many threats, both on land as well as at sea. This paper summarizes marine bird conservation planning in the Pacific Region, including plans that have been developed or that are under development, and their geographic and taxonomic scope. In addition, three general questions are addressed: 1) what are the best tools or mechanisms for implementing conservation priorities; 2) what are the best tools or mechanisms for measuring the success of the conservation actions; and 3) if reasonably unlimited resources were available for conservation, what would be the most important conservation activities that should be initiated?

Conservation Planning in North America

The North American Bird Conservation Initiative (NABCI) is a multinational independent partnership between individuals and institutions to conserve bird species and their habitats by enhancing communication and collaboration between nations and agencies (U. S. NABCI Committee 2000). Within NABCI's conservation program there are four elements: the North American Waterfowl Management Plan (NAWMP), the U.S. Shorebird Conservation Plan (USSCP), Partners in Flight (PIF), and the North American Waterbird Conservation Plan (NAWCP). The NAWMP, USSCP, and PIF have been developed and are in the implementation stage, whereas the NAWCP was the last to come onboard and is still in the development stage. The NAWCP includes all bird species that are not covered under any of the other plans, including seabirds, coastal waterbirds (gulls, terns, pelicans, and cormorants), wading birds (such as herons and egrets), and marshbirds (such as rails, coots, and gallinules). The geographic range of the NAWCP is Canada through Central America, the Caribbean, and the U. S. Pacific Islands (28 countries, 209 species). The NAWCP is important because it provides a continental framework for regional planning efforts; however, conservation ultimately happens at the local scale and therefore individual regional plans need to be developed. Currently, regional plans are in various stages of development; one such region is the Pacific.

Conservation Planning in the Pacific Region

Within the Pacific Region, there are three marine bird conservation plans underway (*fig. 1*).

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California**.

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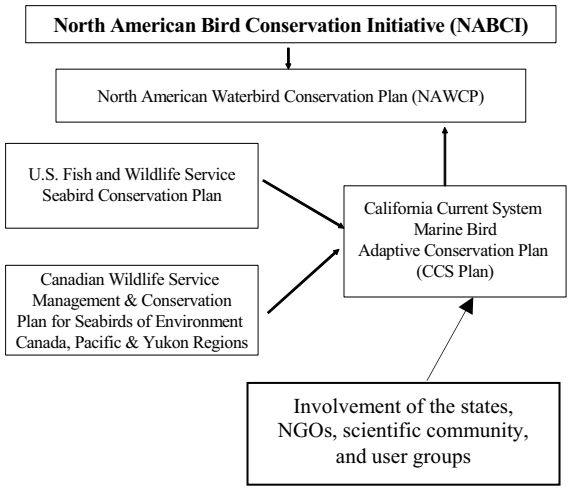

Figure 1— Marine bird conservation plan structure for the Pacific Coast Planning Region.

USFWS Pacific Region Seabird Conservation Plan

The USFWS is currently developing a seabird conservation plan (SCP) for Region One, the Pacific Region. This Region encompasses two of the most diverse seabird assemblages in the United States: the temperate species of the California Current System (Washington, Oregon, California) and the tropical seabirds that breed in Hawaii and the U.S. Pacific Islands. The plan will cover the coastal and marine populations of over 50 bird species, in the orders Procellariiformes, Pelecaniformes, and Charadriiformes. The goal is the long-term conservation of Pacific seabirds. The plan will include a review of seabird resources and habitats; a clear statement of issues and threats; and a summary of current monitoring, management, and needs. The plan objectives are 1) prioritization of bird species by conservation need; 2) identification of priorities for research, monitoring, management, and outreach; and 3) development of a comprehensive strategy to direct USFWS conservation activities and coordination with partners into the future. This plan will provide an overarching review and discussion of seabird conservation in the Pacific Region and outline priority actions needed to ensure the long-term health of these populations. This plan also will facilitate collaborative efforts between the USFWS and various local, national, and international partners in seabird conservation.

Management and Conservation Plan for Seabirds of Environment Canada, Pacific and Yukon Region

The Canadian Wildlife Service has developed an adaptive seabird conservation plan for the British Columbia region with an overarching goal of restoring seabird populations to historical numbers. To achieve this goal, priority actions include developing programs that address the threat of introduced predators to seabirds, seabird bycatch, and oil-spill preparedness. In addition, the protection of important seabird colonies and foraging areas also is considered a high priority (Hipfner et al. 2002).

California-Current Marine Bird Adaptive Conservation Plan (CCS Plan)

PRBO Conservation Science, USFWS, and numerous other national and international partners, in cooperation with scientists and marine managers, are developing a conservation plan for seabirds in the California Current Region. This plan will include coastal and marine regions from southern British Columbia (Canada) to Baja California (Mexico) and out to 200 nautical miles (the Exclusive Economic Zone boundary). The California Current is defined as a large marine ecosystem, which is a term that is used to describe habitats and areas with similar physical and biological processes. The CCS is a well-defined ecosystem, both ecologically and oceanographically, justifying a conservation plan from this ecosystem perspective. Also, many of the threats and management issues within the CCS are similar. The goal of the CCS Plan is long-term conservation of Pacific seabirds. The objectives are to identify marine bird requirements and threats and protect food sources and habitats. The CCS Plan is a multi-species plan, focused on the ecosystem in which these species live and the issues and threats that affect their reproduction and survival. This plan is adaptive in the sense that the planning is a dynamic and ongoing process that will provide an opportunity for updating and modifying portions of the plan as new information becomes available and new threats are identified.

Current Threats to Pacific Seabirds

Marine birds in the Pacific are faced with many threats, on land and at sea, and both natural as well as anthropogenic in nature. Natural threats include ecological factors that limit population growth, large-scale climate change, disease, parasites, and marine biotoxins. The most serious anthropogenic threats include loss or degradation of habitat, human disturbance, introduced species, oil and other marine pollution, contaminants, and fisheries interactions. Fisheries can impact seabirds both directly and indirectly. Direct effects include entanglement in gear or hooking, leading to injury and/or drowning; indirect effects may be caused by a reduction in seabird prey stocks, or by fisheries targeting adult/reproductive fish that might reduce the spawning population and cause a reduction in the juvenile fish that seabirds prey upon. Other indirect effects may include disturbance to seabirds at colonies, oil contamination from fishery vessels, and the introduction of debris into the marine environment.

Current Issues

In addition to management threats, substantial lack of information needs to be addressed in any marine bird conservation planning in the Pacific. For some seabirds, management is hampered by a lack of even the most basic life history information. Seabirds spend most of their life at sea, and it is from the sea that they derive their food. However, most of the research has been conducted at colonies. Information on seabird distribution, abundance, and behavior at-sea is fundamental to understanding seabird ecology and the formulation of scientifically sound solutions to conservation issues and threats.

It is crucial that conservation efforts include recommendations for studies that focus on poorly known species. Other seabirds are identified as species of high conservation priority based on an evaluation of abundance, distribution, population trends, and threats. Status assessments should be conducted for these species wherein existing data are analyzed, specific threats and limiting factors are identified and discussed, and actions to reverse negative population trends and restore healthy populations are listed and prioritized.

Management issues often arise when actions for seabirds are in conflict with management for other species—for example, management for Caspian Terns and endangered salmonids in the Columbia River estuary. Another example is a seabird species with a rapidly increasing population, such as the Double-crested Cormorant. These birds often are labeled 'overabundant' and in conflict with other resources. However, data often are inconclusive, and many times there is a perceived problem rather than an actual problem.

Plan Implementation

Implementation of any marine bird conservation plan will require actions that protect seabirds on land as well as at sea. On land there is the need to protect colonies and important roost sites from threats such as disturbance, 'predator spills' (the introduction of new predators to a sensitive area), and the introduction of non-native species (plants, animals, invertebrates, and so forth). There is also a need to restore lost or degraded habitats, for example by eradication of introduced mammalian predators from colonies. At sea, however, different management tools often are required. The ocean cannot be protected by unilateral or private action to purchase easements or fee title on key portions in the way that land can be protected. Nevertheless, Marine Protected Areas (MPAs) offer a similar solution by protecting key habitats that may provide foraging opportunities for seabirds or may protect prey stocks. One of the most effective tools for addressing threats that seabirds face in the oceans is through regulatory changes. There is a need for seabird biologists and managers to work closely with organizations and agencies that regulate fisheries such as the Pacific Fisheries Management Council, Oregon's Policy Advisory Council, and the various state Fish and Game agencies. This open communication is key to minimizing seabird bycatch and protecting forage reserves for seabirds. Joint Ventures have been used as successful plan implementation tools for other conservation efforts such as the NAWMP, PIF, and the USSCP. The formation of a Joint Venture has potential as an effective method of bringing together the various stakeholders for seabird conservation plan implementation.

Plan Success

A critical element for measuring the success of a conservation plan is a comprehensive seabird monitoring program (Steinkamp et al. 2003). It is essential that this program be able to detect trends in populations, which in turn will help determine whether the conservation actions are successful or need adjustment, thereby implementing the adaptive management approach. For this tool to be accurate and useful, the monitoring system needs to be standardized and sensitive enough to detect declining population trends in a relatively short period of time. The standardization of monitoring programs is crucial for comparing data sets and detecting trends. Collaboration and increased coordination among the many government agencies and private researchers collecting seabird data will also be required to ensure consistent long-term monitoring of key areas and populations. Given the importance of monitoring programs to measuring success of a conservation plan, dedicated funding needs to be secured for such long-term monitoring.

Key Conservation Activities

Identifying high priority conservation activities will be a key component in plan development and implementation. Several key conservation actions include the development and implementation of a standardized system for monitoring seabird population trends, as discussed above. Species diversity, high priority species, and threats to the habitat need to be evaluated, and the habitats and species with the highest conservation priority need to be identified. Conservation actions might involve the removal of invasive species from areas that have declining populations, such as the removal of rats from Anacapa Island (Channel Islands, California) to protect Xantus's Murrelets and Ashy Storm-Petrels, or the removal of *Verbesina* (a noxious

plant) from Midway Atoll (Hawaii) to restore habitat for nesting albatross. As outlined above, fisheries pose a serious threat to Pacific seabirds; therefore, research into gear types and fishing practices that minimize seabird bycatch in commercial fisheries is key. Fisheries observer programs are necessary to accurately monitor the scope and magnitude of seabird mortality in conjunction with commercial fisheries and evaluate the response when regulations are enacted to benefit seabirds.

Conclusion

Marine bird conservation planning in the Pacific Region is well underway. Despite the various planning efforts, the overall goal is the same: long-term conservation of Pacific seabirds. The CCS Plan, linking the various planning efforts, will ultimately form the NAWCP regional plan for the northern Pacific. Implementation and success of the Plan will require involvement and collaboration with regulatory authorities at the local, state, national, and international levels. With other conservation plans as models, the seabird conservation plan has a solid framework, which will ultimately benefit both migratory and resident Pacific seabirds.

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Conservation and Management for Fish-eating Birds and Endangered Salmon[1]

D. D. Roby[2], K. Collis[3], and D. E. Lyons[2]

A conflict involving piscivorous birds and salmonids in the Pacific Northwest pits the conservation of protected migratory waterbirds against the restoration of Columbia Basin salmonids (*Oncorhynchus* spp.) that are listed under the U.S. Endangered Species Act. The Columbia River Avian Predation Project is a cooperative, collaborative research project designed to monitor populations of piscivorous colonial waterbirds on the lower Columbia River and their impact on the survival of juvenile salmonids from the Columbia River basin. The Project includes biologists from Oregon State University, Columbia River Inter-Tribal Fish Commission, U.S. Geological Survey, and RTR Consultants.

A breeding colony of Caspian Terns (*Sterna caspia*) first formed on Rice Island, an artificial dredge spoil island at river kilometer 34 in the Columbia River estuary, in 1986 (G. Dorsey, U.S. Army Corps of Engineers, pers. comm.). The colony grew to 8,000 pairs by the late 1990s (Roby et al. 2002), the largest known Caspian Tern colony in North America (Cuthbert and Wires 1999), and perhaps the world. Caspian Terns are the largest species of tern and they have nearly a cosmopolitan distribution, occurring on all continents except Antarctica (Cramp 1985, Cuthbert and Wires 1999). This one colony represented about 25 percent of North American numbers for this species, and ca. 10 percent of worldwide numbers (Cuthbert and Wires 1999, Wires and Cuthbert 2000)

The largest colony of Double-crested Cormorants (*Phalacrocorax auritus*) on the Pacific coast of North America is situated on East Sand Island at river kilometer 7 in the Columbia River estuary (Carter et al. 1995). This colony first formed in the late 1980s (R. Lowe, U.S. Fish and Wildlife Service, pers. comm.) and subsequently increased to around 8,600 pairs by 2002 (Collis et al. 2002, Anderson 2002). Other populations of Double-crested Cormorants have erupted recently in parts of the Great Lakes, the Midwest, and Deep South, and have become the subject of a nationwide proposal for a Public Depredation Order in an effort to reduce conflicts with aquaculture and fisheries (U.S. Fish and Wildlife Service 2001). Despite the increasing colony in the Columbia River estuary, the west coast subspecies (*P. a. albociliatus*) as a whole has not increased in the last two decades (Carter et al. 1995, Anderson 2002). In fact, it has declined in some portions of its range (Carter et al. 1995), and has not been linked to widespread economic losses or ecological change.

Both of these colonies of fish-eating birds first became established on their respective islands in the late 1980s and subsequently grew very rapidly to their unprecedented size within a decade. What led to the sudden expansion of these two species in the Columbia River estuary? The annual rate of increase in size of these two colonies during some years in the 1990s ($\lambda > 1.50$) far exceeded the maximum intrinsic rate of increase for these species, and could not have occurred without substantial immigration from source colonies. Four factors seem to have played a role in attracting Caspian Terns and Double-crested Cormorants to nest in the Columbia River estuary:

1. Declining forage fish resources along the coast due to poor ocean conditions associated with weak coastal up-welling during the positive Pacific Decadal Oscillation in the 1980s and 1990s (Emmett and Brodeur 2000).

2. A reliable food supply in the Columbia River estuary during the early part of the breeding season due to the production and release of 150-200 million juvenile salmonids (smolts) annually from hatcheries throughout the Columbia River basin (Collis et al. 2001).

3. Anthropogenic alterations to the estuary that provided suitable nesting habitat on islands (deposition of sandy dredge spoil for terns, construction of rock jetties for cormorants; USACE 2001)

4. Loss of nesting habitat at previous colony sites, especially along the outer coast of Washington, but also at interior sites due to drought (Collis et al. 1999, Anderson 2002).

Diet studies indicated that the Caspian Terns nesting on Rice Island fed primarily on juvenile salmonids, and diets consisted of 73- to 90-percent salmonid smolts

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[1] A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California**.

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during 1997-2000 (Roby et al. 2002). Bioenergetics modeling indicated that terns were consuming approximately 11 to 12 million smolts annually, or about 10 to 12 percent of all the young salmon that reached the estuary each year (CBR 2002). Young salmon were not as prevalent in the diet of Double-crested Cormorants nesting on East Sand Island (Collis et al. 2002), but cormorants still consumed about 4 - 6 million smolts annually, or roughly 4 to 6 percent of all young salmon that reached the estuary each year (D. E. Lyons, unpubl. data).

This might have passed as a predator nuisance issue for the salmon hatcheries because most of the juvenile salmonids consumed were of hatchery origin (Collis et al. 2001). However, most of the wild runs of salmon from the Columbia River Basin, which were also consumed by piscivorous waterbirds (Collis et al. 2001), are listed as threatened or endangered under the Endangered Species Act (ESA). Twelve of 20 evolutionarily significant units (ESUs) of salmon from the Columbia Basin are listed (NMFS 2002a), and some are so imperiled that they are predicted to go extinct within 10-20 years (NMFS 2002b). Recovery of passive integrated transponder (PIT) tags from young salmon on the Rice Island Caspian Tern and Double-crested Cormorant colonies indicated that threatened or endangered salmonids were taken by these birds in proportion to their availability (Collis et al. 2001).

While avian predators in the lower Columbia River were not the cause of the dramatic declines in Columbia Basin salmonids, National Marine Fisheries Service, which has management responsibility for anadromous fish and recovery responsibility for listed salmonids in the Columbia Basin, concluded that predation by Caspian Terns in the estuary hinders recovery of listed Columbia Basin salmonids (NMFS 2000c). The Interagency Caspian Tern Working Group was formed in 1998, with representation from the federal, state, and tribal agencies with management authority and responsibility for terns, salmon, and the lands they use. The magnitude of predation on juvenile salmonids by Rice Island terns led to an attempt by the Interagency Caspian Tern Working Group to relocate the colony to East Sand Island, 26 km closer to the ocean, where it was hoped terns would consume fewer salmonids. The Working Group devised a pilot study to test three relevant hypotheses:

1. The Rice Island tern colony can be relocated to East Sand Island using habitat manipulation at both sites and social attraction techniques at East Sand Island.

2. A relocated colony of Caspian Terns on East Sand Island would experience similar nesting success to that of the Rice Island colony; the presence of the colony on Rice Island is not a reflection of unsuitable nesting conditions (i.e., too many nest predators or inadequate food supply) on East Sand Island.

3. A colony of Caspian Terns on East Sand Island will consume a greater diversity of forage fishes, including many marine species, and significantly fewer juvenile salmonids.

The Working Group restored tern nesting habitat on East Sand Island and used social attraction techniques (decoys and playback systems; see Kress 1983) and selective gull removal to attract terns to nest on East Sand Island (Roby et al. 2002). Concurrently, they erected silt fencing and plastic streamers on parts of the Rice Island colony site to help dissuade terns from nesting there (Roby et al. 2002). Within three breeding seasons the Rice Island tern colony had completely relocated to East Sand Island (*fig. 1a*); no destruction of tern eggs or young was involved. About 9,000 pairs of Caspian Terns nested on East Sand Island in 2001, the largest Caspian Tern colony ever recorded (Roby et. al 2002). Nesting success of Caspian Terns at the East Sand Island colony has been consistently higher than at Rice Island; in 2001 nearly 12,000 young Caspian Terns were raised at East Sand Island (Roby et al. 2002).

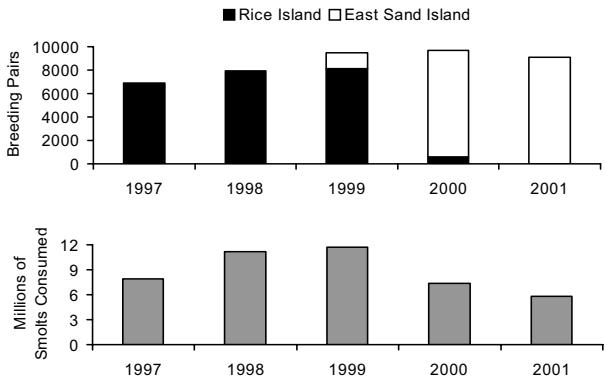

Figure 1— Size of Caspian Tern breeding colonies (number of breeding pairs) on two islands in the Columbia River estuary during 1997-2001 (a), and estimated numbers of juvenile salmonids (in millions of smolts) consumed by all Caspian Terns nesting in the Columbia River estuary during 1997-2001, based on bioenergetics models (b).

Caspian Tern diets shifted from primarily juvenile salmonids at Rice Island to mostly marine forage fishes, such as northern anchovy (*Engraulis mordax*), surfperches (Embiotocidae), Pacific herring (*Clupea pallasi*), Pacific sardine (*Sardinops sagax*), and smelts (Osmeridae), at East Sand Island (Roby et al. 2002). The estimated 5.9 million salmonid smolts consumed by terns in 2001 represented a 50 percent reduction in salmonid smolt mortality due to tern predation compared to 1999 (*fig. 1b*; CBR 2002). To achieve further

reductions in consumption of ESA-listed juvenile salmonids by Caspian Terns in the Columbia River estuary, it may be necessary to relocate a portion of the East Sand Island colony to alternative sites.

In addition to being the largest Caspian Tern colony in the world, the East Sand Island colony is currently the only documented Caspian Tern colony on the outer coast of the Pacific Northwest (*fig. 2*). (A small colony consisting of 100 to 300 pairs was found on the roof of a warehouse in the Port of Tacoma, south Puget Sound in June 2002, but the terns will not be permitted to nest there again in 2003 [M. Tirhi, Washington Department of Fish and Wildlife, pers. comm.].) The colony on East Sand Island represents about two-thirds of all breeding adults in the Pacific coast population of the species (*fig. 2*; Cuthbert and Wires 1999, Wires and Cuthbert 2000). The large concentration of breeding pairs at one site is not typical for this species, and renders it more vulnerable to local catastrophes (e.g., storms, oil spills, disease outbreaks, and disturbance). Eight other locations along the coast of the Pacific Northwest were formerly used as colony sites by Caspian Terns but were abandoned due to island erosion, human development, or other factors (Collis et al. 1999). Restoration of tern colony sites outside the Columbia River estuary and along the coast of the Pacific Northwest has the potential to benefit both Columbia Basin salmonids and Pacific coast Caspian Terns.

The U.S. Fish and Wildlife Service is leading the effort to develop a long-term plan for Caspian Tern management and conservation on the west coast. This will include identifying potential colony restoration sites outside the Columbia River estuary. East Sand Island will presumably remain one of the larger Caspian Tern colonies on the west coast, but perhaps not the largest colony of this species in the world.

In addition to management of Caspian Tern breeding habitat, other activities have been undertaken in the region to reduce avian predation on juvenile salmonids. Passive measures (e.g., wires, excluders, etc.) have been used to dissuade birds at foraging locations such as mainstem hydroelectric dams (Jones et al. 1996) and pile dikes (USACE 2001), where juvenile salmonids may be particularly vulnerable to avian predators. Efforts to reduce avian predation have been only one part, however, of the region's larger struggle to find effective strategies for recovering salmon that have broad support from managers and disparate publics (Lichatowich 1999, NMFS 2000c).

Consensus on avian predation has not always been easy to reach, even among the federal, state, and tribal agencies that make up the Interagency Caspian Tern Working Group. Similarly, various publics and some of the press have attempted to portray the issue as a conflict between Caspian Terns and hydroelectric dams (e.g., Fialka 2000). Some have argued that destroying terns and their breeding colonies could mitigate for the impact of dams on salmonids. Others have advocated that all dams be breached before implementation of any management to reduce avian predation on Columbia Basin salmonids. Finding solutions to issues involving avian predators and ESA-listed prey will require sound peer-reviewed science, new interagency partnerships, innovative management approaches, and outreach to stakeholders.

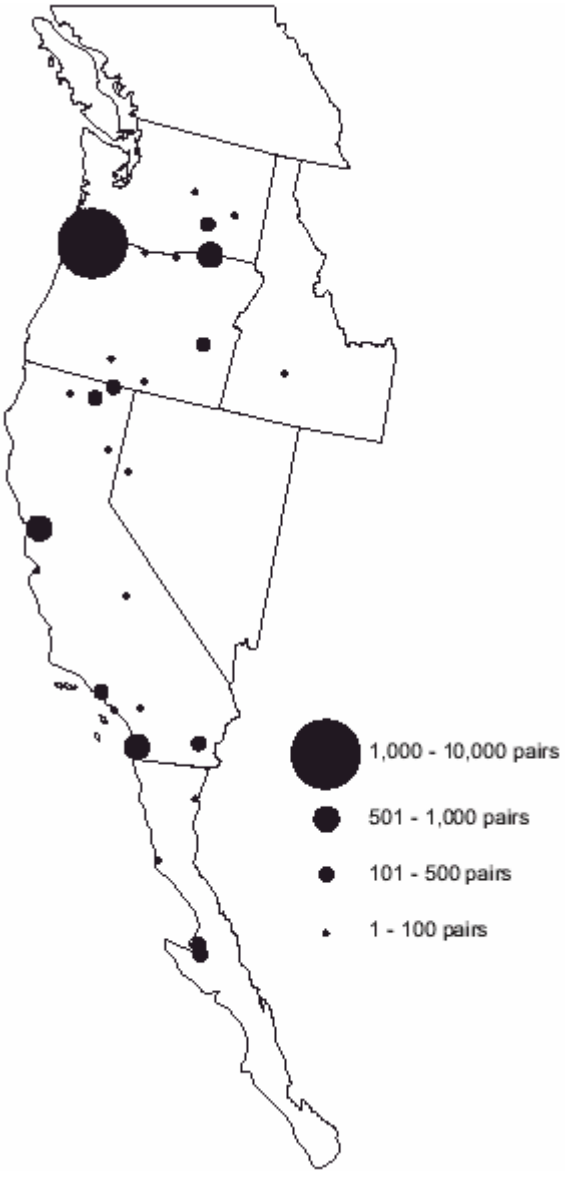

Figure 2— Distribution and size of known Caspian Tern breeding colonies for the Pacific coast population in North America as of the year 2000.

Acknowledgments

The following individuals provided invaluable assistance in the field: S. Adamany, J. Adkins, C. D. Anderson, S. K.

Anderson, M. Antolos, N. Bargmann, B. Begay, K. Brakensiek, E. Bridge, C. Cardoni, N. Chelgren, H. Christy, C. Couch, C. Cowan, D. M. Craig, D. P. Craig, B. Davis, G. Dorsey, C. Faustino, K. Fischer, K. Gorman, R. Kerney, P. J. Klavon, M. Layes, S. Lehmann, L. Leonard, T. Lewis, C. Lindsey, D. Lynch, S. McDougal, A. Meckstroth, D. Moskowitz, A. M. Myers, K. Redman, B. Robertson, D. Robinson, I. Rose, J. Rosier, L. Sheffield, N. Spang, C. Spiering, P. Spiering, R. Suryan, M. Thompson, R. Westra, M. Williams, J. Wolf, and S. Wright. We are grateful for the assistance of the following individuals: R. Anthony, R. Beach, R. Beaty, P. Bentley, B. Bergman, G. Bisbal, B. Bortner, C. Brown, C. Bruce, H. Blokpoel, J. Cyrus, F. Dobler, G. Dorsey, S. Duncan, M. Hawbecker, G. Henning, J. Henry, C. Henson, J. Hill, E. Holsberry, S. Kress, B. Lakey, D. Ledgerwood, N. Maine, D. Markle, K. Martinson, W. Maslen, R. Maziaka, B. Meyer, H. Michael, M. Morin, D. Mostajo, M. Naughton, H. Pollard, R. Ronald, T. Ruszkowski, B. Ryan, K. Salarzon, C. Schreck, S. Schubel, C. Schuler, N. Seto, T. Stahl, E. Stone, T. Tate-Hall, C. Thompson, L. Todd, K. Turco, D. Vandebergh, D. Ward, M. Weiss, D. Wesley, M. Wilhelm, R. Willis, and T. Zimmerman. This research project benefited enormously from the collaboration and cooperation of the Columbia River Inter-Tribal Fish Commission, U.S. Fish and Wildlife Service, U.S. Army Corps of Engineers, National Marine Fisheries Service, Oregon Department of Fish and Wildlife, Washington Department of Fish and Wildlife, and Idaho Department of Fish and Game. This project was funded by the Northwest Power Planning Council, the Bonneville Power Administration, and the U.S. Army Corps of Engineers. R. Altman, M. Naughton, and T. Rich provided helpful comments that improved an earlier draft of this paper.

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Breeding Double-Crested Cormorants and Wading Birds on Isla Alcatraz, Sonora, México[1]

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Introduction

Isla Alcatraz is a small volcanic island in the Eastern Midriff Island region of the Gulf of California, approximately 1.4 km from the fishing community of Bahía de Kino, Sonora, México. The island falls under the protection of the Gulf Island Reserve system for wildlife and migratory birds. Isla Alcatraz is home to one of the largest Double-crested Cormorant (*Phalacrocorax auritus albociliatus*) breeding colonies in western North America (Anderson et al. 1976; Carter et al. 1995). A survey in 1975 estimated a total of approximately 1,500 pairs of breeding Double-crested Cormorants on the island (Anderson in Carter et al. 1995). Except for this initial survey, virtually nothing is known about the Alcatraz population of cormorants. The island is also an important breeding area for Yellow-footed Gull (*Larus occidentalis*) and at least eight species of wading birds, including the threatened Reddish Egret (*Egretta rufescens*). There are over forty other species of birds that roost and forage on or near the island, including Blue-footed Booby (*Sula nebouxii*), Brown Pelican (*Pelecanus occidentalis*), and Peregrine Falcon (*Falco peregrinus*). A number of conservation issues presently and potentially affect the island, including human disturbance, organic and non-organic trash, and the introduction of exotic species. The close proximity of the island to Bahía de Kino increases the potential for human impact. It also, however, increases the potential for community involvement in research, education, and conservation.

For the last two years Prescott College has been monitoring the Double-crested Cormorant and wading bird colonies on the island. The following is a summary of the results of these projects to date.

Methods

The cormorant colony is located on the rocky slopes of the island, where peaks rise approximately 130 m above sea level. Nests are generally located on the ground among the rocks. We conducted our surveys over a two-year period, from October 2000 through April 2001 and from September 2001 to March 2002. During the first year, we conducted weekly surveys throughout the fall, while monthly surveys took place in the spring. During the second year, we conducted weekly surveys throughout the breeding season.

For ease in counting, we divided the colony into eight sections, two of which were surveyed by boat. A minimum of two observers conducted each survey and counted all active nests in each section. A nest was designated "active" if it had one or more birds standing or sitting on it. In each section, observers made independent counts, and then compared their numbers. Final numbers of section counts were averaged to come up with the total for each, and these numbers were summed to obtain a count of total numbers of active nests in the colony.

The wading bird colony is located along the base of the island's northeasterly slope. We divided the colony into four sections based on naturally occurring breaks in vegetation. We monitored the colony on 19 days between 15 February and 19 April 2001, observing the birds from a distance through binoculars and counting all individuals of each species present in each section of the colony. In order to minimize human disturbance, observations were made from a distance of at least 100 m.

Results

Figure 1 shows summary results of cormorant surveys in both years. During the first year, cormorants were already nesting by 2 October 2000, when we counted 353 active nests. The count increased steadily through mid-November and then jumped dramatically in late November. The count peaked on 2 January 2001 (1,225 active nests) and declined throughout the early spring. Between March and April the number of active nests dropped precipitously, plummeting from 496 pairs on 3 February 2001 to only 61 pairs on 7 April 2001.

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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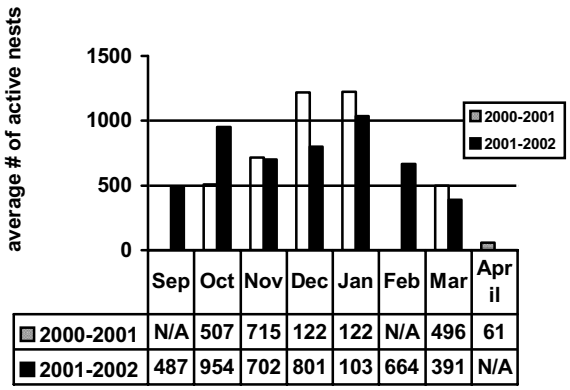
In the second year, we began the study on 12 September 2001, and counted 324 active nests. This number initially increased during September and October to a high count of 1,091, but toward the end of the month numbers decreased significantly to only 513 active nests on 7 November 2001. After this, numbers again increased, reaching a season maximum of 1,093 active nests on 29 November 2001. Numbers dipped again in December but remained relatively stable throughout January (average = 1,036 active nests) until February, when they again began to decline. In March 2002 we counted 391 active nests, indicating the breeding season was drawing to an end.



	Sep	Oct	Nov	Dec	Jan	Feb	Mar	April
2000-2001	N/A	507	715	122	122	N/A	496	61
2001-2002	487	954	702	801	103	664	391	N/A

Figure 1— Average Double-crested Cormorant counts by month, Isla Alcatraz, Bahia de Kino, Sonora. N/A indicates that no data were available for the given period

We observed eight species of wading birds nesting on Isla Alcatraz over a period of three and a half months: Yellow-crowned Night-Heron (*Nyctanassa violacea*), Black-crowned Night-Heron (*Nycticorax nycticorax*), Tricolored Heron (*Egretta tricolor*), Reddish Egret, Cattle Egret (*Bubulcus ibis*), Snowy Egret (*Egretta thula*), Great Blue Heron (*Ardea herodias*), and White Ibis (*Eudocimus albus*)(*table 1*).

Table 1— *Peak counts of nesting wading birds in 2000, Isla Alcatraz, Bahía de Kino, Sonora, México*

Species	Peak Count
Yellow-crowned Night-Heron	149
Black-crowned Night-Heron	34
Tricolored Heron	9
Reddish Egret	41
Cattle Egret	16
Snowy Egret	87
Great Blue Heron	23
White Ibis	26
Total:	385

Our maximum count was 385 individuals of all species. In addition to nesting on the island, we also observed five wading bird species foraging around the island (Yellow-crowned Night-Heron, Tricolored Heron, Reddish Egret, Snowy Egret, and Great Blue Heron).

Discussion

Although cormorant counts in the second year were conducted with a greater intensity than in year one, monthly average numbers of active nests were lower in the second year (*fig. 1*). Reasons for this are unclear, but may be weather related. During the fall and early spring, island vegetation is normally minimal, but heavy rainfall in late fall of 2001 produced increased plant growth, temporarily obscuring views of many nests located on the ground. When we compared average numbers of active nests over the length of the breeding season for both years, we found similar numbers (704 in year one versus 719 in year two). Based on data from these two years, the Alcatraz population appears to be relatively stable.

From 1973 to1991, an estimated 7,150 Double-crested Cormorants nested in the Mexican states of Sonora and Sinaloa, making up approximately 15 percent of the Pacific coast marine population of this species (Carter et al. 1995). Based on these population estimates, approximately 32 percent of the coastal nesting population of the cormorants in the Gulf of California nested on Isla Alcatraz during the 2000-2002 breeding seasons. This represents 5 percent of the overall Pacific coast marine population. Although little is known about the Alcatraz cormorant population in the years between Anderson's initial 1975 survey and this study, it is clear that the island's colony is extremely active and is a vital part of the cormorant population on the Pacific coast.

The unusually high diversity of the Isla Alcatraz breeding wading-bird population emphasizes the biological richness of the island. The island's Reddish Egret population is of particular interest to conservation, as this species is designated "threatened" on the Gulf of California islands. At the peak of the wading bird study, Reddish Egret was the third most abundant species in the colony. Further studies of the Alcatraz population will help conservation efforts for this species in other areas.

Many of the wading birds that nest on Isla Alcatraz appear to forage in the nearby estuaries of Santa Rosa and La Cruz, located on the mainland north and south of Isla Alcatraz, respectively. In addition to these two important areas, the island itself is also a foraging site for wading birds. Having this food source close to the

nesting grounds reduces time spent away from the nest and could decrease nest depredation.

Presently, the major threats to breeding cormorants and wading birds on Isla Alcatraz are human disturbance and exotic species introduction. Human disturbance of the island's shoreline and interior poses a threat to both the breeding and foraging grounds, and further study is needed to determine the impact of these intrusions. Repeated disturbance of the island may cause birds to abandon nesting efforts, or may lower nest success (Kushlan and Hafner 2001). Another potential threat is the introduction of predators such as rats or cats to Isla Alcatraz. At present, although we have documented house mouse (*Mus musculus*) on the island, no predators that could seriously threaten ground-nesting birds have been found. However, the frequent use of the island by people makes future introductions a very real possibility.

Conclusions

The cormorant and wading bird colonies on Isla Alcatraz highlight the biological importance of this small, near-shore island. To ensure the continued success of these colonies, local, state, and federal agencies and institutions must work together to create and implement management strategies for the island. Prescott College is working in collaboration with the Gulf Island Reserve, the community of Bahía de Kino, and other conservation organizations in the region to develop and implement a community-supported management plan for Isla Alcatraz. Involving community members in identifying threats to Isla Alcatraz and developing and implementing management strategies are vital parts in promoting community stewardship of and pride in the island and encouraging island visitors to take responsibility for their actions.

Acknowledgments

We thank G. Suárez-Gracida, B. Pfister, and C. Dodge for invaluable assistance in project design and implementation, and A. L. Figueroa and the Gulf Island Reserve for project support. We thank B. Pfister and T. Leukering for their helpful comments and suggestions for improving this manuscript. Special thanks to L. Meltzer, whose vision of the Isla Alcatraz Program and tireless efforts toward making it a reality made this study possible.

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Current Monitoring and Management of Tricolored Blackbirds[1]

Roy Churchwell,[2] Geoffrey R. Geupel,[2] William J. Hamilton III,[3] and Debra Schlafmann[4]

Abstract

Tricolored Blackbirds (*Agelaius tricolor*) are largely endemic to California. Over 90 percent of the population occurs within the state. Surveys indicate that populations have declined by 37 percent from 1994 to 1997 and by 33 percent from 1997 to 2000. Tricolors are listed as a nongame bird of conservation concern by U.S. Fish and Wildlife Service and a species of special concern by California Department of Fish and Game. Breeding tricolors are colonial, and form the largest colonies of any North American passerine bird. In the 1934 one colony was estimated to have 200,000 nests. Tricolors nest in freshwater wetlands, and upland spiny vegetation such as Himalayan Blackberry (*Rubus discolor*). They forage away from their nesting habitat. The severe population decline is likely a result of land conversion and heavy nest predation by herons, mammals, and corvids. PRBO Conservation Science and California Partners in Flight have initiated a web-based volunteer program to monitor Tricolored Blackbird breeding colonies. The information collected will be used to estimate tricolor abundance, and form management recommendations. An intensive state-wide census is recommended every three years to calculate population size. Lastly, the project will identify key colonies to manage and enhance. Further research and management recommendations for preserving and creating habitat, are still needed to control the precipitous decline of this species.

Introduction

Tricolored Blackbirds (*Agelaius tricolor*) are largely endemic to California, with 90 percent of the population occurring within the state (Beedy and Hamilton 1999). They are highly colonial and a breeding colony found in 1934 was estimated to have 200,000 nests (Neff 1937). Surveys indicate that populations declined by 37 percent between 1994 and 1997 and 33 percent between 1997 and 2000 (*fig. 1*; Hamilton 2000).

Recognizing a threat to the species, the California Department of Fish and Game (CDFG) put Tricolors on their state list of species of special concern in 1992 (CDFG 1992) and they remain on the most updated version (T. Gardali, pers. comm.). In 1995, the U.S. Fish and Wildlife Service (USFWS) listed them as a candidate for threatened status, and a nongame bird species of management concern (USFWS 1995). In 2001 PRBO Conservation Science and the USFWS under the auspices of Partners in Flight assumed responsibility of a volunteer monitoring program for Tricolored Blackbirds. With the help of volunteers, data were collected across the state, and compiled on a web-based data depository. This information will guide management recommendations that may reverse the decline in Tricolored Blackbird populations.

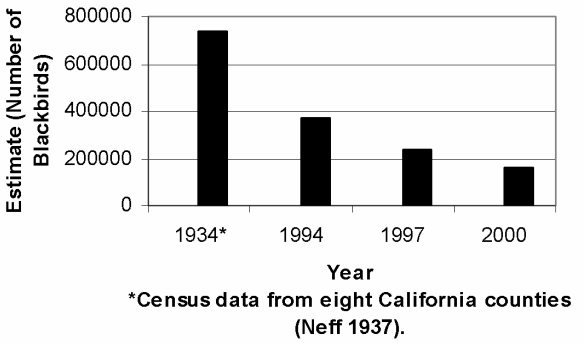

Figure 1— Population estimates of the Tricolored Blackbird population in California from pre-survey data and then three year time periods between 1994 and 2000.

Natural History

Tricolored Blackbirds have three habitat requirements for a successful nesting colony:

1) nearby open fresh water;

2) protected nesting habitat such as flooded marsh vegetation or thorny vegetation;

3) suitable feeding areas near the nesting colony such as rice fields, lightly grazed pasture, dairies, or alfalfa fields. Although the habitat has been greatly reduced, Tricolors still use grass-

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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land and riparian feeding areas (Beedy and Hamilton 1997).

Most Tricolors seem to have little site fidelity, and depending on water and food availability may move to a different colony to nest after completing their first nesting attempt (Hamilton 1998). Colonies may settle to nest as early as late March and additional nesting attempts start 10 days after nests are lost or successfully completed (Payne 1969). Nesting continues through June. The majority of the Tricolored Blackbird population appears to spend the winter in the San Joaquin River Delta and near the central California coast (*fig. 2*; Beedy and Hamilton 1999).

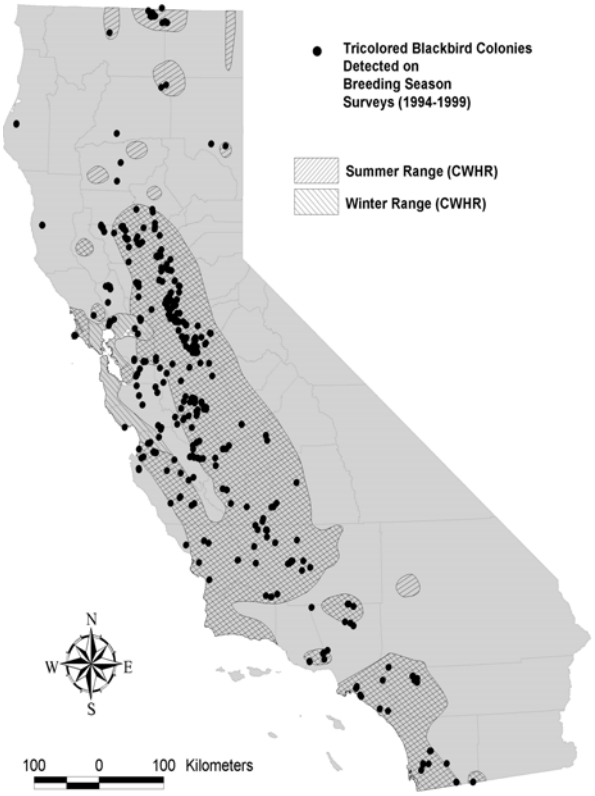


Figure 2– The summer and winter distribution of Tricolored Blackbirds in California.

Threats to the Population

Current threats to the population include:

1) Land conversion of both nesting and feeding areas to intensive agriculture and development;

2) Predation by Black-crowned Night-herons (*Nycticorax nycticorax*), coyotes (*Canis latrans*), raccoons (*Procyon lotor*), and ravens (*Corvus corax*), often causing nearly complete loss of nests at colonies;

3) Mowing of active nesting colonies in grain fields; and

4) Fluctuating water levels (Beedy and Hamilton 1997).

Current Monitoring

In 1993, California Department of Fish and Game, University of California Davis, and Audubon California started a monitoring program with the help of many volunteers. Surveys were done across the state over a period of a few days to avoid the double counting of birds. One of the authors (Hamilton) and Liz Cook also collected data on colony size, success, and population demographics (Hamilton 1993; Hamilton et al. 1995; Beedy and Hamilton 1997; Hamilton et al. 1999; Hamilton 2000). PRBO and the USFWS continued this survey in 2001 using a web based data entry form (see www.prbo.org/Trics.htm; *fig. 3*). This project attempted to collect data through the breeding season so volunteers could return to breeding areas to check the status of a colony. Colonies are often abandoned during the nesting period or used for later breeding attempts.

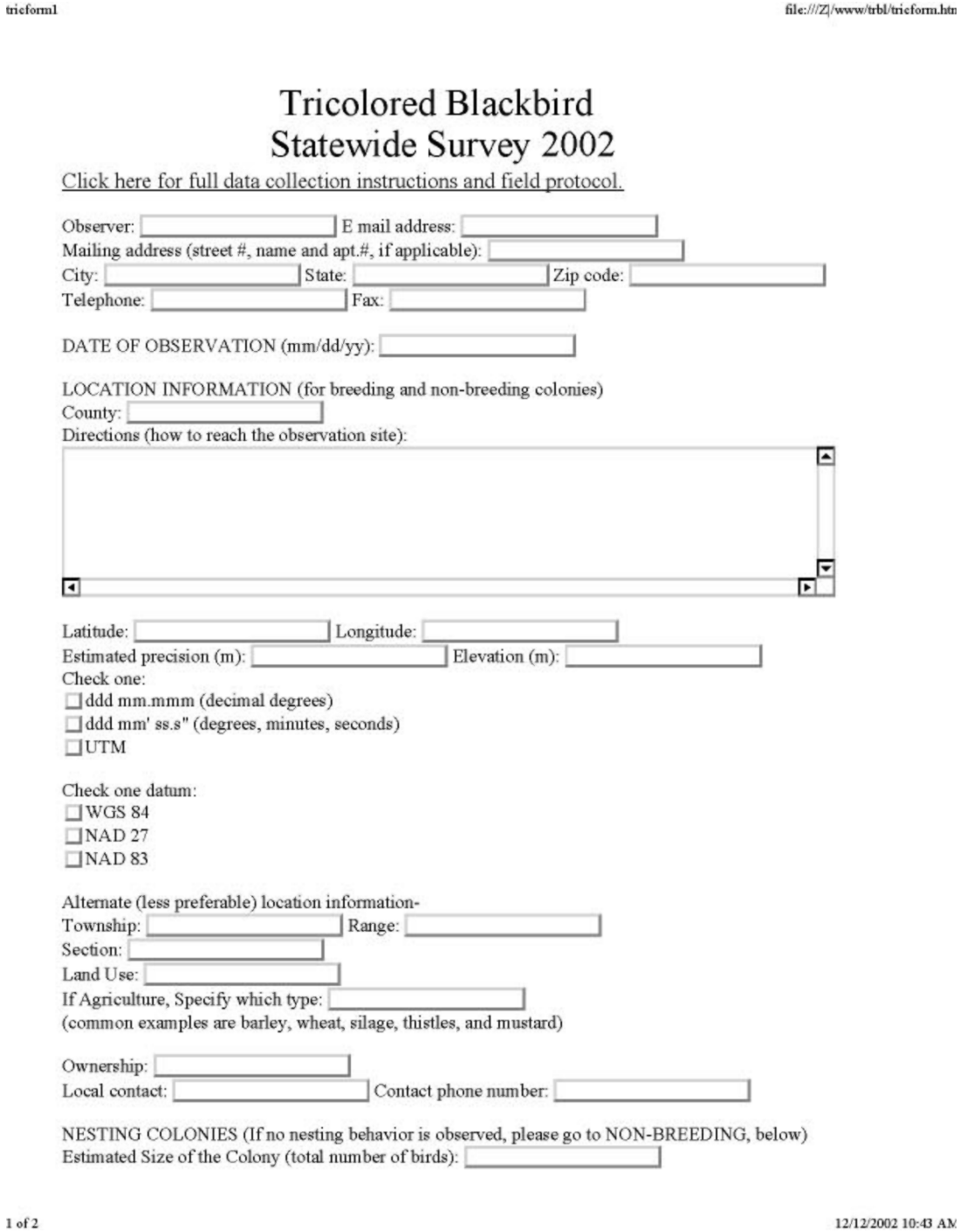
The objectives of the program were to:

1) Locate new Tricolored Blackbird colonies throughout the Tricolored range in California;

2) estimate the number of birds at key sites throughout the season while counting the entire population with an intensive census; and

3) determine the status of nesting colonies with repeated visits.

The intensive census effort is recommended to be conducted every three years (next scheduled for 2003) to compile a regular population estimate of Tricolor numbers and distribution. These data will be used to provide an estimate of Tricolor abundance at key areas and report on colony success, while identifying new colonies to manage and enhance.



tricform1 file:///Z|/www/trbl/tricform.htm

Tricolored Blackbird
Statewide Survey 2002

Click here for full data collection instructions and field protocol.

Observer: E mail address:
Mailing address (street #, name and apt.#, if applicable):
City: State: Zip code:
Telephone: Fax:

DATE OF OBSERVATION (mm/dd/yy):

LOCATION INFORMATION (for breeding and non-breeding colonies)
County:
Directions (how to reach the observation site):

Latitude: Longitude:
Estimated precision (m): Elevation (m):
Check one:
- ddd mm.mmm (decimal degrees)
- ddd mm' ss.s" (degrees, minutes, seconds)
- UTM

Check one datum:
- WGS 84
- NAD 27
- NAD 83

Alternate (less preferable) location information-
Township: Range:
Section:
Land Use:
If Agriculture, Specify which type:
(common examples are barley, wheat, silage, thistles, and mustard)

Ownership:
Local contact: Contact phone number:

NESTING COLONIES (If no nesting behavior is observed, please go to NON-BREEDING, below)
Estimated Size of the Colony (total number of birds):

1 of 2 12/12/2002 10:43 AM

Figure 3— Data entry forms on the PRBO Tricolored Blackbird volunteer survey website.

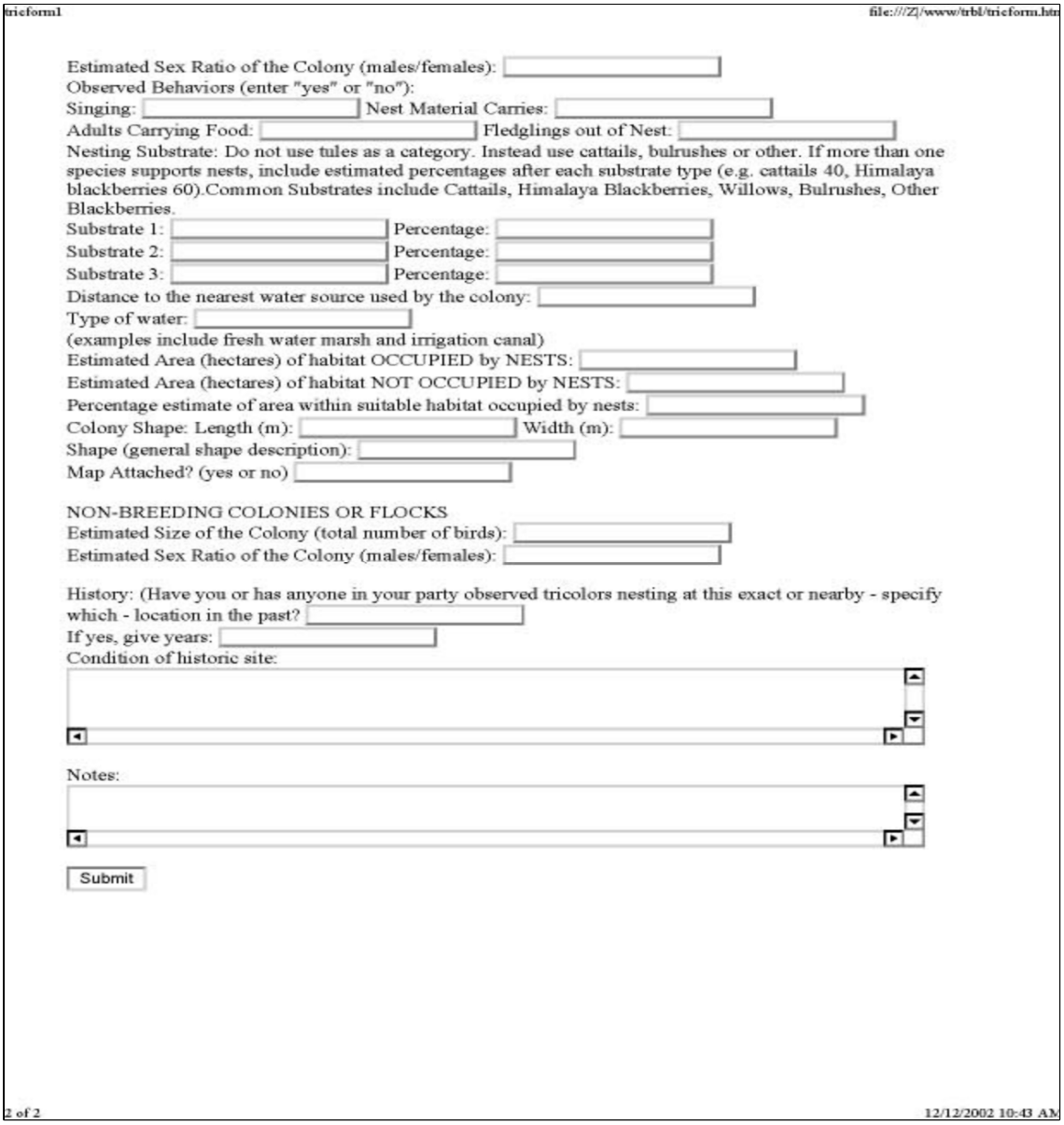


Figure 3– contd.

Table 1— *Top 10 Tricolor colonies in 2001 Tricolored Blackbird survey.*

Site	County	Ownership	Size 2002	Substrate
Merced NWR-E Farm Field 3 Unit	Merced	Public	30,000	Thistle/mustard
Ave 120 Colony 1	Tulare	Private	30,000	Silage
Ave 120 Colony 3	Tulare	Private	15,000	Silage
Fresno 1	Fresno	Private	10,000	Silage
Ave 120 Colony 2	Tulare	Private	8,000	Silage
Grey Hills Duck Club	Colusa	Private	8,000	Cattails
NE Unit 1 Kern NWR	Kern	Public	6,000	Cattails/bulrushes
DCAA Dairy	Kern	Private	6,000	Silage
Merced NWR-E Dowitcher Unit	Merced	Public	6,000	Mustard/thistles
Acre Farms	Colusa	Private	5,000	Cattails

Summary of 2001 Data

During the 2001 season 48 sites were visited. Of these, 31 were active with nesting birds. A total of 142,045 Tricolors were counted at nesting colonies and 4,031 nonbreeders were surveyed. The total number is not comparable to other years because this year was not a population estimate census year, but individual locations can be compared. Five of the largest 10 breeding colonies reported to us were in silage, and were in danger of being mowed before the end of the breeding season (See *Table 1*; Humple and Churchwell 2002). The outcome of many colonies is not known because follow-up visits were not completed.

The following improvements to the web based data entry system, initiated in 2002 are:

1) Standard site names. This could be done with an accurate web-based map.

2) Volunteers should continued to visit locations throughout the breeding season, and not only one time, as was the protocol in for past years.

3) Data should be submitted even if there are no birds seen. More personal contact with volunteers may help solve this problem in the future.

Future Research and Management

Management recommendations to mitigate threats to Tricolored Blackbirds include protecting historic colonies from land use conversion. Habitat should be managed to enhance the three habitat requirements necessary to establish nesting colonies identified above. Water management has improved for tricolors during the breeding season, and the continuation of programs such as the water bank Conservation Reserve Program (USFWS, pers. comm.), which encourages water storage until mid July, should be an objective for the future. Hamilton and Hosea both observed complete loss of Tricolor colonies after spraying for mosquitoes and weeds (Beedy and Hamilton 1997), but little research has been done. Also, more research is needed on the population demographics of Tricolored Blackbirds. One recommendation is an intensive color banding and productivity study at several representative sites across the range of the species to help us track birds and gather reproductive information on the species. Maintenance of populations depends upon habitat enhancement and protection. Since suitable nesting and foraging habitats have different characteristics, improvement of conditions for either may produce a successful colony.

Acknowledgments

We are very thankful to the many volunteer field biologists who have contributed hours of field work each season to monitor Tricolored Blackbird colonies, for without their help we would only have a minute portion of the data and knowledge that we now have. We would also like to thank T. Gardali and G. Ballard for their help with the preparation of this manuscript.

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The Oak Woodland Bird Conservation Plan: A Strategy for Protecting and Managing Oak Woodland Habitats and Associated Birds in California[1]

Steve Zack,[2] Mary K. Chase,[3] Geoffrey R. Geupel,[3] and Diana Stralberg[3]

Introduction

Over 330 species of birds, mammals, reptiles, and amphibians depend on oak woodlands in California (*fig. 1*) at some stage in their life cycle (Barrett 1980; Verner 1980; Block and Morrison 1998). These woodlands are able to sustain such abundant wildlife primarily because they produce acorns, a high quality and frequently copious food supply. The birds of California's oak woodlands are connected to this distinctive habitat mainly through acorns, the fruits of oaks that are eaten and stored by dozens of species. This ecological relationship is also reciprocal: species like Western Scrub-Jays (*Aphelocoma californica*), Steller's Jays (*Cyanocita stelleri*), and Yellow-billed Magpies (*Pica nuttalli*) do not completely retrieve cached acorns and thus act as dispersers of oak seedlings across the landscape. Large oak trees also provide cavities for cavity-dependent nesting birds and other wildlife, as well as caching sites for acorn woodpeckers, nuthatches, and other species. Additionally, Oaks commonly host mistletoe, the fruits of which are an important food for Western Bluebirds (*Sialia mexicana*), Phainopepla (*Phainopepla nitens*), and other species. The ties between oaks and birds are profound and diverse. Oaks also provide important shelter in the form of cavities for nesting. Moreover, oak woodlands are among the most highly prized of California's landscapes, for both aesthetic reasons and utilitarian needs such as firewood collection and grazing.

California's oak woodlands are threatened in many ways. Ongoing loss to development and agriculture (Bolsinger 1988, Thomas 1997), the lack of regeneration of several key tree species of oaks (White 1971; Griffin 1971, 1976), and the recent "Sudden Oak Death" (SOD) crisis (e.g., Svihra 1999 a,b,c; Standiford 2000) are the main threats to oak woodland habitat. Today, only two-thirds of California's original oak woodlands remain (approximately 7 million acres (Thomas 1997)). Of those, only about 4 percent enjoy protected status. Lack of recruitment of young oaks combined with the SOD epidemic affect seven of the ten acorn-bearing species of oak trees in California (*table 1*). The combined effect of these two problems on native wildlife populations is inestimable.

The Oak Woodland Bird Conservation Plan (BCP) (Zack et al., 2002; see also http://www.prbo.org/calpif/plans.html and printed copies (albeit without species' accounts) are available from PRBO) has been developed by California Partners in Flight to guide conservation policy and action on behalf of oak woodland habitats and wildlife, with the goal of supporting the long-term viability and recovery of both native bird populations and other native species. This BCP will serve as a repository for information, published or unpublished, on the ecology, distribution, and status of focal bird species, historic and current threats, landscape patterns, and conservation measures. This plan, along with the associated Geographic Information System (GIS) database of oak woodland habitats and monitoring data maintained at the Point Reyes Bird Observatory (PRBO), is the first iteration of a continuous process of updating habitat conservation recommendations based on the latest scientific monitoring and research data.

Designing conservation efforts for oak woodland habitats based on the needs of birds is useful because birds occupy a diverse range of niches within oak woodlands: from those that nest on the ground (e.g., Lark Sparrow [*Chondestes grammacus*]), to those that nest in the cavities of mature trees (e.g., Western Bluebird), to those that feed primarily on insects (e.g., Blue-gray Gnatcatcher [*Polioptila caerulea*]), and those that rely heavily on the acorn mast (e.g., of course, the Acorn Woodpecker [*Melanerpes formicivorus*], the Western Scrub-Jay, and the Oak Titmouse [*Baeolophus inornatus*]). Evidence and experience indicate that by managing for diversity of birds, diverse oak woodland habitat structure will be maintained and many other elements of terrestrial biodiversity will be conserved.

This BCP addresses the problems facing landbirds in oak woodland habitats throughout California and provides science-based recommendations to both public and private landowners. It outlines specific conserva-

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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tion action items, including detailed management, acquisition, and research recommendations, designed to heighten our understanding of how the threats and issues surrounding California's oak woodlands are and will affect the birds that are intimately connected to them.

At over 120 sites throughout California, monitoring data on oak woodland birds have been collected continuously over the past 10 years. This BCP places an emphasis on a suite of seven bird species (*table 2*) chosen because of their conservation interest to serve as focal species representative of the range of oak habitats in the state. Visit the web site (URL above) to view maps of oak woodland habitat coverage, focal species' ranges and PIF monitoring sites in California. Preliminary analyses of the seven focal species' habitat requirements reveal the following:

- Four of seven focal species have experienced significant population declines, local extirpations, or both. The only species that appears to be significantly and consistently increasing is the Western Scrub-Jay, a bird that adjusts readily to urbanization but is also an important nest predator of many other native bird species.

- Loss of habitat or habitat structure (such as dead standing trees, mature trees with cavities, or a change in the shrubby understory component) is implicated as a likely cause of decline and/or other problems for five of the seven focal species. For example, standing dead trees, or living large trees with dead limbs are an essential resource for Acorn Woodpeckers to cache acorn mast. The creation and defense of the stored mast is central to the biology of this species (Koenig and Mumme 1987). Fire suppression has likely led to an increase in the shrubby understory of many oak woodlands, and thus is likely a contributing cause of the decline of Lark Sparrows (Sauer et al. 2000).

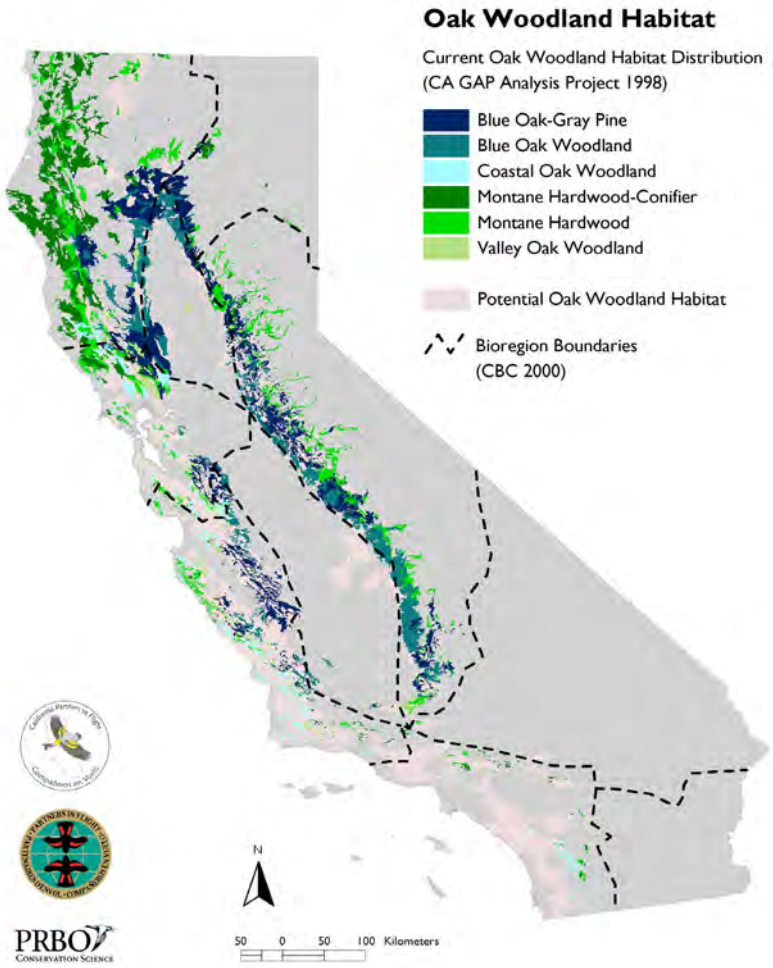

Figure 1—(from Figure 2-1 in Zack et al. 2002) Approximate current coverage of oak woodland habitats throughout California. Based on the California GAP Analysis Project, 1998 and potential coverage based on Kuchler 1976.

Table 1— *The Oak Trees (and Tanoak) of California and the presence/absence of conservation problems discussed in the text. From table 4-1 in Zack et al. 2002.*

Common name	Scientific name	Group[1]	General distribution in California[2]	Recruitment problems?[3]	Infected by SOD?[4]
Tanoak	*Lithocarpus densiflorus*	--	Coastal forests, spotty in Klamaths and Sierras		Yes
Black Oak	*Quercus kelloggii*	Red	Northern foothills	Occasional	Yes
Blue Oak	*Quercus douglasii*	White	Central Valley foothills, dry coastal	Yes	
Canyon Oak	*Quercus chrysolepis*	Interm.	Foothills throughout state		
Coast Live Oak	*Quercus agrifolia*	Red	Central, southern coastal forests	Yes	Yes
Engelmann Oak	*Quercus engelmannii*	White	Extreme southern, coastal CA		
Interior Live Oak	*Quercus wislizenii*	Red	More interior foothills		Yes
Island Oak	*Quercus tomentella*	Interm.	Channel, Guadelupe Islands	Yes	
Oregon Oak	*Quercus garryana*	White	N CA (coastal and Klamaths), spotty along Sierras		
Valley Oak	*Quercus lobata*	White	Central Valley, dry coastal	Yes	

[1]Taxonomic group (from Tucker (1980): Red oaks are those with pointed lobes and densely hairy inner shells of acorns, among other characteristics; White oaks have round lobes and smooth inner shells of acorns, among other characteristics; Intermediate oaks (Interm.) are just that with respect to characters.)

[2]The general distribution was described from range maps of *Lithocarpus* from Tappeiner et al. (1990), and of *Quercus* in Pavlik et al. (1991).

[3]If recruitment (regeneration) is problematic for oaks, as noted by studies from the literature, a "Yes" or "Occasional" is entered in the column.

[4]If oaks have been observed to have symptoms of the new Phytophthora infection ("Sudden Oak Death", SOD), a "Yes" is entered in the column.

Accordingly, a series of conservation recommendations are provided in the plan, focusing primarily on protection, restoration, and management of habitat that will facilitate and promote natural oak woodland regeneration. Key recommendations include prioritizing the protection of sites with intact oak regeneration, encouraging the replacement of weedy annual grasses with native perennial grasses to the oak woodland understory, restoring natural fire regimes to oak woodlands with the use of prescribed fire, and maintain and enhance natural vegetation corridors between oak woodlands and adjacent natural habitats. Other recommendations focus on the need to promote nest success by retaining mature oaks in altered landscapes to provide nest cavities and by keeping down the number of native and introduced nest predators. Species-specific conservation recommendations for the Western Bluebird, Blue-gray Gnatcatcher, and Acorn Woodpecker are also defined.

High priority conservation areas or "portfolio sites," distinguished by their protected status and potential for managing oak woodland habitat through restoration, are identified within the ten bioregions of California as defined by the California Biodiversity Council (CBC 2000). Through a process of adaptive conservation planning, conservation action items will continuously be derived from a synthesis of proven practices, species' distributions and ecologies, and land-use patterns. Information gaps revealed will guide future research and monitoring.

Acknowledgments

California Partners in Flight thanks the Packard Foundation for its financial support. The California Oak Foundation generously provided funds to print many copies of this plan for the numerous and diverse stakeholders of these issues. Thanks to those who wrote species' plans: M. Flannery, S. Guers, D. Humple (two accounts), C. Lee, C. Lu, M. Lynes, and M. Reynolds. The Wildlife Conservation Society and the Point Reyes Bird Observatory offered logistic support.

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Table 2— *Birds associated with oak woodlands in California, with information on their use of acorns, nesting substrate, general foraging habitat in oak woodlands, and whether the species is endemic to California. From table 3-1 in Zack et al. 2002.*

Species	1° or 2° species[1]	Consumes acorns?	Caches acorns?	Nest[2]	Foraging habitat in oak woodlands	California endemic?
Wood Duck	2°	Yes		2° Cavity	Wooded Streams	
Red-shouldered Hawk	2°			Platform	Woodlands	?
Wild Turkey (I)[3]	2°	Yes		Ground	Woodlands	
Band-tailed Pigeon	2°	Yes		Platform	Woodlands	
California Quail	2°	Yes		Ground	Woodland-shrub	
Northern Pygmy Owl	2°			2° Cavity	Woodlands	
Acorn Woodpecker	1°	Yes	Tree, many	1° Cavity	Woodlands	
Lewis Woodpecker	2°	Yes		1° Cavity	Woodlands	
Nuttall's Woodpecker	2°	Yes		1° Cavity	Woodlands	YES
Ash-throated Flycatcher	2°			2° Cavity	Open Woodlands	
Western Scrub-Jay	1°	Yes	Ground, many	Cup	Woodland-Scrub	
Yellow-billed Magpie	1°	Yes	Ground, few	Cup	Woodlands	YES
Oak Titmouse	1°	Yes	Tree, few	2° Cavity	Woodlands	YES
White-breasted Nuthatch	2°	Yes	Tree, few	2° Cavity	Woodlands	
Bewick's Wren	2°			2° Cavity	Woodland-Scrub	
Blue-gray Gnatcatcher	1°			Cup	Woodlands	
Western Bluebird	1°			2° Cavity	Open Woodlands	
California Thrasher	2°			Cup	Woodland-Scrub	YES
European Starling (I)	2°			2° Cavity	Agriculture edge	
Hutton's Vireo	2°			Cup	Woodlands	
California Towhee	2°			Cup	Woodland-Scrub	YES
Lark Sparrow	1°			Ground	Grass - Woodland	

[1]1° species are those for which we have full written accounts in this plan, 2° species are of similar concern, but with no written accounts to date.

[2]Cavity nesting species differ as to whether they excavate their own cavities (1° cavity nester) or they take over disused nests (2° cavity nester).

[3](I) denotes an introduced, nonnative species.

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The Intermountain West Region Waterbird Plan[1]

Gary Ivey[2]

The planning process for the Intermountain West Region component of the North American Waterbird Conservation Plan began in November 2001. This is one of several region-specific plans being developed as part of the Waterbird Conservation for the Americas initiative (Kushlan et al. 2002), as called for in the North American Waterbird Conservation Plan. The plan includes species not covered by the other three bird conservation initiatives (Partners in Flight, U. S. Shorebird Plan, and North American Waterfowl Management Plan). Waterbirds are defined here as wetland-associated species, including both colonial breeders (e.g., gulls, terns, most grebes, cormorants, herons, egrets, ibis and pelicans), and solitary nesting marsh-birds (e.g., cranes, rails, coots, bitterns and loons), but excluding waterfowl and shorebird species.

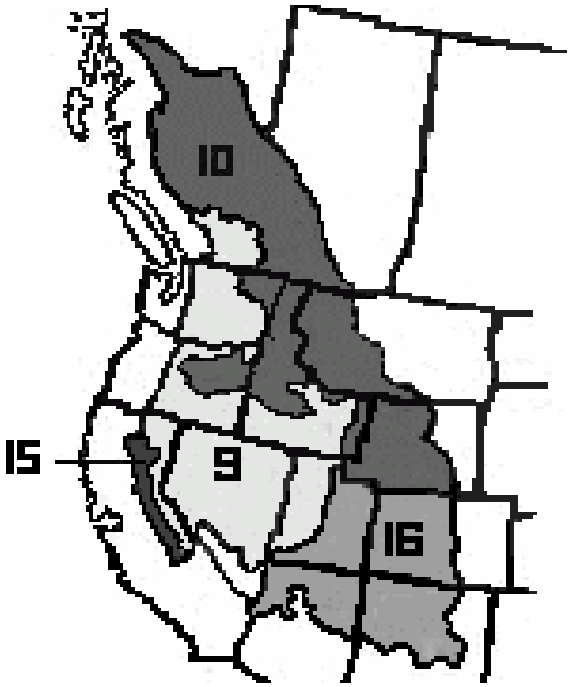

Figure 1— Bird Conservation Regions covered by the Intermountain West Region Waterbird Plan.

This plan addresses populations and habitats in Bird Conservation Regions (BCRs) 9, 10, 15, and 16 (U.S. NABCI Committee 2000) (*fig. 1*), focusing on conservation strategies for the U.S. portion of the region. The purpose of the Plan is to fill knowledge gaps and aid in "all-bird" conservation efforts of the Intermountain West Joint Venture (Intermountain West Joint Venture Management Board 1995), 11 States, and other entities associated with the geographic scope of the Plan. The content of this Plan will be integrated and linked to that of waterbird conservation plans developed for the Canada portions of the Intermountain West Region and for adjacent regions. It is intended that this plan be a working document, with focus towards on-the-ground implementation of projects.

The Intermountain West Region, as its name implies, is bounded by the Sierra Nevada and Cascade mountains on the west, and the Rocky Mountains on the east (*fig. 1*). It includes the extensive Great Basin, Columbia Basin, Colorado Plateau, and the Wyoming Basin. Characterized by diverse basin and range topography, the region provides a variety of habitats for waterbirds including high mountain lakes, rivers and streams, both fresh and brackish basin wetlands, and large terminal alkaline lakes. Due to the arid climate, a result of the rain shadow cast by the mountains to the west, Intermountain West wetlands serve as life-giving yet inconstant oases for aquatic birds.

The region's dispersed lakes, marshes and riparian zones host about 40 waterbird species, including many or most of world's Eared Grebes (*Podiceps nigricollis*) (Jehl 1994), American White Pelicans (*Pelecanus erythrorynchos*) (Evans and Knopf 1993), White-faced Ibises (*Plegadis chihi*) (Ivey et al. 2004), and California Gulls (*Larus californicus*) (Winkler 1996). Most waterbird species using this region must be highly adaptable to constant changing wetland conditions and rely on a landscape-scale association of wetlands.

The competing demands for human uses of water, such as agriculture, development, and recreation pose the greatest threat to waterbird populations here. The presence of contaminants (e.g., mercury, DDT and its breakdown products) is also a significant regional threat. Because of the West's feast-or-famine water regime, the Intermountain West regional plan will stress the necessity of conserving a network of high-quality wetland habitats with secure water sources in

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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order to provide options for waterbirds during drought and flood cycles.

Planning process

Focal Species

Focal species will be identified by our working group for each BCR starting with species priority rankings from Kushlan et al. (2002) and Area Importance scores developed by the Waterbird Conservation Plan Steering Committee. We will consider each species' population status within the planning region and revise their Area Importance scores. Other considerations for final rankings will include: Fish and Wildlife Service Migratory Bird Species of Concern, state species of concern, state Heritage Program ranks, Partners in Flight focal species lists from state Bird Conservation Plans and Physiographic Area Plans. We will also assess degree of threats to breeding and migrating waterbirds. We will develop population and habitat objectives for focal species, and perhaps in some cases, for guilds of species (e.g., emergent nesting habitat objectives for colonial nesting egrets and ibises). When possible, objectives will be quantitative, but in some cases may need to be qualitative.

Focal Habitats

Habitat priorities will be developed as we generate lists of Important Bird Areas (www.Audubon.org/bird/iba) for waterbirds by BCR. We will consider their importance to focal species, their value to multiple waterbird species, degree of threats, and opportunities for conservation projects. We have yet to deal with the issue of secretive waterbirds for which we have no population status or trend information. We will recommend monitoring and research to provide data for these species and set interim habitat objectives to assure no net loss of habitat for these species. We see a need to address both focal areas and best management practices to resolve threats to waterbirds in this region. For example, we need to maintain important habitats such as Mono Lake which supports high numbers of staging Eared Grebes, and also provide guidelines to land managers to protect nesting Common Loons (*Gavia immer*) on recreational lakes.

Measures of success

Success of the plan will be measured by habitat and species monitoring. The planning team will design a monitoring strategy for focal species and important habitats, and identify needed monitoring and/or research to develop trend and/or population data for species for which there are few or no data. We will work closely with the Intermountain West Joint Venture to incorporate waterbird habitat objectives and help develop a project monitoring and evaluation system for habitat projects.

Acknowledgments

Thanks to J. Wheeler who provided editorial comments on an earlier version of this paper.

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Bird Conservation Planning and Implementation in Canada's Intermountain Region[1]

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Introduction

Bird conservation planning in British Columbia and Yukon has been carried out by each of the major bird initiatives. The purpose of this paper is to provide a status report of planning activities and to discuss how integration of the initiatives is being accomplished for efficient and effective implementation of bird conservation actions.

Partners in Flight Landbird Conservation Planning

British Columbia and Yukon hold important habitats for migrating, breeding and wintering birds on the Pacific Flyway. Conservation planning in the region is achieved within an international framework that is the foundation for directing and prioritizing conservation efforts within ecologically defined Bird Conservation Regions. The Partners in Flight-British Columbia and Yukon (PIF BC/Yukon) planning strategy encompasses regional participation based on science. Bird Conservation Regions (BCRs) are the planning units within which practical management for landscape-oriented actions is developed.

Five BCRs lie within British Columbia: Northern Pacific Rainforest, Great Basin, Northern Rockies, Northern Interior Forest, and Boreal and Taiga Plains (U. S. NABCI Committee 2000). These regions correspond well with the ecoprovince units of British Columbia. Four of the BCRs cross international borders and one extends eastward to portions of four provinces and two territories.

Landbird species are prioritized within each BCR based on seven criteria recommended by Partners in Flight (Panjabi et al. 2001). After the initial pool of priority species is created through the PIF assessment process (Carter et al 2000), regional experts review and adjust the list.

Partners in Flight BC/Yukon uses the focal species approach (Lambeck 1997) to set measurable biological objectives and link priority species with specific conservation recommendations. It is a multi-species approach: the ecological requirements of a suite of focal species within each habitat type are used to define an "ideal landscape" to maintain the different processes and habitat attributes required by landbirds and many other taxa. Focal species are generally a subset of priority species, but not always. Each focal species is identified as being most vulnerable to or most limited by a specific habitat component, ecological process or landscape condition (e.g., snags, fire, or patch connectivity). The needs of focal species are used to develop an explicit set of population and habitat objectives regarding the composition, structure, quantity and distribution of habitat patches and other management regimes necessary to ensure healthy populations. They also are used to set subsequent guidelines.

The first priority region for Partners in Flight BC/ Yukon was the Great Basin BCR, where a collaborative effort by many agencies, conservation groups and individuals helped Partners in Flight BC/Yukon to develop Canada's Great Basin Bird Conservation Plan. Initially a group of priority species was selected by using a common database for the entire BCR, following the criteria explained above. Then, in a workshop attended by local experts, priority species for the Great Basin were selected and local threats were identified and scored. Under the "focal species" approach, it was possible to develop a matrix of habitat features and conditions for landbirds on a landscape scale.

The Bird Conservation Plan presents a list of priority species, a set of focal species that were used to define population and habitat objectives for each habitat, and outlines strategies to achieve those objectives. The main purpose is to guide research, monitoring, habitat acquisition, stewardship, education and communication activities within the BCR.

Waterfowl Conservation Planning

The Pacific and Yukon region of the Canadian Wildlife Service has produced a waterfowl management plan that provides an overview of conservation issues, preliminary population assessments, and recommendations for each of the five BCRs in the province. The Canadian Intermountain Region of British Columbia (Great Basin and Northern Rockies BCRs) is of critical importance to waterfowl

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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and supports most of the breeding waterfowl habitat in the province (over 130,000 wetlands or 60 percent of the provincial total) and most of the breeding waterfowl populations (~750,000 pairs or 68 percent of the provincial total). The region is also used by large numbers of molting waterfowl.

The plan identifies priority species based on population status, importance relative to continental populations, management concerns, importance of harvest and knowledge of population size, habitat needs and trends. Priority species for the Intermountain Region are Mallard (*Anas platyrhynchos*), American Wigeon (*A. americana*), Green-winged Teal (*A. crecca*), Ruddy Duck (*Oxyura jamaicensis*), Ring-necked Duck (*Aythya collaris*), Trumpeter Swan (*Cygnus buccinator*), and Canada Goose (*Branta canadensis*). Priority seaduck species include Harlequin Duck (*Histrionicus histrionicus*), White-winged Scoter (*Melanitta fusca*), Barrow's Goldeneye (*Bucephala islandica*), Bufflehead (*B. albeoloa*), Hooded Merganser (*Lophodytes cucullatus*), and Common Merganser (*Mergus merganser*).

Waterfowl conservation issues in the Canadian Intermountain Region center on the activities associated with forestry, ranching, crop-based agriculture and urbanization. Forests make up about 80 percent of the region and the wetlands located in forested areas are affected by timber harvest and management practices. Approximately 80 percent of all the rangeland in British Columbia is found in this region (80 percent of the provincial total). Rangeland is important for nesting waterfowl and grazing is often associated with depletion of vegetation in/around wetlands that reduce nesting and brood rearing cover. Agricultural lands are also important (37 percent of the provincial total) and they provide additional sources of food to breeding or migrating waterfowl. Adverse impacts from these activities include changes in hydrology, increased erosion, wetland destruction, nutrient loading changes and destruction of wildlife trees for cavity-nesting waterfowl.

Habitat objectives and priorities will be determined by tracking the relative value of different habitats types within each BCR in the province for each waterfowl species. The development of this habitat-species matrix will permit GIS queries and lead to the development of models quantifying the habitat needs of individual or groups of species. Plan success will be measured by monitoring population response to habitat programs and by tracking overall changes in habitat availability throughout the landscape. The feasibility of expanded seaduck surveys in the area will be assessed by the Sea Duck Joint Venture. The land management strategies to sustain the number of waterfowl observed in the 1970s are to be developed by the Canadian Intermountain Joint Venture described below.

Shorebird Conservation Planning

The Pacific and Yukon Regional Shorebird Conservation Plan is one of several shorebird conservation plans being developed nationally and internationally in an effort to better manage shorebird populations. The Canadian Shorebird Conservation Plan provides a strategy for national conservation action. Moreover, continental declines of several species are a concern yet the reasons for the declines are not well understood.

In Pacific and Yukon Region, there is no systematic survey for all shorebirds. However, surveys of the Western Sandpiper have shown that declines have occurred over the past 9 years. The region is of particular importance to shorebirds nationally, with 39 species occurring on an annual basis and 18 species occurring during the winter. Of these, Black Oystercatcher (*Haematopus bachmani*), Black Turnstone (*Arenaria melanocephala*), Surfbird (*Aphriza virgata*), Wandering Tattler (*Heteroscelus incanus*), and Western Sandpiper (*Calidris mauri*) are endemic to northwestern North America and dependent on availability of high quality breeding and wintering habitats. To successfully manage shorebird populations in the region, four major actions are proposed: a) secure habitats; b) implement stewardship programs; c) expand monitoring and research programs; and d) increase public awareness.

Implementation of All-Bird Conservation in the Canadian Intermountain and Across Borders

The Canadian Intermountain Joint Venture (CIJV) was established under the North American Bird Conservation Initiative (NABCI). The CIJV will be an important delivery mechanism for the bird plans described above, as well as providing regional-level implementation of the North American Waterfowl Management Plan, The Canadian Shorebird Plan, Partners in Flight: Framework for Landbird Conservation in Canada, and Wings Over Water: Canada's Conservation Program for Seabirds and Waterbirds. The CIJV is distinct from many other North American joint ventures in that it has focused on all-bird conservation from its inception.

The partnership of the CIJV includes federal and provincial government agencies, First Nations, non-governmental organizations, universities, as well as hydro, mining, ranching and forestry industry representatives. Through the CIJV, partner groups and agencies will seek to create and implement programs aimed at maintaining, enhancing and protecting habitat for all birds and other wildlife in the Canadian Intermountain. The boundaries of this area follow the Great Basin and Northern Rockies BCRs in Canada, from the crest of the Coast Mountains to the west, the eastern

crest of the Rocky Mountains, the southern extent of the boreal forest to the north, and the Canada-U.S. border to the south. However, every effort will be made to create linkages across the international border in order to conserve shared bird populations.

The CIJV takes a habitat-based approach to integrating bird conservation. Suites of focal species were used to define critical attributes and structure (e.g., type of snags, composition of shrub layer or emergent vegetation) within each habitat type. Focal species were defined as organisms that are most vulnerable or have the most stringent ecological needs in a given habitat, and may therefore collectively represent the needs of other species. Where sufficient data exists, quantitative population objectives were determined for focal species. In future, quantitative habitat objectives will also be developed to define overall habitat required (e.g., number of hectares of wetlands) to sustain populations. In addition, we will strive to quantify the fine scale critical features identified through focal species (e.g., number of snags required/hectare, density of shrub layer, density of emergent vegetation).

Best management practices for each habitat type will then be derived and offered to land managers. On a broader level, these objectives will be applied to form a mosaic of habitats and habitat conditions to support entire communities of birds and sustain ecosystem biodiversity across the working landscape of the Canadian Intermountain.

Program delivery will address the scarcity of water in the southern areas of the province and impacts from logging, farming, ranching, hydro-electrical operations, urbanization and industrial development on priority habitat availability and quality (including hydrology and water quality, maintenance of critical habitat structures, connectivity and so forth).

The following strategies will be used to meet the objectives:

- Stewardship and extension within and among resource sectors
- Securement of high priority habitat areas through purchase, lease, donation, easement/ covenant, land transfer, or legislation
- Site-specific restoration, enhancement and management of habitats to improve carrying capacity for birds
- Influencing legislation, policy, habitat protection and planning
- Education and outreach

Evaluation of program activities is critical for assessment of success and for adaptive management of birds and their habitats. Population surveys coupled with monitoring changes in habitat, will take place at the site level to evaluate individual projects, at the joint venture level to evaluate program success and at the transboundary BCR level to evaluate the health of bird populations at an ecosystem scale.

Several mechanisms and programs exist to facilitate cross-boundary conservation, sharing of science and ideas, and collaboration on research and monitoring. Examples include: further development of biological objectives for waterfowl through collaboration with U.S. and Canadian governments, Ducks Unlimited Canada and the Pacific Flyway Technical Committee; conservation, research and monitoring of shorebirds through the Pacific Flyway Council, the Western Hemisphere Shorebird Reserve Network and the Program for Regional Integrated Shorebird Monitoring; collaboration with the Intermountain West Joint Venture; Northern Rockies and Great Basin BCR coordinators; and the international bird committees representing waterfowl, shorebirds, waterbirds and landbirds under the North American Bird Conservation Initiative.

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Waterbird Conservation Planning in the Northern Prairie and Parkland Region: Integration across Borders and with Other Bird Conservation Initiatives[1]

Neal D. Niemuth,[2] Gerard W. Beyersbergen,[3] and Michael R. Norton[3]

Abstract

The Northern Prairie and Parkland Region contain millions of wetland basins, which harbor large proportions of the populations of many North American waterbird species, several of which are of high conservation concern. However, knowledge of waterbirds in the region is limited, and there has been little direction for waterbird conservation planning or management. The Northern Prairie and Parkland Waterbird Conservation Plan is being developed to provide an overview of the status and current knowledge of waterbirds in the Region and outline strategies and priorities for monitoring, management, and research. This plan is being developed by Canadian and United States partners under the auspices of the North American Waterbird Conservation Plan and takes a landscape approach to help integrate conservation planning for waterbirds with conservation planning for other species. A working group involving federal, provincial, and state agencies of two countries in conjunction with non-governmental organizations is focusing on plan development with biological rather than political borders. The plan is supported by the Prairie Habitat and Prairie Pothole joint ventures, which largely will coordinate implementation of the plan.

Key words: conservation planning, marshbird, Prairie Pothole Region, waterbird, wetland.

Introduction

Waterbirds, including both colonial and noncolonial species, are an important ecological component of the Northern Prairie and Parkland Region (hereafter Region), which encompasses the Prairie Pothole Region of the United States and the Grassland, Aspen Parkland, and Boreal Transition natural regions of the Canadian prairie provinces. The Region is roughly similar to Bird Conservation Region 11 (U.S. NABCI Committee 2000), with the addition of the Peace Parkland region in east-central British Columbia and northwestern Alberta (part of BCR 6) and other minor differences (*fig. 1*). The Region is characterized by millions of wetland basins and harbors large proportions of the continental ranges and breeding populations of many waterbird species including Pied-billed Grebe, Eared Grebe, American White Pelican, American Bittern, Sora, American Coot, Black Tern, California Gull, and Franklin's Gull (scientific names for all waterbird species in *table 1*). Several waterbirds that breed in the region are of concern because of declining populations or our limited knowledge of them, including Clark's Grebe, Least Bittern, Yellow Rail, Least Tern, and Black Tern. Given the high number of waterbird species and individuals present, the Region is critically important to continental waterbird conservation. However, knowledge of waterbirds in the Region is limited and there has been little direction for waterbird conservation planning or management.

Figure 1— Location of the Northern Prairie and Parkland Waterbird Conservation Region (dark shaded areas) and Bird Conservation Region 11 (black outline) in north-central North America.

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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Table 1— *Breeding status, distribution, and preliminary conservation assessment ratings of waterbird species included in the Northern Prairie and Parkland Region Waterbird Conservation Plan.*

Common name	Scientific name	Colonial or non-colonial	Breeding distribution	Conservation assessment
Common Loon	*Gavia immer*	N	Widespread	Low
Pied-billed Grebe	*Podilymbus podiceps*	N	Widespread	Low
Horned Grebe	*Podiceps auritus*	N/C[1]	Widespread	High
Red-necked Grebe	*Podiceps grisegena*	N/C	Widespread	Low
Eared Grebe	*Podiceps nigricollis*	C/N	Widespread	Moderate
Western Grebe	*Aechmophorus occidentalis*	C	Widespread	High
Clark's Grebe	*Aechmophorus clarkii*	C	Local	Low
American White Pelican	*Pelecanus erythrorhynchos*	C	Widespread	Moderate
Double-crested Cormorant	*Phalacrocorax auritus*	C	Widespread	Low[2]
American Bittern	*Botaurus lentiginosus*	N	Widespread	High
Least Bittern	*Ixobrychus exilis*	N/C	Widespread	Moderate
Great Blue Heron	*Ardea herodias*	C	Widespread	Moderate
Great Egret	*Ardea alba*	C	Peripheral	Low
Snowy Egret	*Egretta thula*	C	Peripheral	Low
Cattle Egret	*Bubulcus ibis*	C	Local	Low
Little Blue Heron	*Egretta caerulea*	C	Peripheral	Low
Tricolored Heron	*Egretta tricolor*	C	Peripheral	Low
Green Heron	*Butorides virescens*	N/C	Widespread	Low
Black-crowned Night-Heron	*Nycticorax nycticorax*	C	Widespread	Moderate
Yellow-crowned Night-Heron	*Nyctanassa violacea*	C	Peripheral	Low
White-faced Ibis	*Plegadis chihi*	C	Local	Low
Yellow Rail	*Coturnicops noveboracenis*	N	Widespread	High
Black Rail	*Laterallus jamaicensis*	N	Peripheral	Moderate
King Rail	*Rallus elegans*	N	Widespread	High
Virginia Rail	*Rallus limicola*	N	Widespread	Moderate
Sora	*Porzana carolina*	N	Widespread	Low[3]
Common Moorhen	*Gallinula chloropus*	N	Peripheral	Low[3]
American Coot	*Fulica americana*	N	Widespread	Low[3]
Sandhill Crane	*Grus canadensis*	N	Widespread	Low[3]
Whooping Crane[4]	*Grus americana*	N	-------	Listed
Franklin's Gull	*Larus pipixcan*	C	Widespread	High
Bonaparte's Gull	*Larus philadelphia*	C/N	Peripheral	Low
Ring-billed Gull	*Larus delawarensis*	C	Widespread	Low[2]
California Gull	*Larus californicus*	C	Widespread	Low[2]
Herring Gull	*Larus argentatus*	C	Peripheral	Low
Caspian Tern	*Sterna caspia*	C	Local	Moderate
Common Tern	*Sterna hirundo*	C	Widespread	Moderate
Forster's Tern	*Sterna forsteri*	C	Widespread	Low
Least Tern	*Sterna antillarum*	C/N	Local	Listed
Black Tern	*Chlidonias niger*	C	Widespread	High

[1]N/C: degree of coloniality varies; most typical behavior is listed first.
[2]May be of higher management concern due to problems associated with locally increasing populations.
[3]May be of higher management concern because of harvest in some locations.
[4]Does not breed in Region.

Goals of the Plan

The Northern Prairie and Parkland Waterbird Conservation Plan is being developed to provide an overview of the status and current knowledge of waterbirds in the Region and outline strategies and priorities for waterbird monitoring, management, and research. The Plan is being developed jointly by Canadian and United States partners under the auspices of the North American Waterbird Conservation Plan (Kushlan et al. 2002) to help integrate conservation of waterbirds with local and landscape-level conservation of other species.

A working group involving federal, provincial, and state agencies of two countries in conjunction with non-governmental organizations is focusing on plan development with biological rather than political borders. The overall goal of the working group is "To provide guidelines for conservation that, when implemented, result in maintaining and managing healthy populations, distributions, and habitats of waterbirds throughout the Northern Prairie and Parkland Region of North America." The plan is supported by the Prairie Habitat and Prairie Pothole joint ventures (PHJV and PPJV, respectively), which will coordinate implementation of conservation programs for the benefit of all target bird groups. This paper presents an overview of plan development and preliminary products.

The plan covers 39 breeding species (*table 1*) and the Whooping Crane, which migrates through the Region but breeds farther north. Because waterbird habitat in the Region is often widely dispersed in numerous small wetlands, the plan takes a landscape approach, rather than focusing solely on conservation of few, key sites. Waterbirds largely have been ignored in previous bird conservation efforts in the region, although some large waterbird colonies have been protected and sporadic, non-standardized surveys have taken place on a local level.

An excellent conservation base and partnership network exists in the Region with the PHJV and PPJV, both of which are committed to the conservation of non-game birds as well as waterfowl. For example, the second stated objective of the PPJV is to "Stabilize or increase populations of declining wetland/grassland-associated wildlife species in the Prairie Pothole Region, with special emphasis on non-waterfowl migratory birds."

Assessment of Species Status

Based on available data, we developed conservation assessments for waterbird species in the Region based on 1) population trend, 2) relative abundance, 3) threats to breeding populations, 4) threats to non-breeding populations, 5) geographic size of breeding distributions, and 6) geographic size non-breeding distributions (see Carter et al. 2000, Kushlan et al. 2002). The proportion of the continental breeding population found within the Region was included as a seventh factor to assess the importance of the region to each species. Assessment categories for this Region include Listed, for species that are federally listed as endangered in Canada and/or the U.S and already have significant conservation plans in place; High Concern; Moderate Concern; and Low Concern, which includes species considered not at risk. Preliminary scores (*table 1*) were reviewed and occasionally adjusted according to input from species experts and updated information. Species assessments in this plan are distinct from assessments reflecting policy of plan partner agencies (e.g., U.S. Fish and Wildlife Service 2002) or assessments developed for other plans (e.g., Kushlan et al. 2002).

Assessments were developed using biological criteria that reflect a species' vulnerability and do not necessarily reflect conservation or management priority, which may differ because of a species' harvest status or nuisance potential. For example, Sandhill Crane and Sora are relatively abundant and increasing in the region and are therefore considered to have low biological vulnerability (*table 1*); however, they are of high management interest as they are harvested in some areas. Similarly, Double-crested Cormorant, California Gull, and Ring-billed Gull are considered to have low biological vulnerability because they also are locally abundant and increasing within the Region, but may be of higher management interest due to the potential impact of cormorants on fisheries and concern about gull depredation of bird nests and fledglings, including those of the threatened and endangered Piping Plover (*Charadrius melodus*). Species assessed as being of High Concern are expected to be of high conservation priority.

Threats to waterbirds are being identified and prioritized in the plan. Some are direct, such as loss of wetlands from drainage or cultivation. Others are indirect, such as sedimentation and contamination of wetlands from land use on surrounding uplands. Habitat loss and degradation, primarily from agriculture, are the major threats to waterbirds in the Region, followed by lesser threats such as contaminants, predation, invasive species, and altered disturbance regimes.

Conservation Planning

Conservation planning will differ somewhat for colonial and non-colonial species. Discrete locations somewhat simplify monitoring and management of colonial species, which nest in aggregations of tens to tens of thousands of individuals. Most existing information on waterbirds in the region is limited to colonial species, but is not necessarily current or precise, and is typically limited to higher profile species. We are developing databases of colony locations and size for many species where colony location is known. However, locations of many colonies are unknown or not recorded, and locations of others have shifted recently due to changes in water level of some wetlands. Quality of colony location data differs among species, regions, and surveys. Even where colony locations are known, foraging range and the effects of landscapes surrounding colo-

nies must still be incorporated into conservation planning and management recommendations. The largest gap in our information base is for non-colonial species. Their dispersion and often cryptic nature complicate monitoring and management, and some of them make heavy use of temporary wetlands, which by definition are ephemeral and therefore difficult to incorporate into planning.

One tool for conservation planning for broadly distributed species is development of spatially explicit maps that predict landscape-level habitat suitability based on conceptual or empirical habitat models. For example, relative probability of detecting Black Tern in North Dakota has been modeled using geo-referenced Breeding Bird Survey stop data in conjunction with landcover and wetland information (*fig. 2*). However, good spatial models require accurate digital wetland and landcover data, the availability, timing, and quality of which vary within the region. In addition, so little is known about some marshbird species in the region that we are presently unable to accurately define the limits of their range, distribution within their range, population sizes, or breeding status. This complicates conservation planning, especially landscape-level habitat modeling, which requires large amounts of geo-referenced bird data. These issues are exemplified in our region by Yellow Rail (Bookhout 1995) and Black Rail (Eddleman et al. 1994); even intensive, focused survey efforts for these species can yield relatively few data (Prescott et al. 2002). In addition, monitoring of waterbird population trends is complicated by changes in wetland numbers. The Region is notorious for frequent drought and wet cycles, and numbers of many waterbird species in the region fluctuate markedly in response to changes in water availability, wetland condition, and vegetation (Niemuth and Solberg 2003).

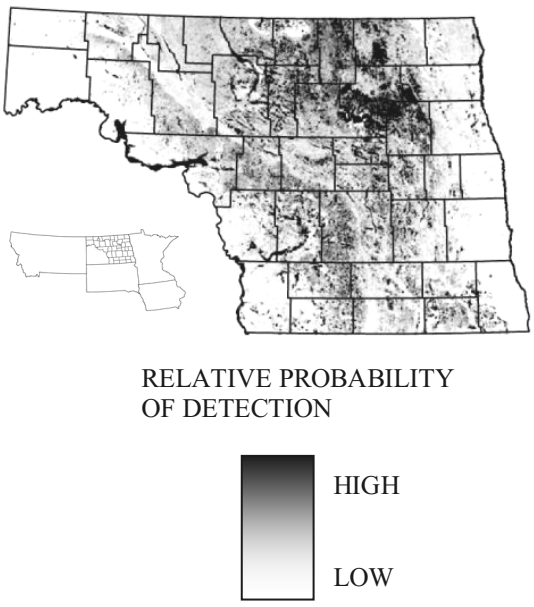

Figure 2— Relative probability of detecting Black Tern in North Dakota as predicted by landscape-level habitat model developed using geo-referenced Breeding Bird Survey stop data and digital landcover and wetland information (preliminary model, USFWS Region 6 HAPET Office, unpublished data).

Integration across Jurisdictions and Species

A key component of the plan will be integration of conservation planning. Integration has many components, one of which is integration across jurisdictions. State and provincial status listings were very similar for many rare species in the Region, and our planning promotes a common approach to conservation of these species. However, integrated waterbird planning across borders is not entirely new in the region. The U.S. Fish and Wildlife Service, Canadian Wildlife Service, and state and provincial governments already cooperate in planning and surveying for migratory bird species that are hunted. The PHJV in Canada and the PPJV in the United States are planning and implementing wetland conservation across landscapes for waterfowl and non-game species. Our planning will not supersede management plans in place for harvested species like Sandhill Crane (Central and Pacific Flyway Councils 1993) or endangered species like Least Tern (U.S. Fish and Wildlife Service 1990). The plan will provide a broader regional context for prioritization and planning of all waterbird species, with an emphasis on priority waterbird species in the region that are not covered by existing initiatives. Development of one waterbird plan under the PPJV and the PHJV will ensure international consistency, but joint ventures will need to tailor implementation according to different political realities in the United States and Canada. Similar habitats along with regional shifts in distribution and numbers emphasize the need for an integrated approach to conservation planning. But integrated conservation within the two joint ventures is only part of the story, as waterbirds breeding in the Region spend only a portion of their annual cycle there, and migration corridors, staging areas, and wintering grounds are also vital to their conservation. Continental planning efforts (e.g., Kushlan et al. 2002) must recognize and support conservation of linkages between different geographic regions.

Conservation planning in the Region will also be integrated with conservation plans for other species. One of the primary planning tools is the development of landscape-level habitat models. Spatially explicit maps predicting presence and density of waterbirds can be combined with maps predicting presence of other spe-

cies of interest such as waterfowl, shorebirds, and grassland birds (Niemuth et al. this volume). Preliminary analyses indicate considerable potential for waterbird conservation efforts to overlap with conservation efforts for waterfowl, shorebirds, and grassland birds in the region, but planning must also consider areas where there is little or no overlap to ensure that all species of conservation concern are adequately covered. Integration among bird conservation plans can be achieved in many ways, such as present efforts in Alberta to determine waterbird habitat relationships by combining waterbird surveys with wetland and habitat information from waterfowl surveys.[1] Even though conservation planning in the region focuses on a landscape approach and broad-scale relationships, local effects and management also must be considered, as fine-grained habitat selection in a given landscape can differ among species. For instance, wetlands with large amounts of emergent vegetation preferred by rails will be avoided by breeding shorebirds such as Marbled Godwit (*Limosa fedoa*), which prefer wetlands with little or no tall emergent vegetation.

Waterbird Conservation Planning in the Region

Much more information will be needed to bring waterbird planning to the level of waterfowl planning in the Region, and we are pursuing that information in an adaptive manner. We have identified numerous information gaps regarding waterbirds in the Northern Prairie and Pothole Region, and the plan will prioritize identified information needs. Accurate population data (waterbird distribution, numbers, and trends) is the top information need, but major gaps exist regarding habitat requirements and factors influencing survival and productivity. Dedicated waterbird surveys along with general and specific research are needed to answer these questions.

However, research is not needed to know that habitat preservation is key to conservation of waterbirds in the Region. Agriculture is the dominant land use and it can dramatically impact habitat quality even when habitat has not been completely converted. Many waterbirds use temporary and seasonal wetlands, and these wetlands have limited protection in both the United States and Canada, particularly during periods of low precipitation, when they are often cultivated. Use of surrounding uplands directly impacts wetland siltation, water quality, vegetation characteristics, and composition of wetland invertebrate communities. Conservation planning for waterbirds in the region must focus on habitat preservation while considering and incorporating use of surrounding uplands.

The Northern Prairie and Parkland Waterbird Conservation Plan will lay the framework for future actions such as monitoring, protection of key sites and landscapes, and identification of priority issues and actions. Many additional public and private partners, including agricultural interests, will be necessary to implement recommendations of the plan given the large amount of private ownership in the region and the landscape approach needed for waterbird conservation.

Acknowledgments

We thank the many people and agencies that have contributed to the development of the Northern Prairie and Parkland Waterbird Conservation Plan, particularly H. L. Dickson, M. E. Estey, K. Hannah, C. A. Lively, R. E. Reynolds, and J. Shaffer. We also thank S. D. Fellows, S. L. Jones, D. S. Klute, C. A. Lively, R. E. Reynolds, and T. D. Rich for helpful comments on an earlier draft of this paper.

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Missouri's Approach to Grassland Bird Conservation Planning[1]

Brad Jacobs[2]

Missouri's state and federal agencies, nongovernmental organizations and citizens have a partnership called the Grasslands Coalition. The Grasslands Coalition was established to help preserve remaining tallgrass prairie. This includes applying a management regime that enhances natural functions and interactions. The coalition is a state-based effort co-sponsored by the Missouri Prairie Foundation and the Missouri Department of Conservation. The long list of partners includes The Nature Conservancy, the Missouri Coalition for the Environment, Pheasants Forever, National Audubon Society, Missouri Native Plant Society, Quail Unlimited, many Missouri landowners, Ozark Regional Land Trust, Missouri Department of Natural Resources, Natural Resources Conservation Service, Prairies Forever, U.S. Fish and Wildlife Service and many more.

Greater Prairie-Chicken (*Tympanuchus cupido*) and Henslow's Sparrow (*Ammodramus henslowii*) top the list of bird species of concern for birds, but the coalition focus is broader and includes protecting and restoring prairie ecosystems at a landscape level. Other priority bird species of the Missouri grassland suite are Dickcissel (*Spiza Americana*), Grasshopper Sparrow (*Ammodramus savannarum*), Northern Bobwhite (*Cotinus virginianus*), Sedge Wren (*Cistothorus platensis*), Bobolink (*Dolichonyx oryzivorus*), Upland Sandpiper (*Bartramia longicauda*), Loggerhead Shrike (*Lanius ludovicianus*), Short-eared Owl (*Asio flammeus*), Northern Harrier (*Circus cyaneus*), and Eastern Meadowlark (*Sturnella Magna*) (Fitzgerald et al., 2000).

The Grassland Coalition partners selected nine Focus Areas (FA) and established partnership teams for each focus area. The target FAs were selected from thirty potential sites based on the areas' potential for immediate conservation action and grassland restoration opportunities. The nine FAs range in size from 4,230 to 18,952 ha. Through combining land cover and grassland bird suites in a GIS assessment, we determined where the highest potential was for effective management. In other word, focus areas are where prairie-chickens and other grassland birds occur in the state, as well as where the highest percentage of grassland is present in the landscape. The FA teams include agency staffs that have the capacity to effect landscape level changes through incentive programs with willing landowners, management on public lands, and restoration efforts funded by grants on both public and private lands. Partnerships, Focus Areas, targeted restoration efforts, and a capacity to conduct landscape level restoration by the partners have all been helpful in securing grant funds.

As part of an education program for agency staff, students, and the general public, the Grasslands Coalition organized a public event called the "Lek Trek." The event occurred over several months and involved 909 km of back roads hiking by many people who signed up to hike for one to several days. The trek route started on the Iowa and Arkansas borders and traveled from Focus Area to Focus Area during the months from July through October, eventually ending at one of Missouri's largest native prairies at Prairie State Park. Special events were organized at each Focus Area. Special "Learner Days" were arranged, and weekend Prairie Festivals, as well as school and community events occurred in nearby towns. An estimated 7,500 people participated.

We conducted both roadside and point count monitoring in the FAs to test the Partners in Flight Bird Conservation Area (BCA) concept (Fitzgerald and Pashley 2000.) The BCA concept includes an 800-ha core of continuous grassland surrounded by a 3200-ha matrix or buffer zone. There is an additional 800-ha of compatible grassland within the matrix with half in tracts 40-ha or larger. Forest cover should be less than one percent in the core and less than five percent in the matrix. BCAs were superimposed over the Focus Areas. A BCA paired area, not managed for bird habitats, and with similar vegetative composition and size, was circumscribed near each BCA.

We used 50-stop Breeding Bird Survey (Sauer et al. 2001) type roadside point counts placed at 0.8 k intervals on all the roads within the BCA and BCA paired areas. These surveys will give us a measure of relative abundances of all bird species in all habitats within the BCA. Over the 10-year study period these surveys will be used to interpret population trends in abundance.

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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We hope to be able to detect any major changes in bird abundances that differ between the managed BCA and the unmanaged BCA.

Other monitoring efforts are underway including point counts in six grassland habitat types to determine where the highest abundances of target species are present. Vegetation monitoring also is being conducted, as is land cover mapping in the bird monitoring areas to facilitate landscape-level analysis. Management within the BCA includes tree removal, shearing invasive woody vegetation off grassland areas, fescue conversion and native prairie restoration. Fire management, rotational grazing, and herbicide control of exotic and invasive species are also tools used in the project.

Partners in Flight has supplied much of the information needed to design the Grassland Coalition's bird monitoring project. Species prioritization, habitat prioritizations, the BCA model, physiographic plans, and effective partnerships already established at the national and regional level, all have been utilized in the project development phase.

As the Grasslands Coalition moves forward, another coalition has been forming called the Missouri Bird Conservation Initiative (MOBCI). It was initiated on 19 April 2001 as a state level implementation partnership and will take on the task of stepping-down the goals and objectives of the North American Bird Conservation Initiative (NABCI). Once the MOBCI is established then the implementation and project-centered efforts will be developed. The intent of this process is to bring along all partners as motivated, knowledgeable, trusting partners with a common mission, set of values, and focused vision.

Currently a steering committee has been established to review the MOBCI goals and objectives. The team is made up of five agency and five nongovernmental organization representatives, but may expand as new members join MOBCI. This group will be a forum for all bird conservation in Missouri.

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Delineating Focus Areas for Bird Conservation in the Central Hardwoods Bird Conservation Region[1]

Jane A. Fitzgerald[2], C. Diane True[3], David D. Diamond[3], Troy Ettel[4], Laurel Moore[5], Timothy A. Nigh[6], Shawchyi Vorisek[7], and Greg Wathen[4]

Abstract

This paper reports on a process used to identify landscape-scale focus areas for the conservation of priority grassland, grass-shrubland, wetland and forest-woodland birds in the Central Hardwoods Bird Conservation Region (CHBCR). The areas were delineated by biologists and other technical staff of partner agencies and organizations in the CHBCR with the use of geospatial data layers that included land cover, maps of areas with large percentages of grass and forest cover, public lands, roads, state and county lines, surface water features, ecological land types, and The Nature Conservancy's ecoregional plan's portfolio sites. There are other areas within the BCR that do or could provide high quality bird habitat. However, focus areas have the highest conservation, restoration and management potential at a landscape scale because they have (1) significant blocks of public lands that can provide a core for conservation efforts, (2) good potential for public-private partnerships, and/or (3) have been identified by The Nature Conservancy or state Natural Heritage Programs as areas with noteworthy levels of biodiversity. We believe the ability to concentrate relatively scant resources for conservation in discrete landscapes will accomplish greater habitat gains at scales relevant to bird populations than will more isolated efforts. The use of both current land use data and ecological classification systems also allowed us to target specific areas for specific suites of priority birds based upon a landscape's ecological and socio-economic potential.

Introduction

The Central Hardwoods (*fig. 1*) is one of 67 Bird Conservation Regions (BCRs) across North America identified by the four major bird initiatives and their conservation partners under the auspices of the North American Bird Conservation Initiative (U.S. NABCI Committee 2000). Support for the Central Hardwoods partnership to date has come from most of the overlapping state wildlife agencies, the U.S. Fish and Wildlife Service, the U.S. Forest Service, the National Wild Turkey Foundation, the Wildlife Management Institute, and American Bird Conservancy. The BCR's priority bird species and their general conservation needs are derived from Partners in Flight (Pashley et al. 2000), the United States Shorebird Conservation Plan (Brown et al. 2001), The North American Waterbird Conservation Plan (Kushlan et al. 2002), the North American Waterfowl Management Plan (North American Waterfowl Management Plan Draft Update 2003), and the Northern Bobwhite Conservation Initiative (Dimmick et al. 2002). However, spatially explicit focus areas, where conservation actions for the various species and species suites are likely to have the greatest potential for success, had not been identified prior to the establishment of the BCR partnership. To fill that gap, biologists, managers and other technical staff from various conservation agencies and organizations across the BCR met in a series of three workshops held during 2002 to identify relatively large landscapes most able to support viable populations of priority wetland, grassland, grass-shrub, and woodland-forest birds. This paper reports on the process and geospatial tools used to delineate those areas.

Background and Conservation Issues

The Central Hardwoods BCR (*fig. 1*) straddles the Mississippi River between Illinois and Missouri; the region to the west is also known as the Ozarks or Interior Highlands, and the region to the east, the Interior Low Plateaus. The BCR occupies a transition zone between what historically were tallgrass prairie, oak savanna, and woodlands to its north and west; pine forests and woodlands to the south; and oak and mixed mesophytic forests to the east. Components of each were interspersed throughout the BCR, with their juxtapositions dependent to a large degree on topography and soils. Glades and

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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barrens (grass-dominated ecosystems on shallow soils) also were prevalent historically.

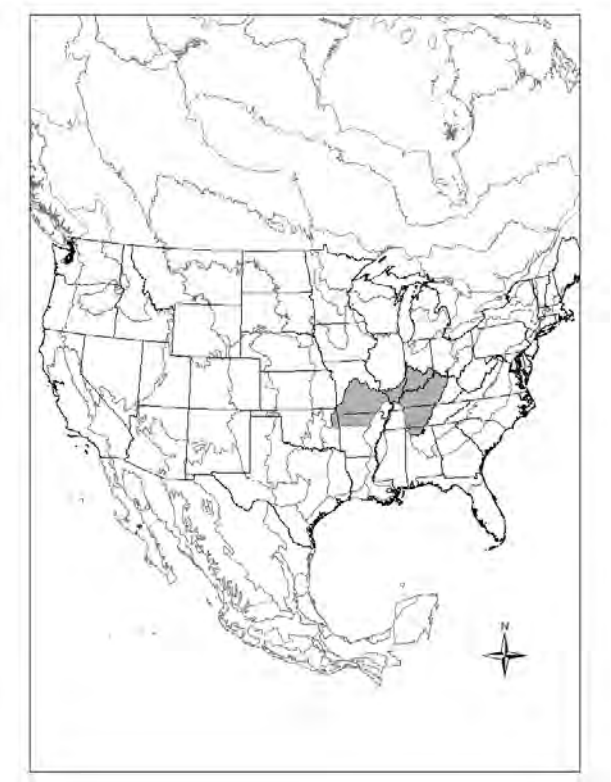

Figure 1—The Central Hardwoods Bird Conservation Region.

However, very little of the BCR's native prairie, with its more fertile and deeper soils, has escaped the plow. The glades, barrens, and extensive pine woodlands have largely converted to oak or oak-pine forests primarily as a result of fire suppression. Yet restoration of those ecosystems, which have been degraded but still persist over much of the region, is feasible. Restoration on public lands could help encourage private landowners in shared landscapes to undertake complementary efforts as well.

Bottomland forests and emergent wetland habitats in the Central Hardwoods largely were associated with the region's large rivers (e.g. the Missouri, Mississippi, Ohio, Tennessee, Cumberland) and their tributaries. All of those rivers are now impounded at least in some reaches, and much of the historical wetland habitat is submerged under large reservoirs or the floodplains drained and converted to agricultural uses. Restoration of wetland habitats has received the most attention where the BCR overlaps one of two Joint Ventures formed under the auspices of the North American Waterfowl Management Plan, and there is both opportunity and potential to do more. Wet meadows, a much more poorly understood and inadequately mapped wetland type, are in great need of attention.

The BCR's priority birds can be grouped into four suites of species based on general habitat affinities: grasslands, grass-shrublands, woodland-forests, and wetlands (see *Appendices 1-4* for a list of the BCR's highest priority bird species). Grassland birds such as Greater Prairie-Chicken (scientific names provided in *Appendices 1-4*), Henslow's Sparrow, and Grasshopper Sparrow typically require fairly large expanses of open grasslands with a minimum amount of woody vegetation before they are attracted to a given site and enjoy a level of reproductive success adequate to sustain local populations (see Fitzgerald and Pashley 2000, Fitzgerald et al. 2000a, Fitzgerald et al. 2000b). Species in the grassland suite were probably most abundant historically in the BCR's prairie and shrub-prairie dominated landscapes and in areas with large expanses of barrens.

The grass-shrubland species suite includes species that occupy a continuum of habitats from more open grasslands with scattered shrubs (e.g. Bell's Vireo and Northern Bobwhite) to those that inhabit a grassland matrix with shrubs in much greater densities (e.g. Prairie Warbler, Yellow-breasted Chat; James 1992). Native habitats that support these species are disturbance-dependent ecosystems such as glades, barrens, savannas, and early-successional forests (Thompson and DeGraaf 2001). There are opportunities for grassland and grass-shrubland bird conservation through private lands programs targeted toward the retirement of marginal agricultural lands. Improving conditions for priority birds associated with the restoration of native habitats and ecosystems also is an important goal of the BCR conservation plan.

The forest-woodland species suite is characterized by species such as Cerulean, Worm-eating and Kentucky Warblers, Acadian Flycatchers, Eastern Wood-Pewee, and Wood Thrush. However, most of the species in the suite are associated with the forests' mid- and understory components (Hamel 1992), and the response of those and other bird species to woodland restoration, which would result in a more open canopy and sparser understory (Taft 1997), has yet to be fully evaluated. Work in Illinois by Brawn (1998) indicated that several priority species we have grouped with the forest species suite are associated with restored woodlands (e.g. Yellow-billed Cuckoo, Whip-poor-will, Eastern Wood-Pewee and Great Crested Flycatcher). Others that were shown to benefit from woodland restoration included grass-shrubland species such as Northern Bobwhite, Brown Thrasher, and Field Sparrow. Several Central Hardwoods priority species that are associated with pine woodlands in the Ouachita Mountains of southern Arkansas (Wilson et al. 1995) either have been extirpated in the Central Hardwoods BCR (e.g. Red-cockaded Woodpecker) or now occur in small, isolated populations (e.g. Brown-headed Nuthatch and Bachman's Sparrow). Because pine woodlands once were much more prevalent in the Ozarks prior to fire suppression (Nigh and Shroeder 2002), efforts to restore both the habitat and its associated avifauna seem appropriate.

Wetlands in the Central Hardwoods presently appear to be most valuable to shorebirds while moving through the area during spring and fall migrations, and to waterfowl during both migration and winter. Some priority waterbirds breed in the Central Hardwoods in relatively small numbers, though populations were presumably larger and more widespread prior to the loss of wetlands to drainage and impoundments. The status of habitat types important to the BCR's priority species suites are summarized in *Appendix 5*.

Methods

Biologists, land managers and other technical staff from the region's conservation agencies and organizations were invited to a series of three workshops held in different regions of the BCR. Each of the workshops began with a day-long series of presentations designed to familiarize participants with the various bird initiatives, key conservation programs, conservation issues, and the ecological requirements of the BCR's priority species associated with four basic habitat types: wetland, grassland, grass-shrub, and woodland-forest. The following day, participants met in breakouts by habitat type to identify focus areas for the various habitat types and species groups. Hard-copy maps of land cover and laptop computers loaded with geographic information system software were available to each breakout. Geospatial data used in delineating bird conservation areas was compiled from a variety of sources. All data were reprojected into Albers Equal Area, NAD83.

Data layers

National Land Cover Data

Derived from the early to mid-1990s **Landsat** Thematic Mapper satellite data, the National Land Cover Data (NLCD) is a 21-class land cover classification scheme applied consistently over the United States. The spatial resolution of the data is 30 meters and mapped in the Albers Conic Equal Area projection, NAD 83. For more information, see: http://landcover.usgs.gov/natllandcover.html. Land cover derived from satellite imagery was used to assess basic land use patterns across the planning unit.

Roads, state lines, county lines

TIGER/Line® files (Topologically Integrated Geographic Encoding and Referencing system) from the U.S. Census Bureau contain data that were updated for the 2000 census. For more information, see: http://www.census.gov/geo/www/tiger/index.html. These were primarily used by the groups as a means of orientation.

Surface Water Features

The National Hydrography Dataset (NHD) is based upon USGS Digital Line Graph (DLG) hydrography data integrated with reach-related information from the EPA Reach File Version 3 (RF3). The NHD contains information about surface water features. For more information, see: http://nhd.usgs.gov/. The locations of rivers and steams were used as a means of orientation but also in the delineation of wetland focus areas.

Grass- and forest-dominated landscapes

Results of Donovan et al. 1995, and Robinson et al. 1995 suggest that reproductive success of forest birds breeding in landscapes with less than 70 percent forest cover within a 10-km radius of the breeding sites often is too low to sustain local populations due to high levels of nest predation and brood parasitism. Because reproductive success in large forested landscapes tends to be greater than needed to sustain local populations, these landscapes are thought to be the "sources" of birds that disperse to breed in forest fragments in other parts of the Midwest region where reproductive success often is extremely low (Donovan et al. 1995). Maintaining forest cover above the 70 percent threshold is therefore critical not only to breeding forest birds in the Central Hardwoods BCR, it may also be pivotal in maintaining forest bird communities and sustaining their ecological services in adjacent BCRs. Research also suggests that the amount of grass cover in landscapes surrounding grassland sites also can affect densities and reproductive success of local grassland-breeding bird populations[8] (Winter and Faaborg 1999; Winter et al. 2000) although the relationships appear to be more variable than those of forest-breeding birds with forest cover. However, as a precaution, Central Hardwoods BCR planners delineated conservation focus areas for open-grassland breeding birds in the Central Hardwoods in landscapes with greater than 30 percent or greater grass cover within a 3-km radius. Maps of areas meeting these thresholds were generated by the Missouri Resource Assessment Partnership using a neighborhood function in ESRI ArcInfo software (version 8.2; ESRI, Redlands, California) to sum the amount of target land cover. Neighborhood functions produce an output in which the value at each location is dependent on the input value at a location and the values of the cells in a specified neighborhood.

Public lands

World Wildlife Fund has put together a database of protected areas (PAD) for the United States and Canada (DellaSala et al. 2001). We supplemented these

[8] J. Herkert, unpublished data

data with updates from individual state and federal agencies. Most of the public land in the Central Hardwoods BCR is administered by BCR partner agencies with a desire to improve the condition of those lands for birds. The ability to overlay the locations of those lands on land cover and maps of grassland and forest-dominated landscapes (features associated with higher densities and enhanced reproductive success of birds in those species suites) was essential to providing those partner agencies with information regarding which species suites were most in need of conservation actions at each site.

Ecological subregions

Although much of the BCR's prairies, wetlands and pine woodlands have been converted to other community types and land uses, rather large expanses of barrens, glades, savannas, oak woodlands and forests still exist, although often in degraded conditions. In order to identify the areas where those ecosystems occurred historically and are most likely to benefit from restoration efforts, maps of ecological subregions identified by the U. S. Forest Service's National Hierarchy of Ecological Units (McNab and Avers 1994) were employed. Section and subsection coverages of the hierarchy were available for the entire BCR and were classified primarily on the basis of lithology, topography and geomorphology, regional soils, and regional potential vegetation. Landtype associations (LTAs), or ecological landscapes, are a finer scale of ecological delineation that further reflect local variation in topography, parent material, soil type, and vegetation communities. Maps of those were developed through the Missouri Ecological Classification System Project but were available for the Ozarks only (Nigh and Schroeder 2002). Landtype associations were grouped for us by Nigh into three categories: prairie and shrub prairie, glades and savanna, and forests and woodlands, with each grouping targeted for grassland, grass-shrubland and forest-woodland priority bird species suites, respectively.

The Nature Conservancy's (TNC) Ecoregional Planning Portfolio Sites

TNC had completed draft ecoregional planning portfolios for both the Ozarks and Interior Low Plateaus regions of the BCR. The portfolio sites typically identified large landscapes containing terrestrial and aquatic ecosystems with rare species and natural communities in need of conservation attention.

Overlay sequence

Maps of landscapes that met the thresholds for forest and grass cover were the first layer planners considered during the process of identifying bird conservation focus areas within the Central Hardwoods BCR for the forest and grassland-grass-shrub species suites, respectively. Discouraging loss and fragmentation of existing habitat in those areas will be important in maintaining adequate levels of nesting success for breeding birds. In the Ozarks, however, many areas that historically were glade-savanna or prairie-savanna complexes are now overgrown with densely stocked trees (Nigh and Schroeder 2002). Maps of landtype associations were used to delineate which areas now classified as forest should be considered for restoration of those habitat types.

Public lands were then overlain upon the percent cover maps. Public lands falling within forested areas were encircled by a 10-km buffer, and those within grassland areas encircled with a 3-km radius buffer to identify the matrix around the public lands that needed to be considered with regards to maintaining reproductive success of forest or grassland birds breeding on those sites.

TNC's portfolio sites were considered next. Biologists involved with the BCR planning effort believed that improving habitat for birds should be done in association with the restoration of the BCR's native ecosystems where possible so that other biodiversity components associated with those systems will benefit as well. TNC portfolio sites often overlaid public lands, but the planners felt that places where the TNC sites intersected largely forest or grass-dominated landscapes without public lands should be considered for future acquisition or easement projects.

Map layers used to identify wetland focus areas included large water bodies identified by the National Hydrography Data Set and lands classified as emergent or woody wetlands from the National Land Cover Dataset. Participants' knowledge of local conditions and wetland habitats also were incorporated.

Results

The workshops produced maps of species suite focus areas (*fig. 2*). Terrestrial habitat types are coded differently for the Ozarks than the Interior Low Plateaus due to differences in the spatial scale and arrangements of habitat types dominated by forests or woodlands versus those dominated by grasses and shrubs. The location and extent of savannas, glades, and prairies in the Ozarks are influenced by differences in soils, slope, and aspect and often are juxtaposed with woodland and forest systems at relatively small spatial scales (Nigh and Shroeder 2002).

Therefore, the focus area code for grassland bird sites in the Ozarks is prairie; glade-savanna-woodland complexes are targeted for the grass-shrub species suite; prairie-savanna-woodland focus areas are targeted for grass-shrub and woodland-forest birds; and woodland-forest for woodland-forest birds. Some large focus areas have components of each and are coded as "all" Although prairies, barrens and glades also can be found within forest-dominated landscapes in the Interior Low Plateaus, much larger expanses of glades and barrens occurred across relatively broad basins between the forest-dominated uplands that rim those landscapes (McNab and Avers 1994). The more distinct boundaries between habitat types in the Interior Low Plateaus allowed for simpler coding of landscape types there, and terrestrial focus area codes are simply grass-shrub for grassland and grass-shrubland birds, and forest for forest and woodland birds.

Discussion

Focus areas for bird conservation in the Central Hardwoods Bird Conservation Region were delineated by biologists and other technical staff of partner agencies and organizations in the CHBCR with the use of geospatial data layers.

While there are other areas within the BCR that do or could provide high quality bird habitat, the focus areas have the highest conservation, restoration, and management potential at a landscape scale because they have significant blocks of public lands that can provide a core for conservation efforts, good potential for public-private partnerships, and/or have been identified by TNC or state Natural Heritage Programs as areas with noteworthy levels of biodiversity. We believe the ability to concentrate the relatively scant resources available for conservation in discrete landscapes will accomplish greater habitat gains at scales relevant to bird populations than will more isolated efforts. The use of both current land use data and ecological classification systems also allowed us to target specific areas for specific suites of priority birds based upon a landscape's ecological and socio-economic potential.

Conservation strategies for the focus areas in the Central Hardwoods Bird Conservation Region will need to vary depending upon its landscape context and the habitat conditions within. Restoration of native grasses and forbs is needed in what historically were grassland and grass-shrubland areas where woody vegetation fragments the grassland landscape and non-native, cool-season grasses now predominate. While reforestation is needed in some forest focus areas to increase block size and reach the amounts of forest cover that have been associated with adequate levels of reproductive success for forest-breeding birds, in other

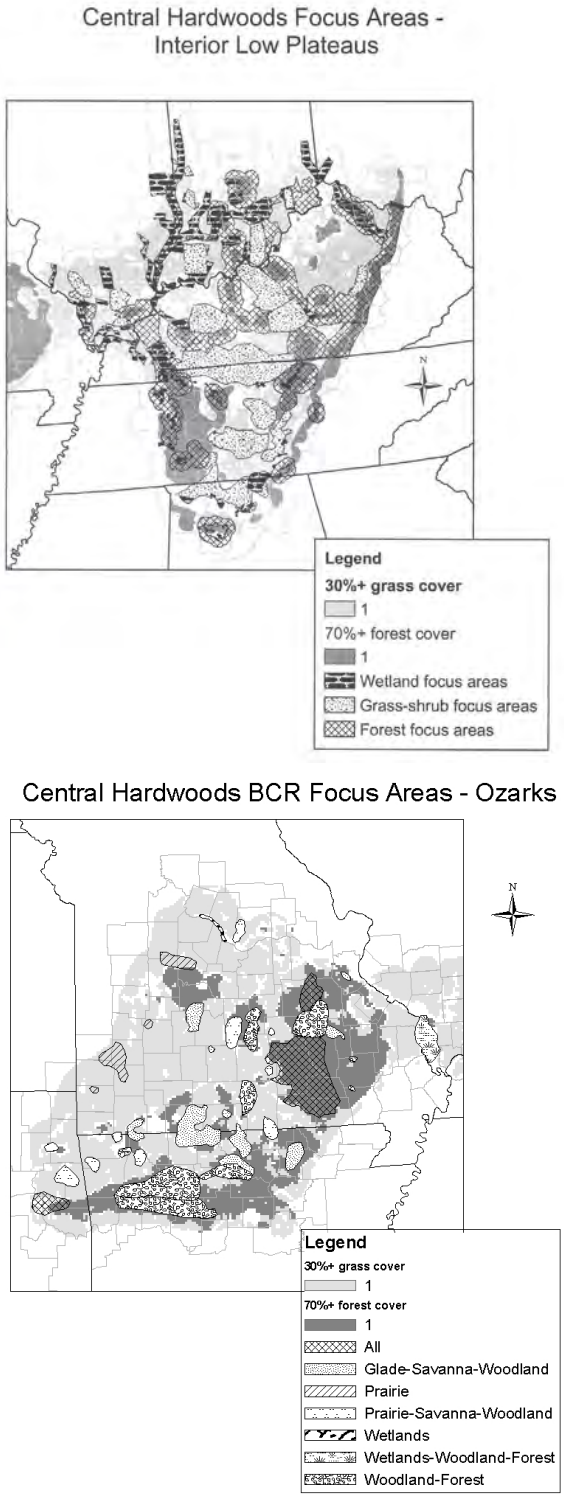

Figure 2—Bird conservation focus areas in the Central Hardwoods Bird Conservation Region.

focus areas the landscape context is adequate, but management is needed to improve the forest structure and perpetuate native oaks and pine as dominant species. Many wetland focus areas are in need of

restoration and especially in areas where the hydrology has been altered almost all will require some form of management. Finally, preventing the conversion of extant native vegetation to other, less "bird-friendly" land use is sure to pose a real and significant challenge as the public's demand for land and its associated resources continues to grow.

Acknowledgments

We would like to thank everyone who participated in the three BCR workshops held during 2002. Their collective expertise and enthusiasm for the project was invaluable to the process of delineating the Central Hardwoods' focus areas. We also thank the Central Hardwoods BCR Steering Committee for their support and their agencies' and organizations' efforts on behalf of all-bird conservation. Financial support that allowed us to build the geographic information system so useful to this endeavor was provided by Federal Aid grant TN M-1-P.

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Appendix 1—*Partners in Flight priority breeding bird species.*

Habitat type	Species	Score[1]	Tier[2]	% pop[3]	Comments
Forest	Cerulean Warbler (*Dendroica cerulea*)	28	I	12	Populations both in riparian areas and uplands
	Worm-eating Warbler (*Helmitheros vermivorus*)	27	I	20	Associated with forest understory on slopes
	Wood Thrush (*Hylocichla mustelina*)	25	I	7	Associated with the mid-canopy
	Kentucky Warbler (*Oporornis formosus*)	24	I	28	Associated with forest understory
	Louisiana Waterthrush (*Seiurus aurocapillus*)	24	I	18	Associated with small streams and riparian zones within forests
	Whip-poor-will (*Caprimulgus vociferous*)	24	I	35	
	Yellow-throated Vireo (*Vireo flavifons*)	23	I	12	
	Acadian Flycatcher (*Empidonax virescens*)	22	I	15	Associated with the mid-canopy
	American Woodcock (*Scolopax minor*)	22	I	4	Associated with stands of small diameter trees, and moist soils
	Chimney Swift (*Chaetura pelagica*)	21	IIA	10	Associated with top-killed trees, but more often with chimneys in urban and rural areas
	Eastern Wood-Pewee (*Contopus virens*)	21	IIA	18	Favors more open forests and woodlands
	Yellow-billed Cuckoo (*Coccyzus americanus*)	21	IIA	14	
	Blue-gray Gnatcatcher (*Polioptila caerulea*)	20	IIA	17	
	Great Crested Flycatcher (*Myiarchus crinitus*)	20	IIA	7	Cavity nester in more open forests and woodlands
	Sharp-shinned Hawk (*Accipter striatus*)	19	IIA	3	Associated with a pine component
Riparian zones	Swallow-tailed Kite (*Elanoides forficatus*)	29	I	0	Extirpated. Once bred in bottomlands with forest components associated with large river systems
	Swainson's Warbler (*Limnothlypis swainsonii*)	26	I	<1	Typically associated with cane thickets in forested riparian areas
	Prothonotary Warbler (*Protonotaria citrea*)	22	I	4	Associated with forested riparian areas
	Belted Kingfisher(*Ceryle alcyon*)	19	IIA	3	Associated with streams and flooded areas in a variety of habitat types
	Green Heron (*Butorides virescens*)	19	IIA	9	Associated with forested riparian areas
Early-successional forest	Blue-winged Warbler (*Vermivora pinus*)	26	I	16	
	Prairie Warbler (*Dendroica discolor*)	25	I	16	
	Field Sparrow (*Spizella pusilla*)	23	I	21	
	White-eyed Vireo (*Vireo griseus*)	22	I	9	
	Yellow-breasted Chat (*Icteria virens*)	22	I	13	

Appendix 1 *continued*

Habitat type	Species	Score[1]	Tier[2]	% pop[3]	Comments
	Brown Thrasher (*Toxostoma rufum*)	21	IIA	8	
	Eastern Towhee (*Pipilo erythophthalmus*)	19	IIA	9	
Pine woodlands	Red-cockaded Woodpecker (*Picoides borealis*)	29	I	0	Extirpated
	Bachman's Sparrow (*Aimophila aestivalis*)	26	I	<1	Now very rare in the BCR; also associated with glades, pine and mixed deciduous forest regeneration cuts.
	Brown-headed Nuthatch (*Sitta pusilla*)	22	I	0	Extirpated throughout much of the BCR, but small populations in the Boston Mountains in Arkansas
	Northern Bobwhite (*Colinus virginianus*)	21	IIA	9	
Grass-shrublands	Prairie Warbler (*Dendroica discolor*)	25	I	16	
	Bell's Vireo (*Vireo bellii*)	24	I	<1	
	Field Sparrow (*Spizella pusilla*)	23	I	21	
	Yellow-breasted Chat (*Icteria virens*)	22	I	13	
	Brown Thrasher (*Toxostoma rufum*)	21	IIA	8	
	Northern Bobwhite (*Colinus virginianus*)	21	IIA	9	
	Eastern Towhee (*Pipilo erythophthalmus*)	19	IIA	9	
Grasslands	Greater Prairie Chicken (*Tympanuchus cupido*)	29	I	<1	Now restricted to small isolated populations in the western part of the BCR and southern Illinois
	Henslow's Sparrow (*Ammodramus henslowii*)	26	I	18	Largest populations in the BCR associated with reclaimed minelands
	Grasshopper Sparrow (*Ammodramus savannarum*)	21	IIA	3	
	Eastern Meadowlark (*Sturnella magna*)	19	IIA	12	

[1] *Score* refers to the total score provided by the Partners in Flight Species Assessment Database (Information on the PIF species assessment process and associated scores are available at: http://www.rmbo.org/pif/pifdb.html)

[2] *Tier* refers to the level of conservation priority that should be afforded a species as suggested by the Partners in Flight species assessment process. Tier I identifies high-scoring species that require conservation consideration wherever they occur in manageable numbers. Tier IIA identifies species that occur in a Bird Conservation Region in relatively large numbers and whose trends are unknown or declining.

[3] *%pop* refers to the percentage of the global population estimated to breed within the Central Hardwoods Bird Conservation Region

Appendix 2— *Priority species from the North American Waterfowl Management Plan.*

Species[1]	Season	Geographic importance[2]	Conservation need[3]
Dabbling Ducks:			
Mallard (*Anas playrhynchos*)	nonbreeding	moderately high	high
American Black Duck (*Anas rubripes*)	nonbreeding	moderately high	high
Northern Pintail (*Anas acuta*)	nonbreeding	moderately low	moderate
American Wigeon (*Anas americana*)	nonbreeding	moderately low	moderately low
Gadwall (*Anas strepera*)	nonbreeding	moderately low	moderately low
Blue-winged Teal (*Anas discors*)	nonbreeding	moderately low	moderately low
Perching Ducks:			
Wood Duck (*Aix sponsa*)	breeding	moderately high	moderately high
	non-breeding	moderately low	moderately low
Diving Ducks:			
Greater Scaup (*Aythya marila*)	nonbreeding	moderately low	moderately low
Lesser Scaup (*Aythya affinus*)	nonbreeding	moderately low	moderate
Canvasback (*Atythya valisineria*)	nonbreeding	moderately low	moderately low
Ring-necked Duck (*Aythya collaris*)	nonbreeding	moderately low	moderately low
Sea Ducks:			
Common Goldeneye (*Buchephala clangula*)	nonbreeding	moderately high	moderately high
Hooded Merganser (*Lophodytes cucullatus*)	nonbreeding	moderately high	moderate
Bufflehead (*Buchephala alveola*)	nonbreeding	moderately low	moderately low
Geese:			
Canada Goose (*Branta Canadensis*)			
Southern James Bay population	non-breeding	moderately high	high
Mississippi Valley population	non-breeding	high	high
Mississippi Flyway Giant	breeding	moderately high	moderate
	non-breeding	moderately high	moderate

[1] Species list is from the June 2003 draft update to the North American Waterfowl Management Plan
[2] Importance of the Central Hardwoods Bird Conservation Region (BCR) to a species based upon a combination of the percentage of the species inhabiting the BCR, its density relative to other BCRs, and threats to its habitat within the region
[3] Level of need for habitat conservation and/or monitoring efforts in the Central Hardwoods Bird Conservation Region

Appendix 3— *Priority species from the Upper Mississippi Valley Great Lakes Shorebird Conservation Plan.*

Species	Season	Priority[1]
American Golden-Plover (*Pluvialis dominica*)	migration	3
Killdeer (*Charadrius vociferous*)	migration and breeding	3
Greater Yellowlegs (*Tringa melanoleuca*)	migration	4
Upland Sandpiper (*Bartramia longicauda*)	migration and breeding	4
Semipalmated Sandpiper (*Calidris pusilla*)	migration	3
Least Sandpiper (*Calidris minutilla*)	migration	3
Solitary Sandpiper (*Tringa solitaria*)	migration	3
Dunlin (*Calidris alpina*)	migration	3
Stilt Sandpiper (*Calidris himantopus*)	migration	3
Buff-breasted Sandpiper (*Tryngites subruficollus*)	migration	4
Short-billed Dowitcher (*Limnodromus griseus*)	migration	4
Common Snipe (*Gallinago gallinago*)	migration	3
American Woodcock (*Scolopax minor*)	migration and breeding	4

[1] Scaled from 1-5, with 5 being the highest priority

Appendix 4— *Priority Waterbirds of the Upper Mississippi Great Lakes Regional Waterbird Plan (draft 2002).*

Species	Season	Priority[1]
Bonaparte's Gull (*Larus philidelphia*)	winter and migration	moderate
Franklin's Gull (*Larus pipixcan*)	migration	moderate
Common Tern (*Sterna hirundo)*	migration	high
Forster's Tern (*Sterna forsteri*)	migration	moderate
Least Tern (*Sterna antillarum*)	breeding season and migration	high
Black Tern (*Childonius niger*)	breeding and migration	moderate
Little Blue Heron (*Egretta caerulea*)	breeding and migration	high
Snowy Egret (*Egretta thula*)	breeding	high
Yellow-crowned Night-Heron (*Nyctanassa violacea*)	breeding	moderate
Black-crowned Night-Heron (*Nycticorax nycticorax*)	breeding and winter	moderate
Least Bittern (*Ixobrychus exilis*)	breeding and migration	high
King Rail (*Rallus elegans*)	breeding	high
Black Rail (*Laterallis jamaicensis*)	breeding	high
Whooping Crane (*Grus americana*)	migration	high

[1] Refers to the species need for conservation action

Appendix 5— *Native habitats of the Central Hardwoods: current status and conservation needs.*

Habitat type	Current status	Conservation needs
Upland forest and woodlands	Although oak-hickory and pine-oak forests and woodlands were once prevalent in various areas within the Central Hardwoods BCR, little of the native pine woodlands or pine-dominated forests exist today.	Restoration of large expanses of native short-leaf pine dominated woodlands is needed to support populations of the now rare Bachman's Sparrow and possible re-introductions of Brown-headed Nuthatch and Red-cockaded Woodpecker. Oak woodlands also should be restored on appropriate land types. A variety of forest management and harvest techniques are needed to provide the range of conditions needed by the entire suite of priority bird species
Shrublands	Native grass-shrubland habitats are provided by barrens, glades, savannas, and shrub-prairies, and forest regeneration cuts. Most of these habitat types have been converted to other land uses or have been degraded by decades of fire suppression.	Restoration of these habitat types are needed not only to enhance habitat for shrubland-associated birds, but also to secure populations of other rare, threatened and endangered species associated with those systems. However, maintaining a shrub component at some stage in the life- cycle of these ecosystems will be important if birds are to benefit.
Grasslands	Native grasslands historically were represented by prairies and shrub-prairies. These habitats were most extensive in the western part of the Ozarks and in the large barrens of the Interior Low Plateaus, although small prairie intrusions were scattered among many woodland land-type associations across the BCR. Only small remnants of those habitat types exist today.	Restoration of native prairies should be attempted wherever possible, especially where the restorations can be embedded within landscapes with containing relatively large amounts of other grassland types. Conversion of fescue to native warm-season grass and forb mixes can also help to provide habitat for the grassland bird species suite, but linear strips of woody vegetation that fragment grassland landscapes should be removed to reduce predation and parasitism rates.
Wetlands	Most of the wetland habitats in the BCR are and were associated with the region's larger river systems. Many of those habitats have been drained and converted to other land uses. However, many restoration projects have been undertaken in the BCR, though they are scattered and fairly isolated at this point. Wet meadows are another potentially important wetland habitat type that are associated with hydric soils in prairie ecosystems.	Wetland restoration projects and the protection of existing wetlands of various kinds continue to be needed in the Central Hardwoods. Locations of wet meadows need to be mapped and the kinds of priority birds they support throughout the year should be assessed.
Bottomland hardwood forest and associated cane thickets	Bottomland forests in the BCR were associated with the floodplains of both rivers and larger creeks across the BCR. Much of the forest acreage has been converted to crop or pasture land. Cane thickets (*Arundinaria gigantea*) once formed extensive corridors along many of the BCR's riparian areas and were an important component of the breeding habitat of the high-priority Swainson's Warbler, but now exist in relatively small and isolated patches.	Extensive tracts of extant bottomland forest need to be identified and secured through acquisition, easements, or voluntary incentive programs. Restoration of bottomland forests should be targeted in areas where existing fragments could be consolidated into large tracts. Restoration of cane thickets should be targeted in areas where existing fragments could be consolidated and restoration efforts would provide thickets along relatively long stretches of river adjacent to large tracts of high quality forest.

Evaluating Partners in Flight Partnership Lands in the Mid-Atlantic Region: Converting Conservation Plans into Conservation Actions[1]

Bryan D. Watts[2] and Dana S. Bradshaw[2]

Abstract

Within the mid-Atlantic Coastal Plain, lands owned or controlled by government agencies and organizations within the Partners in Flight (PIF) program are highly fragmented. These lands represent tens of thousands of habitat patches that are managed by hundreds of individuals responding to a diversity of directives. Moving this patchwork of lands forward to achieve regional conservation goals will require orchestration of management activities on a large scale. Between 2000 and 2002 we conducted an assessment of partnership lands within the mid-Atlantic Coastal Plain to evaluate the status of priority habitats. This project was designed to bridge the disconnect between regional plans and local land management. We interpreted digital orthophotographs and mapped patches of priority habitats within all lands owned by the PIF collective. These properties contained 672,696 ha of land distributed among 19,018 patches. For some priority habitats, the PIF collective appears to control a significant portion of the regional total. Linking habitat and partner-specific data will allow for the development of customized action plans and highlights the role of individual partners in the recovery of species suites. In a very real sense, the application of regional habitat assessments to conservation plans serves to identify the role that individual land managers may play in achieving specific regional targets.

Key words: conservation plan, habitat assessment, land management, mid-Atlantic Coastal Plain, scaling objectives.

Introduction

In 1995, the PIF program initiated a comprehensive planning process. This process culminated in the development of bird conservation plans for every physiographic region in North America (Pashley et al. 2000). Eco-regional plans are intended to serve as "blueprints for action", focusing available funding and manpower on identified research, management, and educational priorities. Since the completion of initial area plans, there has been considerable interest in making the transition from plan development to plan implementation. However, throughout the early phase of this transition it has become increasingly clear that there remains a region-to-local disconnect. Translation of region-based goals down to the management of individual habitat patches is a necessary first step toward the local to regional integration that will be needed to achieve conservation targets. This is particularly evident within those physiographic areas where both habitat and ownership are highly fragmented.

The mid-Atlantic Coastal Plain (PIF physiographic area 44) was the site of the first successful European settlement in North America and its landscape has been subject to influence by European culture for nearly four centuries. The landscape of the region is highly dissected due both to the historic influence of man and to the complex interface between land and water. The urban crescent from Baltimore south to Richmond and east to Norfolk is experiencing one of the fastest human growth rates in North America. The living space and infrastructure required by this expanding human population is continuing to alter the availability and distribution of priority habitats. Hundreds of thousands of habitat patches are distributed among an even larger number of owners. Lands owned or controlled by government agencies and organizations within the PIF program are also highly fragmented. These lands represent tens of thousands of habitat patches that are managed by hundreds of individuals responding to a diversity of directives. Moving this patchwork of lands forward to achieve regional conservation goals will require orchestration of management activities on a large scale.

A bird conservation plan was completed for the Mid-Atlantic Coastal Plain in the spring of 1999 (Watts 1999). Translating this conservation plan into meaningful conservation action will require the integration of region-based objectives with local recommendations. The overarching objective of this project is to bridge the region-to-local disconnect and begin the process of mobilizing the collective partnership embodied in the PIF program from conservation planning to conservation action within the mid-Atlantic region. A series of complimentary sub-objectives have been identified for this purpose including: 1) identification of parcels

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California**.

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controlled by PIF partners, 2) identification of land managers for all parcels, 3) assessment of partnership lands with respect to priority habitats, 4) conducting a collective assessment to determine status relative to regional conservation goals, and 5) development of parcel-specific recommendations. We refer to this approach as scaling down region-based conservation goals to the management of land parcels while simultaneously scaling up local management actions to achieve regional goals. This paper presents the results of the assessment of priority habitats within the region (sub-objective 3 above). Information resources associated with other objectives are available on a dedicated habitat assessment website (http://www.ccb-wm.org) or will be presented elsewhere.

Methods

The habitat assessment presented here is restricted to lands within the "PIF collective" that fall within the mid-Atlantic Coastal Plain (PIF physiographic area 44). This collective includes lands owned and managed by agencies and organizations that are actual signatories to the PIF agreement (for a listing of partners, see: http://www.partnersinflight.org). Within the mid-Atlantic Coastal Plain, this community of landholders includes various agencies of state and federal governments, non-governmental organizations, and private corporations. The mid-Atlantic Coastal Plain currently covers 56,220 km^2 and includes all coastal lands of Virginia, Maryland, Delaware, and New Jersey. The area is bounded to the east by the Atlantic Ocean and to the west by the fall line. The fall line is an erosional scarp where the metamorphic rocks of the Piedmont meet the sedimentary rocks of the Coastal Plain. The geologic formations along this boundary frequently determine the landward extent of tidal influence. The state border of New Jersey forms the northern boundary of the region. The original southern boundary of the region (the boundary used in this study) was the Virginia/North Carolina Border. It should be noted that in recent years the southern boundary for this physiographic region has been shifted north to include only the southern drainage basin of the Chesapeake Bay.

We worked collaboratively with PIF landholders to develop a directory of all properties included in the regional PIF collective. For the purpose of this project, a "property" refers to a parcel or group of parcels addressed by the same name and under a common management team. The directory linked all parcels with their respective management contacts and served as a master list to guide the assessment. Digital shape files that delineated boundaries were compiled or developed for all properties.

The bird conservation plan for the mid-Atlantic Coastal Plain identifies eight different habitat types that are critical to the long-term health of priority bird populations (Watts 1999). In order of regional priority these habitats include pine savanna, barrier and bay island, salt marsh, forested wetland, mixed upland forest, early successional, pine plantation, and fresh/brackish marsh. These habitats are broadly defined with several subtypes being recognized within the conservation plan. To the extent possible, we maintained specified subtypes within the habitat assessment. However, in order to simplify the presentation within this report, information is provided by broad habitat categories.

We conducted the habitat assessment manually by interpreting digital orthophoto quarter quadrangles. Source imagery was color-infrared with a resolution of 5 m. We used ArcView 3.2 (Environmental Systems Research Institute, Inc.© 1992-2000) software for all digital manipulation and interpretation. Digital shapefiles of property boundaries were superimposed onto digital orthophotos to allow for habitat delineation and mapping. For identification of priority habitats, we used the Anderson land-use and land-cover classification system (Anderson et al. 1976). Anderson uses a hierarchical system of classification that scales down to appropriate levels based on the resolution required to distinguish critical habitat features. We used a modified Anderson classification incorporating Levels 2 and 3 of the Anderson system. All habitats were evaluated and mapped at the patch level. For the purpose of this study, a "patch" is a "contiguous area of relatively homogeneous habitat." Patches were delineated from the surrounding landscape by hard boundaries such as rivers or roadways or by rapid transitions to homogeneous areas of other habitat types. All attributes of patches and higher order designations were entered into a central database to allow the greatest flexibility in retrieving information over different spatial scales and to accommodate a wide range of uses.

Results

Within the mid-Atlantic Coastal Plain, lands controlled by the PIF collective are widespread and account for just below 12 percent of the total land surface (*fig. 1*). The collective was found to include 527 separate properties that contained 672,696 ha of land arranged within 19,018 patches of priority habitat (*table 1*). Collectively, government-owned lands accounted for the largest portion (77.6 percent) of landholdings followed by industry (18.1 percent) and NGOs (4.3 percent) respectively. The U.S. Department of Defense was the single largest landholder (21.4 percent of PIF collective) followed by the U.S. Fish and Wildlife Service (19.0 percent), the forest products industry (18.1 percent), and the state of Maryland (15.0 percent).

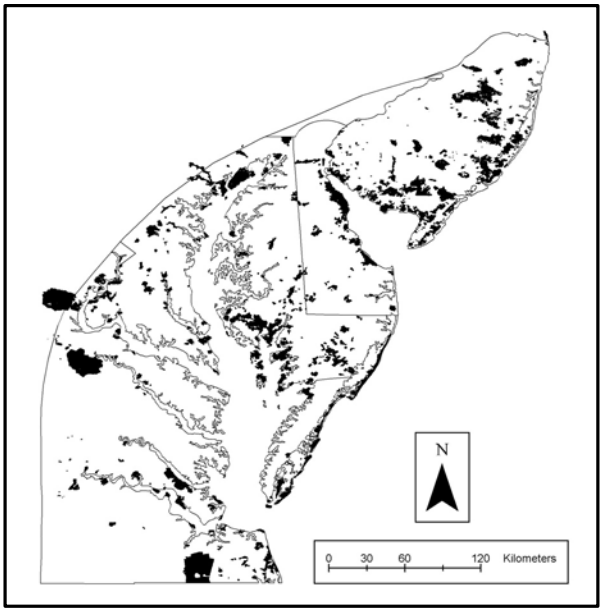

Figure 1—Map of mid-Atlantic Coastal Plain physiographic area illustrating the lands (black polygons) included within the PIF collective. Note that industry lands are not shown due to proprietary interests.

Priority habitats varied considerably in distribution and abundance within the PIF collective (*table 2*). Most of the priority habitat types were well represented within the holdings of the collective and were widely distributed across the region and between partners. Pine savanna was the least abundant priority habitat accounting for only 0.5 percent of landholdings. This habitat type has declined dramatically within the region due to shoreline development and conversion to other land uses. Many of the patches that do remain have been degraded by fire suppression. Wetland habitats are more concentrated within partnership lands than within the region in general and accounted for more than 44 percent of all landholdings. This same general pattern was detected for early successional habitats that accounted for more than 9 percent of landholdings. The barrier and bay islands contained within partnership holdings are the best examples within the region. Other habitats such as upland forests are represented within partnership lands by only a fraction of those distributed throughout the region.

Discussion

The PIF collective within the mid-Atlantic Coastal Plain controls lands that are essential to the recovery and maintenance of many species listed as conservation priorities within the region. Despite the small number of partners currently included, the collective contains a surprising portion of the total surface area within the region. As a whole, the collective likely has higher conservation value per ha than most other lands within the region. Many of these lands were protected because they contain habitats that are regionally significant. In addition, declining or rare habitats appear to occur with higher frequency within the collective. For example, early successional habitats represent 9.4 percent of the area within the collective compared to less than 2 percent of the area within randomly chosen landscape scenes throughout the region[3]. It is also likely that the relative conservation value of these lands will continue to rise into the future as they become increasingly isolated within an urbanized landscape.

[3]Watts, unpublished data.

Table 1—*Summary of assessment results by Partners in Flight (PIF) partner.*

PIF Partners	Properties	Patches	Area (ha)
Federal agencies			
Department of Defense	58	4,258	144,165
Fish and Wildlife Service	30	2,085	127,664
National Park Service	15	685	20,922
State agencies			
Virginia	78	112	13,142
Maryland	85	2,028	100,693
Delaware	18	647	25,715
New Jersey	80	7,323	89,686
Non-governmental organizations			
New Jersey Audubon	10	48	345
New Jersey Conservation Foundation	38	338	2,653
The Nature Conservancy	75	917	25,711
Industry	40	630	122,000
Total	527	19,018	672,696

Table 2—*Summary of assessment results by priority habitat and PIF partner.*

Partner	Pine savanna	Barr/bay island	Salt marsh	Forested wetland	Upland forest	Early success.	Pine plantation	Fresh/brack. marsh
DOD	286	356	3,495	16,773	82,327	23,624	9,331	7,973
FWS	518	2,428	32,523	62,817	6,015	7,059	2,393	13,911
NPS	598	2,489	2,296	1,626	11,164	1,273	652	824
VA	445	5	6,530	1,647	2,492	440	416	1,167
MD	79	251	28,847	19,179	25,368	12,688	7,377	6,904
DE	983	124	3,162	1,744	3,676	5,250	3,728	7,048
NJ	-	133	32,198	23,730	20,901	11,413	92	1,219
NJA	-	-	79	150	8	13	-	95
NJCF	-	-	111	968	1,037	513	-	24
TNC	748	2,538	10,687	4,356	3,902	1,157	716	1,607
IND	-	-	-	-	12,000	-	110,000	-
TOT	3,197	8,324	122,928	132,990	168,890	63,430	134,705	40,772

The composition of holdings within the PIF collective does not appear to reflect the composition of habitats within the region. More than 44 percent of all current holdings are wetlands reflecting the acquisition targets of resource agencies and conservation organizations. For some priority habitats, the PIF collective appears to control a significant portion of the regional total. For example, virtually all of the undeveloped barrier islands are owned by the PIF collective. The habitat composition within the collective also reflects the management objectives of the partnership. These objectives may be considerably different than those within the broader landscape. This difference led to some unexpected discoveries during the course of the assessment. One such discovery was the number of large grassland patches occurring on partnership lands. The assessment located 57 early successional patches that exceeded 50 ha in area, 31 that exceeded 100 ha, and 8 that exceeded 200 ha. These patches were unknown to the conservation community and represent opportunities to manage for species of high priority within the region such as the Henslow's Sparrow (*Ammodramus henslowii*).

Linking the habitat assessment information to individual partners serves, for the first time, to quantify the relative responsibility that each of these landholders have in the maintenance of regional bird populations. The finding that the three large federal agencies account for more than three quarters of the collective landholdings suggests that they have a large potential to influence populations of priority species. The Department of Defense, in particular, has a concentration of installations within the physiographic area. Evaluation of the relationships between partners and individual habitats further refines the role that these partners may play in the maintenance of specific species suites. For example, due to the composition of their holdings and the fact that they control nearly 40 percent of the early successional lands, the Department of Defense must play a lead role in the conservation of grassland species. Similarly, The Nature Conservancy controls significant barrier island complexes and must play a central role in the conservation of beach-nesting birds in the region.

One of the most difficult obstacles to overcome in making the transition from planning to on-the-ground implementation is being able to communicate a regional vision of conservation objectives to the community of land managers who are responsible for the condition of habitats. This project has compiled an electronic directory of land managers that is linked directly to all properties and habitat patches. This connection will allow regional planners to sort for managers who are responsible for particular priority habitats and communicate customized management recommendations. This resource provides a powerful approach to mobilizing the management community in the direction of conservation targets.

Conservation is an iterative process that involves planning, action, and adaptive monitoring. Development of an action plan that translates regional objectives down to local patches where actions may be taken is a difficult process even after goals have been established and an assessment has been completed. This process is ongoing within the mid-Atlantic Coastal Plain. Information from the habitat assessment is being used to evaluate the status of priority species relative to population targets. Research, management, and educational needs are being evaluated on a habitat-by-habitat basis. The unique responsibilities and opportunities of each partner within the PIF collective must be incorporated into an integrated plan. Effective communication will ultimately be one of the most important components of a successful strategy.

Acknowledgments

Foremost we would like to thank R. Dettmers for his vision and support to see this effort through. Additional financial support was provided through A. Milliken and D. Pashley. These three along with K. Rosenberg and the Northeast PIF Working Group also offered constructive review and helped in accessing and compiling various information sources. B. Paxton offered countless hours of technical support, ArcView guidance, and map production. Digitizing could not have been completed without the help of N. Foster, assisted by C. Markham, M. Smith, and T. Whitaker. C. Markham constructed the website to make information accessible. D. DesRochers and K. Grosz provided valuable assistance with ground-truthing problem imagery. Many people assisted with this effort through providing imagery, contact information, or source information of one kind or another. Foremost among those were the following who provided information on at least a state or regional scale: G. Therres, A. Smith, G. Crichton, K. Geisler, and I. Vandegaer. We also thank R. Busch, M. Dey, J. Dickson, A. Smith and T. Stamps for helping us to sort out land manager profiles in different agencies. Many others too numerous to name helped to provide data or imagery, or assisted with resolving mapping or contact information. We also would like to recognize A. Womack and M. Roberts of the College of William and Mary Grant's Office who administered the funding for this project.

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The New York State Bird Conservation Area (BCA) Program: A Model for the United States[1]

M. F. Burger[2], D. J. Adams[3], T. Post[3], L. Sommers[3], and B. Swift[3]

Abstract

The New York State Bird Conservation Area (BCA) Program, modeled after the National Audubon Society's Important Bird Areas Program, is based on legislation signed by Governor Pataki in 1997. New York is the first state in the nation to enact such a program. The BCA Program seeks to provide a comprehensive, ecosystem approach to conserving birds and their habitats on state lands and waters, by integrating bird conservation interests in agency planning, management, and research projects, within the context of agency missions. Several state agencies and conservation organizations are involved in the BCA Program through representation on the Advisory Committee. Since 1998, 25 BCAs have been designated, totaling nearly 73,000 ha (more than 180,000 acres). These sites cover a diversity of habitats across the state, including wetlands along the Niagara River, Lake Ontario, and Long Island Sound; forests in Central New York and along the Hudson River where Cerulean Warbler (*Dendroica cerula*) nest; and high elevation forests in the Adirondack and Catskill Mountains that are home to Bicknell's Thrush (*Catharus bicknelli*). The BCA program employs 4 full-time biologists who work with local site managers to complete management guidance summaries and plan research, management, and interpretive projects for the sites. Management, research, and interpretive projects initiated to date include kiosks and trailside panels containing interpretive materials; invasive plant management; surveys for marsh birds, Cerulean Warblers, and Prothonotary Warblers (*Protonotaria citrea*); and a handicap-accessible plank walkway and viewing platform. See http://www.dec.state.ny.us/website/dfwmr/wildlife/bca/ for more information.

Key words: BCA, environmental conservation law, IBA, interpretive projects, New York, public land, site management.

The New York State Bird Conservation Area (BCA) Program is based on legislation signed by Governor Pataki in 1997 (*Appendix 1*). New York is the first state in the nation to enact such a program, which is modeled after Audubon's Important Bird Area program. This legislation established criteria for designating BCAs on state-owned lands and waters, and seeks to safeguard and enhance bird populations and their habitats on these areas, within the context of the mission of the agency that owns the land. The legislation created a BCA Program Advisory Committee that meets twice annually to advise state agencies on the designation, management, educational research and use of sites identified as part of the New York State Bird Conservation Program. Several state agencies and conservation organizations are involved in the BCA Program through representation on the Advisory Committee.

Detailed criteria for designating BCAs are included in the legislation (*Appendix 1*). An area can be designated as a BCA if it is judged as important habitat for one or more species. Importance is based on: large numbers of waterfowl, pelagic seabirds, shorebirds, wading birds, or migratory songbirds; high numbers of a diverse assemblage of bird species; an unusual species assemblage; species at risk; or a bird research site.

These criteria allow designation of sites that are very specific in their species use and/or habitat; sites that provide habitat for a high diversity of species; and also for species for which an area has a significant percentage of the global population, and therefore, a high responsibility for conservation of that species. Sites will vary from relatively small areas such as colonial nesting bird islands, to large areas such as entire Wildlife Management Areas or State Forest units that support a unique assemblage or diversity of bird species for which New York State has a high responsibility for conservation.

The ultimate goal of the BCA Program is to ensure that conservation of native bird species and their habitats on state lands and waters are explicitly considered in agency planning, management and research projects, within the context of agency missions. In some cases, that mission may supercede what may be best for bird conservation, but awareness of the most important

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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[3]NYS DEC, Nongame and Habitat Unit, 625 Broadway, Albany, NY 12233.

avian resources should ensure that impacts are minimized.

The BCA Program is non-regulatory and is meant to be a cooperative effort involving BCA program staff with central office and regional staff responsible for managing state lands. BCA Program staff has expertise in bird conservation that can help land managers understand the implications of land management decisions on avian resources. BCA Program staff will work with regional staff on issues related to bird conservation on state lands to help elevate the awareness, need, and opportunities for bird conservation. BCA Program staff may make recommendations on how to better manage for bird conservation, but the actual land managers will continue to make the decisions on what they will or can implement.

Designation of a site does not mean that the site will become a bird sanctuary or preserve to be set aside. Active management of these sites for wildlife, forestry, and recreation will continue, and in some case will be necessary to maintain habitat for bird species of concern. Many species of birds use or require early successional habitats, including grasslands, shrublands, and early successional forests. The amount of these habitats in New York and the Northeast has been shrinking for many decades as open lands have reverted to forests. Most species that rely on these early successional habitats are in long-term decline. Likewise, marshes need periodic management to maintain a healthy ecosystem and provide diverse habitats, such as a mix of emergent vegetation and areas of open water that can accommodate many birds, including waterfowl, bitterns, and Black Terns (*Chlidonias niger*). Similarly, many forest birds would benefit from removal of at least some trees to promote more understory and shrub layer growth for the benefit of species such as Chestnut-sided (*Dendroica pensylvanica*), Black-throated Blue (*Dendroica caerulescens*), and Canada Warblers (*Wilsonia canadensis*). With cooperation, management can be accomplished that will maintain or enhance habitat for birds, in concert with the host of other purposes for which state lands are managed.

Perhaps the most important benefit of the BCA Program is to the birds and their habitats. As managers become more aware of opportunities for bird conservation, and the effect of management decisions on birds, birds will benefit. BCAs also can serve as model stewardship programs for bird conservation on state or private lands. In addition, the BCA Program can help identify and implement research, monitoring, and educational programs. The BCA Program has a standard 4-panel design for kiosks that provide a great opportunity for communicating bird conservation messages. We purchase the lumber, help with design, and get professional quality panels produced. We also can help with planning and preparation of grant proposals, and requests for other funds for management, research, and education. An indirect benefit of the program is that BCA program staff continue to develop expertise in bird conservation and management that can be applied to other land areas and issues that state agencies face.

Designation of a BCA will not directly affect existing recreational activities, unless the local land manager decides that a conflict exists. It will result in better opportunities to view birds, better overall management for bird conservation, and improved information to explain why this area is important for birds.

Since 1998, 25 BCAs have been designated (*table 1; fig. 1*), totaling nearly 73,000 ha (more than 180,000 acres). These sites cover a diversity of habitats across the state, including wetlands along the Niagara River, Lake Ontario, and Long Island Sound; forests in Central NY and along the Hudson River where Cerulean Warblers nest; and high elevation forests in the Adirondack and Catskill Mountains that are home to Bicknell's Thrush. The BCA program employs four full-time biologists who work with local site managers to complete management guidance summaries and plan research, management, and interpretive projects for the sites. Management, research, and interpretive projects initiated to date include kiosks and trailside panels containing interpretive materials; invasive plant management; surveys for marsh birds, Cerulean Warblers, and Prothonotary Warblers; and a handicap-accessible plank walkway and viewing platform. For more information, see http://www.dec.state.ny.us/website/dfwmr/wildlife/bca/.

Table 1— *New York State Bird Conservation Areas (BCAs) and their location, size, and date designated*

BCA name	County	Size (ha)	Date designated
David A. Sarnoff Pine Barrens Preserve	Suffolk	941	31 August 1998
Eastern Lake Ontario Marshes	Oswego, Jefferson	1,999	31 August 1998
Buckhorn Island	Erie	259	31 August 1998
Iona Island/Doodletown	Rockland	607	31 August 1998
Catskill High Peaks	Greene, Ulster	1,497	10 June 1999
Nissequogue River	Suffolk	62	28 April 2000
Montezuma Wetlands Complex	Seneca, Wayne, Cayuga	2,610	5 May 2000
Braddock Bay	Monroe	1,043	5 May 2000
Mongaup Valley	Sullivan	4,843	16 June 2000
Bashakill	Sullivan	896	16 June 2000
Fahnestock State Park - Hubbard Perkins Conservation Area	Putnam	4,249	29 September 2000
Constitution Marsh	Putnam	109	18 May 2001
Sterling Forest®	Orange	6,812	26 October 2001
Harbor Herons	Richmond	45	17 November 2001
Perch River	Jefferson	3,182	17 November 2001
Adirondack Sub-alpine Forest	Essex, Franklin, Hamilton	27,924	17 November 2001
Champlain Marshes	Clinton, Essex, Washington	1,133	9 March 2002
High Tor	Ontario, Yates	2,469	12 March 2002
Schodack Island	Rensselaer, Columbia, Greene	350	19 June 2002
Carter's Pond	Washington	181	22 October 2002
Oak Orchard/Tonawanda	Niagara, Orleans, Genesee	3,285	22 October 2002
Pharsalia	Chenango	4,047	22 October 2002
Upper and Lower Lakes	St. Lawrence	3,554	22 October 2002
Ashland	Jefferson	824	6 May 2003
Long Pond	Chenango	159	6 May 2003

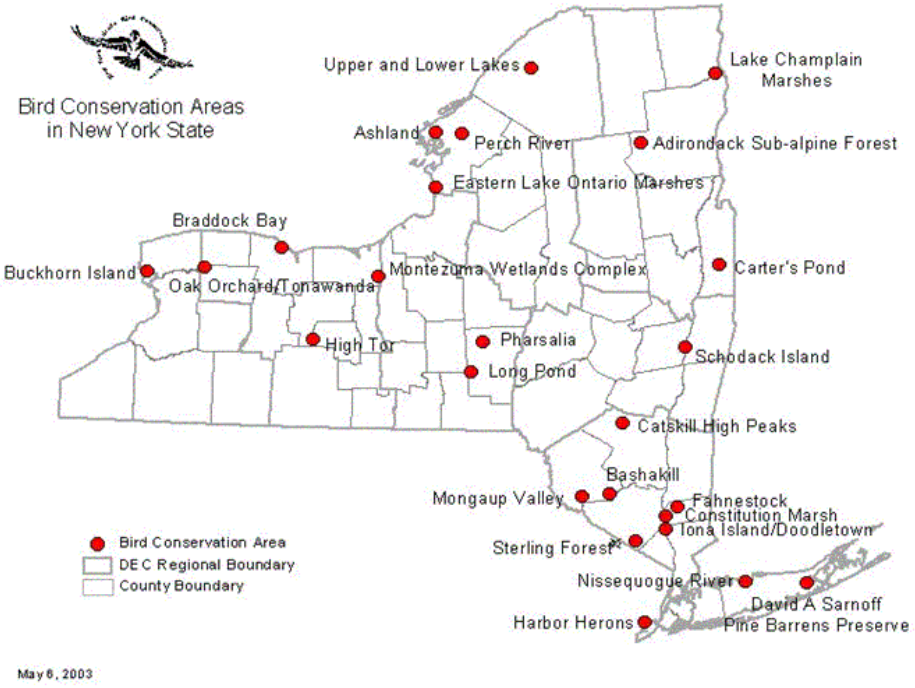

Figure 1— Map of New York State showing the locations of existing Bird Conservation Areas.

Appendix 1.
New York State Bird Conservation Area Law

New York State Consolidated Laws

Environmental Conservation

TITLE 20

NEW YORK STATE BIRD CONSERVATION AREA PROGRAM

Section 11-2001. New York state bird conservation area program.

Section 11-2003. Advisory committee.

S 11-2001. New York state bird conservation area program.

1. There shall be created a New York state bird conservation area program which shall consist of such state-owned waters, lands, or portions thereof as are necessary to safeguard and enhance populations of wild birds native to New York state and the habitats therein that birds are dependent upon for breeding, migration, shelter, and sustenance.

2. Any property designated shall be described and depicted upon a map and a copy of any and all such documents shall be forwarded to the commissioner for inventory, research, and reference purposes for the general public. A master inventory list and maps of properties that are designated as part of the New York state bird conservation area program shall be kept on file by the commissioner who shall also deposit a copy of such at the New York state museum and science service, and at the Cornell Laboratory of Ornithology.

3. For purposes of this title the term "important bird area" shall mean a site providing habitat to one or more species of breeding or non-breeding birds bounded by natural or anthropogenic features or boundaries. To be eligible for designation under this section a site must be an important bird area. Any site that meets or matches one or more of the following criteria in this subdivision shall be eligible for designation as part of the New York state bird conservation area program because it is an important bird area.

   a. Waterfowl concentration site: a location that regularly supports at least two thousand birds such as loons, grebes, cormorants, geese, ducks, coots, and moorhens.

   b. Pelagic seabird site: a location that regularly supports at least one hundred birds of open water such as shearwaters, storm-petrels, terns, fulmars, gannets, jaegers, alcids, and other like birds and/or ten thousand gulls at one time during some part of the year so long as the primary food source for such birds is not anthropogenic.

   c. Shorebird concentration site: a location that supports at least three hundred birds such as plovers, sandpipers, and other like birds during some part of the year.

   d. Wading bird concentration site: a location that supports at least one hundred birds such as bitterns, herons, egrets, ibises, and other like birds during some part of the year.

   e. Migratory concentration site: a location that is a flight corridor rest stopover site for an exceptional number or diversity of migratory songbirds during either spring or fall seasons.

   f. Diverse species concentration site: a location that supports a distinctive group of indigenous bird species that is the consequence of local habitats that are resultant of unique vegetational, geological, geographical, topographical, or microclimatological circumstances.

   g. Individual species concentration site: a location that supports at least one bird species during one or more seasons of the year as a regionally unique, dense (for the species) population.

   h. Species at risk site: (1) a location that supports a significant population of a species that is listed either federally or by New York state as endangered, threatened, or of special concern, or (2) which supports a species that is verified by either the commissioner or the state ornithologist as being rare or declining within New York state, or (3) an exceptional, rare, or remnant native habitat, vegetative community, or landscape segment that supports one or more significant habitat dependent populations of wild bird species.

i. Bird research site: a location where a wild bird population research and/or monitoring project of at least five consecutive years duration is conducted and contributes to the science of ornithology and/or bird conservation policy through publicly accessible scholarly and/or scientific publications.

4. Designation may be accomplished either by (a) the commissioner; (b) the commissioner of parks, recreation and historic preservation; or, (c) the secretary of state, for such appropriate properties as may exist within their respective jurisdictions and consistent with their respective missions.

S 11-2003. Advisory committee.

There shall be created within the department a New York state bird conservation area program advisory committee whose non-governmental members shall serve without pay, meet not less than twice each year, and whose sole purpose shall be to advise as to the designation, management, educational research and utilization of those sites that are individually designated as part of and collectively comprise the New York state bird conservation area program. Provided, however, the utilization of such sites shall be consistent with the respective missions of the department, the office of parks, recreation and historic preservation and the department of state. In addition to representatives of the department, the advisory committee shall consist of, but not be limited to one representative each from the department of state, the Conservation Fund Advisory Board, the Conservation Council, the office of parks, recreation and historic preservation, the state museum, Cornell Laboratory of Ornithology, the Nature Conservancy, the National Audubon Society, Ducks Unlimited, the New York State Biodiversity Research Institute, and the Federation of New York State Bird Clubs. The commissioner may appoint additional members as appropriate, who shall serve at his pleasure.

Incorporating Partners in Flight Priorities into State Agency Operational Plans: Development of a Management System for Wetland Passerines[1]

Thomas P. Hodgman[2]

Abstract

State agencies are often considered the prime avenues for implementation of Partners in Flight (PIF) bird conservation plans. Yet, such agencies already have in place a planning structure, which allows for dispersal of Federal Aid funds and guides management actions. Consequently, superimposing additional planning frameworks (e.g., PIF bird conservation plans) on state agencies may be met with resistance. Maine has successfully overcome these obstacles through an integrated planning approach that uses stakeholder input to set objectives, meets agency commitments under Federal Aid, and culminates in a management system which directs research, management, and outreach activities for species recognized as high priority by PIF. This approach could easily be adapted by other states to better integrate PIF conservation plans into agency operations, and furthermore, offers potential for including public input into development and implementation of state comprehensive wildlife conservation plans.

Key words: assessment, implementation, planning, prioritization, public input, stakeholders.

Introduction

Few persons, if any, back in 1992 thought that implementing conservation programs for landbirds would be simple. Indeed, several authors (Carter et al. 2000, Droege 1993, Smith et al. 1993, Therres 1993) have described some of the various complexities. As a logical consequence, planning has been a featured activity of PIF, since at least 1995, and Donovan et al. (1999) and Mueller et al. (1999) described model approaches toward setting objectives for bird conservation. Donovan et al. (1999) emphasized the need for coordination among local and regional managers. Mueller et al. (1999) appear to have built a coalition of agencies and organizations to set population and habitat objectives for the Mississippi Alluvial Valley. Yet, as of 2002 PIF lacked both the necessary funding and the "foot soldiers" to carry out its work. However, PIF has well documented the needs for bird conservation in its bird conservation plans that, together with a broader partner base, could overcome these limitations.

One of the greatest strengths of PIF has been the development of the bird conservation plans, documents that chart the course for putting landbird conservation on the ground. The power of these plans is in their technical foundations, notably, the species assessment database used to generate the priority species pools. An important weakness, at least for some plans, may be the lack of specific detail in the implementation objectives and the failure to identify who will actually carry out this work. It has been assumed (correctly), that state agencies should take on the primary role of implementing the plans. However, state conservation agencies already employ detailed plans (some more so than others) to direct staff time and expenditures toward wildlife management activities. Additional plans, that may have differing objectives, can be interpreted as unfunded mandates from an outside organization. These can unfortunately detract from agency commitment, building partnerships, and ultimately can form an impediment to landbird conservation. At a time when agencies are developing comprehensive wildlife conservation plans while simultaneously exploring how to include public input into conservation decision-making, an approach that helps to accomplish these would be useful.

The Maine Department of Inland Fisheries and Wildlife (MDIFW) uses a system of stakeholder meetings to set the goals and objectives for state-based wildlife conservation programs. This agency has used this approach extensively for game species and nongame/threatened and endangered species alike. The basic concept was outlined by Anderson and Hurley (1980), but has been modified over time. The MDIFW began to address conservation of passerines in the late 1990s with a report assessing the populations and habitats of over 100 species (Hodgman 1998). That assessment, together with other supporting materials (e.g., PIF plans and priority lists), has been used to launch a series of stakeholder meetings to set state-based conservation objectives for five habitat-based groups of passerines. With these objectives, I began to

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California**.

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focus on devising conservation strategies for songbirds in Maine. The results of these efforts were assembled in a management system that formed the first step toward comprehensive passerine conservation taken by MDIFW.

For the purpose of this report, I define a "management system" as a "planning process that uses public input to set agency objectives for the conservation of species and their habitats." Matula (1988) first described the steps in a management system from which MDIFW decides which and documents how management actions will be taken for a given species. In brief, a management system begins with consensus-driven objectives, documents the decision-making process including data inputs, identifies the management actions (e.g., PR Jobs [conservation programs carried out by state agencies with approval and financial support of Federal Aid]) necessary to accomplish conservation objectives, and provides for annual monitoring of the progress of the system. This approach meets state commitments under the Federal Aid in Wildlife Restoration Act and provides a detailed flowchart of the steps involved in implementation.

In this report, I describe a planning framework that can effectively integrate PIF priorities at the state agency level and give examples (in case-study format) from an actual management system designed for wetland-associated passerines. I hope to provide a model approach that allows the PIF plans and their objectives to be better integrated into existing state programs or to be included in comprehensive wildlife conservation plans.

The Management System Process

Stakeholders Set Goals and Objectives

To be effective, stakeholder groups need to represent the overall community of bird enthusiasts, not merely technical experts. Streamlining this process to include only a subset of the overall community is possible but may lack the breadth of consensus desired. The stakeholder group that I worked with, a subset of the Maine PIF Working Group, was a combination of technical experts, representatives of conservation NGOs, and local birders.

Each stakeholder should begin the process with the same basic understanding of the problem, including species status, current conservation efforts, and other pertinent information. To accomplish this, I found several sources of information useful, including PIF national-level plan (Pashley et al. 2000), the AOU Conservation Reports (Biessinger et al. 2000, Carter et al. 2000), PIF bird conservation plans, PIF Species Assessment Database, and current Breeding Bird Survey (BBS) trends.

Case study

To initiate discussion, stakeholders were asked to itemize their concerns for a species/habitat suite, from which objectives could be set. Participants listed the following issues and concerns for the conservation of wetland passerines:

- Cumulative loss and degradation of wetlands, especially freshwater systems
- Impacts to riparian habitat, especially buffers in coastal areas and along rivers and streams
- Increases in invasive plants
- Recreational use of wetlands (personal watercraft and all terrain vehicles)
- Environmental contaminants
- Water level fluctuations/manipulations
- Forestry practices that alter habitat for long periods or enhance habitat for competitors/predators
- Nuisance situations (damage to agricultural crops, collision with aircraft)
- Outreach needed to increase knowledge and understanding

With these concerns identified, stakeholders drafted an overall goal and several specific conservation objectives for this group of species. The goal is generalized, intended to guide the vision of the stakeholders. The objectives, however, are concise and measurable, attempt to minimize uncertainty, and were determined by stakeholders, not the agency.

Goal: Maintain the diversity and abundance of wetland passerines, and increase understanding and appreciation of wetland passerines and their habitat requirements in Maine.

Population objective: Identify and prioritize species of conservation concern by 2002, determine population trends for these species in Maine by 2009, and develop population objectives for all at-risk species by 2010 (objectives likely will be drafted well in advance of this date, but this timetable allows for collection of preliminary population trend data and sufficient time for Northeast PIF Working Group to draft these objectives for the northeast region and step them down to the state scale).

Habitat objective 1: By 2017, increase the area of upland buffers of salt-marsh habitat in conservation status by 10,000 ha, with at least 4,000 ha in York, Cumberland, and Sagadahoc Counties.

Habitat objective 2: Prioritize peatlands by size, and by 2017 increase the area in conservation status for peatlands by 12,000 ha and adjacent buffers by 24,000 ha.

Habitat objective 3: Identify and prioritize forest riparian and emergent wetland habitats by 2002, and conserve habitat for passerines of forest riparian areas and emergent wetlands at 5 priority sites by 2004 and at 20 additional priority sites by 2017.

Outreach objective: By 2005, develop and begin implementing an outreach program that increases the understanding and appreciation of wetland passerines and their habitat requirements in Maine.

Decision Criteria Identify Management Actions

Despite attempts to be concise, stakeholder-derived objectives may contain multiple tasks within a single objective. Each objective, therefore, may need to be broken into its component parts. I used these components as decision criteria. Individual components are more manageable than the entire objective and should set temporal bounds within an annual workplan.

Decision criteria, when written as a question, lend themselves to yes/no responses suitable for a decision matrix or flowchart (*fig. 1*). Criteria tell exactly what is required for a positive response. They may also contain rules of thumb which identify the quantitative assumptions affecting a positive response.

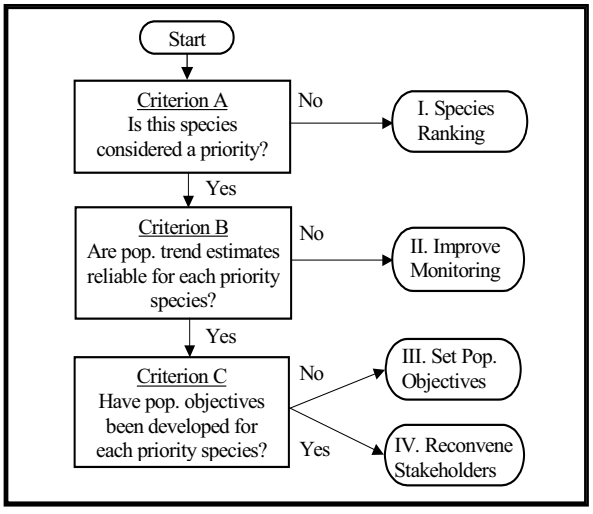

Figure 1— Flow of implementation steps for addressing the population objective and leading to management actions.

Case study: wetland passerines—population objective

Criterion A: Have all species been assessed?

An affirmative response will require that all appropriate prioritization lists (see Management Action I) have been reviewed to determine if any of the species in this group are listed.

Criterion B: Are reliable population trend data available for all priority species?

An affirmative response will require statistically reliable trend estimates based on BBS data for Maine.

> *Rule of thumb:* Trend estimates from the BBS must be based on at least 14 routes with $P < 0.10$ from the most recent half of the BBS period (i.e., currently 1980 to 2002) to be considered reliable.

Criterion C: Have population objectives been determined for all priority species?

An affirmative response is only possible with assistance from a public stakeholder group with input from Northeast PIF Working Group.

Management Actions Accomplish Objectives

Management actions result from responses to decision criteria and identify exactly what will be done, who will do it, and when it needs to be completed. This is an excellent place to re-engage stakeholders in dividing up the tasks necessary to accomplish objectives. The use of volunteer monitors, for example, may be easier to deploy for some stakeholders than others.

Case study: Wetland passerines - management actions

I. Species Ranking

1. Species will be considered a priority and thus addressed by this management system, if species is

   a. Recognized by Partners in Flight as a continental- or regional-level priority (see Rosenberg and Wells, this volume) for either the northern spruce hardwood forest, northern New England, or southern New England physiographic areas, or,

   b. Listed by the U.S. Fish and Wildlife Service as a bird of conservation concern in Region V, or,

c. Considered by MDIFW to be a species of special concern, or,

d. If >5 percent of its global population occurs in Maine.

II. Improve Monitoring

1. If possible, improve BBS coverage by

a. Encouraging long-term commitments by current participants (e.g., to decrease down-time when routes are assigned to new observers).

b. Increasing total number of routes available in Maine. This is not likely as the number of routes was recently increased.

c. Increasing actual participation among currently assigned routes. Increase participation rate to >90 percent of assigned routes run each year. Accomplish this by

- Sending letter to all observers thanking them for their volunteer participation and explaining the importance of BBS data to monitoring species populations.

- Making follow-up phone call to volunteers who have not run their assigned route two or more times in the past five years. Encourage these individuals to resume survey or relinquish route to another qualified individual.

2. Develop separate monitoring programs for species not adequately monitored by the BBS if they are recognized as a priority under Criterion A. This will require additional volunteer support and may be coordinated with Maine Audubon.

III. Set Population Objectives

1. Convene stakeholders to establish population objectives for priority species, based on estimates provided by Northeast PIF Working Group and others.

IV. Reconvene Stakeholders

1. Develop new management system based on accomplishments to date, existing trend data, and revised goals and objectives.

Limitations

A well-crafted plan can be a great accomplishment, but the plan is a waste of time and money if it is never implemented. The above-described process is time-consuming and requires organization and commitment by the agency. Yet, the outcome should engage stakeholders and inject the implementation process with enthusiasm and a sense of ownership. Such detail as I describe is not for everyone, but few agencies would not benefit by adopting or adapting portions of this approach to their operations. Commitment from agency administrators is essential as well (Anderson and Hurley 1980), for if they cannot support the objectives derived by stakeholders, effective implementation may not take place.

Recognizing PIF objectives as a priority can be a challenge given the many competing demands on agency staff. It may be useful to show administrators how participation by their state's staff fits into regional conservation efforts. Successes achieved by flyway technical committees for waterfowl conservation (e.g., regional coordination in setting bag limits, subcommittees made up of agency personnel focused on conservation of a single species or group of species) can serve as an excellent model for an agency. Education of upper administrators by regional (nongame) technical committees or within administrator's organizations themselves probably has been significant in the Northeast.

The approach that I have described is not without shortcomings. The case study was based just on wetland passerines, with other systems developed for forest, shrubland, and grassland species. Hypothetically, other systems would focus on waterfowl, wading birds, and so forth, and, ultimately, objectives could conflict with one another. An integrated system might overcome the taxonomic-based process that I described and that was discussed by the stakeholder group. Furthermore, the management actions are not prioritized nor has a cost estimate been placed on implementing them. This latter step, too, could assist some agencies in further deciding which actions to take first.

Finally, the PIF physiographic plans were used as supporting materials, to bring stakeholders up to speed on bird conservation priorities. Stakeholders did not critique nor modify the PIF plans, and some could argue that the PIF plans should be developed with greater consensus from all partners, thus alleviating the need for this state-based approach. I would suggest, however, that many states, at least in the Northeast, would prefer to build consensus themselves within their states, with the partner organizations that they work with on a daily basis. The state PIF working group is an obvious place where this could take place, but only if it has standing with agency administrators.

To date, the stakeholder group that I worked with has not set population objectives because Northeast PIF has only recently refined state level objectives. At a future stakeholder meeting, I believe the PIF population

objectives, at least for priority species, could be reviewed and incorporated into a revised management system. As Donovan et al. (1999) suggested, a plan should be reviewed annually and significant revisions made at intervals of 5 years with full rewrite and reconvening of stakeholders at no greater than 15-year intervals.

Conclusions

Avian conservation, like many other aspects of resource management is most effective when all parties agree on a common conservation goal and how to reach that desired end point. Unfortunately, this terminus, and the path leading to it, often are not clearly identified, and all too often are not well articulated among stakeholders. Either situation can result in conflict and ultimately in the failure to achieve meaningful conservation. Furthermore, the needs for landbird conservation far outnumber the funds available to address them at this time. As such, efficient methods for prioritizing and sharing the duties of implementation are needed. To its benefit, PIF initiative is replete with priority setting. But, broad consensus between and within states is still needed and, if successfully built, would focus all state-based stakeholders (e.g., agencies, state chapters of Audubon and The Nature Conservancy, and so forth) in a unified direction as well as give them a sense of ownership of the process and in its success.

The North American Waterfowl Management Plan often has been cited as a model for implementing migratory bird conservation (e.g., Mueller et al. 1999). The success of the Waterfowl Management Plan is a result of much hard work by many individuals over many years. Much of that success stems from the commitment by state and provincial agencies to achieve the objectives of the plan and through the teamwork or consensus facilitated through the various Joint Ventures, and, of course, a source of funding though the North American Wetlands Conservation Act (NAWCA).

As a state biologist, I can attest that the commitment by my agency in terms of staff time devoted to wetland acquisition, habitat improvement, and waterfowl monitoring appears pervasive, and by any objective measure is literally part of agency culture. For PIF to approach the same degree of success, parallel conditions should be in place. An upland equivalent to NAWCA or deeper funding of the Neotropical Migratory Bird Conservation Act is an obvious prerequisite. Perhaps if PIF conservation plans are in some way included in state comprehensive wildlife conservation plans, over time we will begin to see greater implementation by states. However, agency commitment at all levels and participation by federal partners and nongovernmental organizations alike, as well as their constituents, will be critical in both a shared vision of what needs to be accomplished (gathered through stakeholder meetings) and in sharing the load of conducting conservation activities.

Acknowledgments

The case study presented here resulted from actual stakeholder meetings held during summer and fall 2000. I'd like to thank all the organizations and individuals who participated in that series of discussions. Comments of G. J. Matula, Jr. were instrumental in revising the draft management system. S. L. Ritchie and R. B. Allen also helped guide me through the process. S. L. Ritchie, K. V. Rosenberg, and an anonymous reviewer critically reviewed drafts of an earlier manuscript.

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Integrated Migratory Bird Planning in the Lower Great Lakes/ St. Lawrence Plain Bird Conservation Region[1]

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Abstract

The Atlantic Coast and Eastern Habitat Joint Ventures hosted two international planning workshops to begin the process of integrating bird conservation strategies under the North American Bird Conservation Initiative in the Lower Great Lakes/St. Lawrence Plain Bird Conservation Region. The workshops identified priority species and habitats, delineated focus areas, discussed population and habitat objectives, and began developing a long-term conservation plan. The objective of this effort is to provide a seamless, coordinated effort to deliver on-the-ground conservation for high priority species among the partners in the United States and Canada in the Lower Great Lakes/St. Lawrence Plain Bird Conservation Region.

Introduction

Habitat conservation planning for migratory birds has evolved at a rapid rate since the signing of the North American Waterfowl Management Plan (Plan) in 1986 that articulated population and habitat objectives for waterfowl across the continent. Since the Plan, three other bird conservation initiatives have begun planning on various scales. These initiatives (Partners in Flight, North American Waterbird Conservation Plan, and the U.S. and Canadian Shorebird Conservation Plans) have completed continental, national, or regional plans that set forth population and habitat goals. The North American Bird Conservation Initiative (NABCI) was established to integrate planning efforts among these initiatives to deliver habitat conservation in a more coordinated and efficient manner. Bird Conservation Regions (BCR), delineated across North America, were adopted by NABCI as a common geographical language to help planning efforts within regions of similar habitat types and species composition.

The Atlantic Coast Joint Venture (ACJV) adopted the NABCI concept in 1999 to plan and deliver habitat conservation for all migratory birds along the Atlantic coast. The South Atlantic Migratory Bird Initiative (SAMBI), the ACJV's first all-bird planning effort, met with great success in identifying important species and habitats and delivering conservation on the ground. The Lower Great Lakes/St. Lawrence Plain International Bird Conservation Initiative (Initiative) is the second all-bird planning effort in the ACJV (*fig. 1*). This effort differs from SAMBI in that it is international in scope with the BCR split about 50 percent in the United States and 50 percent in Canada and involves coordinating with the Eastern Habitat Joint Venture (EHJV), the ACJV's sister joint venture in Canada. The objective of the Initiative is to create a seamless, coordinated effort among the many partners in the United States and Canada to deliver habitat conservation for high priority migratory bird species within the Lower Great Lakes/St. Lawrence Plain BCR.

Process of Establishing International Priorities and Strategies

International Planning Workshops

In December 2000 an initial scoping meeting was held in Gananoque, Ontario to explore a common vision for migratory bird conservation in the Lower Great Lakes/St. Lawrence Plain Bird Conservation Region (BCR 13). The objectives of the meeting were to learn about the structure and delivery mechanisms of the EHJV and ACJV, the status of planning among the four bird conservation initiatives in each country, the importance of BCR 13 to all birds, and potential models for implementation. However, the primary

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objective was to discuss the importance of a cross-border initiative and to begin planning for an international workshop that would identify and set goals for priority species and habitats and develop strategies to deliver conservation within the BCR.

Two international workshops were held to begin the process of integrated bird conservation in BCR 13. The first workshop was held April 17-19 in Alexandria Bay, New York. The emphasis of this workshop targeted planning that involved developing priorities for the BCR. Sixty-five biologists attended representing governmental and non-governmental organizations from the United States and Canada. The major objectives of this workshop were to provide a forum for information exchange regarding the status of planning of each migratory bird initiative within each country, identify priority migratory bird species, identify priority habitats based on the priority species, begin discussion on the process for setting population and habitat goals, and define new or revise existing focus areas. The second workshop was held November 28-29 in Montreal, Quebec. The emphasis of this workshop was on discussing the strategies necessary in achieving the conservation objectives developed in the first workshop. Specifically, the objectives of this workshop were to refine the information generated from the first workshop, discuss potential first-step projects, and generate an outline for a long-term conservation plan. The make-up of the attendees for the second workshop differed slightly from the first. Forty-five biologists attended the second workshop with a greater percentage of land managers than in the first workshop.

One of the primary objectives of the workshops was the exchange information on the status of planning in the United States and Canada relative to the migratory bird initiatives and to create an open communication link and dialogue between the countries and among the state and provincial jurisdictions. Another objective was to become familiar with the structure, process, and modes of implementation between the countries and among organizations and agencies. The first workshop opened with status reports from representatives of the migratory bird initiatives from each country, the ACJV and EHJV, NABCI, and Audubon's Important Bird Areas program. These reports were designed to inform the attendees of the status of planning within each initiative and joint venture. The second workshop focused more on the identification of projects, funding, and the process of implementing on-the-ground activities. In addition, the coordinator from the South Atlantic Migratory Bird Initiative presented the progress of this initiative since its inception in 1999. This initiative has been a very successful effort within the ACJV and the presentation was designed to show attendees the potential success of an all-bird effort.

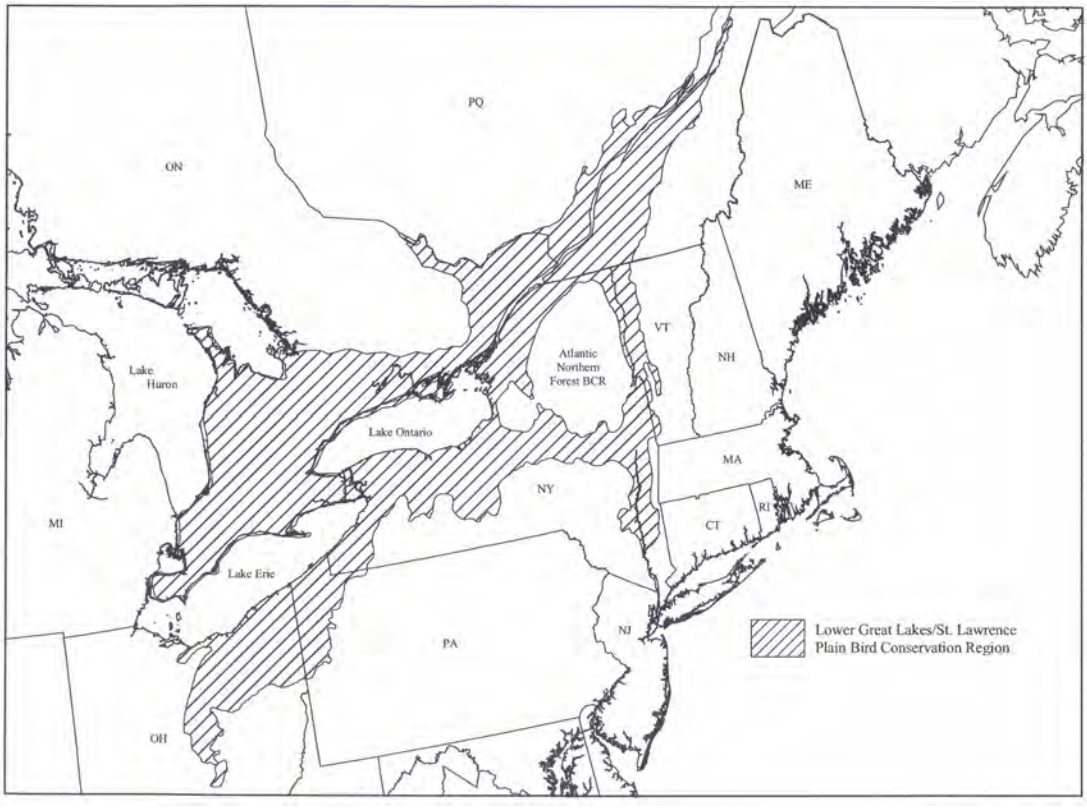

Figure 1— Current boundary of the Lower Great Lakes/St. Lawrence Plain Bird Conservation Region.

The structure of the workshops was centered on breakout groups for each migratory bird initiative; landbirds, shorebirds, waterbirds, and waterfowl. Experts or those interested in a particular initiative met in concurrent and separate groups to develop the information necessary to achieve the goals outlined for each breakout group. In the first workshop each group was charged to develop a list of priority species, priority habitats, delineate focus areas, and discuss the potential for population and habitat objectives. Each workgroup was assigned a United States and Canadian co-leader to guide the discussion and record the information. The information developed during the first workshop was taken back by the representatives of each state and provincial jurisdiction to their respective states or provinces for further discussion and refinement. The structure of the second workshop was similar to the first with each of the initiatives breaking out into separate groups to discuss the information developed in the first workshop and refined by the jurisdictions. Final species lists, priority habitats, and focus areas were generated during the second workshop.

Workshop Results

Priority Species and Habitats

Generating species lists for BCR 13 precipitated discussion on several issues. The lists needed to be inclusive but not so long as to have a dilution effect. We needed to weigh the value of the region to each species. If the species relies on BCR 13 for some portion of its annual cycle, then it should be on the list. However, we recognized that not all species should be treated the same. A three-tiered framework was imposed for including species on the priority list. Tier A included those species in which BCR 13 is critical to their annual cycle, listed as continental or regional priorities by one of the migratory bird initiatives, rare or declining species, or those with significant threats. Tier B species are those birds that are considered important to specific jurisdictions but BCR 13 is not critical to their annual survival. Also, Tier B species may be representative of specific habitat suites considered important in the region. Tier C species are birds of management concern. These include species that have become overabundant or nuisance. Forty-three species were identified in Tier A, 45 in Tier B, and 6 in Tier C (*table 1*).

Priority habitats were identified based on the list of species generated from each working group. Many of the priority habitats identified were very specific to each working group and to specific species. To create a list of priority habitats common to the BCR for integration among the bird groups, the specific habitats were aggregated into broader categories (*tables 2* and *3*). A common habitat language is being developed to help with communicating habitat types, assessment, and conservation needs across the border and among states and provinces. We believe a common habitat language should be broad in scope to facilitate regional habitat analysis and provide easy communication across jurisdictions. Detailed, project-specific, habitat classifications will default to the classification system in use by each individual jurisdiction.

Delineation of Focus Areas

Delineation of focus areas is the key to efficiently and effectively delivering habitat conservation in the Initiative. Although actual conservation of habitat is performed on site-specific projects, it is important that focus areas are developed within the context of landscape-level conservation and biodiversity. Focus areas should be regionally important to one or more life-history stages or seasonal-use periods of migratory birds and they should be discrete and distinguishable habitats or habitat complexes demonstrating clear ornithological importance from surrounding areas (U.S. Fish and Wildlife Service 1996, Wells 1998). Focus areas must be large enough to supply all the necessary requirements for survival during the season for which it is important. However, small disjunct areas important for the survival of migratory birds should be identified along with their biological connection. For example, a feeding area for nesting herons may be several miles from the heronry. Both areas are important to the survival and nesting success of the herons, but the area between the two important habitats may not be important for herons. This area should not be identified as critical to heron survival. In short, focus areas must be ecologically-based areas of special significance to migratory birds where limited financial or conservation-oriented resources can be expended to have meaningful positive effects on migratory bird populations.

Each workgroup identified and delineated preliminary focus areas in the first workshop. The delineations were digitized and distributed to the state and provincial representatives for further consultation and refinement. Changes in focus area boundaries in the United States were submitted to the ACJV for modification. The boundary modifications were presented at the second workshop with further refinements made to the focus areas (*figs. 2-5*).

Table 1— *Priority species list for the Lower Great Lakes/St. Lawrence Plain Bird Conservation Region.*

Work group	Species			
	Tier A		Tier B	Tier C
Landbirds	American Woodcock (*Scolopax minor*)	Henslow's Sparrow (*Ammodramus henslowii*)	Bank Swallow (*Riparia riparia*)	Long-eared Owl (*Asio otus*)
	Bald Eagle (*Haliaeetus leucocephalus*)	Loggerhead Shrike (*Lanius ludovicianus*)	Belted Kingfisher (*Ceryle alcyon*)	Louisiana Waterthrush (*Seiurus motacilla*)
	Bobolink (*Dolichonyx oryzivorus*)	Red-headed Woodpecker (*Melanerpes erythrocephalus*)	Black-throated Blue Warbler (*Dendroica caerulescens*)	Northern Goshawk (*Accipiter gentilis*)
	Brown Thrasher (*Toxostoma rufum*)	Short-eared Owl (*Asio flammeus*)	Canada Warbler (*Wilsonia canadensis*)	Northern Harrier (*Circus cyaneus*)
	Cerulean Warbler (*Dendroica cerulea*)	Upland Sandpiper (*Bartramia longicauda*)	Chimney Swift (*Chaetura pelagica*)	Red-shouldered Hawk (*Buteo lineatus*)
	Golden-winged Warbler (*Vermivora chrysoptera*)	Whip-poor-will (*Caprimulgus vociferus*)	Common Loon (*Gavia immer*)	Sedge Wren (*Cistothorus platensis*)
			Common Nighthawk (*Chordeiles minor*)	Wood Thrush (*Hylocichla mustelina*)
			Eastern Wood-Peewee (*Contopus virens*)	Yellow-bellied Sapsucker (*Sphyrapicus varius*)
			Field Sparrow (*Spizella pusilla*)	Yellow Palm Warbler (*Dendroica palmarum*)
			Grasshopper Sparrow (*Ammodramus savannarum*)	Yellow-shafted Flicker (*Colaptes auratus*)
Shorebirds	American Golden-Plover (*Pluvialis dominica*)	Red Knot (*Calidris canutus*)	Black-bellied Plover (*Pluvialis squatarola*)	Lesser Yellowlegs (*Tringa flavipes*)
	American Woodcock (*Scolopax minor*)	Sanderling (*Calidris alba*)	Dunlin (*Calidris alpina*)	Semipalmated Sandpiper (*Calidris pusilla*)
	Buff-breasted Sandpiper (*Tryngites subruficollis*)	Short-billed Dowitcher (*Limnodromus griseus*)	Greater Yellowlegs (*Tringa melanoleuca*)	Wilson's Phalarope (*Phalaropus tricolor*)
	Hudsonian Godwit (*Limosa haemastica*)	Solitary Sandpiper (*Tringa solitaria*)	Least Sandpiper (*Calidris minutilla*)	
	Marbled Godwit (*Limosa fedoa*)	Upland Sandpiper (*Bartramia longicauda*)		
	Piping Plover (*Charadrius melodus*)	Whimbrel (*Numenius phaeopus*)		

Table 1— *contd.*

Work group	Species				
	Tier A		**Tier B**		**Tier C**
Waterbirds	American Bittern (*Botaurus lentiginosus*)	American Coot (*Fulica americana*)	Sandhill Crane (*Grus canadensis*)		Double-crested Cormorant (*Phalacrocorax auritus*)
	Black-crowned Night Heron (*Nycticorax nycticorax*)	Caspian Tern (*Sterna caspia*)	Sora (*Porzana carolina*)		Great Black-backed Gull (*Larus marinus*)
	Black Tern (*Chlidonias niger*)	Common Moorhen (*Gallinula chloropus*)			Ring-billed Gull (*Larus delawarensis*)
	Common Loon (*Gavia immer*)	Great Blue Heron (*Ardea herodias*)			
	Common Tern (*Sterna hirundo*)	Great Egret (*Ardea alba*)			
	King Rail (*Rallus elegans*)	Green Heron (*Butorides virescens*)			
	Least Bittern (*Ixobrychus exilis*)	Herring Gull (*Larus argentatus*)			
	Virginia Rail (*Rallus limicola*)	Pied-billed Grebe (*Podilymbus podiceps*)			
	Yellow Rail (*Coturnicops noveboracensis*)	Red-necked Grebe (*Podiceps grisegena*)			
Waterfowl	American Black Duck (*Anas rubripes*)	Greater Snow Goose (*Chen caerulescens*)	Barrow's Goldeneye (*Bucephala islandica*)	Northern Pintail (*Anas acuta*)	Canada Goose[b] (*Branta canadensis*)
	Blue-winged Teal (*Anas discors*)	Lesser Scaup (*Aythya affinis*)	Common Goldeneye (*Bucephala clangula*)	Redhead (*Aythya americana*)	Greater Snow Goose (*Chen caerulescens*)
	Canada Goose[a] (*Branta canadensis*)	Long-tailed Duck (*Clangula hyemalis*)	Common Merganser (*Mergus merganser*)	White-winged Scoter (*Melanitta fusca*)	Mute Swan (*Cygnus olor*)
	Canvasback (*Aythya valisineria*)	Mallard (*Anas platyrhynchos*)			
	Greater Scaup (*Aythya marila*)	Wood Duck (*Aix sponsa*)			

[a]Canada Goose includes the Atlantic Population and Southern James Bay Population.
[b]Canada Goose in this list refers to resident Canada geese.

Table 2— *Aggregate wetland habitat types and definitions from the Lower Great Lakes/St. Lawrence Plain Bird Conservation Region workshops.*

Aggregate category	BCR 13 workshop habitat classification	Definition
Open Water (open water)	Open Water - *Waterbirds* Palustrine Open Water - *Waterfowl*	Open water lacking any vegetation. Make up of the bottom is unconsolidated material, bedrock, or unknown. Lacustrine, riverine, palustrine, and estuarine.
Emergent Marsh (open wetland)	Sedge Meadow - *Waterbirds* Freshwater Wetland - *Waterbirds* (Open) Wetlands - *Waterfowl* Marsh-Wetlands - *Landbirds* Small, dispersed, marshy, shallow wetlands (ranging from ditches to lakeshores) - *Shorebirds*	Emergent marshes dominated by persistent and non-persistent vegetation. Lacustrine, riverine, palustrine, and estuarine. Includes sheetwater wetlands important in the St. Lawrence Plain.
Scrub-Shrub	Forested Wetlands - *Waterfowl*	Wetlands dominated by woody vegetation less that 6 m tall. Includes shrubs, young trees, or stunted trees and shrubs. May represent a successional stage leading to forested wetlands. Lacustrine, palustrine, and estuarine.
Submerged Aquatics (open wetland)	(Open) Wetlands - *Waterfowl*	"Open" water wetlands dominated by plants that grow principally at or under the surface of the water. Lacustrine, riverine, palustrine, and estuarine. Includes aquatic beds of NWI.
Forested (treed wetland)	Riparian Forest - *Waterbirds* Floodplain or Bottomland Forests - *Waterfowl* Forested Wetlands - *Waterfowl* Riparian (including beaver flowages) - *Waterfowl*	Wetlands dominated by woody vegetation 6 m or taller. Generally, associated with palustrine systems adjacent to riverine systems, including beaver flowages.
Unconsolidated Shore - Sand	Broad sand and gravel beaches of the southern Great Lakes - *Shorebirds* Mud- and sandflats and sandspits, particularly in the St. Lawrence River and Great Lakes - *Shorebirds* Bare shoreline shoals - *Waterbirds*	Generally, these habitats would be described as sandy shores, exposed sand flats, sandspits, and gravel beaches. The flooding regime is that of irregularly exposed, regularly flooded, irregularly flooded, seasonally flooded, temporarily flooded, intermittently flooded, saturated, or artificially flooded. Lacustrine, riverine, palustrine, and estuarine. Includes unconsolidated bottom. Also, estuarine systems can be both subtidal and intertidal.
Unconsolidated Shore - Mud	Mud- and sandflats and sandspits, particularly in the St. Lawrence River and Great Lakes - *Shorebirds*	Areas dominated by particles smaller than stones with virtually no vegetation. See Unconsolidated Shore - Sand for definition of flooding regimes. Lacustrine, riverine, palustrine, and estuarine.

Table 3— *Aggregate upland habitat types and definitions from the Lower Great Lakes/St. Lawrence Plain Bird Conservation Region workshops.*

Aggregate category	BCR 13 workshop habitat classification	Definition
Deciduous Forest (deciduous forest)	Uplands Associated with Wetlands - *Waterfowl* Deciduous Forest - *Landbirds*	A diverse assemblage of deciduous hardwoods make up the forested component of this BCR including maple, oak, hickory, beech, and birch associations.
Mixed Forest (mixed forest)	Uplands Associated with Wetlands - *Waterfowl* Mixed (northern hardwood/coniferous) Forest - *Landbirds*	See Deciduous forests with a conifer mix. Dominant species?
Shrub/Early Successional (transitional)	Uplands Associated with Wetlands - *Waterfowl* Shrub-early successional - *Landbirds* Early successional woodlots, short shrub - *Shorebirds*	Includes shrubs such as alders and seedling/sapling trees such as aspen and birch.
Grassland - native or artificial (hay and pasture)	Uplands Associated with Wetlands - *Waterfowl* Grasslands - *Landbirds* Agriculture/Grasslands - *Waterbirds*	This category mainly includes pastures, haylands, and fallow fields.
Agriculture (agricultural)	Uplands Associated with Wetlands - *Waterfowl* Onion fields in SW Ontario - *Shorebirds* Agriculture/Grasslands - *Waterbirds*	All agriculture not associated with pastures/grasslands. Row crops.
Artificial Cover	Other - *Landbirds*	Rooftops

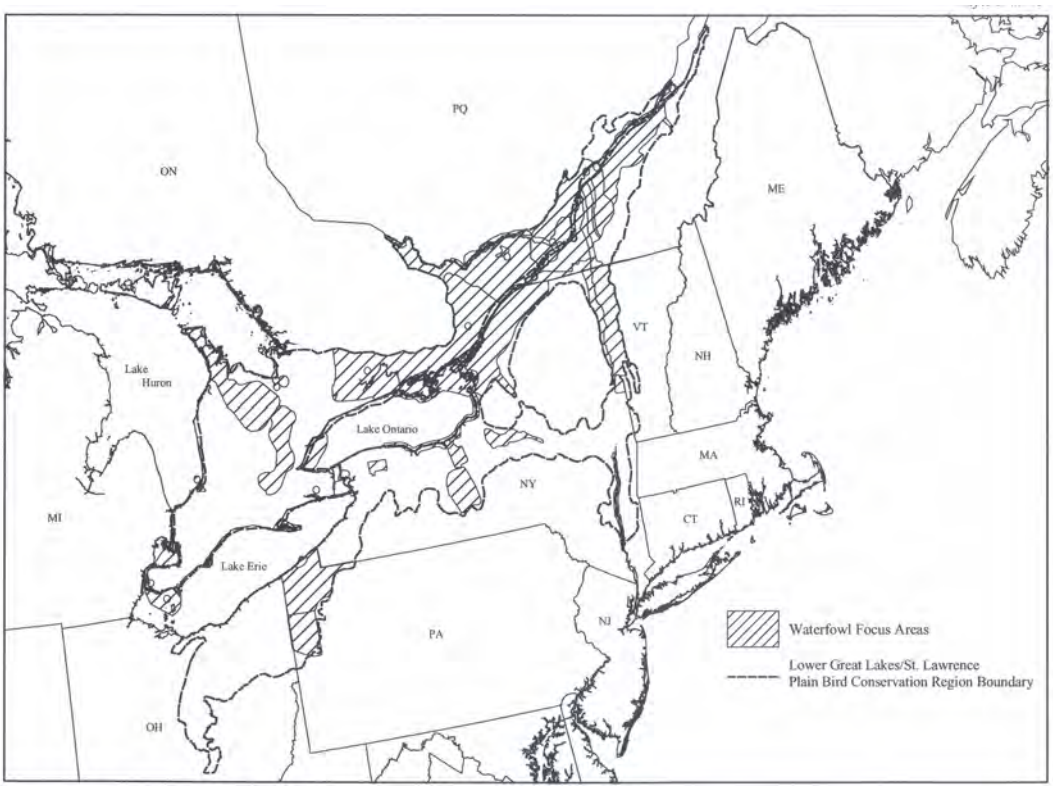

Figure 2— Waterfowl focus areas identified for the Lower Great Lakes/St. Lawrence Plain Bird Conservation Region.

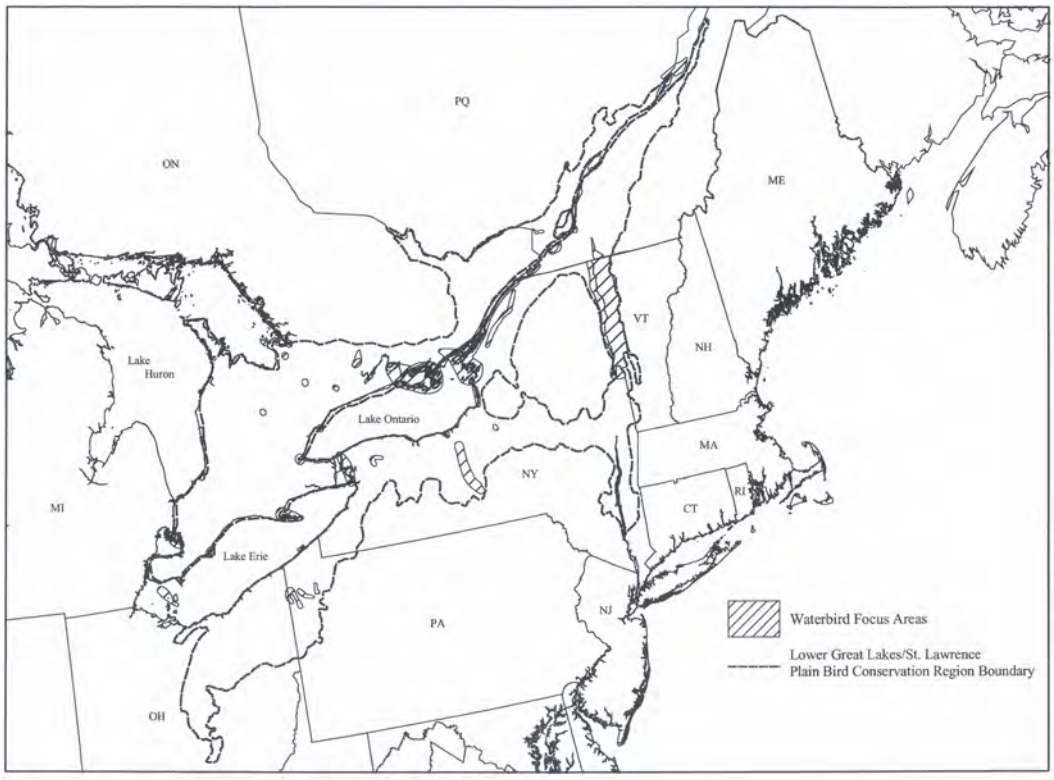

Figure 3— Waterbird focus areas identified for the Lower Great Lakes/St. Lawrence Plain Bird Conservation Region.

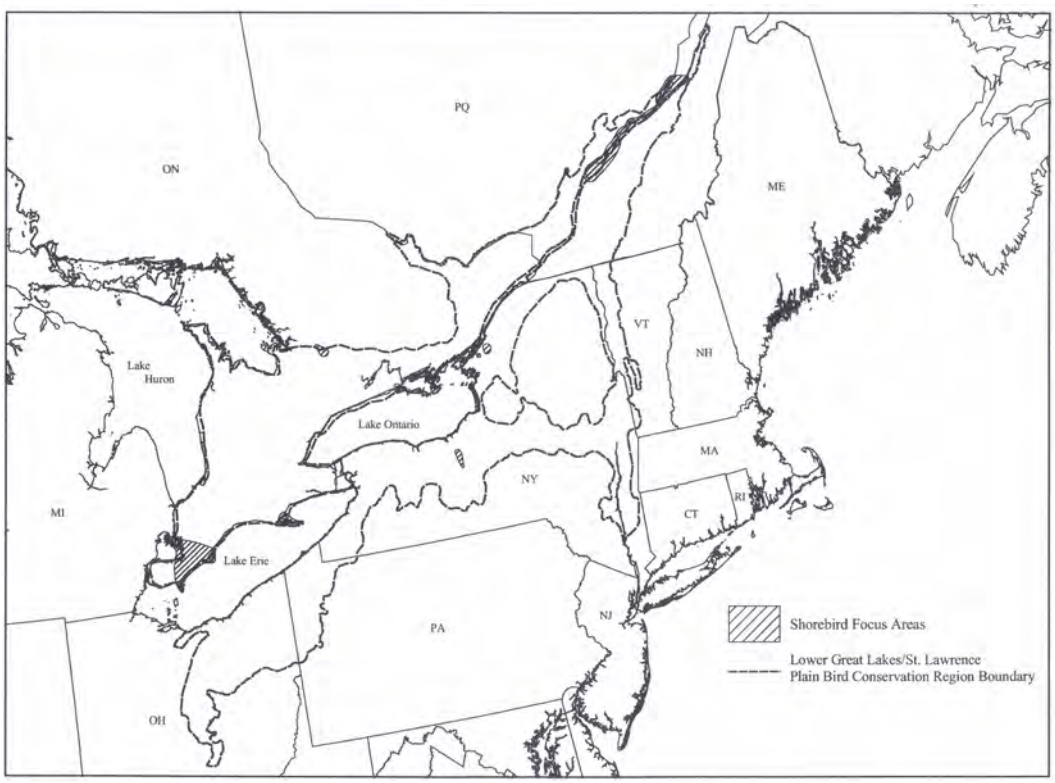

Figure 4— Shorebird focus areas identified for the Lower Great Lakes/St. Lawrence Plain Bird Conservation Region.

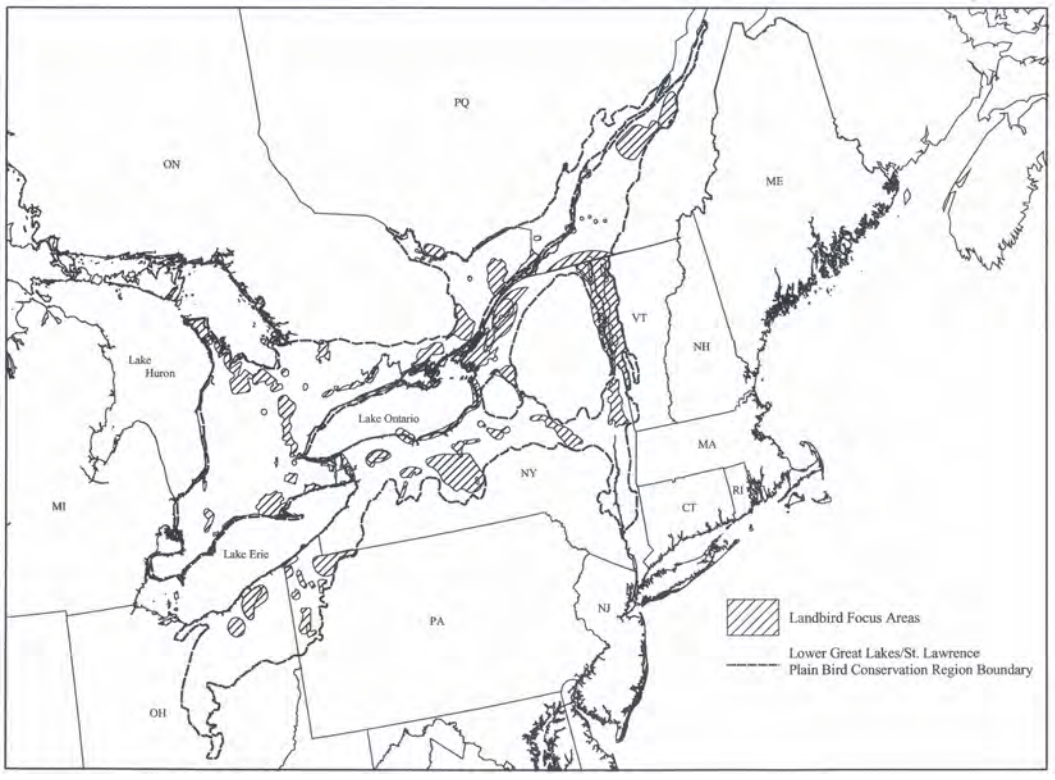

Figure 5— Landbird focus areas identified for the Lower Great Lakes/St. Lawrence Plain Bird Conservation Region.

Population and Habitat Goals

Although population and habitat goals were addressed, specific goals were established for relatively few species. We recognized the lack of basic population information for many species and the migration/staging emphasis of BCR 13. It was agreed that more basic demographic information was needed for most species to establish and monitor population objectives. The lack of discrete population objectives prevented establishing habitat objectives, although the consensus among the working groups was that the lack of population or habitat goals should not impede progress in protecting critical habitats identified by the workshop within focus areas. We may choose to focus on a few key species with the greatest needs to represent other species and priority habitat types.

Population estimates have been derived for the landbird species through the Breeding Bird Survey (BBS) in the Partners in Flight Physiographic Plans (Rosenberg 2001). Habitat objectives have been extrapolated from the estimates. However, alternative methods for population goals were discussed that included monitoring Breeding Bird Atlas blocks for changing distribution in atlas blocks. This method may be more appropriate for those species difficult to detect on the BBS. The landbird group decided to maintain current populations and distribution except where species showed significant declines where the goal would be to stop the decline. The shorebird working group concluded that insufficient information exists to set meaningful population or habitat goals for breeding or migrant species. However, improved surveys would allow for setting justifiable goals. A better understanding of carrying capacity is needed to set habitat goals especially for migrant shorebirds. The waterbird working group developed population goals only for the colonial nesting species (6 of 16 species) because population estimates were not available for secretive marsh-nesting birds. Population goals for many species of waterfowl may not be relevant in this BCR. Only a few species breed in BCR 13 with any density, such as mallards. The waterfowl group agreed that maintenance of quality habitat to support the populations that currently exist would be sufficient until better information becomes available.

Perspectives on Integrated Bird Conservation

The vision statement developed for this Initiative states to "Integrate international planning and implementation efforts among the four migratory bird initiatives across the Lower Great Lakes/St. Lawrence Plain Bird Conservation Region." The workshops were designed to follow the major tenet of NABCI, that is, to maintain the autonomy of each migratory bird initiative but open communication among the initiatives to facilitate integration. We did this by having each initiative develop their own priorities based on established national or regional planning efforts. Integration among the initiatives is generated by bringing together the priorities of each group and evaluating overlaps in these priorities, mainly through priority habitats.

To facilitate developing integrated, cross-border projects, the BCR was divided into three focus regions to pursue first-step projects. These focus regions are areas of overlap of high priority species and habitats and should be more successful at capturing funds, generating multi-agency collaboration, and benefitting the most species. A number of priority species identified use the extensive agricultural landscape in both the United States and Canada and the extensive wetlands within these areas. The focus regions identified for first-step projects were the Lake Champlain/Richelieu River/Ottawa River region, the Lake Ontario Plain/Upper St. Lawrence River Valley region, and Lake Erie/Niagara River region (*fig. 6*). Participants of the second workshop formed breakout groups for each focus region. The breakout groups discussed the priority species and habitats found within each region and potential first-step projects. Although habitat-oriented conservation projects were targeted, it did not limit the discussion. Many topics were discussed including expanding research and monitoring efforts.

Successful first-step projects are a key to building momentum and interest in partners. The South Atlantic Migratory Bird Initiative was able to establish a number of successful first-step projects. These successes have generated interest in SAMBI from a number of different partners and has led to many more projects and, importantly, many new partners. The goal of the first-step projects in BCR 13 is to establish the ability to get cross-border projects identified, funded, and completed. The focus of first-step projects is to be on habitat conservation and generate support for NABCI (i.e., multiple species). The differences in funding processes and timing between Canada and the United States was not considered a problem relative to funding through the North American Wetlands Act, currently the major source of conservation funding. Communication would be critical in establishing linked, cross-border projects. Many of the partners currently are working towards first-step projects with some in the development stage. For example, partners from the United States and Canada are currently working toward a cross-border project in the Lake Champlain/Richelieu River/Ottawa River Focus Region. Also, participants of the BCR 13 workshops recognize the importance of pursuing important priorities for single bird groups such as shorebirds or landbirds. Therefore, future projects will not be dictated solely on their contribution

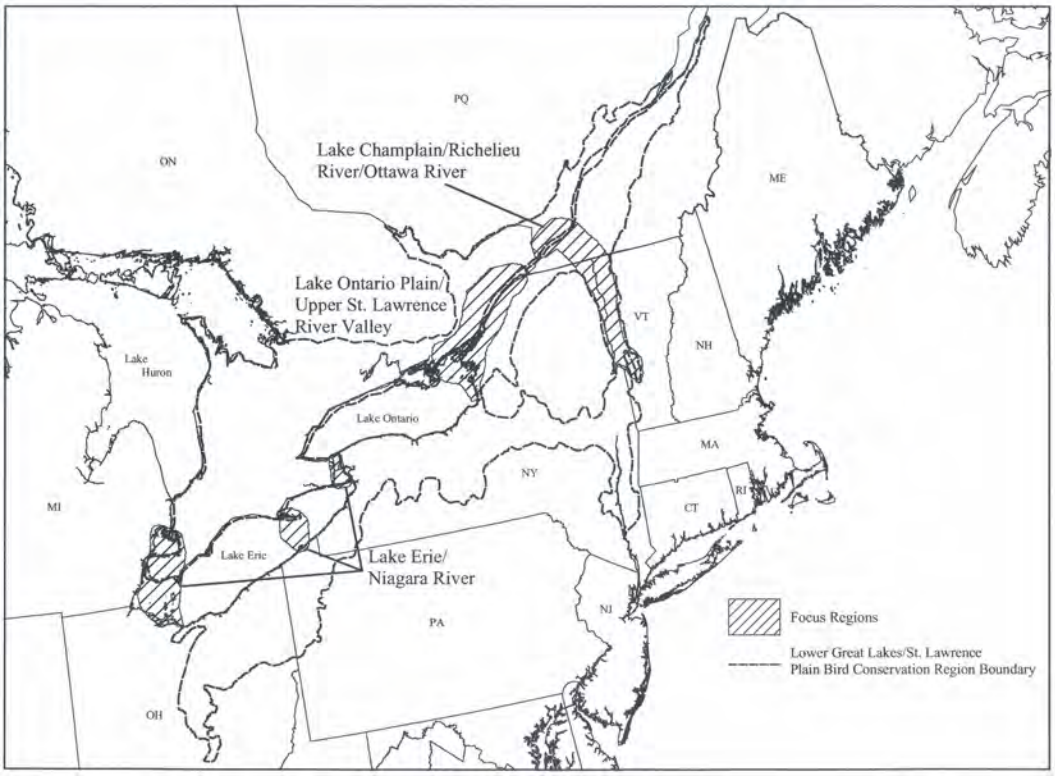

Figure 6— Focus regions identified for the Lower Great Lakes/St. Lawrence Plain Bird Conservation Region.

to multiple species but, also, to their contributions to regional biodiversity.

A conservation plan for the Initiative currently is being developed. The plan will incorporate the objectives developed in the two workshops with periodic updates as more information becomes available. The elements of the conservation plan should provide biological guidance to all jurisdictions regardless of strategies used to obtain goals and it must recognize the role this BCR plays in the continental perspective. It must define what the BCR landscape will be in the future to help guide conservation actions. The science needs of BCR 13 are important and will be addressed. We lack much of the basic information needed to establish defensible population objectives and, thus, habitat objectives. Also, we need to establish evaluation methods to provide feedback in our efforts to protect priority habitats for priority species.

Conclusion

The interest in the Lower Great Lakes/St. Lawrence Plain Initiative proved to be beyond original expectations. The issue of an international border splitting the BCR was not considered an impediment to accomplishing the goals set forth by the workshops. The workshops were very successful in achieving the goals; identifying priority species and priority habitats, delineating focus areas, discussing population and habitat goals, and beginning the process of developing integrated projects. A number of tasks and issues remain to be resolved within the BCR 13 initiative with some of these in a constant state of revision. These include further development of a common habitat language, discussion of population and habitat objectives, pursuit of research and monitoring needs and funding, and continued communication among partners in all the jurisdictions in the United States and Canada. A conservation plan is being developed that will bring all this information together and provide strategies and guidance in achieving the stated goals. The plan will be simple by establishing what we know about the priority species and habitats based on the best information available, establish focus areas, identify science needs and the resources needed to address the needs, and have a vision for the Lower Great Lakes/St. Lawrence Plain Bird Conservation Region that all partners can agree upon.

Acknowledgments

The planners of the BCR 13 workshops would like to thank the breakout group co-leaders for doing the

majority of the work in the workshops. These include B. Pollard (Ontario Ministry of Natural Resources) and D. Odell (New York Department of Environmental Conservation) for waterfowl; B. Miller and B. Swift (New York Department of Environmental Conservation) and C. Weseloh (Canadian Wildlife Service) for waterbirds; S. Brown (Manomet Center for Conservation Sciences), B. Russell (U.S. Fish and Wildlife Service), and K. Ross (Canadian Wildlife Service) for shorebirds; and J. Kennedy (Canadian Wildlife Service) for landbirds.

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Bird Habitat Conservation at Various Scales in the Atlantic Coast Joint Venture[1]

Andrew Milliken,[2] Craig Watson,[3] and Chuck Hayes[4]

Abstract

The Atlantic Coast Joint Venture is a partnership focused on the conservation of habitats for migratory birds within the Atlantic Flyway/Atlantic Coast Region from Maine south to Puerto Rico. In order to be effective in planning and implementing conservation in this large and diverse area, the joint venture must work at multiple spatial scales, from the largest – flyways and Bird Conservation Regions, to the smallest – focus areas and individual projects. In this paper, we describe the activities of the Atlantic Coast Joint Venture at these various scales and discuss the implications and opportunities for all-bird conservation within this large region.

Introduction

The Atlantic Coast Joint Venture (ACJV) is a partnership among the 17 Atlantic Flyway state wildlife agencies, Puerto Rico, federal agencies, non-governmental organizations and others focused on habitat conservation for migratory birds in the Atlantic Flyway of the United States (*fig. 1*). The ACJV was one of the original joint ventures formed under the North American Waterfowl Management Plan and its original focus was on protecting and restoring migration and wintering habitat for American Black Duck (*Anas rubripes*) and other waterfowl species in the Atlantic Coast region of the United States. While the joint venture maintains a strong focus on waterfowl, in recent years its mission has evolved to include the conservation of habitats for all birds consistent with the vision of the North American Bird Conservation Initiative and the major national and North American bird conservation plans (North American Waterfowl Management Plan, Partners in Flight, U.S. Shorebird Conservation Plan and North American Waterbird Conservation Plan). The three principles guiding conservation in the joint venture are: maintaining a strong and diverse partnership, basing conservation actions upon a solid scientific foundation and using a landscape approach to conservation. To be effective in such a large and diverse area, planning and implementation of bird habitat conservation takes place at a variety of scales in the joint venture including flyway, regional, and local scales.

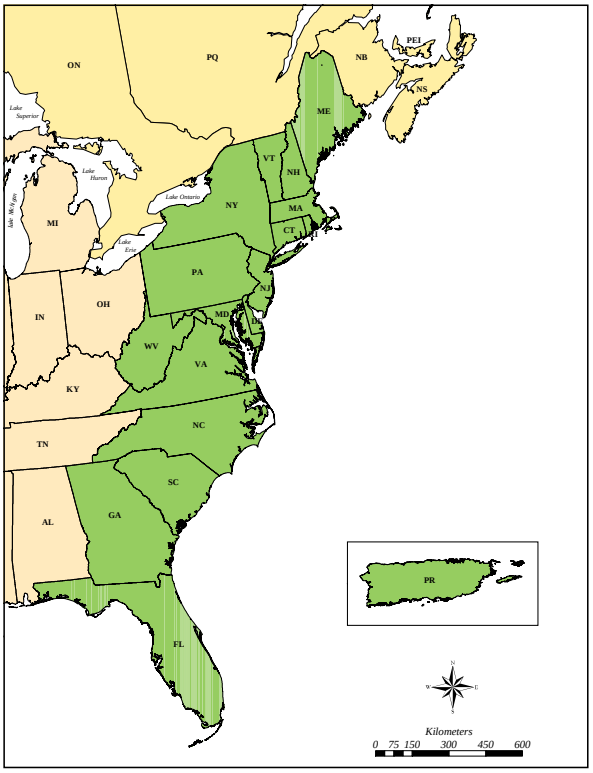

Figure 1— Map of the Atlantic Coast Joint Venture Area. Members of Joint Venture Include Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Delaware, Maryland, Virginia, West Virginia, North Carolina, South Carolina, Georgia, Florida, Puerto Rico, U.S. Fish and Wildlife Service, U.S. Forest Service, National Park Service, National Fish and Wildlife Foundation, Ducks Unlimited, The Nature Conservancy.

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California**.

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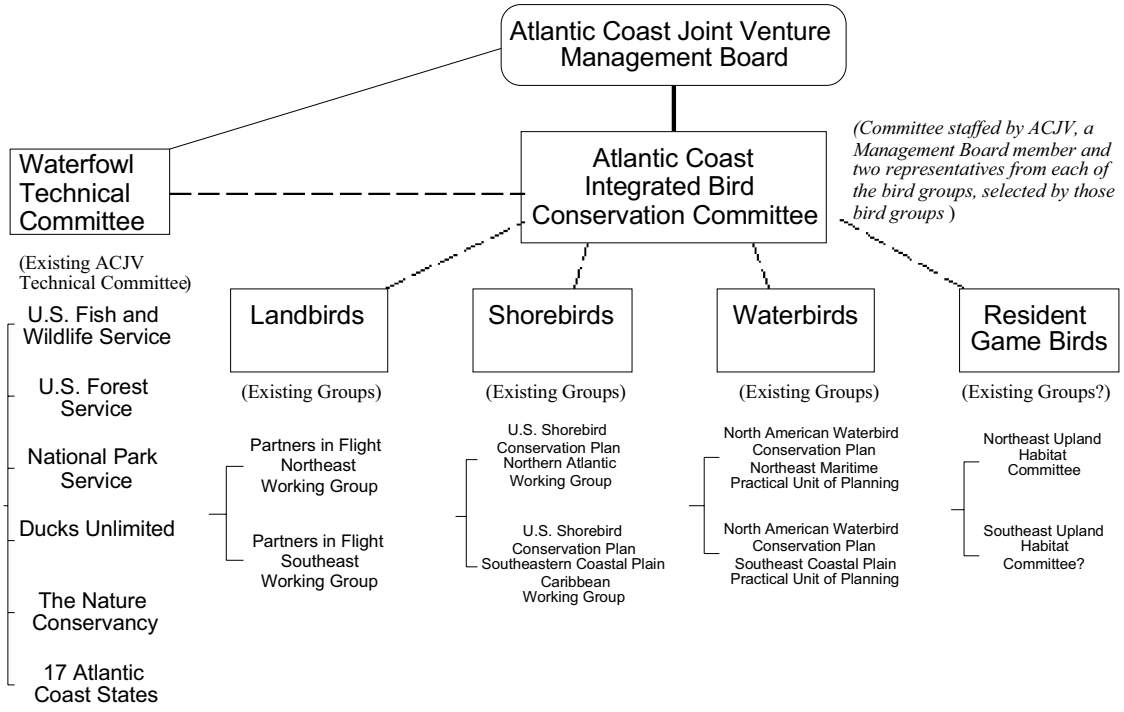

Figure 2— Flow Chart showing the relation ship between the Atlantic Coast Joint Venture Integrated Bird Conservation Committee, Management Board and bird initiative work groups.

Flyway Scale and Coast-Wide Efforts

The Atlantic Coast Joint Venture area includes the entire U.S. portion of the Atlantic Flyway and the entire U.S. Atlantic Coast. In this large area, the joint venture partners have the opportunity to work together to assess the status, trends, and needs of bird populations and habitats and to pool and direct these resources to the greatest needs. Flyways have been used in North America since 1947 as the unit for managing waterfowl in part through Flyway Councils (Jerry Serie, pers. comm.). The flyway concept is useful because it allows land managers to link efforts to conserve migratory bird species and their habitats on breeding, migration, and wintering grounds and to determine the most important limiting factors for these bird species during different stages in their seasonal cycle. The Atlantic Coast Joint Venture Management Board and Waterfowl Technical Committee contain many common members with the Atlantic Flyway Council and Technical Section, respectively, and work cooperatively to manage waterfowl populations and conserve important waterfowl habitat in the Atlantic Flyway.

To coordinate and integrate the many other groups and efforts associated with bird conservation in this large geographic region the joint venture has developed a working group known as the Atlantic Coast Integrated Bird Conservation Committee. This group serves to exchange information among the Northeast and Southeast working groups of Partners in Flight, U.S. Shorebird Conservation Plan, North American Waterbird Conservation Plan, North American Waterfowl Management Plan and various upland game bird initiatives and provides a link between these groups and the joint venture Management Board (*fig. 2*)

By planning at the flyway scale, managers can direct resources to the conservation of specific habitat types and particular geographic regions where these resources will have the most benefit for priority species using the flyway. Basic information on status and trends of habitat types at the flyway scale is helping the joint venture partners guide the prioritization of these resources. For example, the U.S. Fish and Wildlife Service, Adaptive Management and Assessment Team is working with the joint venture to assess the status and trends of wetland habitats in the U.S. portion of the Atlantic Flyway (Koneff et al. 2003). Status and trend information at this scale highlights conservation needs such as loss or conversion of 1.5 million hectares of forested wetlands in the Atlantic Flyway since the 1950s and the especially high rate of loss in the South Atlantic Coastal Plain.

In the near future, joint venture biologists and partners will be developing population models and population-habitat relationships that will allow the partners to better target habitat conservation to the places most likely to benefit populations of priority species. These population-habitat relationships, along with consistent

monitoring of populations, also will allow the partners to measure the success of their habitat efforts on priority populations and to adjust their efforts based on these results. All of this information on habitats and populations will be included in a revised joint venture implementation plan that will include habitat conservation goals, conservation focus areas, and habitat conservation strategies for the joint venture.

Atlantic Coast Joint Venture partners also have a number of efforts underway to cooperatively assess and manage habitats along the entire U.S. Atlantic Coast. One example is an effort to assess and manage the most important habitat types and food sources for shorebirds and waterfowl during the winter and as they move up the coast during spring migration. These assessments can be used to determine where these species concentrate at different times during migration, and to learn how habitats could be better managed to meet these species' needs. Partners are entering and linking together monitoring and management data for shorebirds and waterfowl at key stopover sites up and down the Atlantic Coast through a web-based database system to answer these questions and to allow wetland managers to better assess their role and adjust their water level and habitat management. Another example of a coast-wide monitoring effort is the Atlantic Coast High Priority Shorebird Network, a group of partners identifying priority shorebird species and issues along the Atlantic Coast and seeking funds to complete needed research and monitoring. The initial focus of this group is a better understanding of the status and distribution of breeding and wintering American Oystercatcher (*Haematopus palliatus*) along the Atlantic Coast. By working together, this group has secured funding for a coast-wide wintering survey for oystercatchers, as well as several breeding studies.

Regional Scale Efforts

The Atlantic Coast Joint Venture contains a diversity of habitat types from the boreal forests of Maine to the mangrove swamps and coral reefs of Florida and Puerto Rico. At the regional scale the joint venture is working on integrated planning efforts in the eight Bird Conservation Regions (BCRs) partially or wholly within the Joint Venture (*fig. 3*). These large physiographically-based regions are an appropriate scale and type of region to assess and integrate bird conservation priorities. Because these physiographic regions tend to have similar biotic (e.g. vegetation) and abiotic (e.g. bedrock geology, climate) features, they are particularly useful for assessing conservation priorities for breeding habitats based on these features and determining the importance of a particular region relative to other regions of the continent for species and habitat types (U.S. NABCI Committee 2000). For example, at least 90 percent of the breeding distribution of the rare Bicknell's Thrush (*Catharus bickneii*) occurs in the Atlantic Northern Forest Bird Conservation Region and thus protecting the spruce-fir habitats used by this species is a continental priority for this region.

Within the Atlantic Coast Joint Venture, regional integrated planning and implementation in these bird conservation regions is moving forward through a process of bringing together biologists and land managers in workshops and reaching consensus on priority species and habitats, population and habitat goals, focus areas for conservation, information needs and projects. Examples of these regional integration efforts that have moved forward include the South Atlantic Migratory Bird Initiative (Watson et al. this volume) and the Lower Great Lakes - St. Lawrence Plain Bird Conservation Region (Hayes et al. this volume). This process has resulted in an assessment of priorities that allows the partners to identify, work together and implement priority habitat conservation projects in these regions. These initial assessments can then be refined through habitat analyses and models as appropriate. Implementation happens through partners, including state working groups that have formed as a result of this process.

Bird Conservation Regions are not the only regions being used for regional integrated bird conservation in the Atlantic Coast Region. Other types of regions also are important for planning and implementing habitat conservation in the joint venture, especially in coastal areas where partnerships have formed around major estuaries such as Chesapeake Bay and Delaware Bay. Planning in the watersheds of these estuaries allows managers to set goals for the health of these estuaries, as well as for the fish and wildlife species using them. The Atlantic Coast Joint Venture has a Chesapeake Bay Work Group that exchanges information and works together on wetland conservation projects, seeking funding through the North American Wetlands Conservation Act grant program and the National Coastal Wetlands Conservation Grant Program.

Project/Focus Area Scale

Specific geographic areas that have been identified as important to birds, known as focus areas, have been mapped for waterfowl in the Atlantic Coast Joint Venture and are being mapped in Bird Conservation Regions for other migratory birds. These focus areas are discrete and distinguishable habitats or habitat complexes that are regionally important for one or more priority species during one or more life history stages and are identified within the context of landscape level conservation.

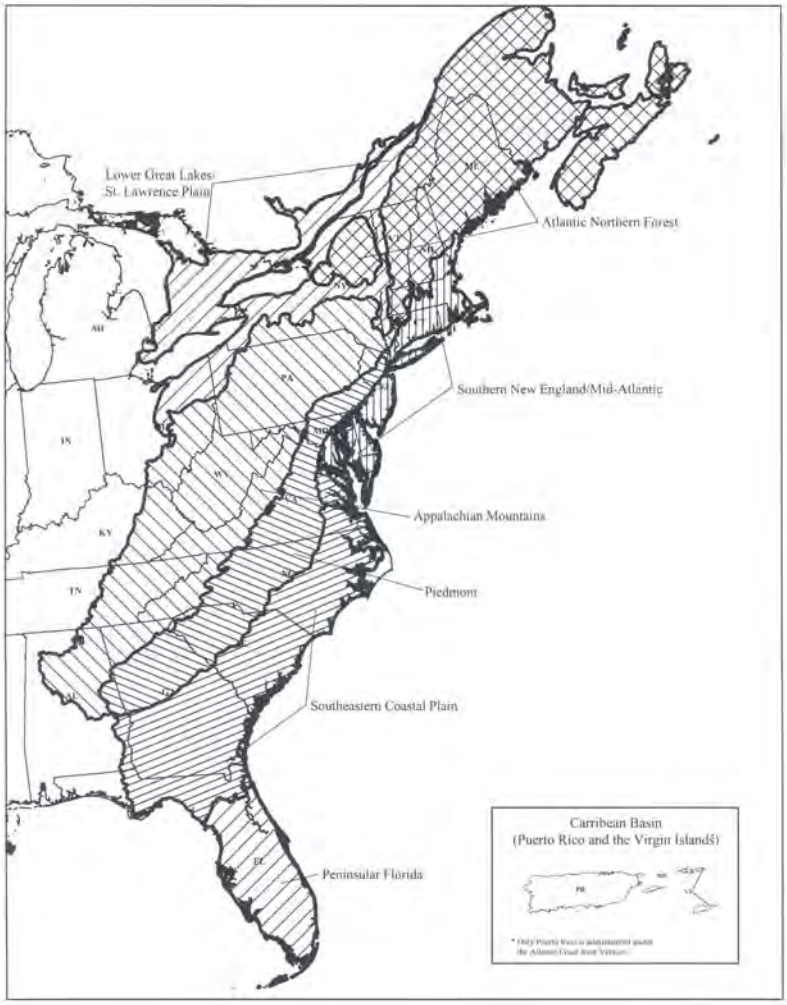

Figure 3— Bird Conservation Regions in the Eastern United States.

Once a particular focus area or project area is identified through regional or flyway scale planning efforts, joint venture partners put together the resources to accomplish habitat conservation projects. An example of a focus-area based effort is the Great Bay Resource Protection Partnership.

The Great Bay Estuary has long been recognized as the foundation for diversity and abundance of wildlife in southern New Hampshire. It was identified as a focus area by the Atlantic Coast Joint Venture in 1988 primarily for wintering waterfowl, but also for its critical role in providing habitat for other migratory birds and as an important fishery. For example, the estuary supports significant population of Saltmarsh Sharp-tailed Sparrow (*Ammodramus caudacutus*), one of the highest priority species identified in regional Partners in Flight plans. Because of the importance of the Great Bay estuary to migratory birds, the Great Bay Resource Protection Partnership was formed in 1994. This partnership is a coalition of public and private entities that have pooled financial and technical resources to help protect critical habitats within and surrounding the estuary.

Conservation efforts of the Partnership are guided by a Habitat Protection Plan that identifies over 14,000 acres of critical habitats within and surrounding the estuary in need of protection from some of the most intense development pressure in the northeastern U.S. The Partnership used field inventory and science-based conservation planning to prioritize protection for the most critical estuarine and upland habitats that are still intact within Great Bay. The identification of these habitats was supplemented with local and regional knowledge from municipalities, local conservationists, and field experts. In addition to identifying land for protection, the Partnership identified strategies needed to achieve their goals. These included conservation education, local land use policies and regulations, state regulations, conservation easement donation and acquisition, fee title donation and acquisition, and restoration and management practices.

The Partnership, spearheaded by a Coordinator, developed into a model for other partnerships centered on focus areas in the Atlantic Coast Joint Venture. Since 1994, the Partnership has been approved for over $3 million in North American Wetlands Conservation Act grants to protect or restore 5,000 acres of wetlands and associated uplands. These grants have been matched by $5.7 million in private partner funds. In addition to the success from the Act funds, the Partnership has received nearly $19 million in federal funding through the Great Bay National Estuarine Research Reserve and the New Hampshire Game and Fish Department. The efforts of the Great Bay Resource Protection Partnership clearly demonstrate that local, active partnerships can make a difference in delivering conservation actions to benefit the diversity and abundance of wildlife in southern New Hampshire and serve as a model for protection of other critical landscapes.

Working at these multiple spatial scales, the partners of the Atlantic Coast Joint Venture have conserved nearly 700,000 acres of priority habitat areas for migratory birds and other wildlife. With the new emphasis on all-bird conservation, these partnerships are poised to implement on-the-ground projects to benefit the highest priority bird species identified by Partners in Flight. We encourage new partners to take advantage of opportunities to include wetland-associated species, such as the marsh-nesting sparrows, Cerulean Warbler (*Dendroica cerulea*), and Golden-winged Warbler (*Vermivora chrysoptera*), in projects aimed primarily at conserving wetlands and associated upland habitats. And we encourage Partners in Flight working groups to use the Integrated Bird Conservation Committee as a means of incorporating land bird priorities into Atlantic Coast Joint Venture plans and projects.

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Conservation Priorities for Terrestrial Birds in the Northeastern United States[1]

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Abstract

As part of the Partners in Flight (PIF) bird-conservation planning process, we assessed breeding land bird species according to seven categories of population vulnerability to derive a priority species pool in each of 12 physiographic areas that overlap the northeastern U.S. We then grouped species into the following habitat-species suites: (1) boreal-mountaintop habitats (stunted conifers) that support a majority of the world's population of Bicknell's Thrush; (2) maritime marsh and ecotonal communities that support nearly all breeding Saltmarsh Sharp-tailed Sparrows, coastal populations of Nelson's Sharp-tailed Sparrows, Black Rail, Seaside Sparrow, and American Black Duck; (3) naturally disturbed and early-successional shrub-scrub habitats that support Appalachian Bewick's Wren (possibly extinct), Golden-winged Warbler, and American Woodcock; (4) natural and agricultural grasslands that support Henslow's Sparrow, Upland Sandpiper, eastern Grasshopper Sparrow, and Bobolink; (5) oak-dominated hardwood forests that support Cerulean Warblers, Worm-eating Warblers, and associated species; and (6) northern-hardwood and mixed coniferous forests that support Canada Warbler, Black-throated Blue Warbler, Bay-breasted Warbler and associated species. The value of these and other habitats (e.g. coastal concentration sites) to stopover migrants is also undoubtedly very high, although this remains largely unquantified. Within each habitat-species suite, we have identified population status, threats to habitats, and research needs, and recommended strategies for conservation action. Results of this PIF planning process will be integrated with objectives for waterbirds, shorebirds, and colonial waterbirds, as part of the North American Bird Conservation Initiative (NABCI) efforts.

Introduction

In 1990, Partners in Flight (PIF) was conceived as a voluntary, international coalition of government agencies, conservation organizations, academic institutions, private industry, and other citizens dedicated to reversing the downward trends of declining species with the purpose of "keeping common birds common." The foundation for PIF's long-term strategy for bird conservation is a series of Landbird Conservation Plans, which identify the highest priority bird species and habitats, set numerical population and habitat objectives, and outline an implementation strategy for achieving these objectives. The geographical context of these plans in the eastern United States is physiographic areas, modified from original strata devised by the Breeding Bird Survey (Robbins et al. 1986). Although priorities and biological objectives are identified at the physiographic area level, implementation of PIF objectives will take place at different scales, including individual states, federal agency regions, and conservation-partnership regions such as joint ventures.

The goal of each PIF Bird Conservation Plan is to ensure long-term maintenance of healthy populations of native landbirds. The conservation plans primarily address nongame landbirds, which have been vastly underrepresented in previous conservation efforts, and many of which are exhibiting significant declines that may be arrested or reversed if appropriate management actions are taken. The Partners in Flight approach differs from many existing federal and state-level listing processes in that it (1) is voluntary and nonregulatory, and (2) focuses proactively on relatively common species in areas where conservation actions can be most effective, rather than the frequent local emphasis on rare and peripheral populations. Partners in Flight landbird conservation planning, therefore, provides the framework to develop and implement habitat conservation actions on the ground that may prevent the need for future species listings. Additional details on PIF history, structure, and methodology can be found in Finch and Stangel (1993), Bonney et al. (1999), and http://www.partnersinflight.org.

In this paper we summarize the results of the PIF planning process for the 12 physiographic areas that comprise the northeastern United States. These results build on the regional assessment of Rosenberg and Wells (2000) by applying a nationally standardized approach and methodology to the planning process.

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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Specifically, we (1) identify the highest priority bird species that are most vulnerable to regional population declines and require conservation attention, (2) identify the habitat types that support these high priority bird species and are therefore in greatest need of protection or management, and (3) discuss the conservation objectives, challenges, and threats to these priority species and habitats, including gaps in our current knowledge that point to specific future research needs. Our primary goal is to draw attention to these terrestrial bird-habitat priorities, so that they may be incorporated into existing and future habitat-based conservation initiatives.

Methods

Twelve physiographic areas overlap the northeastern United States (*fig. 1*); this area also corresponds to the administrative boundaries of USFWS Region-5. For each of these physiographic areas, a landbird conservation plan has been developed and is available at http://www.partnersinflight.org.

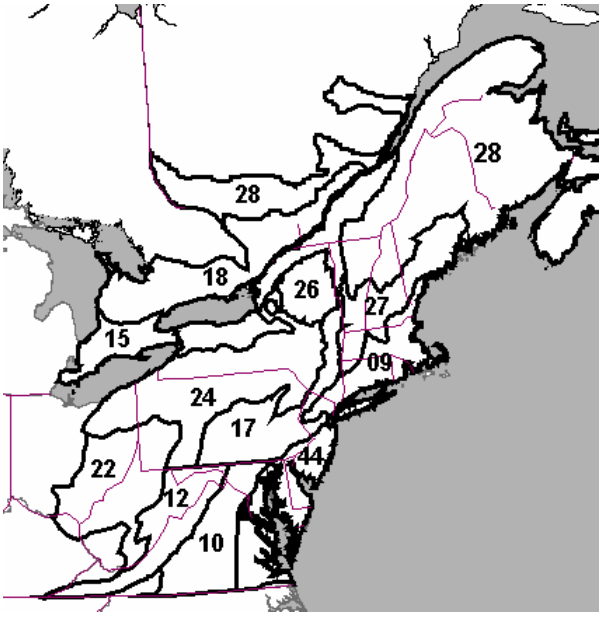

Figure 1–Partners in Flight physiographic areas overlapping the northeastern U.S. 9 = Southern New England; 10 = Mid-Atlantic Piedmont; 12 = Mid-Atlantic Ridge and Valley; 15 = Lower Great Lakes Plain; 17 = Northern Ridge and Valley; 18 = Saint Lawrence Plain; 22 = Ohio Hills; 24 = Allegheny Plateau; 26 = Adirondack Mountains; 27 = Northern New England; 28 = Eastern Spruce-Hardwood forest; 44 = Mid-Atlantic Coastal Plain.

Prioritizing Species

Within each plan, we follow a standardized procedure for identifying the pool of breeding species that represents priorities for conservation action within the physiographic area (modified from Carter et al. 2000). The different reasons for priority status (e.g., global threats, high concern for regional populations, large populations) are identified by levels or tiers in the species pool. The PIF species assessment process initially ranks species according to six measures of conservation vulnerability. These include four range-wide measures (i.e., they do not change from area to area), as well as two that are specific to each physiographic area. Although this process has been refined and improved to reflect the recent consensus of avian conservation biologists and land managers (Panjabi 2001), it remains conceptually very similar to that described in (Carter et al. 2000; reviewed by Beissinger et al. 2000).

For each factor contributing to conservation vulnerability (*table 1*), a species is scored on a scale of 1 to 5, as follows: "1" roughly represents *resistance to vulnerability* (positive association with human disturbance, significantly increasing populations, etc.); "2" represents *stability or lack of perceived vulnerability* due to that factor; "3" represents *moderate or unknown vulnerability* due to that factor; "4" represents *high vulnerability* leading to future danger of regional extirpation or significant population decline if not addressed; and "5" represents *imminent danger of regional extirpation or intolerable rates of population decline*, due to that factor. In addition to these measures of vulnerability, each species is given two scores to reflect the importance of each physiographic area to its overall conservation needs. The first is a 1-5 *Area Importance* score (AI), based on the relative abundance of a species in a physiographic area relative to the maximum abundance attained by that species in any area (see Carter et al. 2000). The second is an estimate of the percentage of the species' range-wide population that breeds in a physiographic area (see Rosenberg and Wells 2000). Both of these measures allow the incorporation of regional responsibility, as well as regional concern, into the overall conservation assessment for species, based on the rationale that conservation will be most effective where a species is most abundant or concentrated, rather than where it is rare or peripheral (Rosenberg and Wells 1995, 2000).

The primary source of information on species' abundances and population trends is the Breeding Bird Survey (BBS), a volunteer-based, standardized survey begun in 1966. The BBS is a cooperative effort between the U.S. Geological Survey's Patuxent Wildlife Research Center and the Canadian Wildlife Service's National Wildlife Research Centre to monitor the status and trends of North American bird populations (Sauer

Table 1—*Conservation vulnerability and area importance parameters used in the Partners in Flight species assessment process (see Panjabi 2001 for details).*

Assessment Parameter	Definition
Population Size (PS)	Estimated total population of a species throughout its range
Breeding Distribution (BD)	Size of breeding range for entire species
Nonbreeding Distribution (ND)	Size of smallest area of range used during all or part of the nonbreeding season.
Threats Breeding (TB)	Assessment of future threats to global or regional populations of a species during the breeding season
Threats Nonbreeding (TN)	Assessment of future threats to global or regional populations of a species during the nonbreeding season
Population Trend (PT)	Long-term (30-year) trend in population numbers, usually based on Breeding Bird Survey or other survey data
Area Importance (AI)	Relative abundance of a species in a region, compared with maximum abundance in any region.
Percent of Population (%pop)	Percentage of total population of a species occurring in a particular region.

et al. 2003; http://www.mp2-pwrc.usgs.gov/bbs/). For species lacking or poorly represented on BBS, individual scores were provided by a consensus of regional or species-group experts. A complete matrix of all vulnerability and area-importance scores for each species in each physiographic area is maintained in a database at Rocky Mountain Bird Observatory and can be accessed via http://www.partnersinflight.org.

Within regional bird conservation plans, categories of conservation status are determined by examining combinations of parameter scores, as well as the total rank score, which is a measure of overall conservation vulnerability. This process of identifying priority species has been standardized across all physiographic areas of North America (although application varies across regions). There are five entry levels into a priority species pool, as follows.

High Continental Importance

Species on the *PIF Continental Watch List* (see Rich et al. 2004) are those which are typically of conservation concern throughout their range. These are species showing high vulnerability in a number of factors, expressed as any combination of high global parameter scores, with AI > 2 (so that species without manageable populations in the region are omitted.

High Continental Concern - High Regional Responsibility

Species for which this region shares in major conservation responsibility; i.e., conservation in this region is critical to the overall health of this species. These are species with AI of 3 - 5, or a high percent population.

High Continental Concern - Low Regional Responsibility

Species that are uncommon, but for which this region can contribute to rangewide conservation objectives where the species occurs. Species with AI of 2.

High Regional Importance

Species that are of moderate continental priority (not on *Continental Watch List)*, but are important to consider for conservation within a region because of various combinations of high parameter scores, as defined below; total of 7 parameter scores ≥19.

High Regional Concern

Species that are experiencing declines in the core of their range and that require conservation action to reverse or stabilize trends. These are species with a combination of high area importance and declining (or unknown) population trend; total of 7 parameters ≥19, with AI + PT ≥ 8.

High Regional Responsibility

Species for which this region shares significant responsibility for long term conservation, even if they are not currently declining or threatened. These are species of moderate overall priority with a disproportionately high percentage of their total population in the region; total of 7 parameters ≥19, with AI = 5 or percent population > threshold. These species require long-term planning to ensure healthy and sustainable populations in the region.

High Regional Threats

Species of moderate overall priority that are uncommon in a region and whose remaining populations are threatened, usually because of extreme threats to sensitive habitats. These are species with high breeding threats scores within the region (or in combination with high nonbreeding threats outside the region); total of 7 parameters ≥19 with TB + TN > 6, or local TB or TN = 5.

Results

Regional priority species

Sixty-seven species were identified as being of conservation priority in at least one of the 12 physiographic areas of the northeastern United States (*table 2*). Of these, 24 species are on the PIF continental Watch List (Rich et al. 2004) and are considered of conservation importance in any region in which they have manageable populations. Note that Black Rail, Upland Sandpiper, and American Woodcock also meet criteria for the Continental Watch List, but are not listed by PIF. Continentally Important species for which portions of the Northeast support important populations (i.e. this region shares a major responsibility for their overall conservation) include American Woodcock, Bicknell's Thrush, Wood Thrush, Blue-winged Warbler, Golden-winged Warbler, Prairie Warbler, Cerulean Warbler, Kentucky Warbler, Canada Warbler, Henslow's Sparrow, Saltmarsh and Nelson's Sharp-tailed Sparrows, and Seaside Sparrow. These species may be considered of highest overall priority for conservation action wherever they occur throughout the Northeast region.

The remaining 40 species of regional importance represent a combination of species that either are declining in the core of their range, have disproportionately high populations in the Northeast (high responsibility), or whose smaller (often peripheral) populations are highly threatened in the region. Many of these species (e.g. Louisiana Waterthrush, Scarlet Tanager, and Field Sparrow) are widespread and are priority species in half or more of the physiographic areas, whereas others (e.g. Bewick's Wren, Yellow-throated Warbler, and Spruce Grouse) are priorities only in a small part of the region.

Regional Priority Habitats

Based on the primary habitats of the species identified above, seven broad habitat types are considered most in need of conservation attention in the northeastern United States (*table 2*). Species of continental importance within each habitat suite that overlap in habitat requirements with other regional priority species are considered as focal species in the physiographic area plans (Lambeck 1996). Pine-savannah habitat is restricted to portions of the southernmost physiographic areas and is more characteristic of the southeastern U. S.. We do not consider this habitat-type further, but see (Watts 1999; Mid-Atlantic Coastal Plain PIF plan). Of the remaining habitat-types, grassland/agricultural and shrub-scrub/successional habitats are the most widespread, with representative, high-priority bird species occurring in virtually every physiographic area. Other important habitat types are restricted either to coastal physiographic areas (maritime salt-marsh) or to either northerly or southerly portions of the region. Below we synthesize information on each habitat type from the detailed accounts presented in the individual physiographic-area bird conservation plans.

Boreal-Mountaintop Conifer Woodland

The recognition of Bicknell's Thrush as a separate species (Ouellet 1993, AOU 1995) has elevated the importance of its primary habitat, high-elevation conifers, to a top regional conservation priority (Rosenberg and Wells 2000). Preferred habitat has been described as dense, stunted stands dominated by balsam fir, with varying amounts of white birch, mountain ash and sometimes red spruce and other species (Wallace 1939, Atwood et al. 1996). This habitat type occurs naturally at high elevations (approximately >900m in U.S.; >500m in Canada) from the Adirondack and Catskill Mountains of New York, northeastward through northern New England, western New Brunswick to the Gaspé Peninsula of Quebec. Its distribution is therefore naturally fragmented at the landscape level, with most patches estimated to be <1000 ha in extent (Atwood et al. 1996). The other bird species associated with Bicknell's Thrush, such as Blackpoll Warbler and Yellow-bellied Flycatcher, tend to be species of open coniferous and disturbed forests in the more northern portions of their range, but are specialists on mountaintop conifers in New England and New York.

Distribution and Populations

Bicknell's Thrush appears to be the only species that is restricted to this habitat nearly throughout its range. In Canada, additional populations of this species may occur locally in habitats of similar structure along the windswept coasts of the Maritime provinces and Quebec, and in some second-growth industrial forest habitats at lower elevations inland (Erskine 1992, Ouellet 1993, Gauthier and Aubry 1996, Nixon 1999). Thrushes were present on mountaintop islands as small

Table 2–*High priority breeding landbird species in Northeast U.S. Physiographic areas, based on Partners in Flight species assessment process (see Panjabi 2001). Priority levels refer to tiers or entry levels into regional priority species pools as described in text: C-R = Continental concern-high regional responsibility; C-L = continental concern-low regional responsibility; R-C = High regional concern; R-R = High regional responsibility; R-T = High regional threats.*

Species	Habitat	Physiographic area											
		44	9	10	12	15	17	18	22	24	26	27	28
	Boreal-mountaintop												
Bicknell's Thrush, *Catharus bicknelli*										C-L	C-R	C-R	C-R
	Pine-savannah												
Red-cockaded Woodpecker, *Picoides borealis*		C-L											
Brown-headed Nuthatch, *Sitta pusilla*		C-L		C-L									
Bachman's Sparrow, *Aimophila aestivalis*		C-L		C-L									
	Salt marsh												
Black Rail, *Laterallus jamaicensis*		C-R	C-L										
Clapper Rail, *Rallus longirostris*		R-R											
Virginia Rail, *Rallus limicola*		R-C											
Marsh Wren, *Cistotherus palustris*		R-C											
Saltmarsh Sharp-tailed Sparrow, *Ammodramus caudacutus*		C-R	C-R									C-L	
Nelson's Sharp-tailed Sparrow, *Ammodramus nelsoni*												C-L	C-R
Seaside Sparrow, *Ammodramus maritimus*		C-R	C-R										
	Oak-hickory/deciduous forest												
Chimney Swift, *Chaetura pelagica*		R-C	R-C	R-C					R-R				
Red-headed Woodpecker, *Melanerpes erythrocephalus*		C-L	C-L	C-L	C-L	C-L	C-L	C-L	C-L	C-L		C-L	
Acadian Flycatcher, *Empidonax virescens*		R-R		R-C	R-R				R-C				
Eastern Wood-Pewee, *Contopus virens*		R-C			R-C		R-C						
Yellow-throated Vireo, *Vireo flavifrons*		R-C			R-C				R-C				
Wood Thrush, *Hylocichla mustelina*		C-R	C-R	C-R	C-R	C-R	C-R	C-R	C-R	C-R	C-R	C-R	C-L
Yellow-throated Warbler, *Dendroica dominica*									R-R				
Cerulean Warbler, *Dendroica cerulea*		C-L	C-L	C-L	C-R	C-L	C-L	C-L	C-R	C-L			
Black-and-white Warbler, *Mniotilta varia*			R-C								R-C		
American Redstart, *Setophaga ruticilla*											R-C		
Worm-eating Warbler, *Helmitheros vermivorus*		C-R	C-R	C-L	C-R	C-L	C-R		C-R	C-L			
Swainson's Warbler, *Lymnothlypis swainsoni*		C-L							C-L				
Louisiana Waterthrush, *Seiurus motacilla*		R-T	R-T	R-R	R-R	R-T	R-R		R-C	R-R			
Prothonotary Warbler, *Protonotaria citrea*		C-R		C-L		C-L			C-L				
Kentucky Warbler, *Oporornis formosus*		C-R	C-L	C-L	C-R		C-L		C-R				
Hooded Warbler, *Wilsonia citrina*					R-R				R-R				

Table 2 (contd.)

Species	Habitat	Physiographic area											
		44	9	10	12	15	17	18	22	24	26	27	28
	Oak-hickory/deciduous forest (contd.)												
Scarlet Tanager, *Piranga olivacea*		R-C	R-C	R-R	R-R		R-R		R-R	R-C	R-C	R-C	
Baltimore Oriole, *Icterus galbula*			R-C			R-C	R-C	R-C					
	Shrub-successional												
Northern Bobwhite, *Colinus virginianus*		R-C		R-C									
American Woodcock, *Scolopax minor*		C-R	C-R	C-R	C-L	C-R	C-R	C-R	C-R	C-R	C-R	C-R	C-R
Whip-poor-will, *Caprimulgus vociferus*		R-C		R-R	R-C			R-T				R-T	
Willow Flycatcher, *Emidonax trailli*		C-L	C-L	C-L	C-L	C-R	C-R	C-R	C-R	C-R	C-L	C-L	C-L
Bewick's Wren (Appalachian), *Thryomanes bewickii altus*					C-R				C-R				
Brown Thrasher, *Toxostoma rufum*		R-C	R-C		R-C	R-C	R-C	R-C					
Blue-winged Warbler, *Vermivora pinus*		C-L	C-R		C-L	C-R	C-R	C-L	C-R	C-R		C-L	
Golden-winged Warbler, *Vermivora chysoptera*			C-L		C-R	C-L	C-R	C-R	C-R	C-L	C-L	C-L	
Chestnut-sided Warbler, *Dendroica pennsylvanica*											R-C	R-C	R-C
Prairie Warbler, *Dendroica discolor*		C-R	C-R	C-R	C-R	C-L	C-R		C-R			C-L	
Yellow-breasted Chat, *Icteria virens*					R-C				R-C				
Indigo Bunting, *Passerina cyanea*					R-C				R-C				
Eastern Towhee, *Pipilo erythrophthalmus*		R-C	R-C	R-C	R-C		R-C		R-C	R-C			
Field Sparrow, *Spizella pusilla*		R-C	R-C	R-C	R-C	R-C	R-C		R-C	R-C			
	Grassland-agriculture												
Northern Harrier, *Circus cyaneus*								R-T					
Upland Sandpiper, *Bartramia longicauda*		C-L	C-L	C-L		C-L	C-L	C-L	C-L	C-L	C-L	C-L	C-L
Short-eared Owl, *Asio flammeus*		C-L	C-L			C-L		C-L		C-L		C-L	C-L
Sedge Wren, *Cistothorus platensis*		R-T			R-T	R-T	R-T	R-T	R-T	R-T		R-T	R-T
Loggerhead Shrike, *Lanius ludovicianus*		R-T		R-T	R-T	R-T	R-T	R-T					
Grasshopper Sparrow, *Ammodramus savvanarum*		R-T	R-T	R-T	R-T	R-T	R-T	R-T		R-T			
Henslow's Sparrow, *Ammodramus henslowi*		C-L	C-L	C-L	C-L	C-L	C-L	C-L	C-R	C-R			
Bobolink, *Dolichonyx orizivorus*						R-C		R-C		R-T			R-C
	Northern hardwood/coniferous forest												
Spruce Grouse, *Falcipennis canadensis*											R-T		R-C
Black-billed Cuckoo, *Coccyzus erythropthalmus*			R-C			R-C		R-C	R-C	R-C	R-C	R-C	
Black-backed Woodpecker, *Picoides arcticus*											R-T	R-T	R-T
Least Flycatcher, *Empidonax minimus*												R-C	R-C
Olive-sided Flycatcher, *Contopus cooperi*					C-L		C-L				C-L	C-L	C-R
Veery, *Catharus fuscescens*											R-C		R-C

Table 2 (contd.)

Species	Habitat	Physiographic area											
		44	9	10	12	15	17	18	22	24	26	27	28
	Northern hardwood/coniferous forest (contd.)												
Northern Parula, *Parula americana*					R-C								R-R
Black-throated Blue Warbler, *Dendroica caurulescens*					R-T						R-C	R-R	R-R
Bay-breasted Warbler, *Dendroica castanea*											C-L	C-L	C-R
Blackburnian Warbler, *Dendroica fusca*			R-T		R-T						R-R	R-C	R-R
Cape May Warbler, *Dendroica tigrina*													R-R
Ovenbird, *Seiurus aurocapillus*											R-R	R-R	R-R
Canada Warbler, *Wilsonia canadensis*			C-L		C-R	C-L	C-L	C-L		C-R	C-R	C-R	C-R
Rose-breasted Grosbeak, *Pheucticus ludovicianus*			R-C					R-C		R-R	R-C	R-C	R-C
Rusty Blackbird, *Euphagus carolinus*											C-L		C-L
Purple Finch, *Carpodacus purpureus*												R-C	R-C

as 1.5 ha (Atwood et al. 1996), and area of available habitat was not a significant predictor of occupancy (Atwood et al. 1996). Despite the small size of most available habitat patches, Bicknell's Thrush and other associated species occur there in high densities. Recent estimates of Bicknell's Thrush densities on Mt. Mansfield in Vermont range from about 40 to 60 pairs per 40 ha of continuous habitat (Rimmer et al. 1996), but these do not take into account more recent discoveries of highly skewed sex ratios (1.8 males:1 female) and very patchy distributions within suitable habitat. Using the most up-to-date GIS data available, K. McFarland (unpubl. data) estimates a maximum of 53,000 breeding Bicknell's Thrush occurring within the U.S. portion of the range, though the actual number could be as low as 15,000-30,000 individuals. Erskine (1992) estimated an additional 1000 pairs breeding in the Maritime provinces, although the number of birds in Canada remains highly uncertain (Nixon 1999).

Population trends for species in this habitat are difficult to assess, because BBS routes do not sample such high-elevation sites. Multi-year research in Vermont indicates that reproductive success is highly variable from year to year, with nest failure primarily attributed to predation by red squirrels and red-backed voles. Nest predation is highest in years following high spruce-cone abundance and may involve an upslope movement of predators from lower-elevation forests (K. McFarland, pers. com.). In addition, an unusual spacing and mating system in this species has been documented, including lack of male territoriality, high degree of promiscuity, and large movements of individuals within habitat patches. These factors contribute to the difficulty in monitoring population size and reproductive success.

Threats and Conservation Issues

Current threats to the habitat fall into three categories: (1) global climate change; (2) atmospheric pollution (including acid precipitation); and (3) recreational and other development. The first factor, a global warming trend resulting in the shrinkage or retraction of cool-temperate forests regionwide, has been postulated to influence bird distribution and abundance (Erskine 1992, Atwood et al. 1996). Indeed, recent models for change in CO_2 indicate that high elevation conifer habitat, especially fir, will eventually disappear from the region (http://www.fs.fed.us/ne/delaware/atlas/). Although such an effect cannot be controlled by bird-conservation efforts alone, we must make every effort to influence the larger factors that ultimately may determine the fate of this entire habitat-species suite. Atmospheric pollution in the form of acid rain has been shown to adversely influence the health of balsam fir and spruce-dominated communities in New York and New England, resulting in heavy mortality in some

areas (Miller-Weeks and Smoronk 1993). Although studies of the effects of acid rain on bird communities in these areas have just begun, a likely factor is the reduction of available calcium in the soil, ultimately reducing egg production and egg-shell thickness in nesting birds (Hames et al. 2002).

High elevation habitats are currently protected to some extent by existing laws in Vermont, New Hampshire, and Maine, but Bicknell's Thrush is listed as a species of Special Concern in only Maine and Massachusetts. Recreational development, primarily for ski resorts is a growing threat to high-elevation habitats in parts of New England, but is less of a factor in the Adirondack Mountains of New York. The effects of lighter recreation, such as hiking and camping, are not well known. In addition, the recent proliferation of communication towers on mountaintops may represent another potential threat.

Needs and Recommendations

A strategy for protecting high-elevation habitats and ensuring a stable population of Bicknell's Thrush and associated species should include the following elements (not necessarily sequential):

- identification and characterization (habitat size, quality, land ownership) of all potential habitat patches, using GIS (now complete for Vermont; K. McFarland unpubl. data);
- completion of on-the-ground inventories to determine numbers of breeding Bicknell's Thrushes at all sites;
- identification and designation of most important sites, through state Important Bird Area programs;
- identification of specific threats to particularly important sites;
- incorporation of research on reproductive success of Bicknell's Thrush and other species into ongoing studies of forest health, in relation to pollution and development;
- explicit and "official" recognition of Bicknell's Thrush and its associated habitat as a high conservation priority in public agency and private land-use planning efforts;
- if future declines in habitat availability or Bicknell's Thrush populations warrant, legal mandates for implementation of habitat-protection objectives.

Several ongoing research efforts are now focusing on mountaintop bird communities and the breeding biology of Bicknell's Thrush. These and additional studies should be supported at the highest level of conservation priority. Specific research and monitoring needs that are most relevant to implementation of this conservation plan include the following:

- application of GIS and GAP analyses to determine distribution and conservation status of all habitat patches;
- continued censuses of Bicknell's Thrush and other species at all sites;
- studies of Bicknell's Thrush demography, to be applied to source-sink dynamics modeling and metapopulation analysis throughout this region;
- studies of calcium availability in relation to acid precipitation and avian reproductive success at high elevation sites;
- determination of potential limiting factors affecting Bicknell's Thrush on its nonbreeding grounds, in winter and at migration-stopover sites;
- development of efficient monitoring protocols for evaluating Bicknell's Thrush population trends.

Recommended protocols for surveying breeding Bicknell's Thrushes are now available (Rimmer et al. 1996). A potential technique for monitoring this species along its migration routes may employ the recording of distinct nocturnal flight calls (Evans 1994). Studies of Bicknell's Thrush on its wintering grounds and development of a conservation plan for this species in the Dominican Republic are also ongoing (C. Rimmer, pers. comm.).

Maritime Salt Marsh

Priority species for northeastern maritime salt marshes include Black Rail, Saltmarsh Sharp-tailed Sparrow, Nelson’s Sharp-tailed Sparrow, and Seaside Sparrow. In the Northeast, all of these species occur only in this habitat. Virtually the entire world breeding range of Saltmarsh Sharp-tailed Sparrow occurs within northeastern salt marshes. This habitat occurs within the four physiographic areas of the northeast that contain coastal zones: Eastern Spruce-Hardwood, Northern New England, Southern New England, and the Mid-Atlantic Coastal Plain. Other bird species of regional priority that are dependent on salt marshes for at least part of their annual cycle include American Black Duck, Northern Harrier, Clapper Rail, Willet, Short-eared Owl, and Sedge Wren.

Distribution and Populations

The four focal species of maritime salt marsh occur in a narrow band along the coastline of the northeast U.S. Of the four, Nelson's Sharp-tailed Sparrow has the smallest distribution within the northeast, with the coastal subspecies (*A. n. subvirgata*) occurring entirely from the New England and Maine coasts north through the Maritime Provinces. In Maine, recent inventories show an estimated 1000 Nelson's Sharp-tailed Sparrow (Hodgman pers. comm.). Saltmarsh Sharp-tailed Sparrow breeds from southern Maine south to the northern part of coastal North Carolina so that its entire population is almost completely confined to the northeast U.S. during the breeding season. Surveys for Saltmarsh Sharp-tailed Sparrows have been undertaken in Maine, where there an estimated 500 individuals (Hodgman pers. comm.), and parts of New England, but information is generally lacking over the remainder of the species range. Recent research in the contact zone between the two sharp-tailed sparrows has shown that the zone of overlap between the two species is three-times larger than previously documented (Hodgman et al. 2002). Seaside Sparrow has a more extensive breeding range along the Atlantic and Gulf coasts, but within the northeast occurs from Massachusetts south through the region. No information is available on estimated population sizes for Seaside Sparrow. Black Rail distribution and abundance is not well documented because of the species' secretive nocturnal habits, but the species does occur in isolated pockets extending from Connecticut and Long Island south through coastal Virginia. The species is not abundant anywhere but occurs in higher densities southward from southern New Jersey. Breeding Bird Survey data do not permit estimates of population trends for any of the four focal species in this region because of the general inaccessibility of salt marsh habitat.

Within this region, Black Rail, Nelson's Sharp-tailed Sparrow and Saltmarsh Sharp-tailed Sparrow show a preference for the higher marsh zone characterized especially by *Spartina patens*. In contrast, Seaside Sparrow prefers the lower marsh zone which is dominated by *Spartina alterniflora*. The three sparrows of saltmarshes show comparably rather short incubation and fledging periods that generally must be completed between high tide events, which are the biggest factor causing reproductive failure (Post and Greenlaw 1994).

Threats and Conservation Issues

Within the mid-Atlantic region, a substantial number of salt marshes have been lost over the past 200 years (Tiner 1984). Between 1954 and 1978, loss rates were extremely high, primarily due to urban and industrial development (Gosselink and Baumann 1980). However, since the passage of protective legislation, loss rates have declined dramatically. Many of the largest marshes are also now part of federally-owned U.S. Fish and Wildlife Service Refuges.

Current threats to maritime salt marshes include habitat degradation from loss of buffer habitats along the upper margins of marshes and encroachments from roads and other development. In many areas, the invasion of *Phragmites*, which is not inhabited by salt marsh obligate species, has replaced large amounts of salt marsh habitat. In addition, the control of *Phragmites* through the manipulation of water levels, can itself destroy salt marsh habitats and is often carried out without consideration to the needs of salt marsh bird species. Similarly, projects to restore tidal flow to salt marshes to benefit some species are often done without consideration to the needs of the focal salt marsh bird species.

Current protection for this habitat type includes marshes existing within National Seashores, coastal National Wildlife Refuges, state-protected areas such as natural areas and wildlife management areas, and properties owned by conservation organizations or land trusts. Many of the most important sites have been or will soon be identified through state and national Important Bird Areas (Wells et al. this volume, Wells 1998). Fortunately, many of the remaining large marshes are already under some form of protection from development.

Needs and Recommendations

Bird species of these coastal marshes are not well monitored by standard programs such as the Breeding Bird Survey. Conservation needs of these birds therefore fall into two categories: implementation of targeted monitoring and inventory programs; and protection and management of high-marsh habitats that support populations of high-priority marsh birds. Specific recommendations are as follows:

- complete inventory for all four focal species, with particular attention to the northern range limit for Saltmarsh Sharp-tailed Sparrow and range-wide distribution of Black Rail;
- develop program (perhaps using volunteers) to monitor populations of focal species at five-year intervals at key sites.
- identify threats to the most important sites for saltmarsh sparrows and Black Rails and develop ways to diminish these threats;
- increase protection of high-marsh borders and buffers to maximize habitat availability for focal species;
- incorporate needs of these nongame focal species into management projects for waterfowl or marsh

restoration, especially for projects under the Atlantic Coast Joint Venture.

Grasslands and Agricultural Habitats

Priority species for grasslands and agricultural habitats include Upland Sandpiper, Sedge Wren, Henslow's Sparrow, Grasshopper Sparrow, and Bobolink. All have experienced significant declines in the region (Vickery 1992, Askins 1999, Wells and Rosenberg 1999). Most other grassland species are declining as well, and concern is high for these species throughout the region. For example, Eastern Meadowlark, Vesper Sparrow, and Horned Lark are declining rapidly, but do not rank highly in regional plans because of large populations remaining elsewhere in their large ranges (Wells and Rosenberg 1999). These species often are listed as threatened or endangered by individual states (Vickery 1992). Grassland and agricultural habitats occur in all 12 physiographic areas, though with restricted amounts in the northern forest areas such as the Adirondack Mountains and northwestern Maine.

Debate over whether native grasslands were a historically significant part of the landscape of the northeastern U. S. has tempered conservation efforts targeting grassland birds. There is evidence, however, that large native grasslands existed in the northeast U. S. in precolonial times (Askins 1999, 2000). Perhaps the most compelling evidence is the existence of certain subspecies of grassland birds native to the region, in particular the extinct Heath Hen (*Tympanuchus cupido cupido*) and the eastern subspecies of Henslow's Sparrow (*A. h. susurrans*) (Askins 1999, 2000). Natural fires and those set by native Americans (Vickery and Dunwiddie 1997), beaver activity, ice and wind storms all contributed to the creation and persistence of grassland habitats in the northeast U.S. Complicating the historical record though, much of the native grassland and heathland habitat was among the first to be lost to development. For example, more than 98 percent of the once vast Hempstead Plains on Long Island, New York has been lost (Noss et al. 1995).

Distribution and Populations

Grassland bird inventories have been completed throughout much of the northeast U.S., with especially thorough coverage in New England and New York (Shriver et al., this volume). This inventory work has shown that in much of the region, sites harboring the greatest abundance and diversity of grassland species are located at airfields, particularly on military installations (Shriver et al., this volume). Other important sites include some relict native sandplain grasslands, reclaimed strip mines, and less intensively-managed agricultural fields. In New England, there are 10-15 sites that harbor significant breeding populations of Upland Sandpipers and/or Grasshopper Sparrows, the largest being those at Westover Airforce Base in western Massachusetts (Jones and Vickery 1997), the Elizabeth Islands in coastal southeastern Massachusetts, Rentschler Field and Bradley International Airport, Connecticut, the Champlain Valley of Vermont, the blueberry barrens of eastern Maine, and Kennebunk, Maine (Shriver et al., this volume; Comins et al. 2003).

Significant areas for Henslow's Sparrows include the St. Lawrence Plain of New York, grasslands in Otsego County, New York, and several large reclaimed strip mines in western Pennsylvania. In total there are thought to be fewer than ten sites in the northeast U.S. that have 50 or more pairs of Henslow's Sparrows. The areas supporting significant numbers of Henslow's Sparrows typically harbor even larger numbers of Grasshopper Sparrows. Knowledge of the habitat and area requirements of most grassland species is relatively well-known and several grassland management manuals have been produced for use in the northeast U. S. (e.g. Jones and Vickery 1997).

Threats and Conservation Issues

The greatest threats to grassland birds in the northeast U.S. are through the effects of habitat loss. This includes continued loss of remnant grassland sites to development, abandonment of dairy farms or switching from hay cultivation to growing row crops, and the more intensive modern management of hay crops with much earlier and multiple cuttings. The number of farms in the northeast has declined by 50 percent since 1950 (Comins et al. 2003), with much of this habitat lost to development. Loss of habitat to development is greatest in the coastal plain from New England south to Virginia and within commuting distance of major urban areas like New York, Philadelphia, Pittsburgh, etc., where urban sprawl has increased greatly in the last 20 years. In regions like the St. Lawrence Plains, Great Lakes Plain and Allegheny Plateau, most loss of grassland habitat is through the abandonment of farms and subsequent reversion of habitat to shrub and, later, forest.

In addition to the loss of habitat to development and succession of abandoned farmland, much current acreage of agricultural lands is being more intensively managed so that it is unsuitable for grassland birds. Hayfields that are converted to row crops are effectively lost as habitat for grassland birds. Fields managed for feed hay are now routinely harvested so early in the season and so frequently over the season (because of the development of new, faster-growing feed hay varieties) that birds that nest in those fields experience little or no nesting success.

Some of the largest remaining grasslands in the northeast U.S. are at commercial and military airports which are typically mowed annually to maintain maximum visibility for air safety. Mowing these sites during the breeding season is obviously detrimental to birds but still occurs at many airports, probably because managers are unaware that later mowing would benefit these birds. In addition, since the prevention of collisions between wildlife and airplanes is of high concern to airport managers, there is often a view that birds and other wildlife should be discouraged from using habitat near airstrips. Paradoxically, the short grass that remains after mowing is more likely to attract flocking species (e.g. European Starling) and large species (e.g. Canada Goose, Ring-billed Gull) that are a much greater hazard to airplanes than are the small, non-flocking, and low-flying species of breeding grassland birds that occur in taller grass.

In Maine, blueberry barrens support the greatest numbers of priority grassland birds and more than 90 percent of the state's commercial blueberry fields have been sprayed with herbicides (Vickery et al. 1999). Such herbicide treatment has been shown to result in decreased densities of Grasshopper Sparrow, Savannah Sparrow, Bobolink, and Eastern Meadowlark (Vickery et al. 1999). With continued regular herbicide treatment of these areas it is expected that these species will suffer large regional population declines (Vickery et al. 1999).

Needs and Recommendations

- Complete grassland bird inventories for states south of New York and especially document the current important remaining Henslow's Sparrow breeding populations in Pennsylvania and West Virginia.
- Study demographics of Henslow's Sparrow populations in the region.
- Protection and restoration of native, remnant grassland habitats should be a high priority of public agencies and conservation organizations that manage wildlife habitat.
- Direct acquisition of large blocks of these habitats should be a priority in places like central and eastern Maine, eastern Long Island, and in portions of the coastal plain of Delaware, Maryland, and Virginia.
- Develop a comprehensive grassland bird management plan for all commercial and military airfields that support significant grassland bird populations in the region.
- Develop a coordinated program to ensure that publications that provide private landowners with information on the status of grassland birds, ways to manage for grassland birds that are not incompatible with farming, and knowledge of government incentives are distributed to the hundreds of thousands of land managers and owners that have the ability to affect the long-term health of grassland bird habitats.
- Develop a comprehensive program to catalyze existing farmland protection and management initiatives at the state and local levels to focus on sites with significant grassland bird populations on private agricultural lands that are being heavily impacted by development.

Shrub-Scrub/Early Successional

The priority bird species of shrub-scrub/early successional habitats are American Woodcock, Golden-winged Warbler, Blue-winged Warbler, Prairie Warbler, as well as the Appalachian subspecies of the Bewick's Wren (*T. b. altus*). Other species of regional importance that show up on many northeastern physiographic area plans include Whip-poor-will, Brown Thrasher, Eastern Towhee, Field Sparrow, and Indigo Bunting. In addition Yellow-breasted Chat is important in more southerly areas, whereas Chestnut-sided Warbler represents this habitat suite in the northern forest areas.

In pre-settlement times, fire likely maintained successional areas along sandy portions of coastal areas (locations of some of today's pine barrens), while major weather events, such as hurricanes, tornadoes, and ice storms, along with beaver activity, generated scattered thickets of shrubby habitat further inland (Askins 1998). Human settlement, beginning with Native Americans and followed by European colonization, brought increased disturbance to the region. With European settlement, large-scale changes in land cover occurred, with widespread clearing of the inland forests for agriculture and wood products. By the mid 1800s, forest cover in New England had dropped from >90 percent to <50 percent (Litvaitis 1993, Litvaitis et al. 1999). During a subsequent period of farm abandonment and reforestation during the late 1800s and early 1900s, large amounts of early successional habitat became available, and the suite of early successional bird species experienced a population boom in the Northeast. In recent decades, as the resulting second-growth forests grew beyond the early seral stages used by shrubland birds, populations of these species began to decline again with the reduction in amount of habitat available to them.

Distribution and Populations

Most species of this habitat type are showing significant rangewide declines according to Breeding Bird Survey trend analyses, and often the species showing steepest population declines within an area are birds of early successional habitats. The most dramatic example is the Appalachian Bewick's Wren, which once occurred commonly across the Appalachian region from southeast New York to Georgia, but is now virtually eliminated from this entire range (Kennedy and White 1997). Golden-winged Warbler has experienced a range-wide decline of 2.5 percent per year from 1966-2002 (Sauer et al. 2003). The species has expanded its northern range limit into Canada, but has disappeared from much of its former range in New England and has declined sharply in New Jersey, New York, and Pennsylvania. Within the Northeast U.S., populations of Golden-winged Warblers remain in the Appalachians of West Virginia, Pennsylvania, the New York-New Jersey Highlands, and the St. Lawrence Valley of northern New York. The ongoing Golden-winged Warbler Atlas Project is currently documenting population concentrations of this species, as well as location of the current hybrid-zone with blue-winged Warblers (Rosenberg and Barker 2002). In areas where direct conflicts with Golden-wings are minimal, the Blue-winged Warbler is itself a high priority for conservation. This species too has expanded its range eastward and northward, but has also shown subsequent declines in southern New England and New Jersey. Prairie Warbler is another species experiencing widespread declines, while expanding at the northern edge of its range. In the Northeast, largest populations remain in the Mid-Atlantic Coastal Plain, Piedmont, and Ohio Hills physiographic areas.

Along with other species in this suite, American Woodcock has shown declines of 2.3 percent per year from 1968-2002 in the eastern U.S. according to USFWS singing-ground surveys (Kelley 2002). The species remains quite broadly distributed across the eastern U.S. with highest densities across the northern portion of the breeding range including the St. Lawrence Plain, Eastern Spruce-Hardwoods, and Adirondack Mountains physiographic regions. Other species, such as Brown Thrasher, Eastern Towhee, and Field Sparrow, remain abundant in many parts of the region, but continue to show troubling rangewide declines.

Habitats used by species within this group include successional shrublands resulting from natural disturbances (wind-storms, ice-storms, fires, landslides, beaver activity), and natural barrens and heathlands, as well as a variety of habitats created by human activities (e.g. forestry, agriculture, power-line cuts, mining). Habitat requirements for priority species in this habitat suite are broadly similar, and there is overlap in management recommendations between species. In particular, management practices for American Woodcock, the only priority early-successional species that is extensively managed for, may have important benefits for Golden-winged Warbler and other focal species populations. Detailed habitat studies and recommendations for management of Golden-winged Warblers may be found in Confer (1992) and Confer et al. (1999).

Threats and Conservation Issues

Shrubland habitat has decreased significantly in the Northeast since the early 1900's for a variety of reasons, chief among them the reforestation of abandoned agricultural lands and lands previously cleared for timber harvest. In certain physiographic areas and near urban areas of the Northeast, the major threat to birds of this habitat type is now loss and fragmentation from urban development. Especially troubling, large acreages of natural pine barren habitat recently have been converted to housing lots. Remaining tracts of pine barrens, even if protected, are threatened by cessation of natural fire cycles.

In addition to outright loss of remaining habitats to development, lack of current management in regenerating forests also results in fewer opportunities for early successional bird species. Balancing the needs of both shrub- and forest-nesting species in the Northeast represents a major challenge for managers and conservation planners. For example, a forest can be cleared to make early successional habitat within a year or two of clearing but it may take dozens or even hundreds of years for the forest to grow back to a condition that is suitable for species dependent on large, mature forests. Deciding which areas and the size of areas to convert or maintain in early successional habitat and whether or not natural disturbance regimes are adequate to meet the needs of these species in some areas is difficult and requires a landscape level perspective.

For Golden-winged Warblers, the continued hybridization with and competitive exclusion by Blue-winged Warblers is a major threat that may be exacerbated by human-caused habitat changes that have allowed Blue-wings to inhabit higher elevation habitats than originally used. Therefore, habitat-based management plans to enhance Golden-wing populations must consider local interactions between the two species, and these may not succeed at all in regions where Blue-winged Warblers are common.

Needs and Recommendations

An overall strategy for conserving shrub-nesting species should start with assessment and protection of naturally disturbed habitats, such as pine- and other

barrens. Management to mimic or replicate natural disturbance processes, especially on public lands, should balance the needs of early- and late-successional species, in a landscape context. Conservation needs for shrub-nesting birds include a combination of habitat-based protection and management actions and basic research on the biology of high priority species, especially for the Golden-winged Warbler. Specific needs for this species on the breeding grounds include:

- determine range of suitable habitats and identify present breeding sites for Golden-winged Warbler in this region. (Present breeding sites are being surveyed through the Golden-winged Warbler Atlas Project by the Lab of Ornithology, with field work being conducted for this project continuing from 2000-2004);
- develop improved monitoring program for Golden-winged Warbler that considers their patchy distribution and low population size;
- identify sites where significant populations of Golden-winged Warblers coexist with Blue-winged Warblers; manage these sites as potential "safe havens" for sustaining Golden-wings within their historic range;
- compare early successional habitats resulting from natural disturbances vs. forestry and other management practices, with regard to suitability for high-priority species;
- determine effects of woodcock habitat management techniques on other priority, early-successional bird species;
- develop specific recommendations about burning regimes in managed or protected sites;
- develop management guidelines and policy for utility right-of-ways and other shrub habitats maintained in early-successional states;
- survey for any extant populations of Appalachian Bewick's Wren.

Oak-Hickory Deciduous Forests

Highest priority species for this habitat suite include Cerulean Warbler, Worm-eating Warbler, Kentucky Warbler, Louisiana Waterthrush and Wood Thrush. In addition, several widespread forest species are considered regional priorities in many physiographic areas, making this the largest habitat-species suite (21 species) of any considered (*table 2*). In many of the southern physiographic regions especially, this habitat makes up the highest proportion of the habitat in the landscape and often occurs in relatively large unbroken forest blocks. The avifauna of these forests are also primarily southern, and some species are near the northern limit of their range.

Distribution and Populations

Cerulean Warbler had the greatest decline of any North American warbler between 1966 and 1982 (Degraaf and Rappole 1995) and the decline was estimated at 4.0 percent per year from 1966-2002 (Sauer et al. 2003). Although expansions into portions of the Northeast were documented through the 1900s, these populations do not appear to be expanding at present, and in some areas (e.g. New Jersey) subsequent declines have been noted. Largest populations in the Northeast region occur in the highlands of West Virginia but significant populations also occur in the Ridge and Valley and Lower Great lakes Plain physiographic areas. The recently completed Cerulean Warbler Atlas Project (Rosenberg et al. 2000) identified the most important sites for this species in each state. Cerulean Warbler populations occupy mature oak forests on dry ridge tops, mixed-mesophytic forests on slopes, and tall bottomland forests of sycamore, cottonwood, or maples. The common feature of these habitats appears to be mature trees, a tall and uneven emergent canopy layer, and large tracts of land (Hamel 2000, Rosenberg et al. 2000).

Among the other focal species, Kentucky Warbler and Wood Thrush also are showing significant long-term declines, with losses of over 50 percent of the total population in the Northeast since 1966. Wood Thrush is the most widespread and abundant of the priority species of this habitat suite, with highest densities occurring in West Virginia (Sauer et al. 2003). In contrast, Kentucky Warbler is more abundant to the south of our region, with highest densities along the coastal plain and Piedmont regions.

Worm-eating Warbler is vulnerable to population declines because of its dependence on large tracts of forest for nesting and as a result of significant losses of over-wintering tropical broadleaf forest habitat (Petit et al. 1993). The BBS data show increasing populations in southern New England and the Mid-Atlantic Coastal Plain, whereas declines were noted in areas supporting the highest densities in south-central Pennsylvania and West Virginia (Sauer et al. 2003). Similarly, the Louisiana Waterthrush is believed to have relatively stable populations overall in Canada and the U. S., with local declines in high-abundance areas such as West Virginia perhaps offset by recent expansions at the northern edge of the range (Sauer et al. 2003).

Threats and Conservation Issues

The greatest threats to oak-hickory/deciduous forests of the Northeast include continued loss and fragmentation of forests near rapidly growing urban centers and degradation of forest habitat from excessive deer browse, disease, and invasive plants. In some areas there are specific threats, including the massive loss of habitat from mountaintop removal mining in West Virginia within the areas of highest density for breeding Cerulean Warblers. In addition to habitat loss, changing forest structure is of critical importance to many bird species. In particular, most priority species are associated with some form of forest disturbance, especially gaps and openings that create dense shrubby understory. Management to induce or replicate patterns of local disturbance may be important for sustaining forest bird populations, yet applying such management on public lands is often controversial. Furthermore, balancing the needs of species requiring small-scale local disturbance with those that need more extensive disturbance management remains one of the most challenging issues in bird conservation in the Northeast.

An estimated 80 percent of forest land in the eastern United States is privately owned. Outreach should be targeted at owners of private woodlots and large timber companies to manage (or not manage) their land for the benefit of priority forest birds. Proactive management on private lands would benefit conservation efforts and landowner interests. The largest tracts of oak-hickory dominated forests exist, however, on the relatively small amount of public lands in the region. These include several large National Forests in Virginia, West Virginia, and Pennsylvania, as well as numerous state parks and state-owned forests. These public lands are extremely important for the conservation of forest-dependent species in this region.

Needs and Recommendations

Implementing the broad objectives for this habitat-species suite will require a comprehensive forest management plan for the entire region that acknowledges the long-term importance of maintaining large source populations of priority forest birds. Elements of such a plan that are most relevant to the high-priority birds include:

- maintaining a balance of forest-age structures, including adequate amounts of mid-successional as well as late-successional forest;
- ensuring long-term tree-species composition; i.e. preventing loss of particular species, through disease or selective harvest;
- ensuring adequate structural diversity, especially regarding canopy and understory components (shrubs, treefalls); monitoring effects of natural disturbances (e.g. wind storms) as well as insect outbreaks, deer browsing, and forestry practices;
- setting maximum allowable levels of forest fragmentation due to forestry practices or planned development; e.g. do not allow any 10,000 km^2 landscape to fall below 70 percent forest cover.

Specific implementation strategy for the highest-priority species, Cerulean Warbler, includes:

- identify important populations and sites on public land; determine habitat needs and implement policy to protect or enhance populations;
- identify important populations and sites on private land; prioritize and target sites for easement, acquisition, or voluntary implementation of habitat protection or enhancement;
- monitor long-term use and suitability of key sites in relation to land use trends.
- determine best forest management practices for Cerulean Warblers to enhance populations.

Northern Hardwood and Coniferous Forest

Priority species for this habitat suite at the continental level include Olive-sided Flycatcher, Bay-breasted Warbler, Canada Warbler, and Rusty Blackbird, though the number of priority species that occupy this habitat is quite large (18 species - *table 2*). Additional species of regional concern or high responsibility include Black-billed Cuckoo, Yellow-bellied Sapsucker, Boreal Chickadee, Black-throated Blue Warbler, and Blackburnian Warbler. This habitat suite occurs in all 12 physiographic areas, though it is quite restricted in many of the southern regions. In many of the northern physiographic areas these habitats make up the highest proportion of the habitat in the landscape and often occur in relatively large unbroken forest blocks.

Distribution and Populations

Several priority species in this suite are at the southern limit of their range in the Northeast U. S. A majority of species are showing moderate to steep population declines in the Northeast and throughout their ranges. For example, Canada Warbler has shown a decline of -1.9 percent per year from 1966-2003, while Olive-sided Flycatcher has declined by an estimated -3.5 percent per year. Highest densities of both species in the region are in northwestern Maine (Sauer et al. 2003). Black-billed Cuckoo, Cape May Warbler, and

Rusty Blackbird are showing even steeper regional declines since 1966. In contrast, Northern Parula, Blackburnian, and Black-throated Blue Warblers have shown stable or increasing long-term trends (Sauer et al. 2003). Declining species are primarily those associated either with disturbance regimes within the forest (e.g. shrubby understory, edge), or with mature conifer stands (especially Bay-breasted and Cape May Warblers).

It is noteworthy that several of the species in this suite undergo marked population fluctuations in response to spruce-budworm outbreaks; these species exhibited large increases during the period 1966-1979 and then subsequent declines during the following decades. Setting population objectives for such species is extremely difficult.

Threats and Conservation Issues

Northern hardwood and mixed forests, usually dominated by sugar maple, beech, and birch, represent the most widely distributed habitat-type within the more northerly physiographic areas of the Northeast U. S. As mature softwoods (especially white pine) in these areas were extensively harvested in the past century, hardwood forests have regenerated over most of the region during the past 80 years. The major issues affecting this habitat suite today relate to trends in commercial timber production and management, forest habitat degradation (including effects of acid rain and deer overbrowse), and, in some areas, loss and fragmentation of habitat from development.

Coniferous (i.e. softwood) tree species are currently preferred for commercial timber production (pulp and paper) in this region, and vast acreages of coniferous forest are under management for commercial forestry. In addition, because of shorter rotation cycles, age-class distribution of conifer forest is favoring younger and more even-aged stands. These trends suggest that a shortage of mature spruce-fir forest may exist in the near future. It is these mature coniferous forests that support a large number of high priority bird species, and if projections are accurate these species may decline throughout the region. Unlike the patchily distributed mountaintop communities, where protection of specific sites is critical, conservation strategies for mature coniferous forest will need to focus on maintenance of minimum percentages of the landscape mosaic to prevent local loss of this habitat type and its associated dependent species. This goal may best be achieved through cooperative agreements with large landowners.

For conservation lands that support coniferous forest, maintenance of considerably larger percentages of land area in mature or overmature age classes is desirable to offset potential shortfalls or temporal bottlenecks. The shifting mosaic paradigm requires that no species be lost from a landscape unit over time (Hagan et al. 1997). To meet this seemingly simplistic objective requires maintenance of all habitat types in that landscape unit for a specified period. In the Adirondack Mountains, for example, vast areas are within state-owned forest preserve, whereas other large areas are under active timber management on private lands. This mosaic of ownership and land-use presents both a challenge and an opportunity for largescale bird conservation in the region.

Needs and Recommendations

General management guidelines for priority species in northern hardwood and coniferous forests do not exist at present, although much research has been conducted on habitat relationships and effects of silviculture in local areas. Many of the priority species have been shown to respond positively to various silvicultural practices. In particular, Canada and Black-throated Blue Warbler populations were enhanced by modest timber harvesting in Maine (Hagan and Grove 1995). Because songbirds have small area requirements and frequently dense populations, greater consideration should be given to the diversity and arrangement of habitats at the landscape-level rather than focusing on species abundance at the stand level (Hagan et al. 1997). No single silvicultural practice benefits all species of neotropical migrant birds (DeGraaf et al. 1993); rather, forest management activity can benefit most species at some time in the rotation cycle. Strong associations of dense understory to populations of Black-throated Blue and Canada Warbler (Holmes 1994, Conway 1999) suggests that certain forest harvesting practices (on appropriate sites), like selective cutting or group selection, could be especially useful at creating or maintaining suitable habitat.

Developing predictive habitat suitability models for priority species at landscape scales is a high priority in this forest type. This effort would benefit from research directed at the following specific needs:

- GIS analysis of public and private lands to identify, catalog, and prioritize forest stands in terms of species composition, age structure, and amount of understory;
- determine specific habitat needs (and causes of declines) for Canada Warbler; why, for example, is Canada Warbler declining while Black-throated Blue Warbler is stable, if both require shrubby understory of mature forest?
- better understanding of landscape-level effects of land-use practices on forest bird populations;

- better understanding of role of stand age and stand structure on habitat quality and ultimately survival and reproductive success of priority species;
- better methods for monitoring species that use patchily distributed components of the forest, such as treefall gaps, wetlands, peatlands, snags.

Conservation of birds in northern hardwood and coniferous forests will be best implemented in partnership with Canadian agencies and organizations. Recent efforts in the Atlantic Northern Forest Bird Conservation Region (BCR 14) through the Atlantic Coast and Eastern Habitat Joint Ventures represent an excellent beginning.

Acknowledgments

We thank the many participants in the PIF Northeast Working Group who helped develop regional bird conservation plans and who shared insights and unpublished information on priority bird species. Especially important to our habitat summaries were contributions from D. Brauning, R. Canterbury, J. Confer, R. Dettmers, T. Hodgman, A. Jones, K. McFarland, C. Rimmer, and B. Watts. This manuscript benefited from comments by E. Iñigo-Elias.

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Avian Conservation Planning in the Caribbean: Experience and Recommendations from the Dominican Republic[1]

Steven C. Latta[2,3] and Eladio Fernandez[4]

Introduction

The Dominican Republic, on the island of Hispaniola, supports more bird species than any other Caribbean country except Cuba. More than 300 species of birds have been recorded in the country, including 285 native residents and 27 endemics (Keith et al. 2003). The Dominican Republic is also a major wintering site for Neotropical migrants. Despite this richness, the avifauna is perhaps the least studied in the Greater Antilles and is under increasing pressure from habitat alterations, hunting, trafficking of birds for the pet trade, pollution, and other effects of the human population. Although the Dominican Republic has set aside more than 16 percent of its territory in 40 protected areas for the benefit of wildlife (Ottenwalder 2000), many of these sites are effectively unprotected, and only a few have written management plans (Ottenwalder 2000). There are no management plans for individual threatened species or habitats.

In 1998 a broad-based, grassroots-oriented avian conservation-planning workshop was organized in the Dominican Republic to set priorities and coordinate planning efforts among researchers, managers, educators, activists, and politicians in the Caribbean nation. Avian conservation needs and priorities with respect to each of these disciplines were generated at the workshop. The design of the planning process, and the results of the avian conservation workshop, were previously described by Latta (2000) and Latta and Lorenzo (2000). Here we report, four years after the workshop, on the successes and failures of this planning effort, and make further recommendations for those planning similar coordinated strategies for avian conservation in developing nations.

The 1998 Avian Conservation Workshop

The 1998 avian conservation workshop sought to meet five objectives: 1) increase communication and cooperation between all parties interested in avian conservation; 2) familiarize participants with resources pertinent to avian conservation that were already available; 3) increase communication between researchers and managers, especially to encourage the transfer of information from foreign to Dominican biologists; 4) promote the concepts of long-term avian monitoring, avian conservation plans, and species management plans; and 5) evaluate means by which ornithological research, environmental education, public policy, and land management can promote avian conservation and develop a strategy to promote the conservation of birds in the Dominican Republic.

Working groups made the following recommendations

Research and Monitoring

Researchers called for the following actions: 1) additional field studies detailing the distribution, abundance, natural history, and habitat selection of all Hispaniolan birds; 2) immediate initiation of a national avian monitoring program; 3) specific studies on the effects of deforestation, other types of environmental degradation, and introduced species on bird populations; and 4) identification and prioritization of species and habitats requiring immediate attention. Because baseline data on population size, trends, and habitat loss did not exist, researchers used primarily personal experience and evaluations made by Birdlife International (draft reports which later appeared in BirdLife [2000]) in evaluating threatened species and habitats. Among birds, endangered endemic species demanded top priority. High elevation cloud forests and moist broadleaf forests were selected as priority habitats for attention.

Management

Managers concluded that representative parcels of all major habitats were already protected by law but were unable to evaluate whether additional parcels of land required protection. Managers emphasized that basic data were lacking to make many management decisions and recommended that departments focus on small,

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achievable goals until additional data and funds become available for larger projects.

Education

Educators sought a means to create a national culture that supports environmental protection. Toward this end they sought interdisciplinary actions to: 1) train community organizers in environmental education, focusing in particular on communities near protected areas; and 2) design and introduce a national curriculum on environmental education in general, and on birds in particular, in the public schools.

Public Policy

The public policy group, citing the fragmentation of environmental responsibilities within the government, placed emphasis on creation of a comprehensive Wildlife Law and establishment of a Department of Environmental Impact Studies.

Update: Four Years Later

Research and Monitoring

Soon after the workshop, a plan was developed for the initiation of a long-term avian monitoring effort based on the North American Breeding Bird Survey (Robbins et al. 1986, Ralph et al. 1993) and the Breeding Bird Biology Research and Monitoring Database (BBIRD) protocols (Martin et al.1997). As a top priority of the researchers, the monitoring plan met with universal support, except from funding agencies that have appeared hesitant to involve themselves in monitoring or multi-year endeavors. Funds to implement this monitoring plan were sought each year since then. Only in 2002 were the beginnings of a monitoring program funded with limited monitoring taking place in the form of point counts and constant effort mistnetting in four national parks, and nest monitoring initiated in one park. Significantly, Dominicans are intimately involved in the planning and execution of these monitoring efforts. However, almost all new research initiatives continue to come from foreign biologists, including the University of Missouri, Vermont Institute of Natural Science, and Cornell University, which has recently developed a Biodiversity Lab at Punta Cana.

Management

Little progress seems to have been made in terms of management issues, with the significant exception that in the past year the government, with the help and encouragement of the ornithological community, has focused considerable resources on infrastructure development in Sierra de Bahoruco National Park and parks of the Cordillera Central, a priority emphasized by workshop participants. However, this has occurred without management plans in place despite recommendations to first develop such plans. Conservationists were given a significant boost in late 2002 when the United Nations recognized the biological uniqueness of several protected areas with the creation of a new UNESCO Biosphere Reserve (UNESCO 2002). The Jaragua-Bahoruco-Enriquillo Biosphere Reserve covers almost 500,000 hectares of a complex mosaic of habitats, ranging from the unique Enriquillo Lake lying 40 m below sea level, through the lagoons and coastal habitats of Jaragua National Park, to the montane mixed-pine and broadleaf forests and cloud forests of the Sierra de Bahoruco. This first biosphere reserve on the island reflects international and, perhaps more importantly, national recognition of the unique nature of the site, and the responsibility to steward the reserve for sustainability. It is hoped that United Nations' recognition of the Jaragua-Bahoruco-Enriquillo Biosphere Reserve will help secure funding to develop management plans and infrastructure, and promote tourism and the local economies.

Education

Fundación PROGRESSIO and The Nature Conservancy obtained funding for the establishment of a national training center and the development of a comprehensive training program in environmental education and avian monitoring techniques at Ebano Verde, but this project seems to have collapsed due to institutional failures. A working group also began meeting to begin the work of designing an environmental education curriculum but this, too, seemed to have not survived. A photographic guide to common birds of the Dominican Republic (Latta 2002) has been completed by members of the re-organized Sociedad Ornitológica de Hispaniola (SOH) and will be distributed to schools and public institutions. A scholarship fund for graduate training of promising ornithologists has been started with leadership coming from the Vermont Institute of Natural Science.

Public Policy

A working group met to begin to draft a new, comprehensive wildlife law that would regulate everything associated with wildlife management and help ensure the independence of the wildlife department, but this activity seems to have been overtaken by larger political events. Although not a result of the workshop recommendations, the National Parks Directorate and the Department of Wildlife have been consolidated and function under an appointed Secretary of the Environment for the first time. The new Secretary has been proactive in support of conservation issues, thereby emphasizing the importance of larger political issues in determining conservation priorities, successes, and failures.

In summary, over the past four years, progress has been made as the result of the avian conservation-planning workshop, but this progress has been limited and slower than expected. Despite many initial cooperative efforts, few of these have gone forward. Significant exceptions include the SOH coordination with the Secretary of the Environment in infrastructural improvements in the Sierra de Bahoruco and Cordillera Central and coordination among several non-governmental agencies (NGOs) and foreign ornithologists in monitoring efforts. There is a general consensus among conservationists that the conservation workshop served as an important stimulus for a number of small groups and for quite a few new people to become involved in conservation issues. But the workshop has not spawned the level of cooperation among NGOs or between NGOs and the government that the organizers anticipated. This may be due to a combination of 1) a general lack of respect for government institutions and personnel, and a perception that the government 'does nothing'; 2) a perception that the government provides little direction or aid to NGOs; 3) a corresponding perception by government personnel that the NGOs do not approach them with research or management projects or concerns; and 4) a strong tradition of division among NGOs in terms of conservation priorities and areas of practice. Nevertheless, conservationists from NGOs and the government in the Dominican Republic persist in their activities with the knowledge that change sometimes comes slowly and that some ideas must be repeatedly brought forward in many arenas and over a long period of time before they are ultimately successful.

Recommendations

Here we offer our top ten recommendations for comprehensive avian conservation planning based on our experience in organizing a grassroots-oriented planning workshop and follow-up conservation efforts in the Dominican Republic.

1) Plan sufficient lead time when developing a planning workshop, both for organizational aspects and for collection and dissemination of preparatory materials. Remember that this project will not be everyone's top priority even if they are supportive.

2) Begin the planning process with as broad a coalition as possible. Be aware of key players, especially those who may have ownership issues around avian management and conservation, and include them early in the planning efforts. Also be sure to include sectors of the natural resource community that may not be traditionally thought of as conservationists (i.e. hunters) as they often need to be part of the solution.

3) Questionnaires can be a very useful organizing tool, but remember they also require extensive follow-up.

4) Allow participating organizations in planning and conservation efforts to contribute in a way and a form in which they feel most comfortable. Take advantage of skills and services available through your network. This reduces costs and helps insure broader ownership of the planning and conservation process.

5) Recognize that you may possess less-than-adequate scientific knowledge, but don't let it freeze all progress. Use the current level of knowledge as a base from which to build research and management strategies as well as educational efforts.

6) While prioritization of conservation needs will be recognized by funding agencies, it does not guarantee immediate funding. Be persistent and creative in your efforts to fund projects that will increase your knowledge base and grow your conservation programs.

7) Special efforts may be needed to break down impediments to coordinated actions between government departments and NGOs.

8) A lack of graduate-trained ornithologists in the government departments with management responsibilities, and in NGOs, may be an impediment to some conservation practices, but it can be addressed with increased emphasis on collaborative training programs and support for scholarship funds.

9) Personal and organizational poverty is a strong barrier to effective organizing and can be partially addressed by institutional grants from funding agencies and support for permanent or long-term staff positions within NGOs.

10) A long history of suppression of grassroots organizing (at least in the Dominican Republic) has resulted in a poverty of organizing capabilities and continues to affect the success of NGOs involved in environmental education and conservation. Training in community organizing and environmental advocacy skills would be useful.

Acknowledgments

Steven Latta's work on Hispaniola has been supported by the American Bird Conservancy, Association of Avian Veterinarians, National Fish and Wildlife Foundation, National Geographic Society, University of Missouri Research Board, USDA Forest Service North-Central Forest Experiment Station, U.S. Environmental Protection Agency, and the Wildlife Conservation Society. T. D. Rich, K. Wallace, and members of the Sociedad Ornitológica de Hispaniola provided comments on previous drafts of the manuscript.

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The Nature Conservancy's Gulf Wings Project – A Case Study in Conservation Planning for Migratory Birds[1]

Charles Duncan[2, 3], Becky Abel[3, 4], Danny Kwan[3, 5], and David Mehlman[6]

Abstract

The Nature Conservancy has adopted a framework for mission success called *Conservation by Design.* We plan at the ecoregional level to define conservation targets and the portfolio of sites needed to protect them. We consider threats and strategies for abating them at these key sites, and we define measures of success to hold ourselves accountable. Migratory birds stretch our methods, crossing multiple ecoregions and requiring differing habitats temporally. Their viability is hard to assess, and population data are fragmentary at best. The Conservancy's new Gulf Wings initiative is a multi-ecoregion project to protect critically threatened stopover habitat around the Gulf of Mexico. We use it as a case study of how the Conservancy and our partners address the challenges of planning for conservation of migratory birds.

Key words: conservation, Gulf of Mexico, Gulf Wings, migratory birds, The Nature Conservancy, planning, stopover habitat.

Introduction—How the Conservancy Plans to Complete its Mission

In order to achieve its mission of preserving the plants, animals and natural communities that represent the diversity of life on Earth, The Nature Conservancy (the Conservancy) has adopted a framework for mission success called "Conservation by Design." This process has four iterative steps (*fig. 1*) (The Nature Conservancy 2001).

The first step, "setting priorities," involves planning at an ecoregional scale. This includes identifying conservation targets and information about them, setting goals for the number and distribution of the targets, assessing their viability, and assembling an efficient network of conservation areas ("the portfolio") that, if protected in its entirety, will ensure the preservation of biodiversity within the ecoregion. Targets can include species, natural communities, and ecological systems.

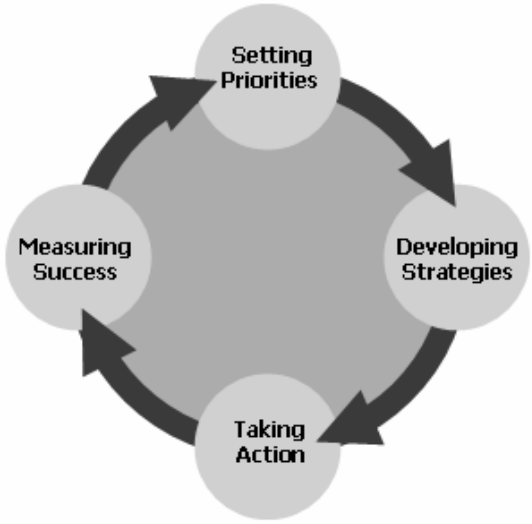

Figure 1— The four steps used by The Nature Conservancy in its conservation approach.

In the second step, strategies to protect the portfolio of conservation areas are developed. The Conservancy uses a process called Conservation Area Planning that begins by identifying the species, native communities and ecosystems that will be the focus of conservation in an area. Subsequent phases identify the stresses that threaten the conservation targets, such as habitat fragmentation or changes in natural flow patterns of waterways, as well as the sources of these stresses. Practical strategies for reducing or eliminating threats are then developed. A key part of Conservation Area Planning is the explicit assessment of progress in reducing threats, and in improving the biodiversity and ecological health of a focal conservation area.

The third step, "taking action," involves applying both familiar and novel conservation tools to implement the highest priority strategies. These tools may include

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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acquiring and managing key ecological areas, offering training to partners and local governments, and collaborating with resource-based industries to modify their business practices to reduce environmental impacts.

The fourth step of the process, "measuring success," evaluates the long-term reduction of critical threats and uses ecological benchmarks to measure sustained maintenance or enhancement of biodiversity health. This is accomplished by regular measurement of the size, condition, and landscape context of selected conservation targets in an area, and by measuring the level of threat to conservation targets within the area. Collectively, these measures quantify our conservation impact. To hold the organization accountable for results, the Conservancy intends to measure success across full portfolios of sites, not just those conservation areas where the Conservancy itself is taking direct action.

The Challenges of Migratory Birds

Migratory birds stretch the limits of scale in conservation planning. They present a challenge for the Conservancy's approach to setting priorities, developing strategies, taking action, and measuring success. Their population size and demography are poorly known, their viability is hard to assess, and they cross ecoregional and political boundaries. In many cases there is marked temporal variation in habitat use, both within and across years. Frequently, spring (northbound) migration routes are not the simple reverse of autumn (southbound) routes.

Forest-dwelling migratory birds breed in many portfolio sites in North America, and winter in equally numerous portfolio sites south of the U.S.-Mexican border. Identified conservation areas do not automatically protect habitat *en route* between the geographic ends of the birds' life cycles, however. Even when portfolio sites do provide adequate habitat for *en route* birds, conservation area plans have rarely identified specific conservation strategies, appropriate ecological management, or reliable methods for measuring success for the conservation of migratory species.

A particularly thorny part of designing a comprehensive conservation program for migratory birds has been how to protect "stopover habitat," those places that migratory birds use en route, between the breeding and wintering seasons. As Moore (2000) has said, "Protect all the breeding woodland in North America and all the appropriate habitat on the wintering grounds and populations of intercontinental migrants will still decline unless habitat requirements during migration are factored into the conservation equation." The Conservancy and other groups have struggled with how to incorporate stopover habitat into their prioritization schemes. Partners in Flight, itself a cooperative effort involving partnerships among many groups and agencies, is notable among these.

As a response to this challenge, the Conservancy's Migratory Bird Program (then known as "Wings of the Americas"), Great Lakes Program, and Southeast Division joined to consider the implications of protecting stopover habitat for our work. We organized a three-day expert workshop in May 2001 in Moss Point, Mississippi, to discuss stopover site protection for forest-inhabiting migratory birds along the Gulf Coast and Great Lakes. The meeting was attended by 34 experts drawn from academia, government agencies, and non-profit groups. The goals of this event were to

- define "important" stopover habitat
- examine the adequacy of sample ecoregional portfolios for protecting stopover habitat
- develop consensus on if, and how, stopover sites can be prioritized
- develop consensus on how best to incorporate stopover habitat into the Conservancy's planning methods

The results of this highly successful meeting are summarized and explored elsewhere (Duncan et al. 2002). Chief among these was a categorization of stopover habitat based on landscape context and function, that we call "the Framework." The term "fire escape" is applied to sites that are generally used only under emergency conditions of adverse weather, and provide few resources other than shelter and perhaps fresh water. They are located next to ecological barriers such as large bodies of water. "Convenience store" sites are those sites located along migratory routes that typically provide only low-quality resources, sufficient for migrants to move on to the next stopover site. Finally we use the term "full-service hotel" for resource-rich sites, large enough to maintain landscape-scale integrity, where a given migrant bird may spend several days refueling for the rest of its journey.

Other key outcomes of the Moss Point meeting were

- a consensus that the Conservancy's ecoregional portfolios of conservation areas in the eastern United States are reasonably adequate for protecting migratory birds
- a recognition that considerable research is needed before Mexican areas can be identified
- the finding that "stopover habitat" is an appropriate systems-level conservation target for Conservancy planners

- a recommendation for scale-dependent studies of stopover habitat and ecology (Moore, undated ms.)

As a result of the Moss Point workshop, the Conservancy explicitly recognized its responsibility to ensure the protection of stopover habitat. This will entail identifying a network of stopover sites; designing and implementing strategies, especially multi-site strategies, to address common threats to stopover habitat; and measuring success of stopover habitat conservation to hold itself accountable.

Protecting Stopover Around the Gulf of Mexico

The Gulf of Mexico is, by virtue of its size and location, the single greatest barrier that many migratory landbirds encounter when traveling between the wintering grounds in the neotropics and breeding grounds in the United States and Canada. Some species avoid the water crossing through circum-Gulf migratory routes, while many make trans-Gulf flights. A few species exhibit a broad-front migration, with individuals selecting either route (for instance, Dunn and Garrett 1997). Coastal areas are crucially important as stopover habitat no matter which route is involved. Projections of human population change suggest an increasing threat to these natural areas (Simons et al. 2000, Barrow et al. 2000). The Southeast Partners in Flight network, the Gulf Coast Bird Observatory's conservation plans, and the Gulf Crossings partnership (http://www.gcbo.org), were among the first to bring conservation action to this region.

There are numerous other areas, including the Great Lakes and sites along the Atlantic Coast of the United States and Canada, that also require attention to stopover issues. Nonetheless, capacity limitations within the Conservancy dictated that stopover protection efforts be directed to one region initially. The Gulf of Mexico became the obvious choice, with the hope that lessons learned there and best practices developed can be exported to other areas. The Conservancy's efforts to protect stopover around the Gulf of Mexico were consolidated under the project title of "Gulf Wings," parallel with its Prairie Wings conservation program (McCready et al., this volume) in August 2001.

The mission of Gulf Wings is to conserve the critically threatened stopover habitat around the Gulf of Mexico crucial to the survival of the many North American bird species whose migratory routes converge on this area. The conservation vision for the project is to enhance the site-based conservation efforts of The Nature Conservancy and its partners around the Gulf of Mexico by bringing attention, coordination, resources, and scientifically sound planning to conserving habitats needed by migratory birds traveling between their North American breeding grounds and their wintering areas both in the region and farther south.

Distinctions from the Work of Others

It is worth considering explicitly how Gulf Wings is different from the work of other conservation groups working around the Gulf of Mexico. As part of The Nature Conservancy, Gulf Wings uses the Conservancy's strategy for mission success called "Conservation by Design," described above. Part of the contribution that Gulf Wings makes is to inform the priority-setting process where birds, and especially migrant birds, present unique challenges to the Conservancy's planning methods. Indeed, it is the job of Gulf Wings to ensure that stopover sites around the Gulf of Mexico, from small, infrequently used "fire-escapes" to large landscape-scale forests ("full-service hotels"), are sufficiently included in the Conservancy's overall planning priorities for the relevant ecoregions.

Thus, the Conservancy's planning methodology is used both to delineate important areas for birds within the larger context of protecting overall diversity, and also to decide where to allocate limited resources for the best return of investment. Both identification and prioritization of important stopover habitats are shaped by the over-arching Conservancy mission to preserve biological diversity at the landscape level.

Gulf Wings takes conservation action through the Conservancy's operating units and their partners—at sites that have identified as being high priority through the ecoregional planning process. Ultimately, Gulf Wings delivers tools to locally based conservationists.

Gulf Wings also attracts and leverages resources to integrate bird conservation into the broader biodiversity work of the Conservancy. As an example, Gulf Wings is helping to fund a staff position at the local level in the cheniers and bottomlands of the Upper Texas and Louisiana coasts. This person will not work exclusively on bird conservation, but by contributing to the protection of key habitats, will ensure that the appropriate actions relevant to birds are taken.

Gulf Wings, and indeed the Conservancy itself, is focused on protection of land and waters for biodiversity conservation. That tight focus on habitat protection means that good and useful activities such as environmental education or public outreach are not automatically within the Conservancy's realm. When such activities are identified as important strategies for abating key threats to stopover habitat, the Conservancy seeks partnerships with any of a number of other

groups more highly skilled and experienced in education and outreach.

The issue of the scale of Gulf Wings is important. The portfolio of sites we have identified as needing conservation action to conserve stopover habitat around the Gulf is enormous, about 7 million hectares in the United States alone. To achieve lasting tangible conservation results for stopover habitat protection, the Conservancy believes that this is the correct scale. Only by working with established Conservancy operating units and their partners, does this scale become achievable.

The Gulf Wings project will be of finite duration, about 36 months. At the end of this period, Conservancy operating units will have been informed of the importance of stopover habitat, and will have incorporated it into their ecoregional and conservation area plans. Moreover, the permanent conservation and management of these portfolio sites will address the needs of migratory birds. Responsibility and the needed tools will have been transferred to the relevant operating units of The Nature Conservancy and ultimately, their partners.

Building an Internal Constituency

A key step in planning the Gulf Wings project was to decide on the specifics of its geography. In doing so, we considered the boundaries of the Conservancy's ecoregions (Groves et al. 2000) that border the Gulf of Mexico. In Mexico, ecoregions have been aggregated into ecological planning units or EPUs and we chose to use these for consistency. Additionally we considered the boundaries of existing Joint Ventures and bird conservation regions, http://www.nabcius.org/aboutnabci/bcrjv.pdf, as well as various constant-distance-from-the-coast schemes. Ultimately, we were guided by a simple concept: the project should encompass sites that were roughly within a single night's travel of the coast for a migrating songbird. The resulting working version of the project boundaries (*fig. 2*) extends around the Gulf of Mexico from roughly the Suwannee River of Florida to the Caribbean coast of the Yucatan Peninsula of Mexico.

To ensure that the project we envisioned met the needs of the Conservancy's operating units, we met with internal stakeholders in November 2001. Twenty-five people, representing the Conservancy's field offices of the five Gulf coastal states of the United States, and the Northeast Mexico program attended the meeting, held in Baton Rouge, Louisiana. To this group we presented the drafts of the project's mission and vision; the concepts of the Framework categorizing stopover site according to landscape context and function; spatially explicit information about protected areas, important bird areas, the Conservancy's own completed ecoregional portfolios; and the draft project boundaries. For Mexico, where the Conservancy has not completed ecoregional plans or their equivalents, we presented information about priority terrestrial sites identified by the Mexican National Commission for the Understanding and Use of Biodiversity (CONABIO, from its acronym in Spanish). Those present were highly supportive of the project and agreed that the initial project boundaries were a sensible starting point.

Setting Priorities

We asked participants at the Baton Rouge meeting to nominate stopover areas chosen from the ecoregional portfolios within their own area of responsibility, classified using the Framework concepts where possible. Again, where possible, those two or three sites considered of highest priority were identified within each ecoregion. This set of conservation areas was thus selected as an initial set of areas where the Conservancy's operating units and the Gulf Wings project would focus attention on stopover protection (*fig. 3*).

We had thus made progress toward two important aspects of the priority-setting process: we had identified the conservation target (stopover habitat) and a set of priority areas where the Conservancy and its partners could engage. It was, however, recognized that while there may be some relatively few sites in the United States that are not yet identified, the level of the group's knowledge about stopover sites along the Mexican coast of the Gulf of Mexico was especially inadequate and would need to be addressed in another forum. This issue was considered in depth at an experts' workshop we organized in the state of Veracruz, Mexico in September 2002. Participants working in groups organized by geographic regions of the Mexican Gulf coast identified key stopover areas (41 sites, 11 million ha), threats and sources of threats and in some cases, proposed conservation strategies. Moreover, Mexican participants at the workshop decided to form a regional alliance for the conservation of birds to be called ARCA.

Designing Strategies

A first step toward designing one or more conservation strategies is to identify the threats and the sources of these threats that endanger the biodiversity that we seek to protect. While actually abating these threats and their sources may be enormously challenging, we have found it essential to summarize them as an initial planning step.

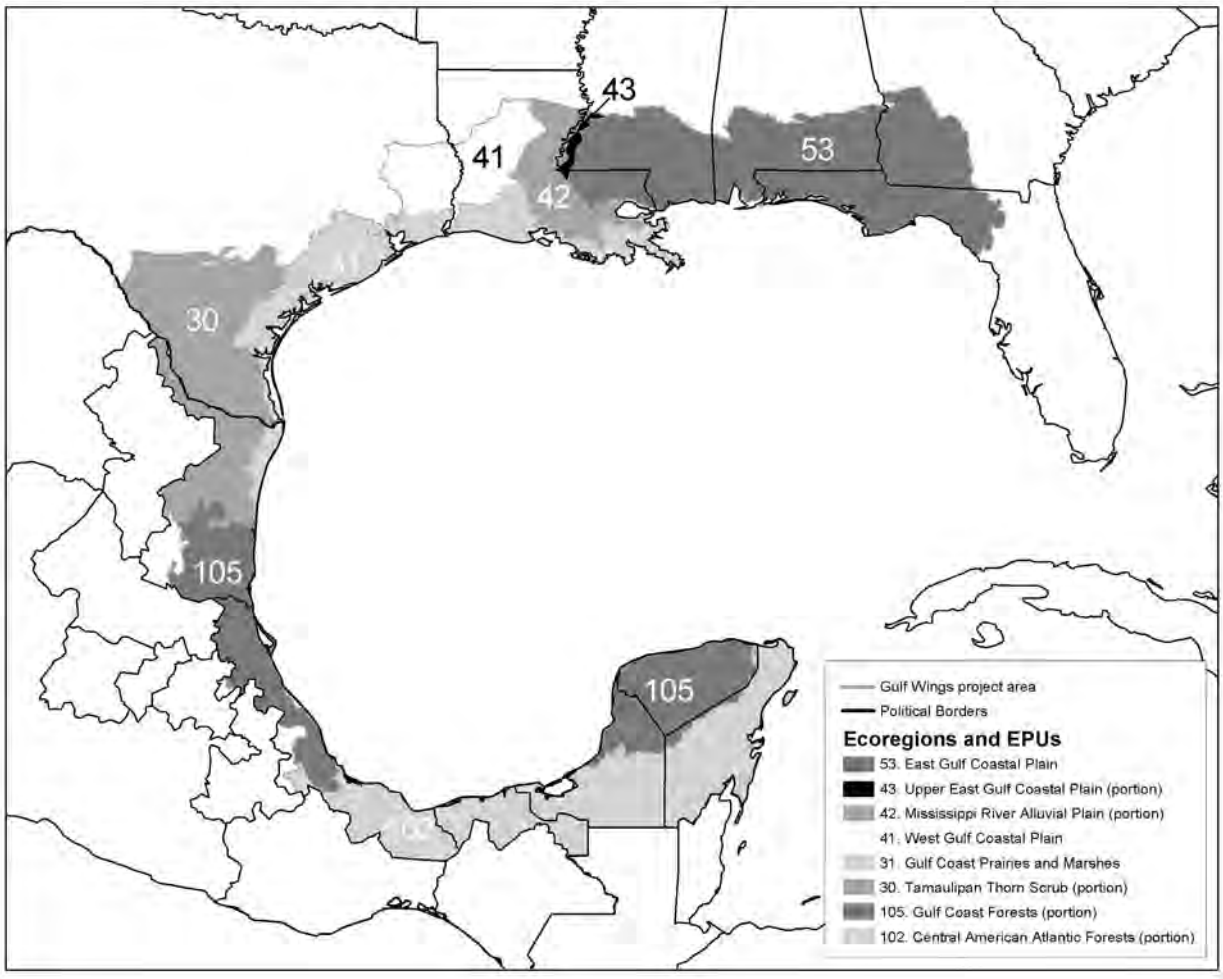

Figure 2— Boundaries of the Gulf Wings project were selected to include the Gulf coastal ecoregions of the Unites States and the ecological planning units (EPUs) bordering the coast in Mexico. The two U.S. ecoregions aligned roughly north-south along the Mississippi River (numbers 42 and 43) were truncated with a line connecting their neighboring ecoregions. In Mexico, the EPUs included were truncated at the state boundaries so that only coastal Mexican states are included. The numbering scheme is that used by the Conservancy for its entire ecoregional map.

The threats and their sources that we have so far identified as endangering stopover habitat include the following:

- **Habitat Destruction** is a critical threat that affects stopover habitat as well as habitat for other conservation targets. Migratory birds are affected by habitat destruction over a larger spatial scale than many other conservation targets. While migrating birds do not need the same specific habitat they need for breeding, they still have general habitat needs. For example, migrating forest birds are dependent on a range of forest habitat types. The sources of this stress are site- and context-specific.

- **Habitat Alteration** is a critical threat that affects many conservation targets but may have serious implications for stopover sites. This is especially true if forest structure is simplified and/or forest composition is altered. The sources for this stress are many, including nonnative invasive species and industrial forestry. Subcategories of Habitat Alteration include:

    - *Lack of critical resources*: This is a threat specific to migratory birds, as they are dependent on high-quality food and freshwater resources for survival. Current management or past land use may have eliminated key resources from Stopover Habitat. Especially significant are freshwater sources in Fire Escape and Convenience Store stopover sites. Changes in species composition, especially those caused by invasive species, may also have caused corresponding changes in the kinds, quantity, and quality of food resources.

- *Extraordinary predation*: A critical threat specific to migratory birds and a few other organisms (e.g., lizards, snails, some plants). The significance of this threat is unknown but may be considerable in small Fire Escape or Convenience Store stopover site types functioning as habitat islands. The sources of this stress can be feral or domestic cats, and elevated levels of native predators such as raccoons (*Procyon lotor*) and foxes (*Vulpes* sp.).

- *Increased aerial mortality*: A potentially critical threat caused by communication towers, lighted buildings, plate-glass windows, and wind-powered generators. The impact of this threat is increasing with the growing number of cellular phone and digital television towers, and the spread of urban and suburban development.

- *Habitat fragmentation*: While migratory birds are apparently not as sensitive to habitat fragmentation en route as during the breeding season, and may even congregate in edge habitat where insects are often abundant, some species may still seek out areas away from edges and human disturbance. Research, however, is sparse and ambivalent. The sources of habitat fragmentation include roads, utility corridors, residential/commercial development, and industrial development.

Multi-site stresses and sources of stress for stopover habitat identified by meeting participants included

- residential and urban development
- incompatible forestry practices
- incompatible grazing
- incompatible recreation

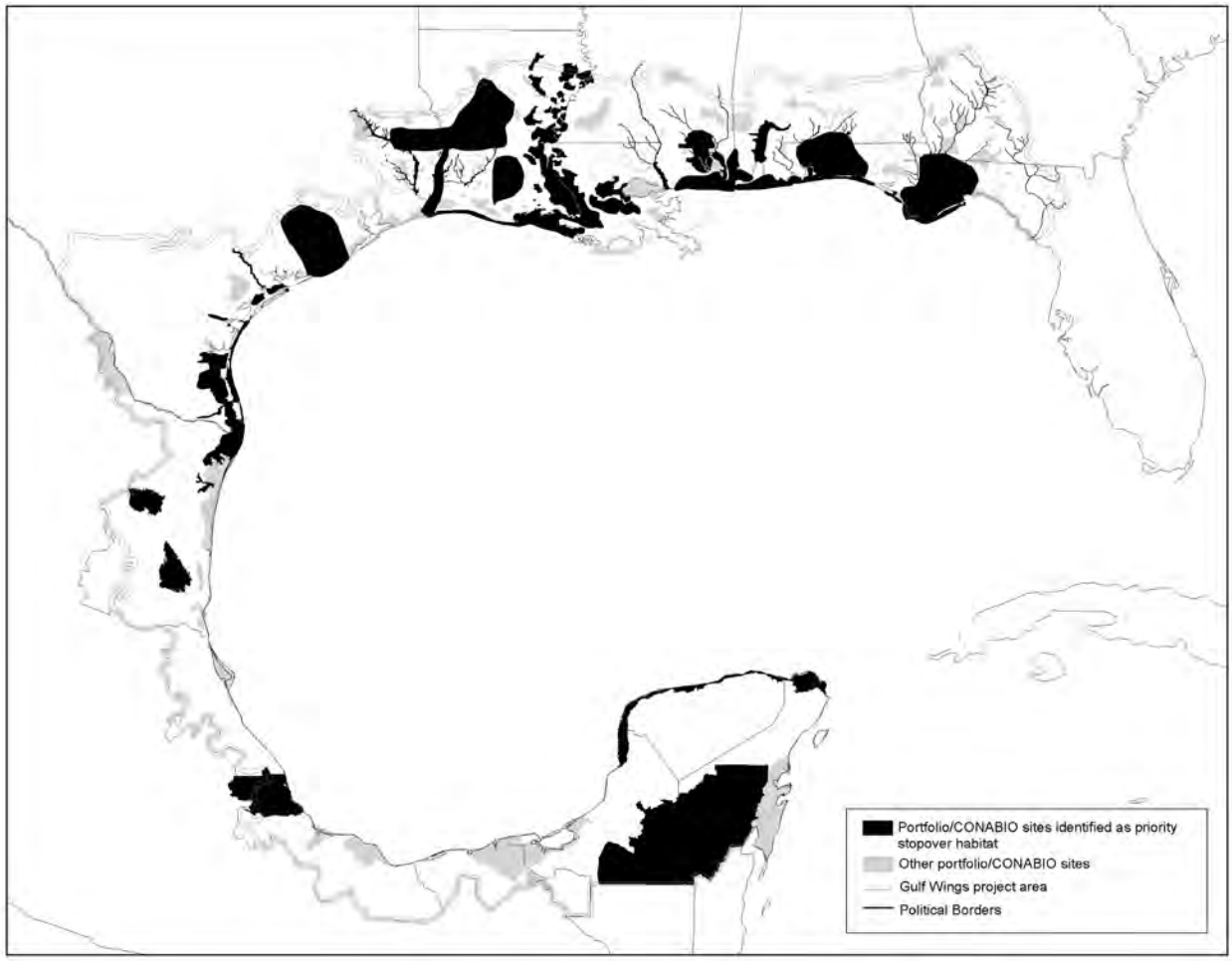

Figure 3— Areas shown in black are sites chosen from the Conservancy's ecoregional portfolios in the United States and from the CONABIO list of priority sites in Mexico, that are believed to be priority areas for protecting stopover habitat. Areas shown in gray are other Conservancy (U.S.) portfolio sites or CONABIO (Mexico) priority areas.

- introduction of exotic plants and animals, with the Chinese tallow tree (*Sapium sebiferum*) being a key example
- altered hydrology through dams, levees, and water withdrawal
- gas wells on terrestrial sites
- altered fire regimes, with both negative and positive results depending on bird species considered

In some cases, threat abatement strategies will be site-specific. In others, where stresses and their sources are common to several locales, a multi-site strategy may be applicable. A sample of such multi-site strategies includes

- developing a certification program for migratory bird-friendly housing development with recommendations concerning amount of cover, shrub species to be planted, and preventing cats from roaming
- contributing to a network of conservation practitioners
- spurring management action by federal land-managing agencies such as the U.S. Forest Service, U.S. Fish and Wildlife Service, and Department of Defense
- holding Conservation Area Planning workshops for stopover sites
- providing matching money to local governments for protection of critical areas for birds
- contributing to networks that can accomplish site-based surveys of en route migratory birds
- partnering to strengthen conservation capacity, including fundraising, of local Audubon groups, bird clubs, and land trusts
- affecting public policy concerning rebuilding after hurricanes and conversion of small isolated wetlands

Taking Action

The Gulf Wings project has already begun to implement some of the recommended actions for stopover-habitat conservation, and it will work to achieve others. To date (August 2002), we have

- contributed $140,000 for habitat acquisition along Mississippi's Pascagoula River
- encouraged and empowered Alabama's Friends of Dauphin Island Audubon Sanctuaries to undertake a $4 million capital campaign
- begun collaborations with ornithologists using weather-surveillance radar to identify stopover habitat along the northern Gulf Coast
- committed funds to hire a Conservancy employee to work on cheniers and woodlots in the Gulf Coast Prairies and Marshes ecoregion
- begun collaborations with the U.S. Fish and Wildlife Service concerning stopover habitat protection in the Florida Panhandle
- prepared an issue paper (Duncan et al. 2002) to inform Conservancy planners, senior managers, and partner groups of the importance of stopover protection and strategies for conserving it
- partnered with Pronatura Veracruz and the Instituto de Ecología, A.C. to organize an experts workshop to identify stopover sites along the Mexican coast of the Gulf of Mexico, as well as needed research

Measures of Success

A significant challenge for projects seeking to protect migratory birds is how to measure the positive impacts of the project. Ideally, protected stopover habitat reduces mortality and stabilizes or increases populations of relevant species. Measuring abundance, mortality or condition of migratory birds at even a single site is operationally difficult and labor-intensive. Even if such measures were available at an entire suite of stopover sites, their interpretation would be challenging. Annual changes in migratory bird populations will be confounded by events remote from the conservation area (e.g., nesting success on the breeding grounds) as well as stochastic weather variations during migration.

The Gulf Wings project, therefore, proposes to use alternative measures of success. The most efficient measures of success for conserving stopover habitat are those that monitor change in the spatial aspects of the habitat (spatial area, continuity, configuration, fragmentation and surrounding land uses) and the ecological processes that maintain the habitat structure and composition (hydrologic regime, fire, wind/storm events). Such measures can be taken for large landscapes by remote sensing or selected site-specific measurements. These metrics do not measure the migratory birds themselves, but rather the spatial aspects of their required habitat.

Secondly, Gulf Wings uses the Nature Conservancy's (2001) standard Conservation Area Planning method to evaluate the changes in status of threats to stopover habitat (for example a threat ranked "high" is reduced to "medium" or "low").

Finally, Gulf Wings also uses the Conservancy's measures of operational performance to judge its work. Among these measures are the following:

- number of landscapes where the project is engaged
- number of partners, including federal, state and local governments as well as non-government organizations
- quantity of private funds raised and directed to stopover protection
- public funds secured and directed to stopover protection

Acknowledgments

We greatly appreciate the many contributions to this project made by D. Ewert, S. Mabey, R. Sutter, and M. Woodrey. We thank the participants of the Moss Point workshop and their home institutions for their many contributions and their generosity in sharing without concerns for issues of "turf." D. Cimprich's analogy comparing some stopover sites to fire escapes has proven to be an extraordinarily powerful unifying tool in thinking about stopover conservation, and we are grateful to him for sharing it.

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The South Atlantic Migratory Bird Initiative – An Integrated Approach to Conservation of "All Birds Across All Habitats"[1]

Craig Watson,[2] Chuck Hayes,[3] Joseph McCauley,[4] and Andrew Milliken[5]

Abstract

In 1999, the Management Board of the Atlantic Coast Joint Venture (ACJV) embraced the vision and framework of the then newly emerging North American Bird Conservation Initiative (NABCI). Traditionally a Joint Venture focused on the conservation of waterfowl and wetlands habitat, the ACJV expanded its role throughout the Atlantic Flyway to all resident and migratory birds. As a first step, the ACJV launched the South Atlantic Migratory Bird Initiative (SAMBI) in the Southeastern Coastal Plain Bird Conservation Region. Biologists, land managers, and planners, representing non-governmental organizations, state and federal agencies, and private interests from five states (Florida, Georgia, South Carolina, North Carolina, Virginia) assembled to begin the process of developing a regionally based biological plan, integrating the objectives of four major bird conservation initiatives: the North American Waterfowl Management Plan, United States Shorebird Conservation Plan, North American Waterbird Conservation Plan, and Partners in Flight. The primary objectives were to develop population and habitat goals for priority species, delineate "all bird" focus areas, develop a long-term framework for bird conservation in the Southeastern Coastal Plain, and develop and seek funding for "all bird" projects. This effort has been tremendously successful, receiving nearly $18 million dollars for sixty projects within the ACJV for "all bird" conservation over the period from March 2000 to June 2003. Many of these projects focused on the conservation of waterfowl and wetland-dependent species, as well as landbirds, a very non-traditional approach by a waterfowl Joint Venture. These projects benefited a wide variety of other bird species, affected a variety of land ownerships, and stimulated additional conservation partnerships throughout the South Atlantic Region. Because of the success of SAMBI, it serves as a model for "all bird" conservation.

Background

One of the original waterfowl Joint Ventures formed under the North American Waterfowl Management Plan in 1988, the Atlantic Coast Joint Venture (ACJV) has evolved geographically from it's original delineated boundaries in 1988 (*fig. 1*) to include the 17 Atlantic Flyway states and the Commonwealth of Puerto Rico (*fig. 2*). With these expanded boundaries came expanded responsibilities for the conservation of waterfowl and other wetland associated species. During this period of growth, several other bird conservation initiatives had begun planning at various scales. These initiatives included Partners in Flight (Pashley et al. 2000), United States Shorebird Conservation Plan (Brown et al. 2001), and the North American Waterbird Conservation Plan (Kushlan et al. 2002). These initiatives have developed continental, national or regional plans that addressed species population and habitat goals.

The North American Bird Conservation Initiative (NABCI) was established to facilitate the common goals and objectives of these initiatives and create a more efficient mechanism for the delivery of bird conservation (U.S. NABCI Committee 2000). Bird Conservation Regions (BCRs), were delineated by NABCI as ecological planning units. Also, other single species bird conservation initiatives have been, or are being, developed for Northern Bobwhite (*Colinus virginianus*; Dimmick et al. 2002), Mourning Dove (*Zenaida macroura*), and American Woodcock (*Philohela minor*). Currently, only the Northern Bobwhite Conservation Initiative is complete.

In March 1999, the Management Board of the ACJV unanimously adopted and embraced the framework of NABCI to deliver conservation of "all birds across all habitats." The ACJV was the first NAWMP Joint Venture to officially endorse NABCI. The first task of integrated bird conservation planning began in 1999 in

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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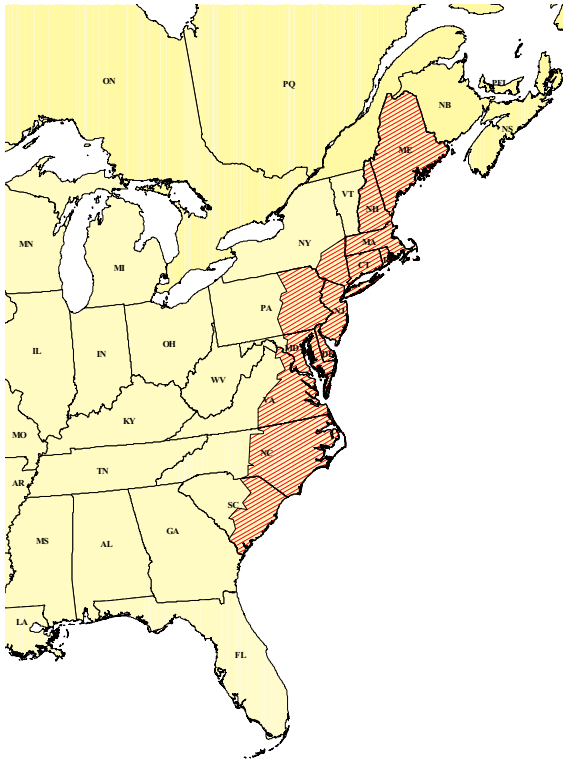

Figure 1— Original Boundary of the Atlantic Coast Joint Venture (1988).

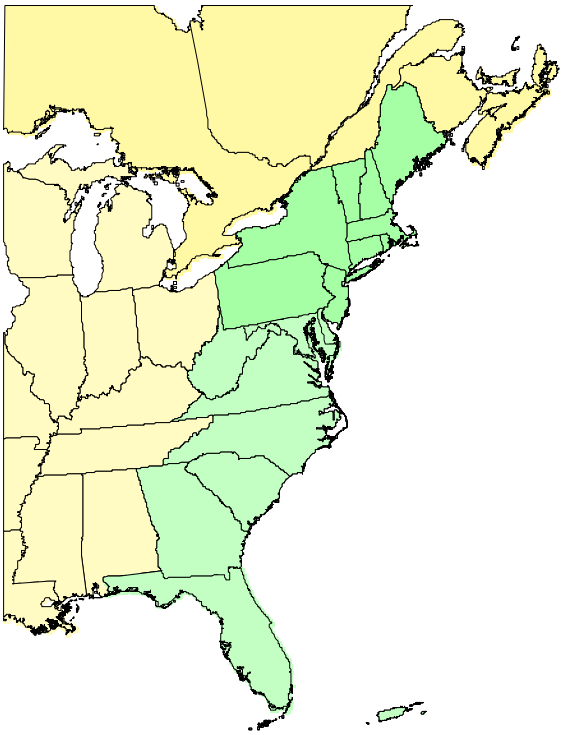

Figure 2— Area of the Atlantic Coast Joint Venture in 2002.

the Southeastern Coastal Plain Bird Conservation Region (BCR 27).

Process of Preparing and Conducting an Integrated Bird Conservation Planning Workshop

In May 1999, the Management Board initiated integrated bird conservation planning in the southeast, initially focusing on Georgia, South Carolina, and North Carolina. Approximately 45 land managers, biologists, scientists, administrators, and planners met in June 1999 near Garnett, South Carolina in the first workshop.

The objectives of the workshop were to 1) develop population and habitat objectives for priority species 2) delineate "all bird" focus areas, 3) identify priority habitats, 4) develop projects for implementation, and 5) develop a long-term dynamic framework for integrated bird conservation planning in BCR 27. This initiative is known as the South Atlantic Migratory Bird Initiative (SAMBI). Because the ACJV administratively encompasses only a portion of BCR 27, the planning area was limited to the coastal plain of Florida, Georgia, North Carolina, South Carolina, and Virginia (*fig. 3*).

Figure 3— Geographic Planning Area – South Atlantic Migratory Bird Initiative (1999).

The first workshop opened with reports on the status of bird conservation planning for each of the major bird initiatives, followed by presentations on several different approaches to developing population and habitat objectives for shorebirds and waterfowl in the United States. The purpose of these presentations was to pro-

vide information about the ACJV, the status and evolution of bird conservation planning in the United States and North America, and demonstrate that a vision of integrated bird conservation could become a reality through a coordinated effort.

All sessions, breakout and plenary, were conducted with a facilitator. The structure of the first workshop centered on breakout groups by state (FL, GA, SC, NC, and VA), with experts in waterfowl, landbirds, shorebirds, and waterbirds, present. These groups, known as State Working Groups (SWG), became the fundamental planning and implementation body for SAMBI. Technical personnel from each state formed the BCR Technical Committee. The primary objectives of the breakout groups were to 1) delineate "all bird" focus areas, 2) develop strategic population and habitat objectives for each major bird group or at least representative or high priority species within each bird group, and 3) identify preliminary projects for implementation at the state level. During this process, SWGs were asked to identify information gaps and needs relative to developing habitat and population objectives for BCR 27. Additionally, the entire group was asked to express their hopes and concerns about the meeting's purpose, and their vision for what this effort might be if successful. After the breakout and general sessions were complete, an open discussion was held on the process undertaken at this meeting, noting comments on how the process could be improved. In closing the first workshop, action items and future activities were identified by the larger group.

The second workshop was held on 4-5 November 1999, in Greensboro, North Carolina. There were no breakout sessions, meeting attendance was reduced, and attendees were comprised mostly of technical personnel. The primary focus of the second meeting was to report and present to the group the completion of action items from the first workshop, prioritize habitats and species, prioritize habitat conservation needs, prioritize projects by state, develop research needs, and begin developing a project to be submitted to the North American Wetlands Conservation Act (NAWCA) for funding. Action items for the group and each SWG were generated at the end of the workshop.

A third meeting was held on 19 January 2000, in St. Petersburg, Florida. The primary purpose of this meeting was solely devoted to developing a multi-state, multi-project proposal to be submitted for funding through NAWCA using a new integrated framework of bird conservation planning in the southeastern United States.

Workshop Results

Priority Species and Habitat

Priority species for landbirds, shorebirds, and waterbirds have been identified in each major bird initiative's national and/or regional plans; Partners in Flight (Pashley et al. 2000, Hunter et al. 2001), United States Shorebird Conservation Plan (Brown et al. 2001, Hunter et al. 2002), and the North American Waterbird Conservation Plan (Kushlan et al. 2002). Priority waterfowl species were selected based upon annual population analyses at the continental level, regional knowledge of waterfowl populations and habitat, local knowledge of waterfowl issues, and North American Waterfowl Management Plan priorities (U.S. Fish and Wildlife Service 1998a, U.S. Fish and Wildlife Service 2003). The BCR Technical Committee concurred with the list of priority species outlined in the various bird plans, adjusting priorities where applicable, and designating species of special management concern for the SAMBI planning area (*table 1*). Priority species outlined for SAMBI generally occupied priority habitats, therefore encompassing the conservation needs of suites of species. Additionally, regional responsibilities and areas of importance for some species were identified. For example, eastern North Carolina was identified as having both regional responsibility and supporting a highly significant wintering area for tundra swan (*Cygnus bicolor*) for the entire Atlantic Flyway.

Priority habitats for each of the bird groups also are clearly identified in regional bird conservation plans based on the list of priority species. To describe these habitats in a concise and yet meaningful manner, they were lumped and placed into categories (*table 1*). SWGs often had additional habitats of local importance they wished to have included in the list of priority habitats. These habitats were lumped into the broader categories (*table 2*), yet they remained discreet at the SWG level. Additionally, SWGs identified priority areas for conservation within their jurisdiction.

Delineation of Focus Areas

A primary objective of SAMBI was to delineate focus areas, areas in which conservation actions are implemented for high priority species and habitats. Focus areas are biologically based, and conservation actions are dictated by both biological foundation and opportunity. It is important that focus areas be large enough to provide all the necessary seasonal requirements for a wide variety of species. At the same time, small, distinct and sometimes disjunct areas that are important to high priority species should be included. Essentially, focus areas are important to the life history of a wide variety of high priority birds where financial and

Table 1-- *Priority Species List for the Southeastern Coastal Plain Bird Conservation Region (BCR 27).*

Work group	Species		
Landbirds	Painted Bunting *Passerina ciris*	Henslow's Sparrow *Ammodramus henslowii*	Cerulean Warbler *Dendroica cerulea*
	Black-throated Green Warbler *Dendroica virens*	Northern Bobwhite *Colinus virginianus*	Prothonotary Warbler *Protonotaria citrea*
	Bachman's Sparrow *Aimophila aestivalis*	Prairie Warbler *Dendroica discolor*	Chuck-will's Widow *Caprimulgus carolinensis*
	Swallow-tailed Kite *Elanoides forficatus*	Red-cockaded Woodpecker *Picoides borealis*	Whippoorwill *Caprimulgus vociferus*
	American Kestrel *Falco sparverius*	Red-headed Woodpecker *Melanerpes erythrocephalus*	Louisiana Waterthrush *Seiurus motacilla*
	Brown-headed Nuthatch *Sitta pusilla*	Wood Thrush *Hylocichla mustelina*	Saltmarsh Sharp-tailed Sparrow *Ammodramus caudacutus*
	Swainson's Warbler *Limnothlypis swainsonii*	Northern Parula *Parula americana*	Nelson's Sharp-tailed Sparrow *Ammodramus nelsoni*
	Common Ground Dove *Columbina passerine*	Hooded Warbler *Geothlypis nelsoni*	LeConte's Sparrow *Ammodramus leconteii*
	Common Barn Owl *Tyto alba*	Worm-eating Warbler *Helmitheros vermivorus*	Yellow-throated Warbler *Dendroica dominica*
	Loggerhead Shrike *Lanius ludovicianus*	Yellow-billed Cuckoo *Coccyzus americanus*	Seaside Sparrow *Ammodramus maritimus*
Waterbirds	Black Rail *Laterallus jamaicensis*	Sandwich Tern *Sterna sandvicensis*	Least Bittern *Ixobrychus exilis*
	Yellow Rail *Coturnicops noveboracensis*	Wood Stork *Mycteria americana*	Limpkin *Aramus guarauna*
	Brown Pelican *Pelecanus occidentalis*	King Rail *Rallus elegans*	Black Tern *Chlidonias niger*
	Black Skimmer *Rynchops niger*	Double-crested Cormorant*** *Phalacrocorax auritus*	Royal Tern *Sterna maxima*
	Gull-billed Tern *Sterna nilotica*	Clapper Rail *Rallus longirostris*	Common Tern *Sterna hirundo*
	Least Tern *Sterna antillarum*	American Bittern *Botaurus lentiginosus*	Little Blue Heron *Egretta caerulea*
Shorebirds	Buff-breasted Sandpiper *Tryngites subruficollis*	Marbled Godwit *Limosa fedoa*	Willet *Catoptrophorus semipalmatus*
	American Woodcock *Scolopax minor*	Stilt Sandpiper *Calidris himantopus*	Purple Sandpiper *Calidris maritima*
	Red Knot *Calidris canutus*	Spotted Sandpiper *Actitis macularia*	Whimbrel *Numenius phaeopus*
	Piping Plover *Charadrius melodus*	Semi-palmated Sandpiper *Calidris pusilla*	Least Sandpiper *Calidris minutilla*
	American Oystercatcher *Haematopus palliates*	Short-billed Dowitcher *Limnodromus griseus*	Ruddy Turnstone *Arenaria interpres*
	Wilson's Plover *Charadrius wilsonia*	Western Sandpiper *Calidris mauri*	Dunlin *Calidris alpina*
	Black-bellied Plover *Pluvialis squatarola*	American Avocet *Recurvirostra americana*	Sanderling *Calidris alba*

Table 1. *(contd.)*

Work group	Species		
Pelagic	Black-capped Petrel *Pterodroma hasitata*	Cory's Shearwater *Calonectris diomedea*	Sooty Tern *Sterna fuscata*
	Bermuda Petrel *Pterodrama cahow*	Greater Shearwater *Puffinus gravis*	White-tailed Tropicbird *Phaethon lepturus*
	Roseate Tern *Sterna dougallii*	Long-tailed Jaeger *Stercorarius longicaudus*	Manx Shearwater *Puffinus puffinus*
	Audubon's Shearwater *Puffinus lherminieri*	Common Loon *Gavia immer*	Red-throated Loon *Gavia stellata*
	Bridled Tern *Sterna anaethetus*	Northern Gannet *Morus bassanus*	
Waterfowl	Black Duck *Anas rubripes*	Greater Scaup *Aythya marila*	White-winged Scoter *Melanitta fusca*
	Wood Duck *Aix sponsa*	Mallard *Anas platyrhynchos*	Canada Goose* *Branta canadensis*
	Tundra Swan *Cygnus columbianus*	Redhead *Aythya americana*	Northern Pintail *Anas acuta*
	Canvasback *Aythya valisineria*	Ring-necked Duck *Aythya collaris*	Blue-winged Teal *Anas discors*
	Lesser Scaup *Aythya affinis*	Surf Scoter *Melanitta perspicillata*	Canada Goose** *Branta canadensis*
	Black Scoter *Melanitta nigra*		

*Atlantic and Southern James Bay Canada Goose
**introduced established resident populations of Canada goose
***overabundant species in many areas

Table 2—*Habitat-species suites in the eastern portion of the Southeastern Coastal Plain Bird Conservation Region (BCR 27).*

Habitat	Priority species**	Description
1) Grasslands, savannas, pastures, and associated wetlands	Henslow's Sparrow, Loggerhead Shrike, Northern Bobwhite, LeConte's Sparrow, Buff-bellied Sandpiper, Sandhill Crane	Forest-dominated landscapes with pitcher plant bogs, prairies, sedge lands, savannas, barrens, glades, and sod farms
2) Managed and palustrine emergent wetlands and mud-flats	King Rail, Yellow Rail, Black Rail, Least Bittern, American Bittern, Buff-bellied Sandpiper, Stilt Sandpiper, Whimbrel, Northern Pintail, Black Duck, Ring-necked Duck, Wood Stork	Freshwater marshes and mudflats-freshwater emergent tidal marshes, managed im-poundments, dredge spoil, exposed mudflats (managed and shallow water)
3) Early-successional shrub-scrub	Bachman's Sparrow, Henslow's Sparrow, Loggerhead Shrike, Prairie Warbler, Northern Bobwhite, American Wood-cock, Field Sparrow	"Old-field", hedgerows, fire maintained plant communities under mature pine forests, bogs, and remnant cedar (*Juniperus* spp.) glades
4) Forested wetlands (alluvial)	Swallow-tailed Kite, Prothonotary Warbler, Black-throated Green Warbler, Cerulean Warbler, Swainson's Warbler, Yellow-throated Warbler, Wood Duck, Mallard	Bottomland hardwood forests, alluvial forests, and swamp forests, alluvial floodplain, major forest types are cottonwood (*Populus* spp.), oak (*Quercus* spp., oak/hickory (*Carya* spp.), cypress (*Taxodium* spp.) /tupelo (*Nyssa* spp., and sweetbay *(Magnolia* spp./redbay *(Persea* spp.)

Table 2. *(contd.)*

Habitat	Priority species**	Description
5) Forested wetlands (non-alluvial)	Black-throated Green Warbler, Swainson's Warbler, Prothonotary Warbler, Worm-eating Warbler, Red-cockaded Woodpecker, Brown-headed Nuthatch, Red-headed Woodpecker, Chuck-will's-widow, Wood Duck, Yellow-throated Warbler, Northern Parula	Pocosins, Carolina Bays, and other non-alluvial wetlands, pond pine dominated pocosins, palmetto (*Sabal* spp.), laurel oak (*Quercus laurifolia*), loblolly pine (*Pinus taeda*)
6) Maritime forest/shrub-scrub	Painted Bunting, Prairie Warbler, Common Ground Dove, Northern Parula, Yellow-throated Warbler, Bicknell's Thrush, Kirtland's Warbler, Cape May Warbler, Black-throated Blue Warbler, Connecticut Warbler	Live oak (*Quercus virginianus*), palmetto (*Sabal palmetto*), loblolly pine (*Pinus taeda*), coastal hammocks with numerous understory species, shrub-scrub thickets of wax myrtle (*Myrica cerifera*) and yaupon holly (*Ilex vomitoria*)
7) Estuarine emergent wetlands	Nelson's Sharp-tailed Sparrow, Salt Marsh Sharp-tailed Sparrow, Seaside Sparrow, Black Rail, Yellow Rail, Black Duck, Wood Stork, Blue-winged Teal	Estuaries - tidal flats, emergent wetlands, and border maritime woodlands
8) Beaches and dunes	Red Knot, Piping Plover, Snowy Plover, Wilson's Plover, Least Tern, Royal Tern, Black Skimmer, American Oystercatcher, Reddish Egret	Beaches, dunes, overwash areas, oyster bars, rock jetties, dredge spoil areas
9) Open ocean (Gulf Stream)	Black-Capped Petrel, Bermuda Petrel, Audubon's Shearwater, White-tailed Tropicbird, Roseate Tern, Black Scoter	Open ocean waters near the Gulf Stream paralleling the South Atlantic Coastal Plain
10) Longleaf pine communities	Red-Cockaded Woodpecker, Northern Bobwhite, Loggerhead Shrike, Prairie Warbler, Bachman's Sparrow, Henslow's Sparrow, Brown-headed Nuthatch, American Kestrel	Longleaf pine (*Pinus palustris*) flatwoods and savannas, and longleaf sandhills, system is maintained by fire
11) Loblolly-Shortleaf pine	Field Sparrow, Brown-Headed Nuthatch, Prairie Warbler, Bachman's Sparrow, Northern Bobwhite, Red-cockaded Woodpecker	Mature loblolly, shortleaf (*Pinus echinata*), and slash pine (*Pinus elliottii*) forest; much of longleaf historic longleaf pine and shortleaf pine have been replaced with loblolly and slash pine stands
12) Short-rotation pine plantations	Northern Bobwhite, Bachman's Sparrow, Field Sparrow, Prairie Warbler, Henslow's Sparrow, Wood Thrush	Primarily loblolly and slash pine
13) Oak-hickory/tulip poplar (*Liriodendron tulipifera*) /pine forests	Priority species here are the same as for longleaf sandhills	Turkey oak (*Quercus laevis*) and scrub oak (*Quercus* spp.) species in the sandhills, and southern mixed mesophytic forests along bluffs and ravines
14) Riparian/mixed mesic hardwoods (southern mixed, hammocks)	Swainson's Warbler, Kentucky Warbler, Acadian Flycatcher, Louisiana Waterthrush, Cerulean Warbler	Riparian-streamside areas, bottomlands and all palustrine wetlands on coastal plains and prairies, upland riparian areas; Hammocks-narrow bands of vegetation confined to slopes between upland sand/clayhill pinelands and bottomlands
15) Urban/suburban backyards, rural woodlots	Important for transient nearctic neotropical species	Riparian areas, mature woods, other non-forested areas
16) Other inland habitats	Least Tern, American Avocet, Blue-winged Teal, Wood Duck, Wood Stork, Painted Bunting, Stilt Sandpiper, Semipalmated Sandpiper	Rooftops, dredges spoil areas, flooded croplands, river bars, lakeshores, pasture and other agricultural lands

**Scientific names provided in *table 1*.

conservation resources can be expended to have positive effects on these bird populations (Hayes et al., this volume).

During the first workshop, SAMBI participants noted that focus areas should link important habitat areas, guard against fragmentation, and include upland areas. Public lands were considered to serve as anchors from which to base delineation of focus areas. Existing waterfowl focus areas were used as a starting point to delineate "all bird" focus areas. Waterfowl focus areas had already been described (U.S. Fish and Wildlife Service 1988b), and were known to provide critical habitat for waterfowl, shorebirds, and waterbirds. Additionally, SAMBI participants agreed that focus areas should be places where all disciplines could work together, and that geopolitical boundaries should be ignored.

State Working Groups were asked to delineate distinct focus areas for landbirds, shorebirds, waterbirds, and waterfowl. We used 1:250,000 topographic maps to delineate distinct focus areas for each bird group (*fig. 4*). Although North Carolina is used as an example, similar areas were delineated for South Carolina and Georgia. Once these areas were delineated for each bird group, the areas could be superimposed, displaying the overlap of focus areas. This exercise demonstrated the high degree of overlap of important areas for waterfowl, shorebirds, and waterbirds (*fig. 4e*). This layering of the various bird focus areas can be displayed to represent one large "all bird" focus area for each state, and each of the five states can be combined to display one large "all bird" SAMBI focus Area.

This effort allowed the participants to visualize differences in amounts and types of habitats across their own jurisdiction as well as across the entire BCR. Some states, such as North Carolina, worked on distinct focus areas for Northern Bobwhite (*Colinus virginianus*) and other early successional species. In North Carolina, a new program called CURE (Cooperative Upland Habitat Restoration and Enhancement) has delineated landscape scale focus areas in which to direct efforts for the conservation of high priority early successional species (*fig. 4f*).

It is important to note that focus areas for each bird group, whether at the State or regional level (SAMBI), are important to each bird group for conservation projects, contributing to conservation of priority bird species at the local, regional, flyway, and continental level. Additionally, SAMBI partners recognize that

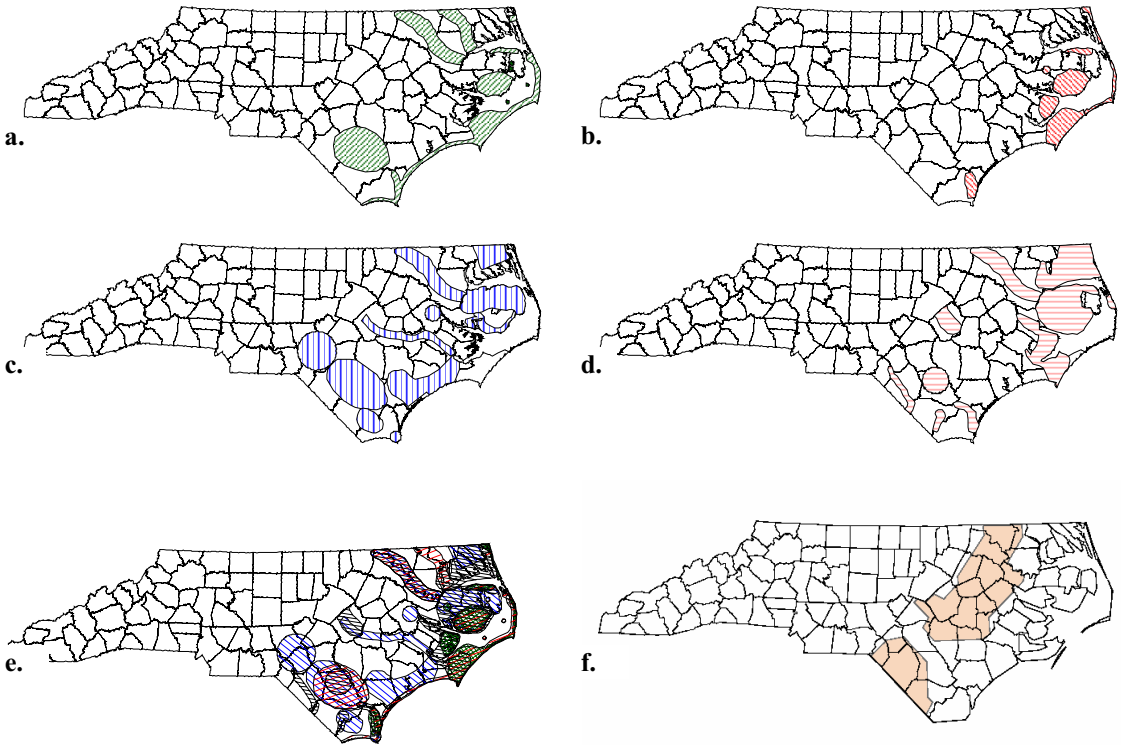

Figure 4— Example of "All Bird" Focus areas in North Carolina. a) Waterbird focus areas; b) Shorebird focus areas; c) Landbird focus areas; d) Waterfowl focus areas; e) Overlay of bird group focus areas; and f) Cooperative and Upland Habitat Restoration and Enhancement (CURE) focus areas.

these focus areas are important for pursuing single bird group projects, such as for waterfowl or shorebirds, or even projects focused on a single high priority species. Thus, projects in focus areas need not necessarily contribute to multiple bird group conservation, but contribute to regional biodiversity.

Population and Habitat Objectives

Population and/or habitat objectives were derived for many of the priority species of each major bird initiative based upon existing national and regional plans (Pashley et al. 2000; Brown et al. 2001; Hunter et al. 2001, 2002; Kushlan 2002; Kushlan et al. 2002), bird initiative workshops, and local/regional knowledge and expertise. These regional plans are quite detailed in objectives for both population and habitat for many of the high priority species. Because the SAMBI planning area is essentially the same as the planning area or area of geographic importance for priority species in these plans, objectives outlined in these plans are directly applicable to SAMBI.

Similar objectives for waterfowl have not been developed in a regional plan, and current objectives for waterfowl within the ACJV are area based and categorized by state and focus area (U.S. Fish and Wildlife Service 1988b). Factors influencing existing waterfowl objectives have significantly changed since 1988, warranting a revision of the current ACJV Implementation Plan and its objectives. For SAMBI, the Noffsinger method (Noffsinger, unpubl. ms.) was used to calculate waterfowl objectives by state (Balkcom, pers. comm.; Harrigal, pers. comm.; Luszcz, pers. comm.). The Noffsinger method is a modified calculation of the bioenergetics model that was used in the Mississippi Alluvial Plain to calculate both waterfowl and shorebird objectives (Loesch et al. 2000).

The SAMBI BCR Technical Committee developed habitat and/or population objectives for species they felt important but that were not specifically addressed in regional plans. Additionally, they adjusted existing population and habitat objectives for some priority species to better address local conservation needs. Finally, State Working Groups of the BCR Technical Committee stepped down regional objectives to state objectives for certain species. For example, the goal for Swallow-tailed Kite (*Elanoides forficatus*) in the Partners in Flight Bird Conservation Plan for the South Atlantic Coastal Plain (SACP) is to provide eight patches of at least 40,500 ha of bottomland hardwood forests. However, this plan does not indicate where in the SACP these large forest patches should be distributed. State Working Groups evaluated the availability and potential of such habitat within their respective states and assigned a portion of these eight patches to individual states. As an example, Georgia and South Carolina allocated, respectively, two and three patches of the recommended eight patches to their states. Additionally, by allocating these patches to their states, the Swallow-tailed Kite goal also incorporated goals for Wayne's Black-throated Green Warbler (*Dendroica virens waynei*) and Swainson's Warbler (*Limnothlypis swainsonii*).

Project Implementation

Another primary goal of SAMBI was to develop projects to meet the goals and objectives outlined in the first two workshops. Members of the BCR technical committee decided to package eleven projects from a three-state area (GA, SC, and NC) into a NAWCA proposal. Project proposals included acquisition and restoration of bottomland hardwoods, enhancement of managed wetlands, restoration of native grasslands, and restoration of early successional habitat for colonial waterbirds. These eleven projects proposed to benefit 31 wetland-associated species as listed in the application package for NAWCA (U.S. Fish and Wildlife Service 2000). All projects were located in ACJV focus areas and SAMBI "all bird" focus areas. Additionally, all project areas were located within wetland types that are decreasing nationwide, and the areas proposed are to be held in perpetuity. Partners contributed approximately $4 million in matching funds, and most match tracts were disjunct from project proposal sites.

The BCR representatives who packaged this project voiced two concerns regarding the approach they used. First, concern was raised whether a proposal with eleven projects over a three state area would be funded. Typically, projects funded under NAWCA are single projects, sometimes with multiple activities, in a single state. Secondly, match dollars and tracts required under NAWCA are typically within or adjacent to the project proposal site. However, in this multi-state multi-project proposal match tracts were generally disjunct from most of the project proposal sites, perhaps raising doubt about the contribution of the match tracts to the overall project. However, under the framework of SAMBI, disjunct tracts did contribute to the overall goals and objectives of SAMBI. We believe this link to the framework of SAMBI was critical to the project. This project was funded at $1 million in 2000, launching SAMBI into a phase of project implementation that has been extremely successful. This first multi-state multi-project project was called the South Atlantic Migratory Bird Initiative Habitat Conservation Project.

SWGs have used the framework of SAMBI to submit additional projects for funding, and in fewer than four years, 60 projects have been funded at $18.2 million. Over 200 partners have contributed over $79 million in matching funds and approximately 45,765 ha have been conserved. Funding was primarily sought through

NAWCA, the National Coastal Wetlands Grant Program, and the Neotropical Migratory Bird Conservation Act. An additional $75,000 has been provided by the ACJV to various partners for habitat conservation, research, and education and outreach. Finally, funding foundations are soliciting project proposals under this initiative, a true testimony to the success of SAMBI.

Discussion

To our knowledge SAMBI was the first effort at integrated bird conservation planning at the BCR level under the NABCI. The South Atlantic Migratory Bird Initiative began as the framework of NABCI was emerging and when BCRs were still being developed. Although excellent integrated bird conservation planning has been conducted and successful throughout North America, SAMBI was unique in that the planning area was relatively large area and brought together a large number of partners from five states to conduct integrated planning at a level that had not been done in the ACJV, or perhaps in North America. When SAMBI first began we had no model or template to follow, and no one knew where this initiative would lead. It has led to an extremely successful effort, and key to this success is the enthusiasm and confidence that the SAMBI participants have in the process. Participants had the opportunity to apply their skills and knowledge toward regional and landscape-oriented bird conservation, giving each of them ownership in the process, and goals to achieve within their jurisdiction. Communication between technical personnel within and between states is occurring to coordinate project development and collaborate on strategies to optimize project funding and implementation.

Another important first step to the success of SAMBI was the immediate funding of the SAMBI Habitat Conservation Project described above. Eleven projects were implemented in three states with the funding of this one project, which generated interest, built confidence, and provided momentum for SAMBI. SWGs began developing their own projects under the framework of SAMBI for funding. State Working Groups continue to meet on their own and recently SWG meetings have been conducted or scheduled to update information and retain the communication network that has been established. SWGs also have been responsible for stimulating other initiatives by linking regional and national issues to SAMBI. A few examples are: establishing a South Carolina Shorebird Habitat Management Group focused on working with private landowners to provide critical habitat during spring and fall migration; developing a SAMBI Pelagic Bird Conservation document and SAMBI Pelagic Bird Conservation Working Group; developing a SAMBI website for land managers to view real-time data for wintering waterfowl and shorebird migration, and areas being managed for both; establishing a Painted Bunting Working Group; and establishing a Shrub/Scrub Early Successional Species Working Group. An Implementation Plan is currently being written for SAMBI, providing a biological framework for partners to use in project implementation.

Most recently the American Bird Conservancy, working with the Tri-national NABCI Committee, has identified and linked BCRs in Canada and the United States with those in Mexico. Bird Conservation Region 27 is one of those, and SAMBI has a distinct link with Mexico in the Yucatan, El Triunfo, and Chamela-Cuixmala with species such as, but not limited to, Chuck-will's Widow (*Caprimulgus carolinensis*), Wood Thrush (*Hylocichla mustelina*), Worm-eating Warbler (*Helmitheros vermivorous*), Swainson's Warbler, and Louisiana Waterthrush (*Seiurus aurocapillis*). It is highly likely that partners in SAMBI will establish relationships with partners in Mexico and Canada to address conservation needs for some of these common species.

Conclusion

The South Atlantic Migratory Bird Initiative has been extremely successful and has generated much interest in the rapidly evolving world of bird conservation. Additionally, SAMBI was used as a template for a similar planning effort coordinated by the ACJV in the Lower Great Lakes-St. Lawrence Plain Bird Conservation Region. Similar efforts are planned for the remaining BCRs in the ACJV (Milliken et al., this volume). Much of the process of SAMBI is being used for "all bird" workshops being conducted for state conservation agencies by the International Association of Fish and Wildlife Agencies. There are many reasons why SAMBI has been successful, and many of these items are outlined in a well-summarized unpublished paper describing the components of conducting a successful BCR workshop (Pashley et al., unpubl. ms.). The initial objectives of SAMBI have been met, and SAMBI will continue to be a dynamic planning process to implement conservation of "all birds across all habitats." There are some tasks and issues that remain to be addressed, such as monitoring needs, plan evaluation, and project evaluation. It is important to meet regularly at the working group level and the BCR level. Communication is extremely important, particularly in coordinating projects and assigning priority to projects competing for the same funds. Participants must have ownership in the effort to generate enthusiasm and keep the momentum of the initiative continuing. An Implementation Plan is being written to provide gui-

dance and strategies for achieving the goals and objectives of SAMBI. The South Atlantic Migratory Bird Initiative, in a sense, has been an integration of human resources, resources that have met an unforeseen challenge and led the way in the conservation of "all bird across all habitats" in North America.

Recommendations for a Successful BCR Planning Effort

Because this effort has been extremely successful in implementing our vision of integrated bird conservation, we offer the following recommendations as a basis for conducting similar successful regional conservation planning efforts:

1. Key persons in the BCR should be identified and contacted prior to any formal meetings. These persons should identify all potential partners who should attend any upcoming workshops and meetings.

2. A pre-workshop meeting should be held to discuss all activities associated with the initial workshop. Key persons identified above should meet and develop an agenda and items necessary to carry out an initial formal workshop, including where the meeting should be held, list of material and supplies needed (maps, supplies, etc.) and desired outcomes.

3. One person should be designated as the coordinator or planner to ensure that any follow up actions, recording of meetings, future meetings, and essential coordination takes place.

4. A communication network should be established to facilitate and promote coordination.

5. Meetings should be held regularly to facilitate communication, update various aspects of the planning effort, and to sustain the continuity and momentum of the initiative.

6. Design and implement significant short term conservation projects. This will demonstrate to partners that success is possible, and it will provide ownership in the initiative by the partners.

7. Finally, an Implementation Plan should be written, providing goals and objectives for the region, and providing guidance and strategies to accomplish these goals and objectives.

Acknowledgments

We thank the Management Board of the Atlantic Coast Joint Venture, and specifically J. Frampton of the South Carolina Department of Natural Resources and M. King of the U. S. Fish and Wildlife Service (USFWS) for their visionary decision and leadership for the conservation of "all bird" under the framework of NABCI. We also thank M. Gantt of the USFWS who kept all participants on track for the very first and critical meeting of SAMBI partners. We thank K. Babcock of Ducks Unlimited, Inc., for his continued support. We express our gratitude to C. Hunter of the USFWS whose hard work provided much of the biological foundation and framework for this initiative. Presenters at the first workshop that need to be recognized are S. Mott, now of the Division of Bird Habitat Conservation (USFWS); B. Wilson of the Gulf Coast Joint Venture; B. Noffsinger of the USFWS, J. Collazo of the USGS Coop Unit at North Carolina State University; and D. Gordon of the Coastal Program, USFWS. We also thank all of the participants and various partners of SAMBI: D. Shipes, R. Johnson, K. Rosenberg, J. Hamilton, R. K. "Kenny" Williams, D. Harrigal, T. Murphy, J. Cely, D. Wilson, J. Kilgo, R. Dettmers, E. J. Williams, D. Mehlman, J. Bowers, G. Balkcom, D. Luszcz, T. Kohlsaat, F. Collazo, Brad Winn, M. Prevost, B. Perry, M. Johns, D. Allen, S. Rockwood, B. Ford, D. Norris, J. Stanton, G. Peters, F. Bowers, C. Kelly, A. Huckabee, S. Lohr, B. Dukes, B. McTeer, T. Moorman, G. Wallace, and D. Pashley, The Nature Conservancy, Ducks Unlimited, Inc., Florida Fish and Wildlife Conservation Commission, Georgia Department of Natural Resources, South Carolina Department of Natural Resources, North Carolina Wildlife Resources Commission, Virginia Department of Game and Inland Fisheries, U.S. Fish and Wildlife Service, U.S. Forest Service, and the 131 partners that contributed cash or property toward projects within SAMBI.

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What Have I Learned about Broadleaf Forest Migrants from Long-term Attendance at Migrant Bird Symposia?[1]

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Abstract

Our understanding of the ecology and conservation of migratory birds has changed dramatically in the past 25 years. In the Smithsonian symposium of 1977, scientists shifted from the idea of North American birds invading the tropics to that of tropical birds using the temperate zone, with little mention of conservation. By the Manomet meeting of 1989, declines on the breeding grounds led to our focus on conservation and answering, "Where have all the birds gone?" The first Partners in Flight meeting in 1992 had a strong management focus and provided much of the theory used in PIF bird conservation plans that are still being developed. Fewer meetings occurred in the past decade but research progress continued. Here, I synthesize what we have recently learned about the ecology of migrant birds during breeding, winter, and migration periods. I also note what I feel we have yet to learn to design effective conservation plans for the future.

Key words: broadleaf forest, management, migrants, symposia

Introduction

I think it is safe to say that studies of birds from the eastern broadleaf forests have been the dominant force in our understanding of the evolution and ecology of New World migration. This region also was pivotal in the establishment and development of Partners in Flight. For example, the analysis of trends in populations of Neotropical migrants from Breeding Bird Survey data focused on declines in migrant species from eastern forests and its early successional stages (Robbins et al. 1989a); populations of birds in the western United States did not show clear patterns of decline. Early studies of habitat fragmentation which documented the absence of many species on small fragments and which showed low rates of reproductive success on these fragments occurred almost solely in eastern forested habitats (see, for example, Hayden et al. 1985, Robbins et al. 1989b, Whitcomb et al. 1981). Startling data suggesting declines in migrant populations focused on trans-Gulf migrants, most of which are birds of eastern broadleaf forests (Gauthreaux 1992). Finally, those early studies that dealt with wintering ecology and its possible limiting effects focused on such eastern species as the Hooded Warbler (*Wilsonia citrina*; Morton 1980), Wood Thrush (*Hylocichla mustelina*; Rappole et al. 1989), and Cerulean Warbler (*Dendroica cerulea*; Robbins et al. 1992) or documented community-wide declines in winter populations of common eastern forest birds (Faaborg and Arendt 1989).

Our understanding of Neotropical migrant birds has changed dramatically in the past three decades. My goal here is to summarize the state of our present knowledge about the ecology and conservation of migrant birds of broadleaf forests, including its early successional stages, note how we got where we are, and suggest those areas where further work is needed. Much of our current knowledge has been summarized expertly by speakers in this or other symposia at this conference, as will be noted. To provide an appreciation of where we are and how we got there with regard to the conservation of migrant birds, I begin with a review of major changes in our knowledge of migrants as shown from the various migrant symposia that preceded this one. Only then can I properly note the current state of the art and the future scientific information needed to make future Neotropical migrant conservation as science-based as possible.

Historical Changes in the Migrant Bird Paradigm

When I started graduate school in 1971, there certainly was no focus on studies of migrant birds as a group. Researchers might study the natural history of a migratory species on its breeding grounds or document its occurrence in winter, but little work had dealt with migrants as a group. Most tropical ornithologists focused their work on poorly studied tropical residents, often recording information on wintering birds only because these birds appeared in point count or capture rate samples taken of tropical birds. Migrants were known to be common in parks and gardens, so if there was a general dogma at the time, it was that these winter residents moved into sites

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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that residents did not use or took advantage of seasonally superabundant food resources like fruit.

As far as I know, the first quantitative measures of migrant abundances in different Neotropical habitats occurred in work by Tramer (1974) from the Yucatan and Karr (1976) from Panama. These papers tended to promote the idea of winter residents using surplus resources, but Karr, in particular, did an excellent job of showing the variety of roles that winter residents filled in Panama. While doing his work at the Smithsonian Tropical Research Institute, Karr interacted with resident ornithologists Eugene Morton and Neal Smith, among others, who also were gathering data on migrant ecology.

At the same time, several graduate students, including Russell Greenberg, Richard Hutto, John Rappole, and Mario Ramos, were doing graduate projects whose focus was the ecology and distribution of migrant birds that winter in tropical habitats. These studies occurred because ecologists of that day were trying to delineate and understand patterns of diversity and abundance in the tropics, which included an understanding of seasonal movements in this region and how such movements might evolve. Migrants were a notable and sometimes major part of all these tropical bird communities.

This small burst of interest in migrants of the neotropics led Eugene Morton and Allen Keast to host a symposium on migrant birds at the Smithsonian facility at Front Royal, Virginia, in 1977. The results of this symposium, published as *Migrant Birds in the Neotropics: Ecology, Behavior, Distribution, and Conservation* (Keast and Morton 1980), greatly expanded our knowledge about tropical migrants and totally changed the way we thought about them. Although the symposium was originally announced as one that would explore how "North American" birds fit into the tropics, one of the solid, take-home points of the symposium was that many of these migrants must be considered tropical birds. Most migratory species have specialized niches within the tropical communities, even in mature, undisturbed habitats. The observation that these species might be constrained through habitat selection, territorial behavior, distribution of foraging flocks, or other ecological factors in the tropics made the possibility of winter limitation worthy of consideration. Almost no mention of conservation was made at this symposium, but in a chapter added to the volume, Terborgh (1980) suggested that the fact that the winter range of most migrants that breed in North America was in Mexico and the West Indies, an area about 1/8th the size of the breeding range that was being dramatically modified by humans, meant that the future for these migrants did not look bright.

I am certain that the Keast and Morton (1980) volume stimulated new research on the role of migration in tropical bird communities, but for the decade following the Front Royal meeting, this was in the guise of "pure" science. The situation changed dramatically in the late 1980s when a variety of studies suggested that Neotropical migrant birds might be in decline. This lead the Manomet Bird Observatory to sponsor a symposium at Wood's Hole, Massachusetts, in 1989 to examine patterns in migrant bird populations and possible causes for population declines. Evidence of declines came from a variety of sources. In particular, the Breeding Bird Survey (BBS) had shown strong patterns of decline in birds of the eastern US during the 1980s, with the most pronounced declines among those birds that wintered in the tropics (Robbins et al. 1989b). Another extensive study suggested that the intensity of trans-Gulf migration had decreased dramatically by the late 1980s (Gauthreaux 1992). Wayne Arendt and I added to the frenzy by showing how captures of winter resident warblers in our Puerto Rican study site had declined precipitously during the period 1973 to 1989 (Faaborg and Arendt 1989).

A number of studies using Breeding Bird Census (BBC) or Christmas Bird Count (CBC) added other evidence of local declines. Possible mechanisms for declines were presented, with numerous fragmentation studies showing how predation and brood parasitism increased in fragmented habitats, leading to low rates of nesting success in these sites. Additionally, the loss of primary forest in the tropics was well documented, making it fairly easy to see how loss of rainforest or other habitats in the tropics could be causing declines in breeding numbers of Neotropical migratory birds.

Although the symposium volume *Ecology and Conservation of Neotropical Migrant Landbirds* (Hagan and Johnston 1992) did not appear until 1992, word of its results spread like wildfire. Numerous popular articles with titles like *Death of the Dawn* and *Silent Spring Returns* soon appeared, suggesting that loss of the tropics was causing the declines seen at home. Most importantly, John Terborgh published *Where have all the birds gone?* (1989), which documented evidence for declines of migrant birds and made a strong case that tropical habitat loss was at work. Although there were those who questioned this conclusion (Faaborg and Arendt 1992, James and McCulloch 1995), the general consensus seemed to be that Neotropical migratory birds were facing a crisis.

The response to this possible crisis was the development of the Neotropical Migratory Bird Conservation Program, which we know as Partners in Flight (PIF). PIF was formed at a meeting of managers, researchers, and other conservationists held in Atlanta in December 1990. This meeting was an exceptional mix of professionals from governmental agencies, NGOs, academic institutions, and other conservation groups. Participants agreed that there was a serious enough problem that a response was needed, and they designed the response with the complex (and

sometimes bewildering) array of committees that compose PIF. Among these committees was one for Research, which has had the involvement of most of the best migrant bird researchers throughout its history.

Among the first activities of the Research Committee of PIF was the scheduling of another symposium in the fall of 1992, which resulted in both *Status and Management of Neotropical Migratory Birds* (Finch and Stangel 1993) and *Ecology and Management of Neotropical Migratory Birds* (Martin and Finch 1995). Unlike the Manomet symposium that considered whether or not a problem existed, the goal of this symposium was to get researchers and managers together so that we could see what the patterns were, why they were occurring, and how things could be fixed. Conservation was the reason this symposium occurred.

Unfortunately, because the Estes Park symposium was only 3 years after the Manomet symposium, there were not a lot of new research findings to present. Some fragmentation studies presented new gloom-and-doom scenarios, with predation and parasitism rates that were nearly unbelievable. Further documentation of declines from BBS data were presented, along with more information on tropical habitat conversion rates. Breeding season managers could see that they needed larger tracts of habitat and might have to control cowbirds, while those from the wintering grounds were not told much that could be converted to effective management other than the preservation of native habitats. There were few positive notes from this symposium, but it was one of the first places where the idea was presented that landscape management and regional source/sink dynamics might be important to our understanding of the demographic situation on the breeding grounds. In addition, it was suggested that analytical methods for BBS results had been giving us some misleading trends, or at least impressions (James et al. 1996).

Although our knowledge of how migrant bird populations were limited was still very primitive at the Estes Park meeting, the leaders of PIF seemed to feel that we knew enough to start managing. Thus began what I call the "no-meeting decade," although that is not completely true. A major PIF conference was held in Cape May, New Jersey, in 1995. Research constituted a small part of this meeting, and my research colleagues who attended told me that they felt that they were not very welcome. The results from this conference did not appear until 2000, and then the distribution of the results was much less than that of the Estes Park meeting. A cowbird meeting in 1993 produced some great new information; this publication (Smith et al. 2000) also did not appear until 2000, although it was then readily available. An international meeting on the role of mist netting in monitoring populations also occurred in 1993, but it still has not been published.

Although symposia volumes were not published during this period, many important research findings did occur. Fortunately, the interaction between researchers and managers that was a result of the PIF structure meant that most of the people developing the regional Bird Conservation Plans of PIF continued to consult researchers. For this reason, most of the regional plans do seem to be as timely as possible. Three major areas of research during the late 1990s were critical to our current understanding of migrant bird populations: First, researchers expanded their demographic studies to include large tracts of habitat, where they often found that reproductive success was high, even high enough for these areas to serve as regional sources (Robinson et al. 1995). Second, landscape level studies of breeding birds helped to explain some of the regional variance of fragmentation studies, including variance in edge effects in different locations, cowbird populations, and predators (Donovan et al. 1995, Donovan et al. 1997). Finally, studies of winter social behavior in the American Redstart (*Setophaga ruticilla*) showed strong social interactions that could lead to population limitation and sex ratio skews on the breeding grounds (Marra et al. 1998). All of these breakthroughs are critical to our current understanding of Neotropical migrant bird ecology.

The "no-meeting decade" ended in February 2002, with the "Birds of Two Worlds" symposium sponsored by the Smithsonian Institution. This symposium was very international in nature, including numerous Old World researchers talking about Asian and African birds. Most of the papers could be called "pure" science, and the word "conservation" was rarely spoken, although, as we shall see, some of the findings may be useful to future work on migrant conservation. A month later we had contributions such as this in the third international Partners in Flight conference.

A Modern Paradigm for Migrant Bird Conservation in Broadleaf Forests

So what do we know about migrant bird conservation as we start this new millennium? First of all, we must remember that a Neotropical migrant bird population can be limited by conditions on the breeding grounds, by conditions on the wintering grounds, or by conditions that occur during migration itself. In any given year, one or more of these locations/situations could be limiting. Of course, the effects of limitation from one season may be expressed at another season, so even a clear understanding of mechanisms at one time of the year requires an understanding of how these effects may extrapolate to other periods (Marra et al. 1998).

Breeding season management: Modern breeding season management for Neotropical migrant birds must

focus on the maximization of reproductive success rates, either through local manipulations that control artificially high predation or parasitism rates or through the protection of large areas which serve as regional source pools for migrant populations. Fragmentation studies have shown that many species have minimum area requirements that must be recognized in management schemes. Unfortunately, such minimum area requirements may vary depending upon whether one is measuring presence/absence, density, pairing success, or reproductive success (Winter and Faaborg 1999); scientists have discriminated these different minimum area requirements for few forest species. Rather, we have fallen back on pointing out the importance of large regional forests that may serve as the source population of even larger regions with fragmented habitats.

Thompson (this volume) does an excellent job of pointing out the logic used to develop our current ideas about forest bird management. He shows clearly how landscape factors may ameliorate fragmentation or edge effects, with the accompanying lessons for managers. He also points out how management for early successional species (especially those of regenerating forest) can be balanced with the negative effects of timber harvest on mature forest birds, with the observation that some second-growth species may require clearcuts of some minimal size. Villard (2002) expands some of these ideas to show the effects of natural disturbance and silviculture on bird distributions and management. Friesen et al. (this volume) also show how these rules fit into urbanizing landscapes.

An attempt to convert the modern theory to regional conservation practice was made with the development of grassland Bird Conservation Areas (BCAs; Fitzgerald et al. 1998). Here, a BCA was suggested to be effective if it had an 800 ha core area of high quality habitat plus a regional landscape with a large percentage of smaller habitat fragments. It appears that the Greater Prairie-chicken (*Tympanuchus cupido*) was used to develop the details of this model, with the idea that a management area large enough for chickens would be more than large enough for smaller passerines. Unfortunately, a recent test of the suitability of these grassland BCA constraints has provided less than satisfying results (Johnson and Winter, this volume).

Even without the details, we know that larger protected areas have a better chance of supporting healthy bird populations, although one must take into account the dynamics of the habitats within these protected areas. As we better understand the limitations of such regional management, we can better fit migrant management into other management schemes. We already have mentioned the trade-off between managing for mature forest vs. second-growth species within the broadleaf forest region, with the realization that one cannot manage for both in a single location. Yet, in forested landscapes, second-growth birds often have high nesting success because the landscape is free of predators and parasites. Regional management schemes also may be flexible enough to allow specialized management for sensitive species with restricted habitat requirements, such as the Golden-winged (*Vermivora chrysoptera*) and Cerulean warblers discussed by Hamel et al. (this volume). These landscape-level guidelines also often can fit within broader conservation schemes, as discussed by Uihlein (2002).

Winter management: Individual survival is the key factor with which a migrant bird must deal during the 6 to 8 months that it is not on the breeding grounds or in transit.

Although we have learned much about the winter behavior of migrants in the last decade, we have not made nearly as much progress with regard to management suggestions for this time period when compared to the breeding season. The work of Richard Holmes, Tom Sherry, and Peter Marra on American Redstart has shown how rigidly structured winter distributions might be for this species and how behavioral constraints might have breeding season repercussions for species with similar constraints of habitat and behavior. But Morton and Stutchbury (this volume), Baltz, (2000), Latta and Faaborg (2001, 2002), and Wallace (1998) have shown that a great variety of wintering strategies seems to exist among migratory birds. For some species we are still not sure what constitutes the winter range (Remsen 2001), let alone what habitats are truly required. While we must accept that some species may act like American Redstarts on the wintering grounds, we also know that others show markedly different behavior and must accept the fact that too few species have been examined in detail.

Stopover ecology and management: As birds are migrating between what are often fixed wintering and breeding sites, they require access to sites with high food availability and protection from predators. In some cases, particularly when large barriers such as the Gulf of Mexico or Great Plains must be crossed, these sites may be limiting. This has been discussed in two recent books (Able 1999, Moore 2000) and in a symposium at this conference. Although this period may be critical to annual demography, the evidence that stopover habitat is limiting is weak for most eastern broadleaf forest birds. In particular, the development of forest fragments throughout the Midwest has probably made migration easier for most migrants in this region. Yet, those cases where stopover limitations occur may be very important, so further work in this area is needed.

What Else do We Need to Know: Breeding Season?

Although I think we have made tremendous progress in the past decade with regard to our understanding of how migrant bird populations are regulated, we mostly have hypotheses that need further testing. Our "Midwest model" of landscapes and source/sink dynamics has a lot of demographic support, but we have no evidence that dispersal rates are actually driving this system (Faaborg et al. 1998). We need to better understand the demographic characteristics of all the component regional populations and determine where dispersal does and does not occur before we get very comfortable with, for example, a "protect the Ozarks and Missouri is OK" attitude.

On the contiguous forest end of the landscape scale, we need to be careful with determining what spatial constraints a landscape really has before we push for too much forest cutting because of its favorable effects on second-growth birds. In fragmented sites, we need better demographic studies to determine how one can optimize what are generally sink conditions. These also might allow us to initiate special cases of predator or parasite control when necessary, but we must have good demographic data before we initiate expensive conservation practices. For example, we know that parasitism is high in many midwestern forest fragments, but cowbird eradication in most of these cases would be useless, because nest predation rates are the ultimate factor controlling populations. We need more information, but our success of the last decade means we now can ask much better questions than we could before.

What Else do We Need to Know: Winter?

We need sound data on the habitat requirements of winter resident birds throughout their winter ranges. We must recognize that migrant birds use nearly all habitat types, such that converting primary vegetation types to secondary types affects some species negatively but may affect others positively. We must determine which habitats a wintering species truly needs to maximize survival over the winter. This research is not always easy to do, as there is a lot of noise in determining winter habitat selection in these migrants. Our long-term study in dry forest in Puerto Rico has captured 16 species of warblers in the winter, but we only consider this habitat to be a major wintering habitat for 4 of these. We need to determine which species have strong social dominance systems, like the American Redstart, such that subordinate age or sex groups are forced into what may be limiting habitat; these may show winter limitation sooner than those species with more egalitarian distribution systems in winter. Can we develop monitoring systems that allow us to detect those species whose post-breeding populations seem larger than their available winter range? As we attempt to understand the potential for winter limitation, we need to keep in mind that habitat modification affects wintering birds differently. For example, converting rainforest to sugar cane is disastrous to Wood Thrush but good for Indigo Bunting. The future is most likely one of a different spring, rather than a silent spring.

We will need to fit the needs of winter resident conservation into broader plans that deal with the conservation of tropical resident birds. As shown by a whole symposium at this conference, winter residents are only a small component of the forces driving avian conservation in many tropical countries. Along this line, some studies have suggested that winter residents do not respond negatively to habitat fragmentation on their wintering range. First of all, we need to verify that this is true. Just because winter residents may use fragments in high abundance does not mean that they survive there as well as in contiguous forest. Once again, solid demographic data are needed to see if this hypothesis is true. More importantly, even if it is true that migrants survive as well on fragments as contiguous forest, we must remember that habitat fragmentation is generally devastating to resident tropical bird species diversity. Any statement that suggests that fragmentation is acceptable because of its value to winter residents must be presented within the context of the severe loss of resident diversity that nearly always accompanies habitat fragmentation in the tropics.

Our Ultimate Goal: Understanding How Populations of Migrants are Regulated on Large Spatial and Temporal Scales

We must always remember that populations of Neotropical migrant birds are regulated over large spatial scales on annual or longer time scales (Sherry and Holmes 1995). Even excellent studies of local limitation have reduced value when extrapolated range-wide, whether this study is on the breeding or wintering range. Until we can actually link breeding and wintering sites, we are constrained in our population and demographic inferences. Ideally, we need broad scale studies of the evolutionary fitness of individual migrants throughout the annual cycle to make the most scientifically sound management plan. This will never be easy to do, in part because the migrant strategy involves so much mobility that is difficult to track. Although new technology using DNA traits (see Mila et al. this volume) or isotope patterns

(Hobson and Wassenaar 2001) suggests that we may be on the verge of making the appropriate linkages between breeding and wintering grounds, we will still be limited to comparing regions rather than actually tracking individuals.

In addition, we must remember that we have 200 or more species that we might consider Neotropical migrants. Each of these is susceptible to the above limiting conditions, but because each species has its own habitat requirements, social system, food habits, and such, the probabilities that each species will be limited by any given season will vary by species. We *must* avoid thinking of Neotropical migrants as a group that will simplistically go up or down as the amount of rainforest or other single ecological factor goes up or down. We might be able to group some species together into functional units, but we should be sure that we are not making some bad assumptions when we do so, and we must accept the fact that at some point we may have to consider each migrant species individually.

Finally, although the migrant strategy is successful enough to have evolved in so many species, it still involves a great deal of individual failure. A healthy population may have over half of its nest attempts fail in a given breeding season and nearly half of the adult birds die each year. This involves billions of deaths annually. As avian ecologists and conservationists, our goal is to sort through all of this noise to eventually understand the details of population regulation for species which may breed across half of North America and winter across all of Mexico and the West Indies. And we must do this well enough to tell the managers what they can do to help these species thrive.

While I am certain we are on the right track, we still have much to learn and, hopefully, many more PIF conferences in the future. I also hope that it is clear from this presentation that research which at one time seemed very "basic" and of little applied value turned out to be critical to the development of the conservation principles on which our current management practices rest; without continued support of migrant bird research that does not seem to have immediate conservation value, we will undoubtedly be limited in the quality of the management schemes we can design in the future.

Acknowledgments

Any positive contributions that I have made to the PIF effort have been the result of many years of wonderful interactions with both colleagues and graduate students. I thank all of them, although a list would be much too long. Certainly, I have been blessed with a bevy of great graduate students. Any weaknesses to the arguments that I have presented here are, of course, my own. I also want to thank the many funding agencies that have allowed my students and me to carry out a variety of studies on migrant birds during nearly all times of the year. T. Rich, C. Hunter and D. Demarest helped improve the quality of this manuscript.

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The Significance of Mating System and Nonbreeding Behavior to Population and Forest Patch Use by Migrant Birds[1]

Eugene S. Morton[2] and Bridget J. M. Stutchbury[3]

Abstract

Migratory birds are birds of two worlds, breeding in the temperate zone then living as tropical birds for most of the year. We show two aspects of this unique biology that are important considerations for their conservation. First, habitat selection for breeding must include their need for extra-pair mating opportunities. Second, non-breeding distributions in tropical latitudes are poorly known. Both geographic distribution and over-wintering habitat are much more limited than generally thought, suggesting that many species may be in more danger of population limitation there than presently thought. Tropical population limitation can result in migratory birds being eliminated from forest fragments, not due to fragmentation per se but to the need for extra-pair mating opportunities.

Key words: Catharus fuscescens, Dendroica chrysoparia, extra-pair mating, forest fragments, social behavior, *Wilsonia citrina,* winter ranges

Introduction

We have two goals in this report. The first is to integrate the social behavior of migratory passerine birds with their choice of breeding habitat. We know that these birds often are absent from forest fragments, but we disagree with the usual explanations. The second goal is to document our urgent need for information on ranges and social behavior in migrants during the critical but neglected wintering period.

Why Migrants are Lost from Fragments: The Role of their Extra-Pair Mating Systems

Extra-pair mating systems characterize temperate zone breeding birds (Stutchbury and Morton 1995). Both males and females leave territories to pursue copulations with neighbors (Stutchbury 1998). The increase in reproductive output in males successful in this pursuit is considerable (Stutchbury et al. 1997). Females choose better males by leaving their own territory to copulate with neighboring males (Neudorf el al. 1997). The extra-pair mating system of the well studied Hooded Warbler (*Wilsonia citrina)* is typical of most temperate zone birds but especially for long distance migrants (Birkhead 1998, Chuang et al. 1999, Stutchbury et al. 2005).

Forest patch size is known to affect the presence of breeding long distance migrants, with some species referred to as 'forest interior species.' However, studies have not shown that patch size alone is the cause of breeding absence. We suggest that smaller forest fragments impact the extra-pair breeding systems such that birds do not settle on them (Morton 1992). Rather than causing loss of breeding birds, fragmentation effects result from birds choosing areas with plenty of neighbors. Only with neighbors can they pursue their extra-pair mating system and abundant and close neighbors occur only in larger fragments.

Recent work proves that fragmentation affects extra-pair mating systems. Norris and Stutchbury (2001, 2002) showed that male Hooded Warblers in isolated fragments spent much more time off their territories in pursuit of extra-pair matings than did males with many immediate neighbors. Radio-tagged males crossed open fields between fragments easily but were forced to spend more effort and time in such pursuits than their counterparts in larger forest tracts. Females, in contrast, made off-territory forays rarely and over short distances (*fig. 1*). Perhaps the cues (song output?) that females with neighbors use to choose extra-pair partners are not available to these socially isolated females. Song, for example, does not travel for long distances over heated open country (Morton 1975). Without cues to choose, females on fragments would not, and did not, pursue extra-pair matings (*fig. 2*). But there were extra-pair matings, apparently due to male off-territory forays, such that extra-pair young accounted for 21

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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percent of the nestlings. This rate is only half that of the rate of extra-pair young found in larger forest environments. It is clear from these studies that fragmentation affects the ability of birds to pursue their customary extra-pair breeding system.

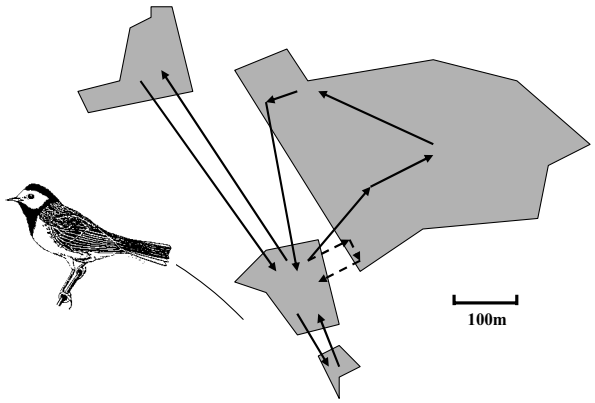

Figure 1— Extra-territorial forays of male (solid lines) and female (dashed line) Hooded Warblers in a fragmented landscape. Males made frequent forays to visit adjacent fragments whereas females rarely left their breeding territories. Nonetheless, 21 percent of the young in fragments were sired by extra-pair males (from Norris and Stutchbury 2001, 2002).

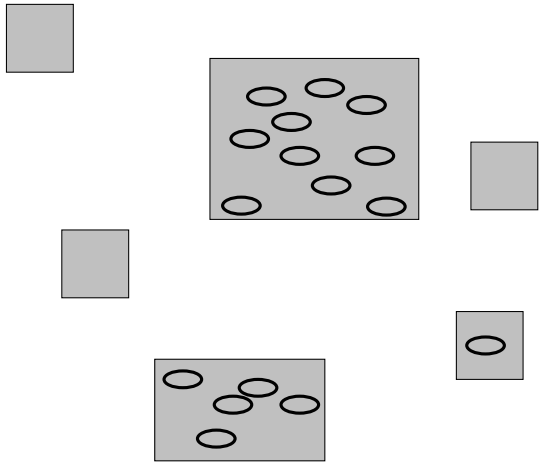

Figure 2— Hooded Warblers favor larger forest fragments for breeding because that is where their extra-pair mating system is best realized.

We suggest that fragmentation effects are due to two factors acting in combination: 1) the extra-pair mating systems of migrants favors settlement into breeding neighborhoods; and 2) if populations are limited during the nonbreeding season, by habitat loss during the wintering period and/or by en route migration habitat, then smaller fragments will loose breeding migrants in favor of larger tracts. Only if breeding populations are sufficiently large will birds spillover into less preferred habitats (Sherry and Holmes 1995), in this case, forest fragments.

An alternative is that migrants avoid fragments because of high cowbird parasitism and predation rates (e.g., Wilcove 1985). However, a longer term or evolutionary view suggests otherwise. The social behavior we discuss has been integral to the evolutionary history of migratory species. In contrast, cowbird parasitism and increased predation documented in forest fragments is a very recent anthropogenic event. It is doubtful that selection could favor birds avoiding fragments in such a short time.

For the reasons presented above, I disagree with the general view that fragmentation, and its associated changes in reproductive output, causes declines in breeding migratory birds. Instead, the extra-pair mating system should be given more weight in explaining the absence of migrants from smaller forest patches. The extra-pair mating systems cause birds to avoid settling in these when there are too few birds overall. When low populations caused by factors such as migration mortality and low carrying capacities of declining wintering-area habitat are considered, few birds remain to be forced to occupy small-forest habitats after larger tracts are saturated. The reason to preserve large forest tracts is that they attract migrants to settle and breed. I suggest that this is most important when populations are low or declining because viable breeding populations can be maintained. The 'crowded neighborhood' that satisfy the requirements of extra-pair breeding systems of migrants are better met in large tracts. But that does not mean that smaller tracts should be ignored or developed because they are thought to be of low value to migratory birds (Morton 1995).

The Unknown Consequences of our Ignorance of Migrants as Tropical Birds

We remain blithely unaware of the true wintering areas needed by migratory birds. Remsen (2001) criticizes the misuse of specimen records to document the winter ranges of migrants. He showed that the winter range of the Veery (*Catharus fuscescens)* is based upon specimens of migrating Veerys, not wintering individuals. A huge wintering area, including much of tropical South America east of the Andes, is described in most references. This huge and largely wilderness area suggests that conservation concerns should focus on breeding or migration habitats.

The big 'however' is that this is based upon false knowledge. Remsen (2001) correctly restricts the true winter distribution to specimens collected from 2 December to 20 February. All 14 of these were collected from two small areas in central Brazil at the southern boundary of the Amazon Basin and another area in southeastern Brazil in São Paulo (*fig. 3*). Veery declines in the breeding season may, therefore, be due

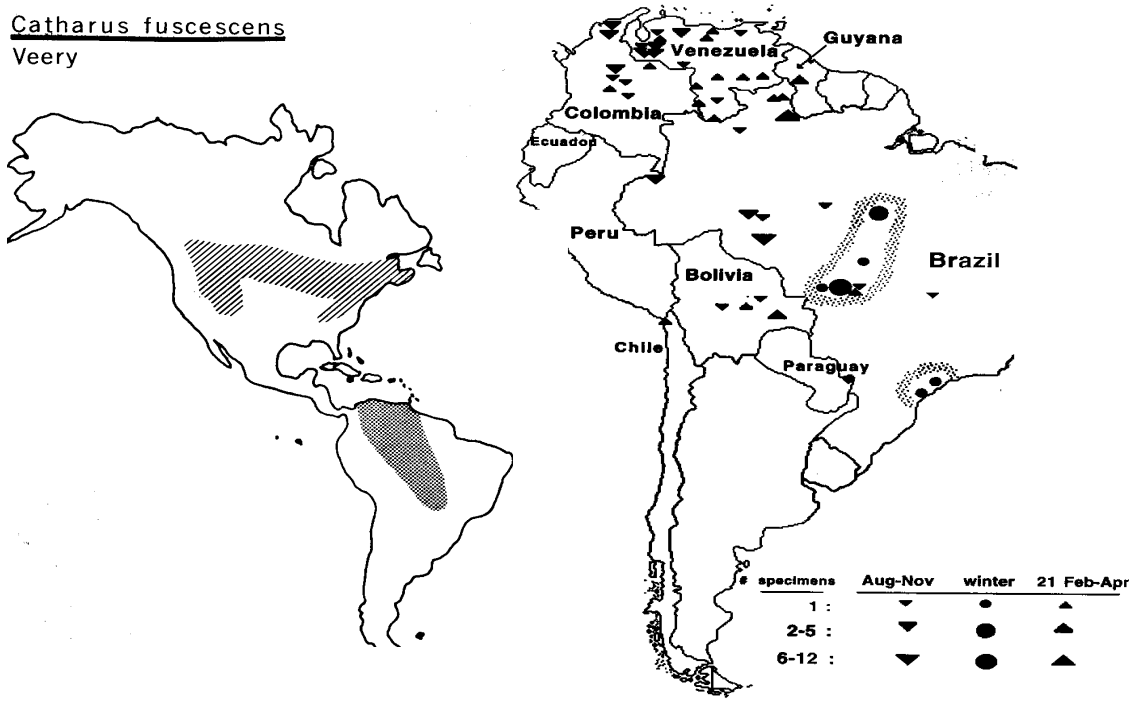

Figure 3— The large wintering range of the Veery, depicted on the left, has been traditionally accepted as the true range. Remsen (2001) proposed a more accurate range based on better criteria. If true, winter limitation is likely based on the relatively small winter range and its location in an area of high deforestation (from Remsen 2001).

to wintering population limitation. Winter ranges need much more scrutiny and soon!

Rappole et al. (1999a, b) studied the habitat requirements of wintering Golden-cheeked Warblers (*Dendroica chrysoparia)*. Their results illustrate another neglected aspect of migrant birds that needs research. Golden-cheeked warblers occurred only in high elevations that contained two species of oaks (*Quercus* spp.). When they mapped the geographic extent of this habitat onto the assumed winter range of the warbler, the resulting area was much smaller than the mapped area encompassing the birds. It was so much smaller that they conclude the species cannot fill all of the currently available breeding habitat in Texas (*fig. 4*). Furthermore, the behavior of the warbler limited the density that could occur in the limited habitat. Golden-cheeked Warblers must have a mixed species flock as part of their territory. This requirement is common in migrants. Golden-winged and Blue-winged Warblers (*Vermivora chrysoptera* and *V. pinus),* Black-and-white Warbler (*Mniotilta varia*), and Worm-eating Warbler (*Helmitheros vermivorus*) are examples of other warblers that need the mixed species flock as a component of their winter territories (Morton 1980). Mixed species flocks range through areas big enough to feed the larger members of the flock, bigger than that needed to feed one warbler (Powell 1985). Mixed species flocks are vulnerable to logging because they require the complex structure of a mature forest to encompass all the foraging niches of their component species. Many tropical birds are obligatory mixed species flock members—they do not live outside of them, just as some ant-following antbirds must have army ants to feed over (e.g., Greenberg and Gradwohl 1986). When tropical forests are fragmented or even altered by selective cutting, the flocks disappear and with them, a major habitat for some migrants (e.g., Lovejoy et al. 1986, Morton 1980, Stutchbury and Morton 2001). When the flocks go, so do the Golden-cheeked Warblers.

Conclusions

We have shown how breeding behavior and overwintering behavior and data on winter ranges are understudied and yet crucial to conservation. Many of the standard management tools for breeding migrants are based upon reasoning that does not encompass these elements. We should continue to preserve large forest tracts for breeding birds but for the right reasons. When we do this, reasons used to devalue small forest remnants become much less convincing.

Winter social behavior is unknown or poorly known at best. There are very few species for which we know the consequences of occupying suboptimal habitat, the size of floater populations, and sex-specific or age-specific strategies to compete for winter resources. This list of "need to knows" requires fieldwork and long term monitoring of banded populations. Remsen (2001) just reminded us that

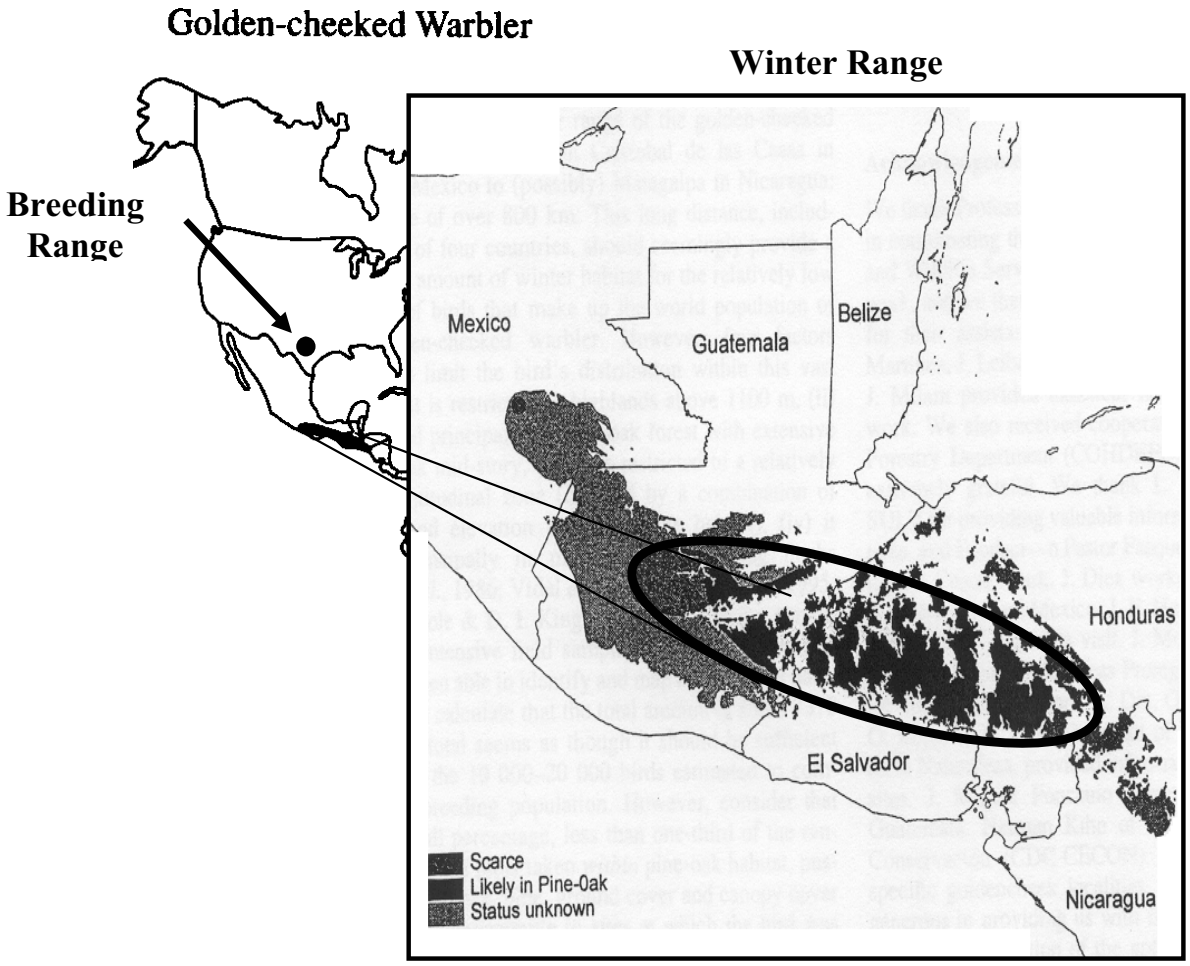

Figure 4— The true winter range of the Golden-cheeked Warbler includes a rare and endangered oak-pine habitat and the need for mixed species flocks. The effective winter range is probably smaller than the breeding range and may be the limiting factor in their population management (from Rappole et al. 1999a,b).

even the winter ranges of many species may be unknown or are more likely to be much smaller than the literature would suggest. Winter ranges and movements within the overwintering months need study because they contribute to the carry capacity of migrants. In general, events during the nonbreeding periods have been ignored, understandably, by those entrusted with managing breeding areas. We hope this essay will show how population size and mating system affect the forest tract choices by breeding migrants and illustrate the connection. There is much to do, and quickly.

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Landscape Level Effects on Forest Bird Populations in Eastern Broadleaf Forests: Principles for Conservation[1]

Frank R. Thompson III[2]

Abstract

Forest fragmentation, urbanization, and forest management are important issues for bird conservation in the eastern broadleaf forest of North America. Fragmentation of forest by agricultural and developed land uses increases the numbers of Brown-headed Cowbirds (*Molothrus ater*) and nest predators in the landscape, which results in decreased productivity of songbirds. Reproductive success is so low in some Midwestern landscapes that the only way populations could persist is through immigration, which provides circumstantial evidence that populations are structured as sources and sinks. Recent hypotheses that put nest-site factors in a habitat context, habitat or local factors in a landscape context, and landscapes in a geographic context provide guidance for conservation planning. At a landscape scale conservation efforts should focus on providing necessary habitats, conserving existing large-contiguous landscapes, and reducing fragmentation in moderately fragmented landscapes. Minimizing habitat fragmentation at a landscape scale may be the best approach to addressing local effects such as edge and patch size effects.

Key words: bird conservation, brown-headed cowbirds, eastern broadleaf forest, edge effects, fragmentation, landscapes, nest predators, patch size.

Introduction

The eastern broadleaf forest in North America ranges from extensively forested to highly fragmented. Important issues for bird conservation in the region are forest fragmentation, urbanization, and forest management. Landscape level patterns and processes, including those above, are key considerations in bird conservation efforts in Eastern forests. Several key studies in the region provide the basis for the fragmentation hypothesis (Donovan et al. 1995, Robinson et al. 1995, Donovan et al. 1997, Thompson et al. 2000; see Thompson et al. 2002 for review). I believe there is sufficient support for the fragmentation hypothesis to consider it a key factor in bird conservation efforts. Fragmentation, however, should be considered along with other factors that occur within a hierarchy of spatial scales that affect bird populations (Thompson et al. 2002).

I review the fragmentation hypothesis, as it pertains to songbird populations, and some of the evidence supporting it. I describe how fragmentation and other processes at larger and smaller scales fit within a spatial hierarchy of factors affecting bird populations, and why this multi-scale model is important to bird conservation in eastern broadleaf forests. While this paper is brief, I refer to key examples, and recent more thorough reviews exist (Faaborg et al. 1995, Walters 1998, Thompson et al. 2002).

The Fragmentation Hypothesis

The fragmentation hypothesis is that reproductive success of forest songbirds is, on average, lower in fragmented forests than in more contiguous forests. Lower reproductive success is the result of a greater abundance of predators and cowbirds in landscapes fragmented by human-dominated land uses such as agriculture and suburban and urban development. Reproductive success is so low in some landscapes that the only way populations could persist is through immigration, which provides circumstantial evidence that populations are structured as sources and sinks.

Important aspects of the fragmentation hypothesis are that it pertains to landscape-level processes and that it is dependent on fragmentation of forests by habitats with greater numbers of predators and or cowbirds. The interspersion of forest with human-dominated habitats results in a numerical increase in predators and cowbirds at the landscape scale. The hypothesis is independent of smaller scale effects such as edge or patch-size effects. For instance, it does not matter if predation and parasitism are greater in edges or small patches than forest interior, but that, on average, predation and parasitism are greater in fragmented landscapes than non-fragmented landscapes. The converse may not be true, however, because edge or patch size effects may be dependent on levels of fragmentation. This simple distinction, while not immediately intuitive, is important

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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because it is the increased numbers of predators and cowbirds in the landscape, not their preference (or lack of) for edge, that results in a fragmentation effect. For example, there is stronger support for the effect of landscape level fragmentation effects than either edge or area effects in the abundance on of predators (Chalfoun et al. 2002). And, irrespective of their preference for edge, it is the amount of agricultural land (which provides feeding habitat) that appears to regulate cowbird abundance in Midwestern landscapes. For example, some landscapes in Missouri and Illinois that are approximately 50 percent forested vary greatly in mean forest patch size and total amount of edge but all have high cowbird parasitism, whereas those that are greater than 70 percent forested generally have low parasitism (Thompson et al. 2000). I believe a landscape focus, not based on area or edge effects, can provide simple and effective guidance for conservation efforts.

Strong evidence for lesser reproductive success in fragmented landscapes than non-fragmented forests comes from several studies in eastern broadleaf forests (Hoover et al. 1995, Robinson et al. 1995, Donovan et al. 1997). These studies were able to detect a fragmentation effect because they occurred in a context where eastern broadleaf forest was fragmented by agricultural land uses and they examined a wide range of landscape conditions. The fragmentation hypothesis may not apply to western landscapes because of different predator communities, habitat relationships, and a greater level of historical, natural habitat interspersion (Tewksberry et al. 1998). Also, other studies may not have detected these effects because they studied a narrower range of landscape conditions or habitat patches rather than landscapes (i.e. Fauth 2000, Fauth et al. 2000). I compiled data from several eastern studies of nesting success of Wood Thrush (*Hylocichla mustelina*) and plotted them with data from Robinson et al. (1995; *fig. 1*). The additional data points increased variation and do not provide a strong case for or against the patterns reported by Robinson et al. (1995) and Hoover et al. (1995). This could be expected, however, because the additional points represent a broader geographic and temporal span and add additional sources of variation that are not accounted for. Estimates of Wood Thrush productivity in the region, however, do provide general support for lesser productivity in fragmented landscapes (*fig. 2*).

Additional support for fragmentation effects comes from recent studies linking population trends and occupancy to fragmentation. Donovan and Flather (2002) found a significant negative correlation between the proportion of a population occupying fragmented habitat and the population trend. Boulinier et al. (2001) found that species richness of area-sensitive, forest species was lesser, and year-to-year rates of local extinction greater, on Breeding Bird Survey routes surrounded by landscapes with a small mean forest-patch size.

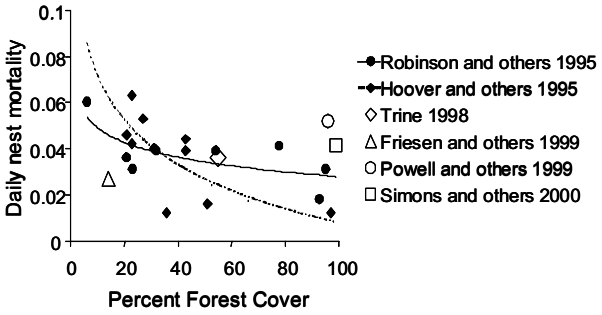

Figure 1— Relationship of Wood Thrush daily nest predation to the amount of forest cover in the landscape based on studies in eastern broadleaf forests. The *R*-squares for regression of log-transformed data are 0.54 for Robinson et al. (1995, solid line) and 0.53 for Hoover et al. (1995, dotted line).

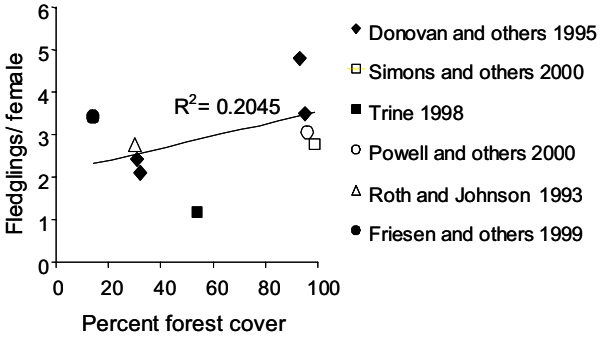

Figure 2— Relationship of Wood Thrush productivity to the amount of forest cover in the landscape based on studies in eastern broadleaf forests. The *R*-square of the regression line is 0.20.

Population Sources and Sinks

The fragmentation hypothesis implies that nesting success is so low in some landscapes that these populations must be population sinks where population persistence depends on immigration from other populations. Evidence for population sinks is circumstantial and based on very low reproductive success in fragmented habitats (Robinson 1992, Donovan et al. 1995, Robinson et al. 1995) and extirpation and recolonization events (Brawn and Robinson 1996). Reproductive success and source sink-status can vary over time and space. Source populations can have years with low reproductive success (Anders et al. 1997) and some populations in fragmented landscapes at can have moderate to high nesting success (Friesen et al. 1999, Fauth et al. 2000).

Nonetheless, the presence of population sinks does not necessarily imply low viability of populations. Donovan

and Thompson (2001) demonstrated that a population could persist even if 40 percent of the habitat is sink habitat. If individuals, however, prefer sink habitat to higher quality source habitat, sinks can function as ecological traps and result in extinction if >30 percent of the habitat is sink habitat. Nevertheless, sink habitat provides habitat within which individuals can reside, and those individuals may have important ecological roles in the community or contribute to the population at a future time.

Multi-Scale Model of Factors Affecting Populations

Conservation and research will be most effective if it acknowledges that factors affecting breeding birds occur over a range of scales and that larger scales provide context or limit responses at smaller scales. These scales include (1) biogeographic—abundance and distribution of animals (breeding birds, predators, and cowbirds) varies geographically; (2) landscape—this includes fragmentation effects and effects of landscape composition; (3) habitat scale—patch characteristics including habitat type, patch size, and distance to edge; (4) nest patch or site—micro-habitat characteristics directly around the nest or the immediate vicinity of the nest (see Thompson et al. 2000, 2002 for a more thorough review of these factors).

For example, we found strong evidence that edge effects in nest predation are dependent on landscape context and that landscape context is a better predictor of cowbird abundance than any other local-scale affect measured (Donovan et al. 1997). In landscapes with <15 percent forest, predation was high in forest edge and interior; at 45 to 55 percent forest cover, predation was high in forest edge and low in forest interior; and at >90 percent forest cover, predation was low in forest edge and interior (*fig. 3*). Cowbird abundance was much greater in landscapes with high levels of forest fragmentation than those with low levels of fragmentation (*fig. 3*).

The results of this research also were confirmed by a meta-analysis of nest predation studies in which researchers compared the landscape context for studies that documented edge effects on predation patterns with those that failed to find edge effects (Bayne and Hobson 1997, Hartley and Hunter 1998). Similarly in a meta-analysis of nest predators Chalfoun et al. (2002) determined that predator responses to edges, patch size, and fragmentation were not independent of landscape context. Predator abundance or activity was related to edge, patch area, or fragmentation in 66.7 percent of tests when adjacent land use was agricultural, 5.6 percent when forest, 16.7 percent when grassland, and 5.6 percent when clearcut forest.

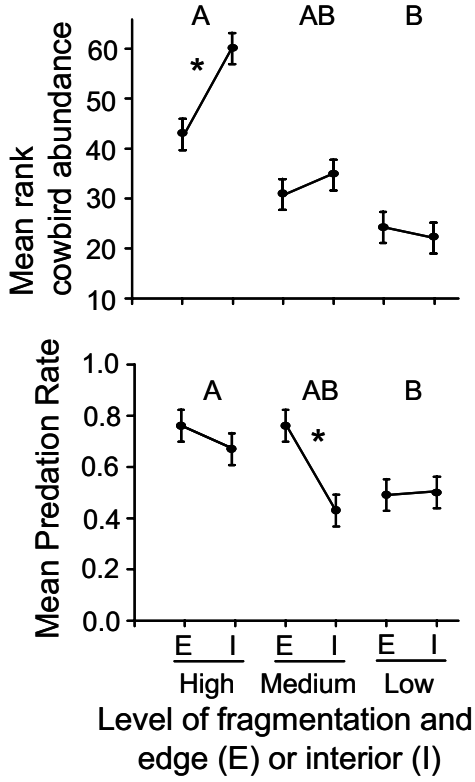

Figure 3— Effects of landscape level of fragmentation and local edge effects on nest predation and cowbird abundance in the Midwestern United States. Fragmentation levels were measured as the amount of forest cover and were: high, <15 percent forest; medium, 45-55 percent forest; and low, >90 percent forest. Edge (E) and interior (I) treatments were 50 m and > 250 m from forest edge, respectively. Levels of forest cover with different letters, and edge and interior treatments with an asterisk are significantly different (ANOVA, P <0.05). Data and figures adapted from Donovan et al. (1997).

Implications for Conservation

I believe the following conservation actions have the greatest potential to benefit breeding birds in eastern broadleaf forests. Planning and management should acknowledge the hierarchical nature of these effects whereby larger scale factors constrain or limit smaller scale effects.

Biogeographic

Be aware of geographic patterns in bird, predator and cowbird abundances. Cowbird abundance and parasitism rates generally decrease with distance from the Great Plains (Hoover and Brittingham 1993, Thompson et al. 2000). The abundance of snakes, key songbird predators (Thompson et al. 1999), varies with latitude. As we learn more about how habitat and landscape factors affect individual species of predators, knowledge of the biogeographic context (i.e. predator community) will become more important factors in bird conservation.

Landscape

Provide required habitats

Consider the full range of habitats needed by species within the region. Because habitat requirements vary among species some prioritization will have to occur. Mandates for threatened, endangered, sensitive species, and species prioritization schemes can provide guidance. The historic range of variability concept also can provide useful guidance (Committee of Scientists 1999).

Reduce fragmentation effects

A priority is to conserve large contiguous landscapes because few of these usually exist. The goal is to ensure there are sufficient heavily forested landscapes within the region to meet the needs of forest birds. Research has not identified specific threshold levels for fragmentation effects but some bird conservation planning has targeted landscapes with >70 percent forest cover as priorities for forest bird conservation (Fitzgerald et al. this volume) on the basis of Robinson et al. (1995). Next, consider actions to increase the strength of sources, or convert marginal sinks into sources by converting or managing agricultural habitats to make them less favorable to predators and cowbirds. Efforts to minimize fragmentation should not hinder efforts to restore other important natural communities such as savannas and shrub lands because there is no evidence that these habitats cause the negative, landscape-level effects that human dominated habitat does. Recognize that some proportion of the global population will reside in population sinks, and that sinks can have some value. Therefore, conservation should focus on ensuring that there is adequate source habitat to balance sink habitat, and not necessarily on eliminating sink habitat.

Habitat interspersion

Habitats can be provided within or among landscapes, depending on desired levels of interspersion and species habitat needs. Consider needs for interspersion and habitats for all life stages including juveniles, non- or post-breeding adults (Anders et al. 1998, Pagen et al. 2000) and migrants.

Habitat

Addressing landscape level fragmentation is the best approach to reducing patch-size or edge effects. I believe ensuring landscapes are mostly composed of forest will be more effective and efficient in conserving forest birds than focusing on the size and amount of edge in individual patches. Patch size or edge effects are not likely to have negative, population-level effects in minimally fragmented, mostly forested landscapes. In greatly fragmented landscapes edge and area effects may be the result of fragmentation effects, not the cause; remember it is the interspersion of predator and cowbird habitat in landscapes that results in more predators and cowbirds and not edge by itself.

Larger patches and less edge are usually better, assuming you provide desired levels of interspersion within or among landscapes. For example, even though clearcutting may be controversial, it can result in less edge and fragmentation of older forest than selection methods. In addition, it will result in larger patches of early successional forest that are of greater value to many early successional birds then selection methods (Brawn et al. 2001, Thompson and DeGraaf 2001).

While my focus has been on landscape-level management, habitat managers should also consider habitat structure within patches. Eastern forests and habitat needs of songbirds vary greatly in composition and structure. A coarse-grain approach is to ensure native plant communities and disturbance processes occur across large landscapes and assume habitat needs of species will be met. Natural disturbance agents, prescribed fire, and silviculture can be integrated in this approach (Thompson et al. 1995, Brawn et al. 2001). More intensive habitat level management is appropriate where habitat needs are known and there is special interest in target species.

Acknowledgments

I thank J. Faaborg, T. M. Donovan, S. K. Robinson, and numerous graduate students for their collaboration on many of the ideas and studies reviewed in this manuscript. J. Faaborg and R. Peak provided valuable review of the manuscript.

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Birds in a Developing Area: The Need for Habitat Protection at the Landscape Scale[1]

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Abstract

We used fixed-distance point counts to monitor bird populations from 1994-1998 in a rapidly urbanizing region of southwestern Missouri. Prior to the early 1990s, the rural landscape was a mosaic of forest, dolomite glades, and pasture but development proceeded rapidly in the 1990s with increased promotion of Branson, Missouri as a vacation and retirement destination. Point count data were collected in areas with native vegetation intact and that are not likely to be developed as the region continues to urbanize (undeveloped sites), and at a 375-ha residential/golf development (developed site). Eleven of 18 regularly-recorded species showed declines, five of them significant, on the developed site relative to their trends on the undeveloped sites. Each of those five species was associated with forest or forest edge habitats. Only one species showed a significant decrease on the undeveloped sites. Notably, some forest species were reduced in the developed site even though patches of forest and other native vegetation remained. We suggest that a regional conservation strategy be developed so that the needs of all species of forest avifauna can be met as urbanization continues its advance on native habitats.

Key words: development, forest birds, Missouri, monitoring, point counts, population trends, urbanization.

Introduction

Individuals of a given species of bird typically are attracted to a breeding site by the structure of the habitat within that site (Cody 1968, Wiens 1969, James 1971), the areal extent of the habitat available (Forman et al. 1976, Galli et al. 1976, Askins et al. 1987, Herkert 1994, Winter and Faaborg 1999) or a combination of patch area and within-patch structure (Robbins 1980, Ambuel and Temple 1983, Lynch and Whigham 1984, Blake and Karr 1987). In landscapes where forests are highly fragmented, smaller woodlots often are dominated by ecological generalists (Martin 1981, Ambuel and Temple 1983, Blake 1983). This pattern appears to be exacerbated when isolation among forests patches is increased and where habitat structure in the surrounding matrix is in sharp contrast to the forest patch (Blake and Karr 1987, Freemark and Collins 1992). Individuals nesting in isolated tracts of forest in the Midwestern United States have been shown to suffer much higher rates of brood parasitism and nest predation than individuals nesting in landscapes that are extensively forested (Donovan et al. 1995, Robinson et al. 1995, Robinson 1996). However, population trends can still appear stable in tracts where reproductive success is below that needed to sustain the population over time, presumably as a result of immigration of individuals to the site (Brawn and Robinson 1996).

In the Midwestern United States, assessments of factors that can affect the relative abundance of birds have taken place primarily in areas where large scale conversions of land from native to non-native vegetation occurred many decades ago. The objective of this study was to assess changes in the relative abundance of birds in a region that had a high percentage of native vegetation in the early 1990's, but was then subjected rather suddenly to ongoing and rapid urbanization. We compare bird species' population trends at a new development site with those in tracts of undisturbed native habitat in the surrounding counties.

Methods

Study Area

This study was conducted in a rapidly urbanizing region of the Ozark Highlands near Branson, Missouri. The greater Branson area is a tourist destination which currently attracts approximately six million people each year to its country music shows and theme parks, and to the recreational opportunities provided by three

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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large reservoirs on the White River (Branson/Lakes Area Chamber of Commerce, pers. comm.). Although the level of tourism was increasing prior to the early 1990s, dramatic increases occurred after the television news magazine, "60 Minutes", aired a segment on Branson in early 1991. Estimates of the number of guests spending one or more nights in the area increased from 2.2 million in 1991 to 4.8 million during the 1998 season (Jerry Henry, Corporate Director of Research, Silver Dollar City, Inc., pers. comm.). In addition to the increase in tourism, many people moved to the area in search of employment, development and retirement opportunities. Between 1990 and 1996, the three-county area surrounding Branson was the fastest growing region of the state, with population increases of 37.5 percent, 35.6 percent and 30.2 percent in Christian, Stone and Taney counties, respectively (Missouri Department of Economic Development). Increases in both tourist and resident populations were associated with a boom in both commercial and residential development as demands for services and infrastructure skyrocketed.

The potential natural vegetation of the study area is oak-hickory (*Quercus* sp.-*Carya* sp.) and oak-hickory-pine (*Quercus* sp.-*Carya* sp.-*Pinus echinata*) forest interspersed with limestone and dolomite glades (Thom and Wilson 1980, McNab and Avers 1994). Glades typically occur on drier south and southwest facing slopes and are dominated by little bluestem (*Andropogon scoparius*) and other native grasses (Nelson 1987). In the early 1990s, the landscape in the Branson area still was comprised of forests and glades, but in some areas pastures replaced native vegetation on ridgetops and bottomlands (*fig. 1*).

Study Sites and Design

We surveyed birds in the undeveloped sites with intact native forest and glade vegetation from 1995 through 1998 using 10-min, 50-m radius point counts. A total of 130 points was surveyed, clustered in 16 routes of eight to nine points each. Points were approximately 250 m apart. The 16 routes were distributed among six locations in the greater Branson area, with two or three routes per area (*fig. 1*). All but two routes were on public land. Four routes, one from each of four different areas, were surveyed three times between 25 May and 30 June. The remaining routes were surveyed once per season. Because survey points were clustered within routes, we used the route as the primary sampling unit, thereby avoiding pseudoreplication.

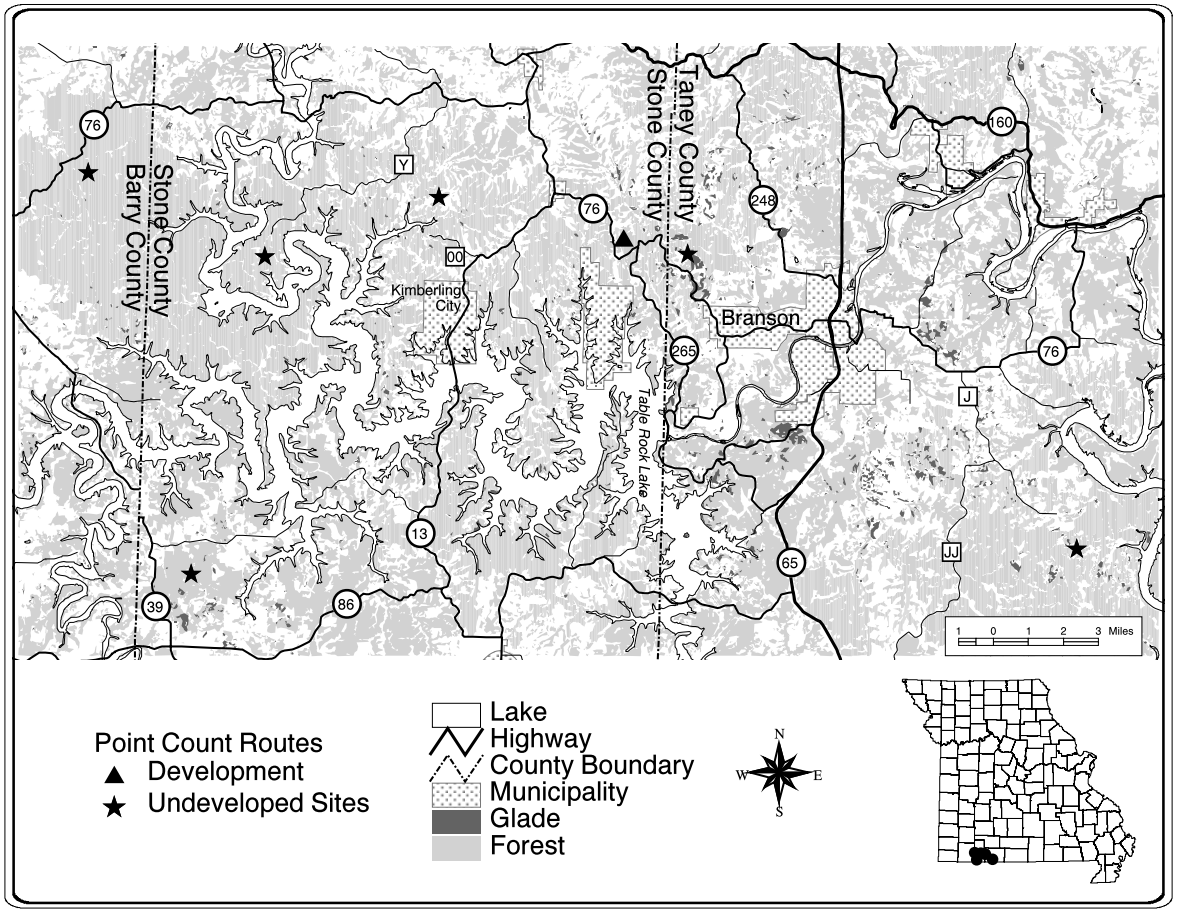

Figure 1— Locations of study sites in the greater Branson, Missouri area.

Thirty-two points, also placed approximately 250 m apart, were surveyed three times per season from 1994 through 1998 at a 375-ha residential/golf development. The development plan included an 18-hole golf course, condominiums, and approximately 200 residential lots ranging in size from 0.5 to 2 acres. In 1993, the land was still a mosaic of forest and glade with small patches of pasture interspersed. Bulldozing for the golf course and road system began in the spring of 1994, roughly commensurate with the beginning of our monitoring there. The condominiums, golf course, clubhouse and many homes were completed by 1998.

The development is designed so that all residential lots adjoin "common property." Most of these areas consist of narrow strips of native vegetation less than 50 m in width, although some larger patches of forest and glade are adjacent to or dispersed throughout the development. All of our census points were located in areas of common property or forest immediately adjacent to the development. Points were treated as independent because they were evenly distributed across the study area. Thus the sample size was the number of points.

Statistical Analyses

Trends were calculated for each primary sampling unit (routes in the undeveloped site; points in the developed site). Proportional change in the trend line between 1994 and 1998 was used as the estimated change during the study. Significance of the changes was determined using a one-sample t-test of the null hypothesis that the mean of the slopes was equal to zero. The changes were compared using $\bar{d}\ \ \bar{y}_d - \bar{y}_u$, where $\bar{y}_d$ and $\bar{y}_u$ are the mean changes at the developed and undeveloped sites, respectively. The significance of the difference was determined with a t-test for independent samples testing the null hypothesis that the mean of the differences was zero. Trends were assessed for the eighteen most commonly recorded species.

Trends likely to occur on the developed site, in the absence of any treatment effect, were also assessed by obtaining Breeding Bird Survey trend estimates (Sauer et al. 2000) for the Ozark-Ouachita province, which the study area was in, for the period 1980-2002.

Results and Discussion

Eleven of the 18 species declined or increased less on the developed site relative to their trends on the undeveloped sites (*table 1*). Five of these species showed significant declines on the developed site while one of them showed a significant decline on the undeveloped site. Three of the differences in trends were significant (P = 0.00, 0.00, 0.02), and two were suggestive (P = 0.12, 0.12). None of the other species showed significant, or close to significant changes, on either the developed or undeveloped site. Breeding Bird Survey data indicate that the five species showing strongest evidence of declines at the developed site have exhibited stable or increasing trends across the Ozark-Ouachita Plateau region as a whole during the period 1980-2002 (Sauer et al. 2003).

Each species that declined significantly at the developed site is associated with deciduous forest or forest-edge habitat (Probst and Thompson 1996, Fitzgerald et al. unpublished data). Immigration did not compensate for the declines of these forest-associated species at the developed site, suggesting the habitat structure has become inadequate to attract individuals of those species. A shift in the structure of the bird community could be occurring as a result.

In conclusion, this study indicates that even a development that leaves some native vegetation intact and is adjacent to larger acreages of native habitat may not be adequate to sustain forest bird communities characteristic of the southwestern Missouri Ozarks. We therefore encourage regional, county and other land use planners to identify, protect and enhance sites that can support all forest-associated species characteristic of their region. Given that forest tracts larger than 10,000 ha may be needed to meet the needs of all area-sensitive bird species, to accommodate natural disturbances within tracts, and to foster levels of reproductive success adequate to support self-sustaining forest bird populations (Rotenberry et al. 1993, Robinson et al. 1995, Robinson 1996), we suggest that the identification and preservation of large habitat blocks become a conservation priority in the greater Branson area.

Acknowledgments

Our work was funded by: Cooper Communities, Inc.; Silver Dollar City, Inc.; The Glen E. Patch Corporation; Boatman's Bank; The Missouri Department of Conservation; The U. S. Fish and Wildlife Service; The Mark Twain National Forest; and many other individuals and businesses in the Branson, Missouri area. We thank them all. The Missouri Resource Assessment Program (MORAP) provided the map of the study area, which also was much appreciated.

Table 1— *Change in mean number of birds recorded on the developed and undeveloped sites. The panels (divided by a dotted line) show species that decreased (upper) and increased (lower) in the developed site relative to the undeveloped site. Within panels, species are arranged by P-values for the difference in trends*[1].

	Developed site			Undeveloped site			Difference	
Species	**1994**	**1998**	**Change (%)**	**1994**	**1998**	**Change (%)**	**Estimate (%)**	**P**
Acadian Flycatcher (*Empidonax virescens*)	0.38	0.10	-74**	0.36	0.30	-17	-57	0.00
Black-and-white Warbler (*Mniotilta varia*)	0.33	0.04	-88**	0.27	0.22	-19	-69	0.00
Indigo Bunting (*Passerina cyanea*)	0.78	0.42	-46*	0.18	0.19	+6	-52	0.02
Red-eyed Vireo (*Vireo olivaceus*)	0.34	0.18	-47	0.77	0.64	-17	-30	0.12
Northern Parula (*Parula americana*)	0.33	0.15	-55*	0.15	0.13	-13	-42	0.12
Northern Cardinal (*Cardinalis cardinalis*)	0.16	0.20	+25	0.09	0.20	+111	-86	0.24
Blue-gray Gnatcatcher (*Polioptila caurelea*)	0.99	0.41	-59**	0.63	0.35	-44*	-15	0.28
Summer Tanager (*Piranga rubra*)	0.16	0.08	-47	0.23	0.16	-30	-17	0.48
Yellow-billed Cuckoo (*Coccyzus americanus*)	0.02	0.05	+150	0.04	0.13	+202	-52	0.84
American Crow (*Corvus brachyrhynchos*)	0.12	0.11	-8	0.08	0.08	0	-8	0.88
Eastern Wood-pewee (*Contopus virens*)	0.07	0.13	+83	0.04	0.08	+100	-17	1.00
Great-crested Flycatcher (*Myiarchus crinitus*)	0.08	0.12	+60	0.06	0.07	+8	+52	0.38
Brown-headed Cowbird (*Molothrus ater*)	0.22	0.22	0	0.21	0.14	+33	+33	0.38
White-breasted Nuthatch (*Sitta carolinensis*)	0.04	0.16	+290	0.07	0.14	+100	+190	0.43
Eastern Tufted Titmouse (*Parus bicolor*)	0.18	0.27	+50	0.30	0.35	+17	+33	0.48
Blue Jay (*Cyanocitta cristata*)	0.02	0.08	+300	0.06	0.08	+33	+267	0.51
Carolina Chickadee (*Parus carolinensis*)	0.15	0.12	-20	0.12	0.09	-26	+6	0.92
Downy Woodpecker (*Picoides pubescens*)	0.08	0.13	+63	0.08	0.12	+50	+13	1.00

[1]Entries under 1994 and 1998 are the mean values for the trend lines fitted to the primary sampling units (points in the developed area; routes in the undeveloped area) using linear regression.
* = P <0.05; ** = P < 0.01.

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The Effects of Timber Harvesting on Neotropical Migrants in Cove Hardwood Forests in the Southern Appalachian Mountains[1]

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Abstract

I compared avian species richness, density, and diversity for neotropical migrants, short distance migrants, and permanent residents following timber harvesting in cove hardwood forests in the Southern Appalachian Mountains of North Carolina. The forest stands were 4-103 years old, had undergone a clearcut or selective tree removal, and represented four successional stages (early, sapling/pole, mid, and late). Neotropical migrants constituted 60.5 to 69.0 percent of species richness. Mean breeding bird density for all species was 225.1 pairs/40 ha (±16.3 se) with an overall mean density for neotropical migrants of 186.2 pairs/40 ha (±5.4 se). Late successional cove hardwood forest habitats provide for a significantly more diverse avifauna with respect to the entire avifauna, and, specifically the neotropical migrants, than does sapling/pole or mid-successional forests. Neotropical migrants are the most substantial avian component of the highly diverse cove hardwood forest habitat, accounting for a minimum of 70 percent of the individual birds in each successional class. Therefore, their needs must not be overlooked in considering the consequences of habitat alterations and management activities.

Key words: breeding bird densities, cove hardwood forests, Neotropical migrants, Southern Appalachians, successional stage, timber harvesting.

Introduction

Studies on neotropical migrants report declines in both distribution and overall population numbers in certain physiographic regions in North America (Terborgh 1989, Peterjohn et al. 1995, Franzreb and Rosenberg 1997). In the Southeast, the number of species that are apparently declining is the highest in the Southern Blue Ridge Physiographic Area (Hunter et al. 1993). Given that neotropical migrants in many areas constitute the majority of the avifauna (Morse 1980); further reductions may result in substantial declining overall population levels. Observed population declines have been attributed to habitat fragmentation on the breeding grounds and to deforestation of the over-wintering areas. In the United States, habitat fragmentation has resulted from a variety of land management practices, including timber harvesting. Current forest management practices on public and private lands provide opportunities for evaluating how migrant populations respond to changing environmental conditions. Because birds are easily observed, they can be monitored relatively conveniently and, thus, can serve as a barometer of possible conditions and the status of less readily detectable species.

Cove hardwood forests are found on moist, fertile soils in concave landforms and ravines nestled well back into the sides of mountains. The vegetative component is highly diverse in all vegetative strata, from the overstory canopy to the herb layer. Much of the forested land base in the Southeast has sustained one or more entries for logging purposes. Relative to diversity and volume of timber produced, the cove hardwood forest is one of the most productive forest communities in this area. Cove hardwood forests are dominated by such species as yellow-poplar (tulip tree), sugar maple, yellow birch, black cherry, American beech, and oaks. Plant scientific names not given in the text may be found in *table 2*.

On the Pisgah and Nantahala National Forests, the largest volume of timber is removed from cove hardwood forests. Hence, evaluating this forest type with respect to birds provides an opportunity to evaluate the effects of a land management practice that is widespread over the landscape. Of the 123,940 ha of cove hardwood forests in the Pisgah and Nantahala National Forests, about 30 percent is in the 41-60 year-old age class and 50 percent is 61-80 years old (Ed Brown, US Forest Service, pers. comm.). As the rotation age for this vegetation type is approximately 80 years, much of the existing cove hardwood forest is approaching harvestable age.

The objectives of this study were to: (1) determine avian species richness, breeding bird densities and bird

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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species diversity in harvested cove hardwood forests in four successional stages (early successional, sapling/pole, mid, and late successional) in the Southern Appalachian Mountains; (2) determine the proportion of the avifauna comprised of neotropical migrants, short-distance migrants, and permanent residents; and (3) provide information that may be useful in developing harvesting programs as part of an overall management plan that includes cove hardwood forests in these areas.

Materials and Methods

Study Area

Dominant tree species are yellow-poplar, American basswood, Carolina silverbell, sugar maple, yellow buckeye, northern red oak, white oak, yellow birch, black birch, black cherry, and American beech. Typical understory trees include eastern redbud (*Cercis canadensis*), Fraser magnolia, mountain maple (*Acer spicatum*), and flowering dogwood. Among the numerous understory shrub species are great rhododendron (*Rhododendron maximum*), flame azalea (*R. calendulaceum*), and mountain laurel (*Kalmia latifolia*). Cove hardwood forests contain a diverse array of herbaceous species with commonly encountered species including wood anemone (*Anemone quinquefolia*), red trillium (*Trillium erectum*), wild ginger (*Asarum canadense*), Solomon's-seal (*Polygonatum biflorum*), and American ginseng (*Panax quinquefolius*).

Twelve study plots were established in cove hardwood forests in the Pisgah and Nantahala National Forests in western North Carolina (Cheowah, Highlands, Appalachian, and Wayah Ranger Districts) (*table 1*). The plots ranged in elevation from 788 m to 1,090 m and varied in size from 19.4 to 117 ha. Slopes varied from 30-55 percent, with an average of 40 percent. The general aspect for 10 of the plots was north or northeast and for the remaining two plots was south or southwest. Age of the plots from time of last entry for timber harvesting purposes varied from 4 to 103 years. The harvesting process varied from clear cutting in the younger stands to selective tree removal (based on minimum trunk diameter) in the older stands. Plot selection was based, in part, on road access so that all plots were within a 1-hour walk of a road. Also we selected stands that could accommodate a square or rectangular plot within the stand with minimal potential for edge effects related to adjacency of dissimilar stands.

Successional stages were defined as early successional (grass/forb and shrub/seedling, up to 10 years old, one plot), sapling/pole (11-40 years old, five plots), mid-successional (41-80 years old, three plots), and late successional (81-120 years old, three plots) (U.S. Forest Service 1999). As a result of the limited amount of recent logging on Forest Service lands on these forests, I was unable to locate more than one suitable stand to assess the early successional stage. In a landscape context, the cove sites were in concave landforms that were surrounded by other types of hardwood stands such as oak-hickory, white pine-hemlock, and maple-beech-birch. There was little information available on a site-specific basis that described land use changes on these sites from historic times to the present day. Eight of the plots were treated post-logging either by chain saw site preparation (Brush Creek in 1991 and Rattler Ford in 1974), thinning (Appletree in 1966, Rhinehart Creek in 1978, Ash Flats in 1968 and 1991, and White Oak in 1989), grape removal (Rattler Ford in 1983), and herbicide application (Jutts Creek in 1978 and 1980 and Bee Cove in 1976). The three oldest plots and one of the mid-successional (Sugarhouse) stage plots received no post-harvesting treatments. Also, I did not sample any old-growth plots (those more than 120 years of age).

Table 1—*Description of cove hardwood forest study plots, southern Appalachians.*

Plot name	Stand age (years)	Successional stage	Mean elev. (m)	Mean slope (%)	General aspect	USGS quad name
Brush Creek	4	Early	1090	55	N	Highlands, NC/GA
Jutts Creek	15	Sapling/pole	955	45	NE	Hewitt, NC
White Oak	18	Sapling/pole	1076	35	S	Celo, NC
Rattler Ford	21	Sapling/pole	879	55	NE	Santeetlah Creek, NC
Bee Cove	23	Sapling/pole	970	40	N	Fontana Dam, NC
Appletree	37	Sapling/pole	970	30	N	Topton, NC
Rhinehart	56	Mid-	1000	30	NE	Wayah Bald, NC
Sugarhouse	56	Mid-	1030	40	SW	Mt. Mitchell-Barnardsville, NC
Ash Flats	68	Mid-	1030	40	NE	Rainbow Springs, NC
Cherry Gap	93	Late	1030	40	NW	Sylva South, SC
Joyce Kilmer A	103	Late	788	35	NE	Santeetlah Creek, NC
Joyce Kilmer B	103	Late	1000	35	NE	Santeetlah Creek, NC

Vegetation

I used the plotless point-quarter method (Cottam and Curtis 1956) to sample trees with diameter at breast height (dbh) >12.7 cm. In the summer of 1994, twenty-five points with four trees each were sampled in 11 of these 12 study plots. There were no trees with dbh > 12.7 cm in the early successional stage. Points were at least 50 m apart and counted from a random starting point along the transect. In each quadrant, the following information was recorded for the tree in each quadrant closest to the center stake: distance to the center point, tree species, height, dbh, and length of the live branch closest to the ground. These data were analyzed to provide tree species density, frequency, dominance, and importance values. Species richness reflects the number of species. Dominance values were derived from basal area figures that rely on measurements of dbh and were expressed as m^2/ha. I estimated the importance value by summing the relative density, relative dominance, and relative frequency of tree species in each plot. Points were selected from those used for establishing the spot map grid (see avian sampling below). Likewise I sampled four saplings (defined as dbh < 12.7 cm) at each of ten points for a total of 40 saplings per study plot. A total of 1,100 trees (n = 11 stands) and 480 saplings (n = 12 stands) were measured. Plant species diversity and structural characteristics that contributed to avian species richness and densities are being analyzed (Franzreb, unpubl. data[1]).

Avian Sampling

Each study plot was 10 ha in size and contained a series of labeled stakes placed 50 m apart along parallel transect lines, which in turn were 50 m from other transect lines. Birds were surveyed using the spot mapping method (Williams 1936, Kendeigh 1944), whereby locations of individual birds were recorded on a map that had a grid system that corresponded to the labeled stakes. Territory boundaries were delineated and the number of territories was estimated for each species, with the assumption that each territory represented one breeding pair. Eight visits were made in each plot for each year of the study. Data for each species were collated for all visits and transferred to a map for each individual species prepared for each breeding season. Densities are reported as the number of breeding pairs per 40 ha for ease of comparing with results of other studies. Estimates of partial territories overlapping with the area outside the plot were included as a percentage of a complete territory. Birds were surveyed from May 27 - July 15 in 1992, May 27 - July 5 in 1993, and May 16 - July 7 in 1994, by the observer systematically walking along the transects and recording the following for each observation: species, activity (singing, foraging, etc.), sex, map location on the grid, date, time, and[1] weather conditions. Distances were estimated using a range finder and with the aid of flagging placed at specific distances parallel to the transect lines. Observations were begun approximately at sunrise and continued up to three hrs. The order that the transects were walked was randomized for each visit. There were a total of five observers, each of whom surveyed one plot per survey day.

Data were averaged over the three years for each of the 12 plots, segregated by migratory class and then consolidated for each successional stage as needed to perform specific statistical tests. A mean for the consolidated data for a successional stage was obtained by averaging the densities for individual species over the three year period. Species were segregated into groups according to their migratory status (neotropical migrant, short-distance migrant, and permanent resident) as per the Breeding Bird Survey classification system (see Sauer et al. 2001). Short-distance migrants were defined as those who do not migrate outside the boundaries of the United States.

Species richness, breeding bird species densities, bird species diversity, and evenness values were obtained for each migratory class in each of the plots. To determine the overlap in species presence from one successional stage to the next, I used the Sorensen index (Sorensen 1948). Comparisons of species overlap (similarity) included early versus sapling/pole, sapling/pole versus mid-successional, and mid-successional versus late successional stages. Single classification analysis of variance (ANOVA) was performed to detect differences between the successional stages for three variables: species richness, density, and bird species diversity. Each of these variables was analyzed on an overall population basis and then separately for neotropical migrants, short distance migrants, and permanent residents. ANOVA tests were followed by Turkey's studentized range tests to compare results between successional stages. One of the assumptions of ANOVA is homogeneity of variances and in cases that involve only one plot, it is not possible to calculate the variance and, hence, not possible to check this assumption. Because the early successional stage was represented by only one plot, thus precluding estimating a variance, it was not included in the ANOVA.

Bird species diversity was calculated using the Shannon formula (Shannon 1948). Evenness (or relative diversity) was calculated as $J = H/H_{max}$ where H is the diversity value, $H_{max} = \log k$ and k is the number of species in the data set (Pielou 1966). In this study, k = 45 species. Pearson correlation coefficients were obtained to test the relationship of bird species diversity

[1] Unpublished data on file at Southern Appalachian Cooperative Ecosystems Studies Unit, Knoxville, TN.

versus successional stage for the entire avifauna and for each individual migratory class for all 12 plots, including the youngest plot.

The potential power of the statistical tests was low because of the small sample size. Thus, to reduce the type II error, all ANOVA tests were performed at the 0.10 significance level and subsequent pairwise comparisons were performed at an experimentwise 0.10 level. Statistical analyses were done using SAS (1999-2000).

Results

Vegetation

All plots had diverse flora typical of hardwood forests in the Southern Appalachians. As the Brush Creek plot was only four years-old when the study was initiated, it contained a large number of saplings (3,846/ha), but no trees (Franzreb, unpubl. data). The importance values for tree species (relative density + relative frequency + relative dominance) showed that yellow-poplar was the most influential species in nine of the 12 plots. It was replaced in importance in the oldest two plots by black cherry, sugar maple, and American basswood (*table 2*). Black birch also was an important tree species in the young and middle-aged stands.

Species Composition and Richness

Successional stage was nonsignificant for species richness for all birds (P = 0.11), neotropical migrants (P = 0.29), short distance migrants (P = 0.81), or permanent residents (P = 0.19). Species richness in the four successional stages ranged from 18.7 ± 1.8 se in the mid-successional stage to 24.3 ± 0.9 se in the late successional stage (*fig. 1, table 3*).

The mean number of neotropical migratory bird species varied from 13.3 ± 0.3 se in the mid-successional stage to a high of 15.3 ± 0.3 se in the late successional stage. Neotropical migratory birds constituted 60.5 - 69.0 percent of the breeding bird species in the successional stages, representing the majority of species present compared to short distance migrants (5.2 - 13.6 percent) or permanent resident species (18.2 - 34.2 percent) (*fig. 2*). The highest proportion of permanent resident species was found in the late-successional stage and short distance migrants in the early successional stage.

Of the migratory classes, the short distance migrants had the lowest degree of species overlap between the successional stages (*table 4*). Species overlap for neotropical migrants increased slightly (0.74 to 0.84) with age of the successional stage. For permanent residents, species overlap increased consistently with age of the successional stage, ranging from 0.50 in the early stage compared to the sapling/pole stage to a high of 0.95 in the mid- compared to late successional stage. When all species are considered, species overlap increased with successional stage.

Avian Species Density

The overall mean number of breeding birds in the four successional stages for the three year period was 225.1 pairs/40 ha (± 16.29 se) and varied from a low of 203.5 pairs/40 ha (± 13.5 se) in the sapling/pole stage to a high of 272.7 pairs/40 ha in the early successional stage (*fig. 3*).

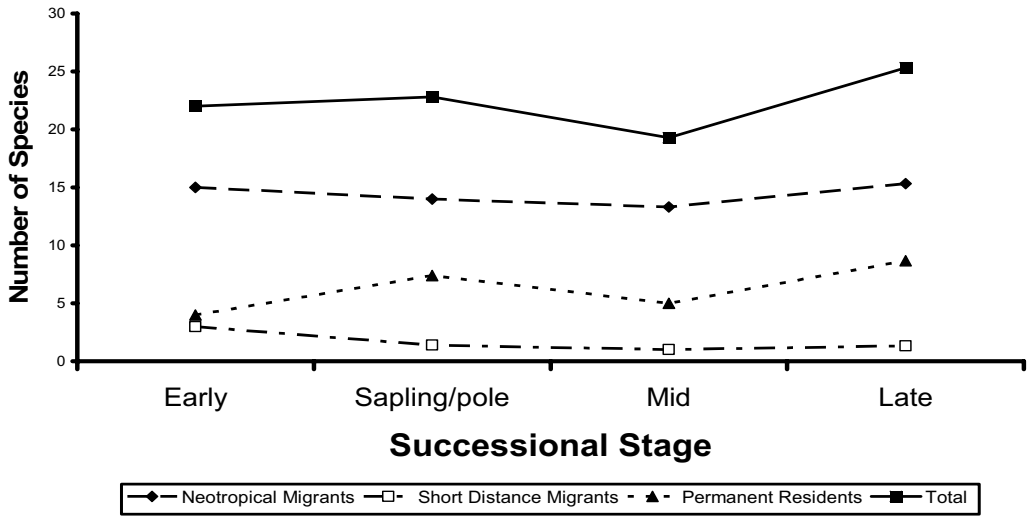

Figure 1—Number of species of birds by migratory class and stand age in cove hardwood forests in the southern Appalachians.

Table 2—*Importance values*[1] *for trees in cove hardwood forest plots, southern Appalachians (1992-1994).*

		Importance Value										
Plant name	**Scientific name**	**Jutt's Creek**	**White Oak**	**Rattler Ford**	**Bee Cove**	**Apple Tree**	**Rhine-hart**	**Sugar-house**	**Ash Flats**	**Cherry Gap**	**Joyce Kilmer A**	**Joyce Kilmer B**
Eastern hemlock	*Tsuga canadensis*		11.7					3.3			21.3	15.4
White pine	*Picea strobus*		2.9									
Mockernut hickory	*Carya tomentosa*	3.0	3.0		3.6	55.1		26.4	76.0	66.6	9.5	2.4
Black birch	*Betula lenta*	43.0	9.3	63.0	54.5	5.8	53.0	5.8	27.3	18.3	23.6	43.0
Yellow birch	*Betula alleghaniensis*							2.5				
Eastern hophornbeam	*Ostrya virginiana*							3.1				
American beech	*Fagus grandifolia*					3.3	8.3	12.6			27.3	20.3
White oak	*Quercus alba*		3.1			29.0		6.2				
Chestnut oak	*Quercus montana*		47.5					30.7	4.4	8.0		
Northern red oak	*Quercus rubra*	26.2	30.9	5.3	3.1	25.2	20.0	36.8	39.9	28.7	26.5	17.0
Cucumber-tree	*Magnolia acuminata*	5.8	3.2	54.4	59.3	22.6		5.4				
Fraser magnolia	*Magnolia fraseri*	15.4				2.6	3.0					
Yellow-poplar	*Liriodendron tulipifera*	79.7	114.6	106.5	100.8	40.8	108.9	76.2	71.2	58.3	15.9	4.4
Sassafras	*Sassafras albidum*				3.0			2.6				
Black cherry	*Prunus serotina*	13.6	26.2		6.3		4.1		3.0	2.8	47.4	52.0
Black locust	*Robinia pseudoacacia*	19.2	18.4	36.2	32.1	2.6	4.7	12.9	18.4	23.1		
Red maple	*Acer rubrum*	10.2	20.6	7.8	14.4	36.7	15.8	18.1	14.5	29.8	9.4	20.2
Sugar maple	*Acer saccharum*	10.5	2.8	12.2	11.9	7.6		12.1	6.2	10.3	47.4	56.1
Striped maple	*Acer pensylvanicum*	2.6	3.0		3.0				2.8	2.6		
Yellow buckeye	*Aesculus octandra*						31.0		9.2	5.8	14.3	21.5
American basswood	*Tilia glabra*	18.4		9.0	5.0	3.1	39.5	11.2	18.3	35.0	42.2	37.9
Blackgum (bk. tupelo)	*Nyssa sylvatica*	5.4				2.7					2.4	2.3
Flowering dogwood	*Cornus florida*	5.3				5.5		17.0	2.6	7.1	2.4	4.6
Sourwood	*Oxydendrum arboreum*	7.2				28.0		7.7	2.7			
Carolina silverbell	*Halesia carolina*	31.8		5.3	3.0	19.1	4.2		3.7	3.6	7.6	
White ash	*Fraxinus americana*	2.7	2.8				7.5	9.5			2.8	2.9

[1]Importance Value = relative density + relative frequency + relative dominance (max. = 300, min. = 0).

Table 3—*Relationship of successional stage to species richness, species densities, and bird species diversity in cove hardwood forests.*

	ANOVA[1]		Mean ± se and Tukey's test[2]		
	F	P	Sapling/pole	Mid-successional	Late successional
Species Richness					
Neotropical migrants	1.45	0.29	14.0 ± 0.89[a]	13.3 ± 0.33[a]	15.3 ± 0.33[a]
Short distance migrants	0.21	0.81	1.4 ± 0.51[a]	1.0 ± 0[a]	1.3 ± 0.33[a]
Permanent residents	2.05	0.19	7.4 ±0.93[a]	5.0 ± 1.52[a]	8.7 ± 0.88[a]
All Birds	2.92	0.11	22.6 ± 1.54[a]	18.7 ± 1.76[a]	24.3 ± 0.88[a]
Species Densities					
Neotropical migrants	0.45	0.65	176.7 ± 12.3[a]	198.0 ± 27.12[a]	182.8 ± 3.64[a]
Short distance migrants	0.72	0.52	4.6 ± 2.00[a]	1.78 ± 0.22[a]	3.2 ± 0.77[a]
Permanent Residents	6.75	**0.02**	22.1 ± 3.72[a,b]	8.11 ± 5.28[b]	34.2 ± 5.22[a]
All Birds	0.20	0.82	203.5 ± 13.50[a]	207.9 ± 32.5[a]	220.2 ± 9.59[a]
Bird Species Diversity					
Neotropical migrants	5.22	**0.04**	0.94 ± 0.02[b]	0.94 ± 0.04[b]	1.04 ±0.01[a]
Short distance migrants	0.62	0.56	0.08 ± 0.05[a]	0[a]	0.09 ± 0.09[a]
Permanent residents	2.21	0.17	0.76 ± 0.06[a]	0.53 ± 0.16[a]	0.80 ± 0.06[a]
All birds	8.96	**0.01**	1.09 ± 0.01[b]	1.01 ± 0.06[b]	1.20 ± 0.02[a]

[1] Numbers in bold = significant difference at $P \leq 0.10$. All df = 2.
[2] Means in a row with the same letter are not significantly different based on Tukey's studentized range test at the 0.10 significance level.

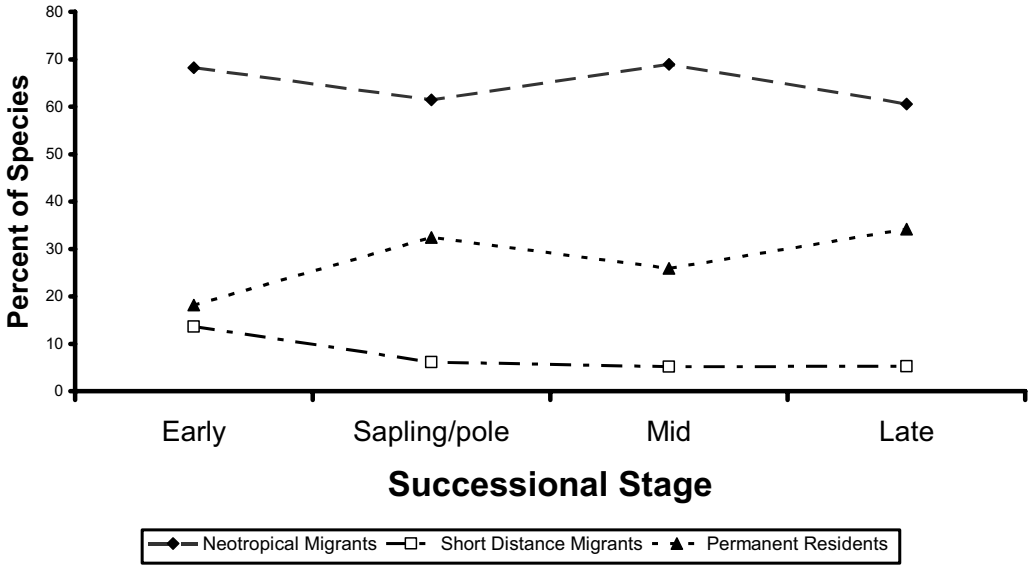

Figure 2—Percent species of birds by migratory class and successional stage in cove hardwood forests in the southern Appalachians.

The youngest stand, 4-year-old Brush Creek, had the highest bird density (272.7 pairs/40 ha), primarily the result of the presence of three high density species, Chestnut-sided Warbler (*Dendroica pensylvanica*) (73.0 pairs/40 ha), Eastern Towhee (*Pipilo erythrophthalmus*) (53.0 pairs/40 ha), and Indigo Bunting (*Passerina cyanea*) (50.7 pairs/40 ha). With the exception of the youngest plot, which had only one pair, Ovenbirds (*Seiurus aurocapillus*) were the most common breeding bird on all plots, ranging in density from 36.0 to 63.7 pairs/40 ha. Black-throated Green Warblers (*Dendroica virens*) and Black-throated Blue Warblers (*D. caerulescens*) were among the most common breeding birds on plots that were 21 years of age or older.

Neotropical migrants comprised the majority of the overall breeding bird population in terms of densities and percent of each successional category (*Figs. 3, 4*). The mean density of neotropical breeding birds varied from 176.7 pairs/40 ha (±12.3 se) in the sapling/pole stage to a high of 198.0 pairs/40 ha (±27.12 se) in the mid-successional stage, with an overall mean of 186.2

± 5.4 se (*table 3*). The percent of the population consisting of neotropical migrants ranged from 70.1 percent in the early successional stage to a high of 95.2 percent in the mid-successional stage. Successional stage was not significantly related to the density of neotropical migrants (P = 0.65) (*table 3*).

Short-distance migrants had a mean density ranging from 1.8 pairs/40 ha (± 0.2 se) in the mid-successional stage to a high of 20.7 pairs/40 ha in early successional stage (*fig. 3, table 3*). The overall mean density for short-distance migrants in the four successional stages was 7.6 pairs/40 ha ± 4.4 se. Short-distance migrants comprised from 0.9 to 7.6 percent of the density of breeding birds (*fig. 4*). Successional stage was not significant for the density of short distance migrants (P = 0.52) (*table 3*).

Densities of permanent residents ranged from a low of 8.1 pairs/40 ha (± 5.3 se) in the mid-successional stage to a high of 60.7 pairs/40 ha in the early successional stage (*fig. 3, table 3*), with an overall mean of 31.3 pairs/40 ha ± 11.2 se. Permanent residents comprised from 3.9 to 22.3 percent of the breeding bird density in the four stages (*fig. 4*). The density of permanent residents was influenced by successional stage (P = 0.02). Mean densities of permanent residents was significantly lower in the mid- versus the late successional stage (8.1 pairs/40 ha vs. 34.2 pairs/40 ha, respectively) (*table 3*).

Bird Species Diversity

Bird species diversity for all birds ranged from a low of 0.62 in the early successional stage, which included one 4 year-old plot, to a high of 1.20 ± 0.02 se in the late successional stage (n = 3) consisting of Cherry Gap (93 years) and Joyce Kilmer A and B (each 103 years old) (*table 5*). The bird species diversity for the 12 plots was 1.06 ± 0.05 se. Species diversity was significantly different between stages when considering all migratory classes together (P = 0.01) (*table 3*). According to Tukey's studentized range tests, bird species diversity for all birds was significantly lower in the sapling/pole versus the late successional stages and significantly lower in the mid-successional versus the late successional stages (*tables 3* and *5*). Bird species diversity and evenness for all birds were positively correlated with stand age (r = 0.54, P = 0.07 and r = 0.54, P = 0.07, respectively).

Table 4—*Species overlap by migratory class and successional stage based on Sorensen index*[1].

Species Overlap	Early successional vs. sapling/pole	Sapling/pole vs. mid-successional	Mid- vs. late successional
Neotropical migrants	0.74	0.76	0.84
Short distance migrants	0.57	0.67	0.50
Permanent residents	0.50	0.76	0.95
All birds	0.66	0.75	0.85

[1]See Sorensen (1948) (max = 1.0, min = 0).

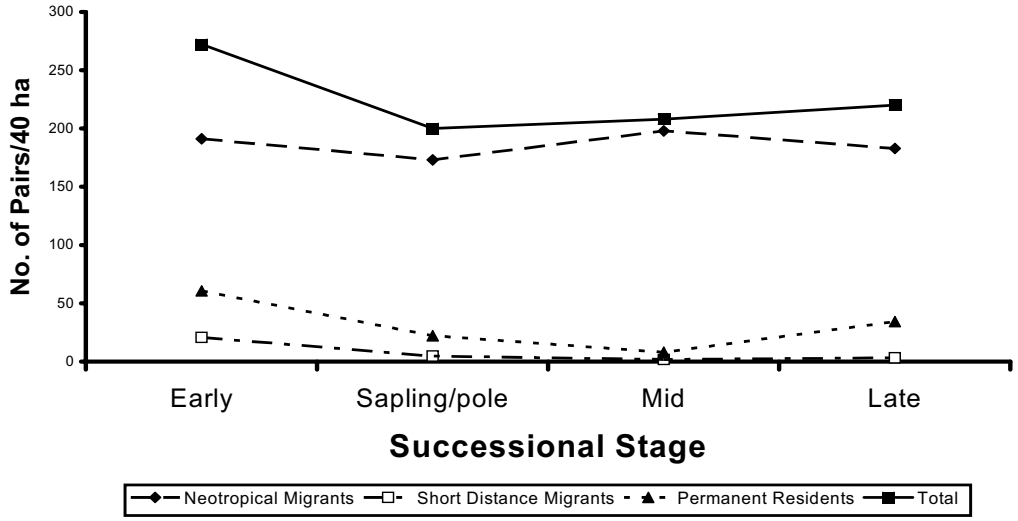

Figure 3—Breeding bird density by migratory class and successional stage in cove hardwood forests in the southern Appalachians.

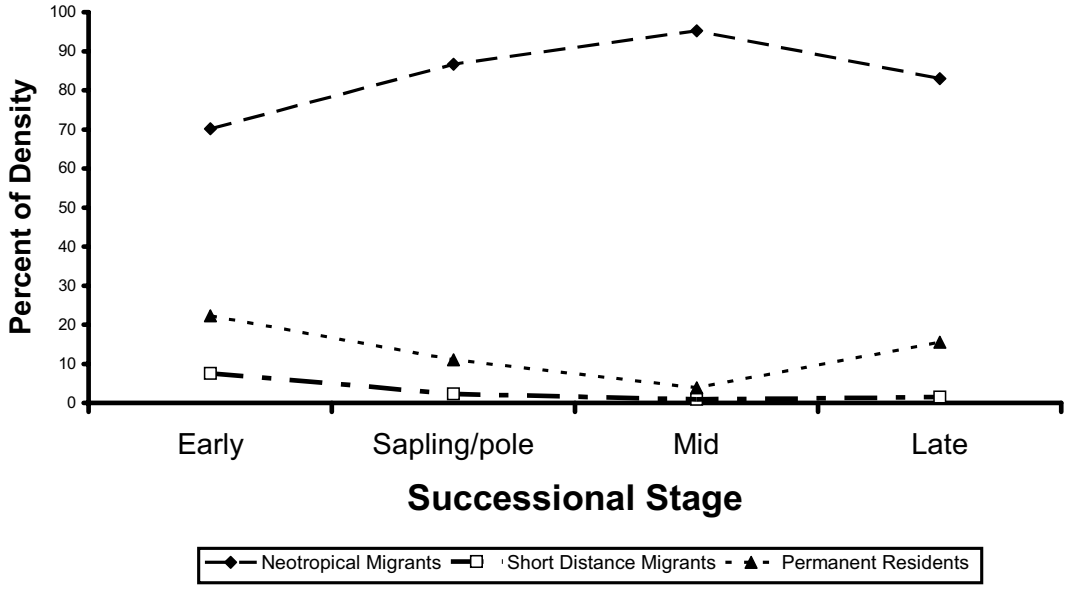

Figure 4—Percent of breeding bird density by migratory class and successional stage in cove hardwood forests in the southern Appalachians.

Table 5—*Bird species diversity and evenness by successional stage and migratory class. Parameter estimates are reported as mean ± se.*

	Successional Stage				
Parameter	**Early (n = 1)**	**Sapling/pole (n = 5)**	**Mid (n = 3)**	**Late (n = 3)**	**Overall (n = 12)**
Mean bird species diversity[1]					
Neotropical migrants	0.78	0.94 ± 0.02	0.94 ± 0.04	1.04 ± 0.01	0.95 ± 0.03
Short distance migrants	0.38	0.08 ± 0.05	0.00	0.09 ± 0.09	0.09 ± 0.04
Permanent residents	0.20	0.76 ± 0.06	0.53 ± 0.15	0.80 ± 0.06	0.67 ± 0.07
All species	0.62	1.09 ± 0.01	1.01 ± 0.06	1.20 ± 0.02	1.06 ± 0.05
Evenness[2]					
Neotropical migrants	0.47	0.57 ± 0.01	0.57 ± 0.03	0.63 ± 0.003	0.58 ± 0.01
Short distance migrants	0.23	0.05 ± 0.03	0.00	0.05 ± 0.05	0.05 ± 0.02
Permanent residents	0.12	0.46 ± 0.03	0.32 ± 0.09	0.48 ± 0.04	0.40 ± 0.04
All species	0.38	0.66 ± 0.007	0.61 ± 0.04	0.73 ± 0.01	0.64 ± 0.03

[1] Shannon-Weiner formula (see Methods).
[2] $J = H/H_{max}$ (see Methods).

Mean bird species diversity for neotropical migrants for all successional stages was 0.95 ± 0.03 se versus 0.09 ± 0.04 se for short-distance migrants and 0.67 + 0.07 se for permanent residents. Neotropical migrants attained their highest species diversity of 1.04 ± 0.01 se (n = 3) in the late stage and their lowest in the early successional stage (0.78, n = 1). Species diversity for neotropical migrants was significantly different between stages for neotropical migrants (P = 0.04), being significantly higher comparing the late successional to either the sapling/pole or mid-successional stages (*tables 3* and *5*). Bird species diversity and evenness for neotropical migrants were positively correlated with stand age (r = 0.73, *P* = 0.01 and r = 0.75, P = 0.01, respectively).

Discussion

Avian community structure is largely determined by the structure and physiognomy of the plant community including the vertical and horizontal heterogeneity (MacArthur and MacArthur 1961, Willson 1974, Balda 1975, Niemi and Hanowski 1984). Silvicultural activi-

ties influence the vegetation and, therefore, have a profound influence on the avian community (Maurer et al. 1981, Thompson et al. 1995). Increased public concern regarding the potential impacts of timber harvesting on wildlife support the need to more fully understand how components of the ecosystem, such as the avifauna, respond to changes in the landscape following harvesting.

Wilcove (1988) censused birds in 10-ha plots using the spot-map method in three cove hardwood forests in the Great Smoky Mountains National Park. One plot was logged sometime in the 19th Century (Lower Ramsey) and, therefore, may correspond to my late successional plots. Because the other two cove plots were virgin forest, they do not have an analog in my study. In Lower Ramsey, the breeding bird density was 218.4 pairs/40 ha of which 186.4 pairs/40 ha were neotropical migrants (Wilcove 1988). My results are strikingly similar to those of Wilcove in overall breeding bird densities in the late successional stage (220.2 pairs/40 ha and 218.4 pairs/40 ha, respectively), in densities of neotropical migrants (182.8 pairs/40 ha and 186.4 pairs /40 ha, respectively), and in the percent of neotropical migrants in the breeding population (83.9 percent and 85.5 percent, respectively). These comparisons are particularly interesting because the census method and plot size were the same.

Bird species diversity reflects not only the number of species but also the proportional distribution of densities of those species. The early successional plot (Brush Creek) had the lowest bird species diversity, primarily because of the presence of three species in high densities - Chestnut-sided Warbler, Eastern Towhee, and Indigo Bunting. Together these three species comprised a total of 176.7 breeding pairs/40 ha out of a total of 272.8 pairs/40 ha. Short-distance migrants were most numerous in the early successional plots primarily the result of the presence of large numbers of Dark-eyed Juncos (*Junco hyemalis*) and American Goldfinches (*Carduelis tristis)*, which were less numerous in older successional stages.

King and DeGraaf (2000) found that number of species and bird species diversity were significantly higher in shelterwood harvested sites than in either clearcut or mature forests. The results of my study are in partial agreement with their findings. Bird species diversity was significantly lower in younger and mid-successional stands than in mature forest for all species combined and for neotropical migrants. Bird species diversity and evenness for all birds and neotropical migrants were positively correlated with successional stage over the full length of successional classes. This is partly explained by the younger stands having been clearcut, whereas the older stands were subjected to harvesting of trees that had attained a minimum trunk diameter (as in high-grading). As trees had not developed yet in the youngest stand, the vegetation structure and diversity in that plot was substantially less than what was present in the other, older stands.

It has been shown that some species of neotropical migrants in the Southern Appalachians responded to habitat gradients representing both microclimate features (tree species, tree basal area, dbh, percent cover, canopy height, height range of vegetation layers, elevation, stand age, and canopy height) and landscape features (proportion of stand types within the landscape) (Lichstein et al. 2002). Early successional species appeared to be most sensitive to landscape composition, perhaps the result of the relative lack of early successional forest in this area (Lichstein et al. 2002). In fact, the scarcity of early successional stage forest habitat made it difficult for me to locate more than one plot in the youngest successional class that was suitable for obtaining data on absolute avian densities. Results from a study on northern hardwood forests in the Northeast suggest that timber harvesting may benefit early successional species as 11 of the 20 species that were observed only on managed areas were associated with early successional habitats (Welsh and Healy 1993). Analysis of long-term breeding bird survey data for the Southern Appalachians indicated that many early successional species in this region appear to have experienced significant population declines (Franzreb and Rosenberg 1997). Therefore, the importance of timber harvesting as a strategy to enhance habitat quality for these species should not be underestimated. I am presently undertaking a more detailed analysis of the vegetation components in my plots to assess how local attributes may have influenced species richness, densities, and diversity (Franzreb, unpubl. data).

Analyzing the responses of birds to timber harvesting as was done in this study advances our understanding of the interactions of harvesting and the avifauna. However, it should be noted that this particular study was limited in three ways. First, limitations on logging of Forest Service land in the forests of western North Carolina precluded me from being able to locate more than one suitable early successional stage plot. Second, although the Joyce Kilmer area has been referred to as old growth, it does not technically meet the definition of old growth for this stand type (>120 years), as it was only 103 - 106 years old when this study was conducted. Hence, there were no plots in this study that were defined as true old growth. Third, all plots were not subjected to the same type of timber harvesting, nor were post-harvesting management actions similar in all the plots. Harvesting of the stands was done over a period in excess of 100 years. When the first plots were logged, clear-cutting had not yet been implemented as a harvesting strategy. It was not until the 1960s that clearcutting became prevalent in this area (John

Blanton, U.S. Forest Service, pers. comm.). Therefore, it should not be surprising that these 12 plots have been dealt with differently. However, it should be emphasized that the logging approach and post-logging treatments in these plots is typical and widespread in this area. Eight of the 12 plots in this study were subjected to some kind of management treatment (e.g., site preparation using chain saws, thinning, and herbicide application) post harvest, whereas four plots sustained no such treatment. It is not known what influence such treatments may have had on the avian community. Because many hectares of Forest Service lands in this area have been subjected to similar logging patterns and treatments, it is worthwhile to explore and examine the bird populations in these sites to try and assess possible differences in the avifauna.

One goal of the Forest Service's forest management plans that cover part of the Southern Appalachians will be to, "Provide breeding, wintering, and migration staging and stop-over habitat for migratory birds in ways that contribute to their long-term conservation." (U.S. Forest Service-FWRBE Team, in prep.). The results of this study demonstrate that neotropical migrants constitute the majority of the bird species present and the bulk of the breeding bird population in all successional forest stages examined. To provide suitable quality breeding habitat for all neotropical migrants will require a variety of management strategies, possibly including various forms of timber harvesting. Logging would be particularly beneficial to species that prefer disturbed forest, including the Partners in Flight category II Golden-winged Warbler (*Vermivora chrysoptera*) (Hunter et al. 1999) that was found in this study. Such harvesting may be useful for early successional species if sufficient tree removal is undertaken, whereas some stands should be maintained in relatively undisturbed condition to provide for those species that are more common in older, mature habitats. In is anticipated that the forest management plans currently being revised will address the conservation of neotropical migrants as a valid management concern.

Acknowledgments

I am grateful to C. Hunter, T. Simons, J. Kilgo, E. Linder and D. Kim for reviewing drafts of this manuscript and to S. Zarnoch and B. Parresol for statistical assistance and review. I thank the field staff who assisted in collecting the data: R. Phillips, R. Carnes, L. Cutshaw, C. Ledford, M. Serio, and J. Murphy. The assistance of numerous Forest Service personnel who aided in identifying possible study plots is greatly appreciated. The use of product names does not imply endorsement of the product by the U.S. Forest Service.

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Potential Effects of Large-Scale Elimination of Oaks by Red Oak Borers on Breeding Neotropical Migrants in the Ozarks[1]

Kimberly G. Smith[2] and Frederick M. Stephen[3]

Abstract

The Arkansas Ozarks are currently experiencing an outbreak of the red oak borer (*Enaphalodes rufulus*), a native insect that has previously not been considered an important forest pest species. As many as 50 percent of the trees in the Ozarks, which has the highest density of oaks in the United States, may be dead by the year 2006. The Ozarks are generally believed to be a source region for Neotropical migratory birds, compared to fragmented areas to the east and north, but that could change very rapidly with the elimination of oaks. The potential impact on migratory breeding birds was assessed, first, by reviewing the impact on birds of other tree species eliminations that have occurred in the eastern United States (American chestnut [*Castanea dentate*], American elm [*Ulmus americana*], American beech [*Fagus grandifolia*], and Frazer [*Abies fraseri*] and Eastern [*A. canadensis*] firs). Those results were incorporated into our studies on migratory breeding birds in the Arkansas Ozarks. Populations of 11 of 20 migratory species are predicted to decline, and some species, such as the Cerulean Warbler (*Dendroica cerula*), may be extirpated. Only five forest species are predicted to increase, but at least five early successional species (e.g. Indigo Bunting [*Passerina cyanea*], Yellow-breasted Chat [*Icteria virens*]), which are currently absent from upland hardwood forests, should increase with the development of a scrub layer as the canopy opens. Thus, the red oak borer infestation has the potential to greatly alter the composition of the avifauna of the Ozarks, which may have far-reaching implications for many species of neotropical migratory birds.

Key words: Arkansas, *Enaphalodes rufulus*, migratory birds, oaks, Ozark Mountains, red oak borer, upland hardwood forests.

Introduction

Bird populations and avian community structure can be influenced and changed by a wide variety of factors, ranging from relatively ephemeral dramatic increases in food supply, such as emergence of 13-year or 17-year periodical cicadas (*Magiciada* spp.) which last only a matter of weeks (e.g., Williams et al. 1993) to the subtle changes in vegetation structure which may take place over decades due to ecological succession (e.g., Holmes and Sherry 2001). Factors may be biotic or abiotic (e.g., Rotenberry et al. 1995), and their importance may differ between breeding and non-breeding seasons (e.g., Rappole and McDonald 1994).

Since the pioneering works by Fran James on quantification (James and Shugart 1970) and analysis of bird-habitat relationships (James 1971), it is generally agreed that structure of the vegetation is one of the most important factors influencing terrestrial breeding-bird community structure. Typically, it is the physiognomy, or structure, of vegetation that is important (James 1971), not individual tree species per se (but see Robinson and Holmes 1984). Although geographic variation in habitat selection exists in widely distributed species such as Wood Thrush (James et al. 1984; scientific names of birds are in tables), the vegetation associated with occurrence (or density) of a particular breeding species is usually predictable on a regional/local scale.

More fundamentally, most temperate passerines prefer to nest in live vegetation, and only a relatively few species nest in dead trees. Termed "secondary cavity nesters," they must rely on other birds ("primary cavity nesters" like woodpeckers) to excavate holes for them or wait for suitable cavities to appear from decay. Conversely, primary cavity nesters prefer to nest in deadwood; the only exception is Red-cockaded Woodpecker (*Picoides borealis*), which nests in live wood of pine trees.

Typically, live trees far outnumber dead trees in the deciduous forests of the eastern United States, and changes in physiognomy would be expected to be slow and occur over a long period of time (Holmes and Sherry 2001). Currently, however, the forests of the Ozark Mountains in Arkansas and Missouri are experiencing a remarkable outbreak of a native, normally endemic insect species, the red oak borer, *Enaphalodes rufulus* (Coleoptera: Cerambycidae). High levels of red oak (genus *Quercus*, subgenus *Erythrobalanus*) mortality were first observed on the

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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Ozark National Forest in 1999, when a U.S. Department of Agriculture Forest Service (USFS) survey estimated that severe damage (>75 percent mortality/decline) existed on 7800 ha and moderate damage (50 to 75 percent mortality/decline) existed on another 9800 ha. By the end of 2001, the USFS estimated >400,000 ha of forest in the Ozark Mountains were being impacted. Extensive oak mortality is anticipated in these forests (Spencer 2001, Spencer and Sutton 2001), with as much as 50 percent of the deciduous trees dead by 2006. The impact of the red oak borer on Ozark forests has been so rapid that there is little research on the actual effects on the forest (Stephen et al. 2001, Heitzman 2003).

The Ozark Mountains and Oak/Hickory Forest Ecosystem

Braun (1950) first coined the term "Interior Highlands" in reference to the forested Ozark Plateau (hereafter, Ozarks) and Ouachita Mountains (*fig. 1*). Whereas the more southern Ouachita Mountains are primarily forested with pines, the Ozarks support the western edge of the eastern deciduous forest (Braun 1950), and have compositional affinities with similar forests stretching east through Ohio, Pennsylvania, and southern New England (Whitney 1994: *fig. 4.3*).

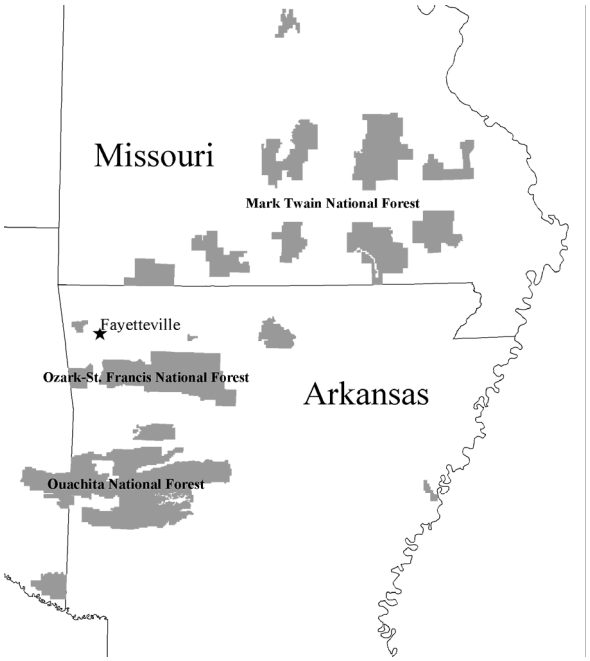

Figure 1— Map of the Interior Highlands in Missouri, Arkansas, and Oklahoma. The outline of the Mark Twain National Forest in Missouri and the Ozark-St. Francis National Forests approximates the Ozark Plateau, and the outline of the Ouachita National Forest approximates the Ouachita Mountains.

The pre-settlement forest of the Ozarks was nearly a monoculture of majestic white oaks (*Quercus alba*), with canopies barely touching, first branches 3 to 5 m from the ground, and a grass understory (see Braun 1950). However, the Ozarks were clear-cut in the period from 1880 to 1900, primarily for railroad ties for the western United States (reviewed in Smith and Petit 1988). The resulting forest today is a nearly even-aged mixture of oaks, hickories (*Carya* spp.), maples (*Acer* spp.), and other deciduous species with some pine (*Pinus* spp.) in the southern portions. Given the even-aged closed canopy, there generally is little or no shrub layer development and the ground cover is predominately poison ivy (*Rhus radicans*). Shelford (1963: 59) referred to the Missouri and Arkansas Ozarks as the largest forest of oak and hickory without pine in North America and, therefore, the world. The Ozarks currently have the highest density of oaks in the United States (McWilliams et al. 2002). Nonetheless, white oak is no longer a dominant feature of the forests, probably due to fire suppression since the mid-1920s and several other factors (see Abrams 2003). Sugar maples (*Acer saccharum*) and red maples (*A. rubrum*) may be replacing oaks as the climax forest in more mesic areas (Pallardy et al. 1988, Abrams 2003).

The Ozark National Forest (*fig. 1*) was established in 1908, and today it includes 14.2 million ha in northwestern Arkansas, north of the Arkansas River. According to the USFS Continuous Inventory of Stand Conditions (CISC) database, only 6 percent of the hardwood forests on the Ozark National Forest are currently <40 years old, while 72 percent are between the ages of 40 and 90 years old (prime mast-producing age), and 21 percent are >90 years old (age of significant decline) (S. Duzan, pers. comm.).

The Ozarks within Arkansas are about 98 percent forested today, and about 75 percent of the forest is composed of a variety of oak habitats (Smith et al. 1998). According to a USFS 1995 Forest Survey, red oaks (*Erythrobalanus*) comprise 46 percent of the live-tree volume, 42 percent of growing stock volume, and 35 percent of sawtimber volume of forested regions in Arkansas (Guldin et al. 2001). Thus, much of the Arkansas Ozarks is covered with oaks, and red oaks, the more numerous subgenus, are of great commercial value to the economy of the state. However, the densities of red oak borers currently being observed in the Ozarks render the timber commercially useless (J. Guldin, pers. comm.). Anticipated loss of trees and degradation of timber from red oak borer may exceed 2.4 million cu board ft. (G.E. Leeds, pers. comm.). On an 800 ha forest in northern Arkansas in summer 2002, Heitzman (2003) documented that the basal area of red oaks had been reduced to 20 percent of pre-outbreak levels and the number of red oak trees per ha was 17 percent of pre-outbreak levels.

Causes for the Current Crisis in the Ozark Mountains

The eruption of the red oak borer in the Ozarks would appear to be a classic example of a forest insect that has existed at endemic levels for a long period of time, but has become epidemic due to some density-independent factor(s), allowing population levels to cross some regulatory threshold (see Berryman 1982: *fig. 1*; Berryman 1987; Berryman et al. 1987: *fig. 5*). Various hypotheses have been suggested as explanations for the cause of the current oak mortality in the forests of the Ozark Mountains (Stephen et al. 2001). The USFS refers to "widespread and locally severe mortality and decline of red oaks…on the Ozark National Forest during the summer of 1999" (Starkey et al. 2000). A USFS fact sheet describes the situation as an "oak decline" event and suggests that there are a variety of causes (Oliveria et al. 2000).

In describing decline etiology concepts, Manion (1991) refers to *predisposing, inciting,* and *contributing* factors. In relation to oak decline in the Ozark Mountains, important *predisposing* factors are older tree age, prolonged drought, poor soils, and low site quality (Starkey et al. 2000). *Inciting* factors are suggested to be the acute, short-term drought stress that occurred in Arkansas through much of the late 1990s (Starkey et al. 2000). *Contributing* factors include defoliation from secondary insects; root diseases, e.g., *Armillaria mellea*, and stem cankers, e.g., *Hypoxylon* sp., both of which have appeared in the Ozarks within the last 10 years (J. Guldin, pers. comm.); and secondary species of borers such as two-lined chestnut borer, *Agrilis bilineatus* (Wargo et al. 1983) and red oak borer (Starkey et al. 2000).

Thus, factors involved with the current outbreak include advanced age of stands (70 to 100 years); xeric conditions associated with shallow rocky soils, exacerbated by three years of drought; and appearance of two fungi, one attacking roots and one attacking above ground, all of which weaken the trees' resistance to attack by red oak borers. Coincident with that opinion is the idea that the logging history of the region, which consisted of continuous high grading of the forests during the early 1900s, resulted in stands that are frequently dominated by red oaks of similar age structure (Ozark-St. Francis National Forests 1978). Non-industrial private forestlands are especially at risk, since red oaks comprise 50 percent of sawtimber volume and 74 percent of live-tree volume on timberland in the private sector (Guldin et al. 2001). Red oak trees also are dying now in Arkansas' urban areas, such as yards and city parks in major cities surrounding the national forest (e.g., Fayetteville, *fig. 1*).

Biology and Life History of the Red Oak Borer

Many forest insect species that have become significant disturbance factors in relatively unmanaged native forests are exotics. The red oak borer, however, is a native species in eastern North America (Donley and Acciavatti 1980) that attacks living oak trees, with preferred hosts being those in the red oak group, including southern red (*Q. falcata*), northern red (*Q. rubra*), black (*Q. velutina*), willow (*Q. phellos*), and Nuttall (*Q. nuttallii*) oaks. It also breeds in the white oak group (Donley and Acciavatti 1980), which includes white and post (*Q. stellata*) oaks in the Ozarks. Red oak borer attacks normally occur at sufficiently low densities that they seldom result in tree mortality (Hay 1972, Petit et al. 1988). Population levels of the epidemic magnitude currently being reported in the Ozark Mountains have never been witnessed within the range of this species (Stephen et al. 2001). Attacks and borer galleries are being seen in trees and limbs as small as 8 cm in diameter. Typically, red oak borer infestations have been local; red oak borers previously have been considered unimportant insect pests in oak forests (Oak 2002).

Throughout the central United States (including the Ozarks), there is a two-year life cycle during which synchronous emergence of adults occurs only in odd numbered years (Hay 1972, Donley and Acciavatti 1980). The main emergence period is about 3 weeks long. Adults do not feed on twigs or foliage, and average longevity of males and females is approximately 3 weeks (Hay 1972, Donley 1978, Solomon 1995). Oviposition continues for about 16 days, during which time females lay about 120 eggs, singly or in small groups, usually in bark crevices or under lichens (Donley 1978). Eggs hatch in 10 to 13 days (Solomon 1995). Larvae chew through the bark and begin gallery excavation in phloem tissue. The young larvae chew back out through the bark and open small oblong holes through which fine frass is ejected during feeding (Solomon 1995). Following their first winter, larvae continue to feed in phloem, then enter the sapwood in summer. They overwinter in sapwood in their second year, and then pupate there in May or June. Adult emergence begins in late May or June depending on latitude.

Petit et al. (1988) found that most infected trees contained a single larva. We (Stephen et al. 2001) conducted a preliminary study to compare population parameters from the current outbreak with historical data and found attack density averaged 244 (± 30.8 SE) per m^2 of tree trunk in fall 2001. Density of mature (2nd year) larvae averaged 21.4 (± 4.4) per m^2, and emerging adult density averaged 18.5 (± 4.3) per m^2. Based on preliminary analysis of data we collected during the emergence in summer 2003, it would appear that the number of emerging adults in 2003

was comparable to that of 2001 and that there definitely will be another large emergence in summer 2005.

Based upon the magnitude of this insect outbreak and the potential for losing upwards of 50 percent of the trees in the Ozarks forests, we examine here the potential impact on birds currently breeding in the forested Ozarks. Our focus is on migratory birds, although undoubtedly permanent resident species also are being impacted.

Methods

We conducted a literature search to determine what was known about bird predation on red oak borers and what effects the demise of dominant tree species from the eastern deciduous forest over the last century had on the breeding populations of neotropical migratory birds. This search focused on the American chestnut (*Castanea dentata*), which was eliminated as a canopy tree by the fungus *Cryphonectria* (= *Endothia*) *parasitica*, technically the "chestnut bark disease," but more popularly, the "chestnut blight"; the American elm (*Ulmus americana*) eliminated by the Dutch elm disease, caused by a fungus (*Certatocystis ulmi*) and carried by a native bark beetle (*Hylurgopinus rufipes*) and a European bark beetle (*Scolytus multistriatus*); the change in physiognomy of the American beech (*Fagus grandifolia*) by the beech bark disease, a fungus, *Nectria coccinea* var. *faginata*, spread by a scale, *Cyrptococcus fagi* and possibly also another scale *Xylococculus betulae*; and woolly adelgids causing the demise of Fraser fir (*Abies fraseri*) in the southern Appalachians by *Adelges piceae*, and to the north, Eastern hemlocks (*Tsuga canadensis*) by *Adelges tsugae*.

Based on our research on bird communities in the Ozarks of Arkansas (Rodewald and Smith 1998, Smith et al. 2004), we compiled a list of neotropical migratory birds that breed in upland hardwood forests. Based on that research and the literature review, we speculate on the impact of oak elimination on breeding neotropical migrants in the Ozarks.

Results

Previous Research on Red Oak Borers and Birds

Little published work exists on the predation of red oak borers by birds. All studies suggest that the only impact is from woodpeckers and that it occurs in winter. The entire immature life cycle is within the tree trunk, and when adults do emerge in summer, all their activity is at night (Solomon 1995). In Mississippi, Solomon (1969) most often found Red-bellied Woodpeckers (*Melenerpes carolinus*) on infested trees, and he less often observed Hairy (*Picoides villosus*), Downy (*P. pubescens*), Red-headed, and Pileated (*Dryocopus pileatus*) woodpeckers. In Ohio and Kentucky, Hay (1972, 1974) observed mostly Hairy and Downy woodpeckers at infested trees and, to a lesser degree, Red-headed and Red-bellied woodpeckers during overwintering dormant periods. He attributed 33 percent of the borer mortality to woodpeckers during the first winter, almost no predation during the first summer, and 3 percent (3 of 113) mortality in the second winter of original larvae, but 30 percent of those available (3 of 10). Some sites showing evidence of woodpecker drilling still produced adults. The only other bird study to mention red oak borers is Petit et al. (1988), who found about 10 percent mortality on larvae during the second winter due to woodpecker predation.

Comparisons with Other Massive Tree Losses within the Eastern Deciduous Forest

American chestnut

Once the major component of the hardwood forests of the eastern United States, American chestnut composed about 25 percent of the forest in central Appalachian forests (Liebhold et al. 1995), but some stands were closer to 85 percent chestnut. The fungus probably arrived in the late 1800s from China or Japan, and it destroyed large numbers of trees in and around New York City in 1904 and 1905 (Anagnostakis 1987, Moss 1973). Once out of New York City, the fungus spread at the rate of 37 km/ year, and within 50 years, trees on 3.6 million ha were dead or dying (Anagnostakis 1987). More recently, the fungus has eliminated chinquapin (*Castanea pumila*) from the Ozarks (Paillet 1993). There are only anecdotal references to the effect of elimination of the American chestnut on animal population dynamics, e.g., suggested increases in woodpecker populations due to availability of dead trees (e.g., Smith et al. 2000).

American beech

References in the nineteenth century spoke of the "great" beech forests in the northern and northeastern United States (e.g., Cogbill et al. 2002, Whitney 1994) and the impact that beech mast crops had on the population dynamics of seed-eating birds, e.g., Red-headed Woodpeckers (Smith et al. 2000). Introduced into Halifax, Nova Scotia about 1890, beech bark disease migrated south; the first outbreaks of the disease were documented about 30 years later in Maine. Most damage occurred in the 1930s and 1940s. Large numbers of mature and over-mature beeches were present because of the low regard for this species as a lumber tree. During the outbreak, large trees were killed or removed in fuelwood salvage cuts. Beech remains part of the forest in terms of numbers of trees and basal area, but today trees are much smaller and form thickets with little or no mast production (Houston 1975).

Apparently no research was conducted on the effects on breeding bird populations.

American elm

Dutch elm disease began killing elm trees in the eastern United States early in the twentieth century (Karnosky 1979). Impacts moved westward through Ohio (1940s) and Illinois (1950s), and reached the western edge of the distribution of elms in Iowa in the 1980s (Smith et al. 2000). Increases in breeding populations of Red-headed Woodpeckers followed closely behind the front, tracking the dead trees for decades (Smith et al. 2000).

Serendipitously, S. C. Kendeigh and colleagues had been studying bird populations from 1927 through 1976 at Trelease Woods, a 24-ha woodlot in southern Illinois. Kendeigh (1982) documented the demise of the American elms and the reaction of the bird community. The most dramatic increases were in four woodpecker populations and those of the European Starling (*Sturnus vulgaris*) while dead trees remained standing. Although not many migratory species occurred in Trelease Woods (*table 1*), shrub-nesting species, such as Northern Cardinals (*Cardinalis cardinalis*), Gray Catbird, Brown Thrasher, Common Yellowthroat, and Eastern Towhees, became much more numerous (*table 1*).

Fraser fir and hemlocks

Over the last 20 years, introduced adelgids (Homoptera: Adelgidae) have reduced conifer populations in the Appalachians. Rabenold et al. (1998) monitored bird populations at a site that experienced a 90 percent decline in Fraser fir over a 13-year period. Over a 16-year period, they documented that 9 of 11 canopy bird species declined and that singing males declined 50 percent. Species that foraged on the ground and those that foraged low in the foliage were less affected (*table 2*). An influx of species characteristic of open and disturbed forests, including some neotropical migrants like Chestnut-sided Warbler (*table 2*), began 10 years after arrival of adelgids.

More recently, Tingley et al. (2002) documented the impact of the elimination of Eastern hemlock in southern New England by adelgids on breeding birds by comparing intact stands with those where hemlocks had declined. Black-throated Green Warbler, Acadian Flycatcher, Blackburian Warbler, and Hermit Thrush were particularly sensitive to hemlock decline, but Hooded Warblers appeared to benefit from canopy mortality opening the understory.

Table 1— *Migratory birds reported by Kendeigh (1982) from his 50-year study of birds at Trelease Woods in southern Illinois. General trends in population levels following elimination of American elm in the late 1950s are given along with comments made by Kendeigh.*

Species	Scientific name	Trend	Comments
Yellow-billed Cuckoo	*Coccyzus americanus*	none	0 to 6 pairs – fluctuated annually
Ruby-throated Hummingbird	*Archilochus colubris*	none	1 pair almost every year
Eastern Wood-Pewee	*Contopus virens*	decreased	8 pairs early – 20 pairs in 1950s – back to 8 in 1970s
Great Crested Flycatcher	*Myiarchus crinitus*	none	3 to 8 pairs – fairly constant
Red-eyed Vireo	*Vireo olivaceus*	decreased	like Eastern Wood-Pewee
House Wren	*Troglodytes aedon*	none	increased in 1950s but not due to food or dead trees
Wood Thrush	*Hylocichla mustelina*	none	fairly constant – unaffected by tree death
American Robin	*Turdus migratorius*	increased	rare before opening of canopy
Gray Catbird	*Dumetella carolinensis*	increased	after canopy opening in late 1950s
Brown Thrasher	*Toxostoma rufum*	increased	after canopy opening in late 1950s
Common Yellowthroat	*Geothlypis trichas*	increased	doubled after canopy opening in late 1950s
Yellow-breasted Chat	*Icteria virens*	decreased(?)	1 pair 1944 through 1960
Eastern Towhee	*Pipilo erythrophthalmus*	increased	occurred after tree death
Indigo Bunting	*Passerina cyanea*	decreased(?)	peaked before tree death and then declined

Table 2— *Migratory birds reported by Rabenold et al. (1998) in their study of the decline of Frasier fir in the southern Appalachians. Data are from censuses in 1974 (pre-adelgid), 1986 (10 years post), and 1990 (14 years post), reported as number of males/20 ha, and occurrence based on a series of point counts performed at seven locations in 1993. Transient species were treated categorically as frequent, occasional, or rare.*

Species	Scientific name	1974 Pre-adelgid	1986 10-yr post	1990 14-yr post	1993 17-yr post
Breeding species					
Strongly affected:					
Solitary Vireo	*Vireo solitarius*	25	9	6	6/7
Black-throated Green Warbler	*Dendroica virens*	6	5	2	3/7
Increased:					
Chestnut-sided Warbler	*Dendroica pensylvanica*	0	1	9	7/7
Black-throated Blue Warbler	*Dendroica caerulescens*	0	0	6	2/7
Canada Warbler	*Wilsonia canadensis*	0	0	0	6/7
Other migratory species					
Veery	*Catharus fuscescens*	8	5	5	7/7
Hermit Thrush	*Catharus guttatus*	0	3	1	2/7
Magnolia Warbler	*Dendroica magnolia*	0	0	0	1/7
Transients					
Broad-winged Hawk	*Buteo platypterus*	rare	0	0	0/7
Chimney Swift	*Chaetura pelagica*	occasional	occasional	rare	3/7
Ruby-throated Hummingbird	*Archilocus colubris*	rare	0	0	0/7
Willow Flycatcher	*Empidonax traillii*	0	0	0	1/7
Blackburnian Warbler	*Dendroica fusca*	rare	rare	0	1/7
American Redstart	*Setophaga ruticilla*	0	0	0	1/7

Potential impact of loss of red oaks in the Ozarks

A greater number of migratory species breed in the Arkansas Ozarks (*table 3*) than in the other areas mentioned above. Of the eight common species, six are predicted to decrease with the elimination of red oaks, and three of the four uncommon species are predicted to decline. Two of the three rare species may increase and five species, currently absent from mature upland hardwoods, should increase as the canopy opens and a shrub layer develops. The only scrub-nesting species that occurs in undisturbed upland hardwood forests of the Ozarks is the Hooded Warbler (Smith et al. 2004).

Discussion

In a typical upland hardwood forest in the Arkansas Ozarks, most migratory species nest in the canopy (i.e., in trees) (*table 3*), a few species nest on the ground (e.g., Ovenbird, Black-and-white Warbler, Worm-eating Warbler), and only one species nests in shrubs (Hooded Warbler). Given the relatively even-age structure of those upland forests, the canopy is closed, and there is little development of a shrub layer. However, opening the canopy and allowing light to penetrate to the forest floor allows shrub development in 1 to 2 years (Rodewald and Smith 1998, Heitzman 2003). This layer can become an almost impenetrable thicket within 5 to 10 years.

Even relatively small openings may have an impact on forest birds, and development of the shrub layer may attract species (e.g., White-eyed Vireo, Blue Grosbeak, Indigo Bunting) not normally associated with forested habitats (Gram et al. 2003, Rodewald and Smith 1998). Opening of the forest canopy either immediately (Kendeigh 1982) or eventually (Rabenold et al. 1998) allowed early successional bird species to colonize new areas that previously were unsuitable habitats. Similarly, Gram et al. (2001) recently documented short-term changes in bird community structure in the Missouri Ozarks with an estimated reduction of 10 percent of the canopy structure. Fragmented forests in Missouri actually have more species than contiguous forests, but the number of Neotropical migrants is greatly decreased in the fragmented forests (Howell et al. 2000).

Table 3— *Migratory birds that breed in the Arkansas Ozarks, current status in mature upland hardwood forests, and predicted population trend if red oaks are eliminated from the Ozarks. Occurrence data and current status from Rodewald and Smith (1998), Smith (1977), Smith (unpubl. data), and Smith et al. 2004). Predicted trends based primarily on Rodewald and Smith (1998) and Smith et al. (2004).*

Species	Scientific name	Current status	Predicted trend
Yellow-billed Cuckoo		Uncommon	Decrease
Ruby-throated Hummingbird		Uncommon	???
Eastern Wood-Pewee		Common	Increase
Acadian Flycatcher	*Empidonax virescens*	Common	Decrease
Great Crested Flycatcher		Uncommon	???
White-eyed Vireo	*Vireo griseus*	Absent	Increase
Yellow-throated Vireo	*Vireo flavifrons*	Uncommon	Increase?
Red-eyed Vireo	*Vireo olivaceus*	Abundant	Decrease?
Blue-gray Gnatcatcher	*Polioptila caerulea*	Common	Increase
Wood Thrush		Common	Decrease
Blue-winged Warbler	*Vermivora pinus*	Absent	Increase
Chestnut-sided Warbler		Rare	Increase
Black-throated Green Warbler		Uncommon	Decrease
Cerulean Warbler	*Dendroica cerulea*	Uncommon	Decrease
Black-and-white Warbler	*Mniotilta varia*	Common	???
Worm-eating Warbler	*Helmitheros vermivorus*	Common	Decrease
Ovenbird	*Seiurus aurocapillus*	Common	Decrease
Louisiana Waterthrush	*Seiurus motacilla*	Rare	Decrease
Kentucky Warbler	*Oporornis formosus*	Uncommon	Increase
Hooded Warbler	*Wilsonia citrina*	Common	Decrease
Yellow-breasted Chat	*Icteria virens*	Absent	Increase
Summer Tanager	*Piranga rubra*	Uncommon	Increase?
Scarlet Tanager	*Piranga olivacea*	Common	Decrease?
Blue Grosbeak	*Guiraca caerulea*	Absent	Increase
Indigo Bunting		Absent	Increase

In most cases, canopy foraging species were negatively impacted by the elimination of live trees in the canopy, and ground and low-foraging species were not (Kendeigh 1982, Rabenold et al. 1998). Cerulean Warbler, a species of conservation concern, is currently a relatively common breeder in the Arkansas Ozarks (James et al. 2001), but it probably will be extirpated with the demise of large oak trees (see Rodewald and Smith 1998). Populations of Black-throated Green Warblers that recently colonized the Arkansas Ozarks (Rodewald 1997) also will be greatly reduced as will most wood-warblers (*table 3*), particularly those mentioned above that nest on the ground (Rodewald and Smith 1998). In the short-term, populations of Chestnut-sided Warblers, another new breeder in the Ozarks (Rodewald 1997), probably will increase (Rabenold et al. 1998).

As mentioned previously, Rabenold et al. (1998) found a decrease in canopy species following the elimination of Fraser fir. Similarly, Davis et al. (2000), in assessing change in community structure that had occurred on plots that had experienced 0 to 26 controlled burns over the last 31 years, found that as restoration proceeded there was a general decline in insectivores, particularly those that fed in the upper canopy, and a general increase in omnivores that fed on the ground and in the lower canopy. They also found that woodpeckers increased and were correlated with the increase in standing dead trees. Kendeigh (1982) also found that primary hole-nesters showed a positive response to the presence of dead trees, followed by a positive response by secondary-cavity nesters. However, unlike the other situations mentioned above where many dead trees were left standing, the trees in the Ozarks are so heavily damaged by borer drilling that they fall over in 1 to 2 years, precluding any increase in hole-nesting species.

In some respects, the effects of elimination of oaks in the Ozarks may be similar to those experienced in forests that have been defoliated by gypsy moth (*Lymantria dispar*) caterpillars. Defoliation allows more light penetration so that understory development increases, which leads to a dramatic increase in Hooded Warblers (Bell and Whitmore 2000). Most canopy nesting species are adversely affected, but shrub nesting species such as Eastern Towhee showed increases (DeGraaf 1987, Bell and Whitmore 1997). Nest predation rates increased with defoliation by gypsy moth caterpillars (Thurber et al. 1994), but Matsuoka et al. (2001), studying forests that

had been decimated by spruce beetles (*Dendroctonus rufipennis* [Kirby]) in Alaska, found that predation rates were not higher, due to concomitant decreases in the number of predators (primarily squirrels).

In general, the forested Ozarks are considered a source region for neotropical migrants compared to fragmented areas to the east and north that have become population sinks (Donovan et al. 1995, Howell et al. 2000, Robinson et al. 1995), and reproductive success among the more common Neotropical migratory species is relatively good (>50 percent; Li 1994). Elimination of oaks from the Ozarks could potentially reverse that situation rather quickly, such that the Ozarks also may become unsuitable for sustained reproductive success for many species.

Acknowledgments

This work benefited greatly from conversations with J. Guldin, USFS, and W. Thompson, Arkansas Cooperative Fish and Wildlife Research Unit, University of Arkansas, Fayetteville. K. G. Smith's participation in this symposium was made possible by an award from the College Travel Fund, Fulbright College of Arts and Sciences, University of Arkansas, and from the Arkansas Game and Fish Commission. This manuscript was written while he was a Charles Bullard Fellow at the Harvard Forest, Harvard University. More information on red oak borer damage is available at: http://www.fs.fed.us/oonf/ozark/oak/oak.html.

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Is Management for Golden-winged Warblers and Cerulean Warblers Compatible?[1]

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Abstract

Conservation of species with high Partners in Flight concern scores may suggest management for apparently conflicting habitat needs on a given property or specific site, such as birds requiring early-successional vs. later-successional broadleaved forests. Two species of concern with distinctly different habitat needs provide a case study for consideration. Declining populations of Golden-winged Warbler (*Vermivora chrysoptera*), which require early successional habitats, and Cerulean Warbler (*Dendroica cerulea*), a mature-forest breeder, each experience difficulties related to breeding habitats. Concern exists for Cerulean Warbler wintering habitat as well. Our responsibility for the conservation of both species includes resolving the dilemma of providing for their simultaneous occurrence in space or time. Approaches to this resolution are instructive for developing conservation strategies for these as well as other species. The questions (and their short answers) are: Are the habitat requirements of Cerulean and Golden-winged warblers compatible within the same property where their ranges overlap? (Yes) What role does disturbance play in the creation and maintenance of habitat for each species? (Its important role is better understood for Golden-winged Warbler.) Can we mimic beneficial forms of disturbance for these species through direct management? (Yes, and anthropogenic disturbance may substitute for "natural.") Is management of this sort compatible with commercial forestry and other ongoing forms of land use? (We believe it is.) Could events outside that region overwhelm conservation action within it? (Unfortunately, yes.).

Key words: adaptive management, deciduous forests, *Dendroica cerulea*, forest ecology, habitat management, management conflicts, Parulidae, rotation length, successional stages, *Vermivora chrysoptera*.

The Charge

Partners in Flight (PIF; Pashley et al. 2000) began in 1990 in response to a need to address reported declines of populations of some migratory birds in North America (Robbins et al. 1989, Terborgh 1989). Initial concern was focused on neotropical migratory birds because clear evidence existed of decline for species such as the Cerulean Warbler (*Dendroica cerulea*; CERW; Robbins et al. 1992). An apparent mechanism precipitating these declines was forest fragmentation on some of the breeding grounds (Robinson et al. 1995). But most initial concern was focused on tropical wintering grounds in recognition that, overall, eastern North America had experienced an increase of forest cover during the period of decline for many forest-associated species (Robbins et al. 1989, Terborgh 1989). As declining numbers of songbirds became a cause celébre to be fought vigorously in the conservation arena (Terborgh 1989, Hamel 1990), substantial gains in understanding (Carter et al. 2000) ensued over the subsequent decade (Bonney et al. 2000, Pashley et al. 2000).

Despite an initial focus on forest-interior species, an increasing awareness developed within PIF that among declining bird species in eastern North America, the greatest number were species of grasslands and other early-successional habitats (Robbins et al. 1989, Vickery 1992, Franzreb and Rosenberg 1997, Askins 2000, Hunter et al. 2001). This number included species dependent on a variety of shrub-scrub habitats, such as Golden-winged Warbler (*Vermivora chrysoptera*; GWWA). Increased attention to declines in shrub-nesting species led to the recognition that a common process defining the habitat occupied by many species of highest concern was vegetation disturbance (Hunter et al. 2001).

The combination of declines in population among species of mature forest (e.g. CERW), as well as those of earlier successional stages (e.g., GWWA) creates a potential for conflict in developing conservation goals for properties in which both groups of species occur. Mature forest birds often are flagships of efforts to protect aesthetically pleasing older forests (e.g., Rosenberg et al. 1999), whereas shrub-scrub species may be less appealing because they require habitats subject to frequent disturbance (Askins 2001). What will happen when species of relatively high concern occupy similar

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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landscapes, forest types, and geographic ranges, but require habitats of different successional stages? Our response to this dilemma is a barometer for our ability to approach conservation of species and their habitats, because it requires balancing the particular needs of multiple species. Both temporal and spatial scales are important in this balancing.

The goal of this paper is to explore, on a landscape or habitat-scale, how to reconcile the needs of two extremely high priority birds and the suites of co-occurring species they represent. We focus this charge in the form of four questions: (1) At what scale are the habitat requirements of CERW and GWWA compatible within their areas of range overlap? (2) What role does disturbance play in the creation and maintenance of habitat for each species? (3) Can we mimic beneficial forms of disturbance for these species through direct management? And (4) is this type of management compatible with commercial forestry and other ongoing forms of land use? We also briefly address what is known about the relative importance of breeding versus wintering habitat to population trends of the two species.

By addressing these questions, we assess whether the arguments presented by pro- and anti-management interests are consistent with existing data. We concentrate our discussion on the oak-hickory (*Quercus-Carya*) dominated broadleaf forests of the Appalachian Mountains and southern Great Lakes regions, where the needs of *V. chrysoptera* are competing for conservation attention with those of *D. cerulea*. The majority of our suggestions can be tested experimentally.

The Species

The GWWA is a ground nesting, dead-leaf foraging, occupant of old-fields and other shrubby habitats that winters in Central and northern South America (Confer 1992). Although the historic range is poorly understood, GWWAs have occupied most of the Appalachian region, northeastern states, and southeastern Canada in a dynamically shifting pattern of expansions and retractions over the past century or more. Today, this species occurs primarily in two largely disjunct regions: along the length of the Appalachian Mountains, concentrated at higher elevations from southeastern New York to northern Georgia, and in a band across the Great Lakes region from northern New York and southern Quebec, west to northern Minnesota and southeastern Manitoba (Golden-winged Warbler Atlas Project; Rosenberg and Barker, unpubl.).

GWWAs have been replaced at lower elevations west of the Appalachians and south of the Great Lakes by an expanding population of Blue-winged Warblers (*V. pinus*). Blue-winged Warbler expansion continues to displace the GWWA range farther north and west. Throughout their range, GWWAs are capable of occupying small patches of suitable habitat (10 ha), which can include small natural or man-made openings in forest. Suitable habitats include alder (*Alnus*) swamps, tamarack (*Larix laricina*) bogs, beaver (*Castor canadensis*)-created wetlands, abandoned farm fields, regenerating clearcuts, and reclaimed surface mines. A century and more ago, GWWAs occurred in open oak woodlands with grassy understories as well (Brewster 1886). Common features of these habitats include dense shrubs as well as herbaceous growth, scattered small trees, and a forest edge (Confer 1992). Area sensitivity of the species is uncertain, as the birds may occupy a small patch of early-successional forest in a large forest, but will not use the central portion of large openings in the forest, absent extensive edge vegetation.

The CERW is a canopy-nesting, leaf-surface foraging, mature-forest denizen that winters in South America (Hamel 2000). CERWs have a patchy distribution throughout much of the eastern United States, with populations contracting in the Midwest and Southeast, while expanding generally toward the northeast. Conventional wisdom states that CERWs typically do not occupy habitat patches smaller than some minimal size characteristic of the region, from 1,000 ha in heavily forested regions to larger, perhaps 10,000 ha, in primarily agricultural landscapes (Hamel et al. 1998, Hamel 2000). A recent rangewide survey has caused us to question this dogma, however, as many CERWs were found in smaller patches of forest, especially in the Northeast (Rosenberg et al. 2000). Habitats used throughout the range form a largely bimodal distribution, with a majority of populations occupying either sycamore (*Platanus occidentalis*)- and cottonwood (*Populus deltoides*)-dominated riparian bottomland forests, or oak-hickory dominated upland forests, primarily on ridge tops (Rosenberg et al. 2000). High densities also occur in mixed-mesophytic forests in coves or slopes, and often on basic soils (Nora Murdock, pers. comm.) in the Southern Appalachians. A common feature of all CERW habitats appears to be a mature, but broken or layered, canopy formed by emergent canopy trees, forest gaps or edges, or steep slopes (Hamel 2000, Rosenberg et al. 2000, Jones et al. 2001).

Despite these differences in habitat, geography, lifestyle, and taxonomy, populations of both birds are declining, and the CERW is under consideration for candidate status under the Endangered Species Act (U.S. Department of the Interior, Fish and Wildlife Service 2002). Modest attention has been paid to each in different studies, primarily on the breeding grounds. Little is known of their biology during migration or on

the winter quarters in tropical and subtropical habitats. Both species occur in a broad range of physiographic provinces in the eastern deciduous forest biome (*table 1*). Regions of current sympatry, however, are confined to the Appalachian ridges and plateaus, including the Cumberland Mountains, and in a narrow band across the Great Lakes. Breeding Bird Survey results (Sauer et al. 2001) indicate consistent declines for both species in some common landscapes, e.g. the Cumberland Plateau (*fig. 1*). Both species have been recorded together on a modest number of Breeding Bird Census plots (*fig. 2*). Highest common density was achieved on a plot in cut-over oak-hickory forest (Thacker et al. 1966).

This Greenbrier Co., West Virginia, plot was harvested

Table 1— *Simultaneous occurrence of Golden-winged and Cerulean Warblers in the Breeding Bird Survey (BBS), 1966-2000 (Sauer et al. 2001). Values in the table represent mean annual population trends and associated statistics for the two species in physiographic areas where at least one of them was abundant enough to report a trend. Trend is the trend value. P is probability that the trend = 0. N is the number of routes on which the estimate is based. Low 95 and High 95 indicate the endpoints of the 95 percent confidence interval about the mean value. Region is the physiographic, geographic, or political division by which the BBS reports results. For each region and each species, concerns about the adequacy of sampling or the abundance of the species in that region are marked by asterisks in the Data Quality column, indicating * - deficiency, and ** - serious deficiency in estimation for the respective species (Sauer et al. 2001).*

Golden-winged Warbler							Cerulean Warbler					
Trend	P	N	Low 95	High 95	Data Quality	Region	Trend	P	N	Low 95	High 95	Data Quality
						Upper Coastal Plain	-11.6	0.23	5	-26.9	3.7	**
						Northern Piedmont	7.6	0.18	6	-1.8	17	**
						Southern Piedmont	-45.1	0.31	2	-91.2	1.1	**
-21.3	0.07	6	-25.8	-16.8	**	Southern New England	10.9	0.34	2	-1.9	23.8	**
-5.1	0.05	39	-10	-0.3	*	Ridge and Valley	-1.8	0.35	23	-5.7	2	*
						Highland Rim	-5.3	0.03	27	-9.7	-0.9	*
						Lexington Plain	-11.4	0.05	6	-19.4	-3.5	**
-7.3	0.02	7	-9.2	-5.3	**	Great Lakes Plain	-2	0.65	10	-10.4	6.4	**
-3.7	0.43	3	-11	3.6	**	Driftless Area	-7.7	0.28	3	-18.1	2.7	**
4.5	0.15	17	-1.2	10.2	**	St. Lawrence River Plain						
						Ozark-Ouachita Plateau	-9.5	0.03	9	-15.9	-3.1	**
-2	0.14	45	-4.7	0.6		Great Lakes Transition	-7.3	0.04	6	-11.5	-3.1	**
-7.4	0.23	9	-18.2	3.3	**	Cumberland Plateau	-3.5	0	22	-5.4	-1.7	
-10.5	0	18	-13.5	-7.6	*	Ohio Hills	-2.7	0	56	-4	-1.4	
-4.3	0.38	5	-11.8	3.2	**	Blue Ridge Mountains	2.9	0.23	4	0.8	5.1	**
-8.3	0	47	-11.3	-5.2	*	Allegheny Plateau	-4.7	0.03	41	-8.9	-0.5	*
-6	0.32	2	-12.6	0.6	**	Adirondack Mountains						
-8.7	0.31	3	-17.7	0.3	**	Northern New England						
0.9	0.6	62	-2.5	4.3	*	N. Spruce-Hardwoods						
						Till Plains	-15.5	0.03	6	-23	-8	**
-2.5	0.01	263	-4.2	-0.7	*	Eastern BBS Region	-4.2	0	222	-5.5	-2.9	*
						Central BBS Region	-10	0.01	13	-15.5	-4.5	**
-1.4	0.06	100	-2.9	0	*	FWS Region 3	-5.7	0	67	-7.6	-3.8	*
-5.5	0.22	9	-13.2	2.3	*	FWS Region 4	-5.4	0	48	-8.5	-2.3	*
-8.1	0	126	-10	-6.2	*	FWS Region 5	-3.4	0	117	-5.1	-1.7	*
-3.5	0	235	-5.1	-1.9	*	United States	-4.3	0	233	-5.6	-3	*
5.4	0.16	28	-1.9	12.7	**	Canada						
-2.5	0.01	263	-4.2	-0.7	*	Survey-wide	-4.2	0	235	-5.6	-2.9	*

five years before the census was conducted, leaving about 10 percent of the original canopy cover, composed of trees 20 cm dbh and less, up to 10 m tall. Dominant overstory was oak-hickory, with dense understory of *Rubus* sp. (Thacker et al. 1966).

Both GWWAs and CERWs have benefited from the abandonment of farmland in the northeastern US and southeastern Canada (Confer 1992, Oliarnyk and Robertson 1996, Rosenberg et al. 2000). Appropriate conditions for both of these species to breed have existed in the eastern North American breeding grounds for centuries, clearly longer than the current modifications brought about by settlement since colonial times. At the landscape scale, then, the two species have been sympatric for a long time.

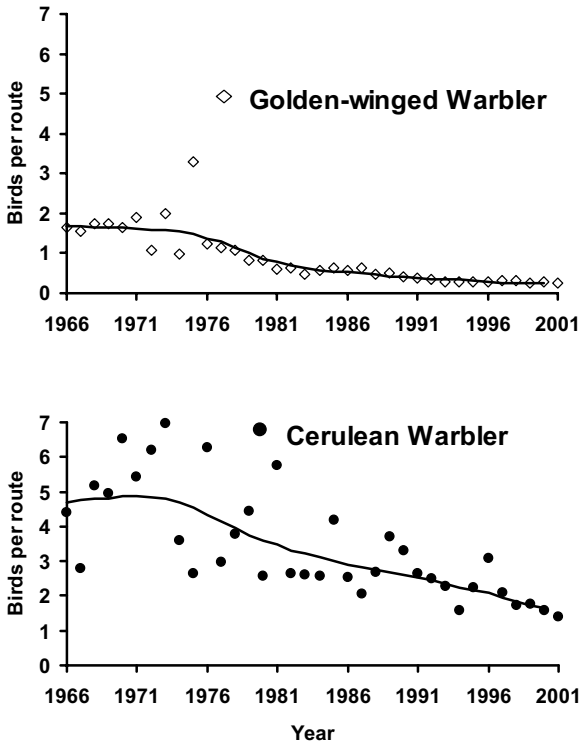

Figure 1— Numbers of Golden-winged and Cerulean warblers recorded on Breeding Bird Survey routes in the Cumberland Plateau. Counts are the mean number of birds recorded per route. Serious deficiency in data quality is indicated for Golden-winged Warbler data set (Sauer et al. 2001). Redrawn after Sauer *et al.* (2001).

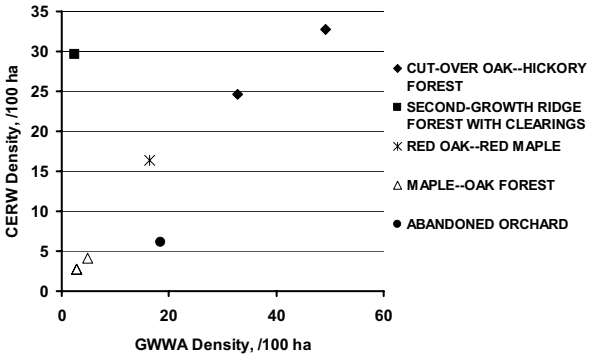

Figure 2— Occurrence of Golden-winged Warbler (GWWA) and Cerulean Warbler (CERW) on common plots in the Breeding Bird Census. Density is expressed as breeding pairs/100 ha (r = 0.35, N = 5 plots, P = 0.56).

Demographic study of each species has indicated that reasonably high reproductive success and productivity can be achieved in stands growing as secondary succession on abandoned farmland. Confer (1992) reported an average of 2.0 young/pair yr-1 produced by GWWAs in shrubby fields occurring early in secondary succession on abandoned farmland in north-central New York. Confer et al. (2003) note that the birds' reproductive success is higher in younger stands. Oliarnyk and Robertson (1996) reported CERWs to produce an average of more than 3 fledglings/successful nest in mature upland hardwood forest growing in secondary succession on abandoned farmland in Ontario. Jones et al. (2002) suggest that this number may not represent sufficient productivity to maintain that population, however. In their demographic study of GWWA in managed forest, Klaus and Buehler (2001) reported 3.7 fledglings/successful nest in recently harvested forest in North Carolina. Similar demographic data are lacking for CERW in relation to forest management practices.

Winter biology of both species deserves additional study. Confer (1992) devotes a single short paragraph to the topic of GWWA winter habitat, noting it to be "Woodland canopy, semi-open or less dense forests and forest borders or gaps." While CERW winter habitat is often considered to be primary forest (references in Hamel 2000), the lone published study of the winter ecology of the species was conducted in shade-coffee plantations (Jones et al. 2000). Both species appear to join mixed-species flocks of resident birds, primarily at middle elevations on humid, subtropical or temperate forested slopes (K.V. Rosenberg, pers. obs.). Although CERW is generally considered to be threatened in winter, Confer (pers. comm.) does not believe this to be the case for GWWA, pointing out that major range contractions have corresponded with changes in temperate breeding habitat conditions and occurred long before winter habitat alterations were a major factor influencing population size.

The Questions

(1) At what scale are the habitat requirements of Cerulean and Golden-winged warblers compatible within their areas of range overlap?

Our knowledge of CERW breeding habitat selection comes from descriptive studies across the range (e.g., Oliarnyk and Robertson 1996, Hamel 1998, Hamel et al. 1998, Rosenberg et al. 2000, Jones and Robertson 2001, Nicholson 2003). These are birds that use large trees for their breeding habitat requirements, often within a structurally diverse forest canopy. Descriptive work also characterizes the habitats of GWWAs (Will 1986, Confer 1992, Klaus and Buehler 2001, Confer et al. 2003). These birds breed in openings in which herbaceous vegetation, shrubs and small trees grow in close proximity to one another.

It is informative to consider anecdotal evidence from real situations in which these two species co-occur in close proximity within tracts in the same landscape. The first example comes from Sterling Forest State Park and vicinity in the Hudson Highlands region of southeastern New York (J. Confer pers. comm; K.V. Rosenberg, pers. obs.). This largely forested area supports one of the largest populations of CERWs in the state, primarily on oak-dominated slopes and uplands. This same area is dotted with natural openings in the form of alder swamps, and these support a large and important population of GWWAs. GWWAs also nest in a series of narrow power line rights-of-way that cross the forested park. In this region, CERW often occurs at the edge of forests. In at least one location, CERWs have nested for four years in a small forest isthmus with GWWA territories on both sides. In Sterling Forest State Park, CERWs nest in forest adjacent to a utility right-of-way and along roadsides. Management plans for the state park focus on maintenance of continuous forest, but ignore the disturbed habitats that support GWWAs and other species. Clearly the long-term persistence of both warblers is possible in this landscape with proper attention to the needs of each.

A very similar situation exists in northwestern New Jersey at High Point State Park and adjacent Delaware Water Gap. Here CERWs occupy both oak-dominated forests at higher elevations and sycamore-dominated riverine forest in the valley. As in nearby New York, GWWAs occur in alder wetlands and stream corridors at higher elevations, as well as in power-line corridors and abandoned farm-fields on the slopes and along the Delaware River. It is not uncommon to find both species in close proximity, especially because CERWs often sing from patches of tall trees at the edge of clearings. Whereas CERWs have increased in this area as forests matured, GWWAs are threatened by loss of early-successional habitat, incompatible management of utility corridors, and recent invasion by Blue-winged Warblers.

Further south, both CERW and GWWAs occur at high density throughout the large landscape of southern West Virginia (R. Canterbury, pers. comm.), with CERWs concentrated along forested ridges and GWWAs concentrated at abandoned surface mines intermingled among dense forest. Here too, it is not uncommon to find both warbler species in close proximity near the edges of forest. Finally, in the Cumberland Mountains of Tennessee, CERWs occur across a range of mid-successional forest conditions, including on the edges of old strip-mine benches, with GWWAs occupying the early-successional habitats on the benches (C. Nicholson and D. Buehler, unpubl. data).

These examples suggest that at the landscape scale, where separate patches of habitat may be managed specifically to produce habitat for each of the species, management for the two species appears to be possible. It may be possible, therefore, to create or maintain GWWA habitat in predominantly forested landscapes without seriously reducing quantity or quality of habitat for CERWs. For example, creation of small openings or narrow corridors will not result in negative effects normally attributed to forest fragmentation, and could actually enhance local CERW density by providing locally more diverse canopy structure. Another strategy would be to manage aggressively and repeatedly those disturbed or early-successional habitats that already exist and support GWWAs to ensure their continued presence, without affecting nearby CERW habitats. Additional monitoring of such approaches will be necessary to evaluate the success of any management strategy and to evaluate how other priority species respond to prescriptions designed for CERW and GWWAs. Thompson and Angelstam (1999) stress the importance of care in conducting management for special species such as these two birds.

(2) What role does disturbance play in the creation and maintenance of habitat for each species?

Natural or anthropogenic disturbance of the landscape plays an important role in habitats of GWWAs range-wide (Confer 1992). The high reproductive success of the species in clearcuts in the Southern Appalachians, while the species is disappearing from areas without management intervention (Klaus and Buehler 2001), argues strongly for repeated disturbances in these landscapes. Likewise, modest disturbance to the landscape, such as provided by limited area windstorms, and ice storms (Jones et al. 2001), and probably moderate amounts of forest harvest, also may benefit CERW

(Hamel 2000). Evidence to this effect is circumstantial where CERWs have been absent from some areas but have appeared after natural or anthropogenic forces have created canopy openings. Controlled experiments are needed to increase the strength of the inference, but it is clear that disturbance plays an important role in the biology of both of these birds.

(3) Can we mimic beneficial forms of disturbance for these species through direct management?

Because of the numerous examples of sympatric occurrence of the birds at the landscape and even the forest stand level, development of a management system that accommodates the needs of both these birds seems feasible. The most important issue is the temporal and spatial scales at which it is accomplished, leading to several questions. Do we provide habitat for the two species on the same 10 acres, somewhere within the same 10,000-acre landscape, or at another scale? Do we provide habitat for the two species on the same ownership or on different ownerships? What is the appropriate role for different types of landowners in providing habitat for these two species? Private landowners might most easily provide early-successional habitats while public landowners might more easily provide later-successional habitat. What are the particular conditions of soil and bedrock that are most suitable for each or both of these species?

Based on interpretation of habitat studies, we can infer possible management strategies for both species. In areas where habitat is already suitable (i.e., CERWs are already present), forest protection may be the most logical strategy. In areas with potential but unoccupied habitat, a silvicultural treatment may be useful for improving habitat suitability and increasing the likelihood that the birds will occupy the site. Hints that some harvesting may be useful, or at least not detrimental, to CERWs are implicit in Hamel (2000). Specific experiments involving purposeful habitat manipulations designed to test response to those treatments are necessary to assess whether the hypotheses arising from these hints are reasonable (Morrison et al. 2001).

Klaus and Buehler (2001) showed that, for GWWA, productive breeding habitat can result from habitat disturbance by timber harvest. In the Northeast, GWWA habitat is produced by maintenance of powerline rights-of-way (J. Confer, pers. comm.). Studies of Red-cockaded Woodpeckers (*Picoides borealis*; Saenz et al. 2001), and game birds such as Northern Bobwhite (*Colinus virginianus*, Brennan 1999), as well as Black-capped Vireos (*Vireo atricapillus*; Grzybowski 1995), have shown that certain forestry practices, particularly controlled burning, can mimic natural disturbances to a degree sufficient to create favorable conditions for certain wildlife species. In addition, controlled fire can indeed imitate small-scale natural fires in favoring vegetation productive of certain species. Some kinds of disturbances, such as stand-replacement fires, are useful habitat producers for some species, such as Kirtland's Warbler (*Dendroica kirtlandii*, Mayfield 1992). However, use of such fires is less feasible in landscapes increasingly home to numbers of people. Land use conflicts and air-quality issues in this urban-wildland interface will make active management difficult in the future (Smith 2002).

(4) Is this type of management compatible with commercial forestry and other ongoing forms of land use?

Some of the insights gained through descriptive research on the breeding biology of both CERWs and GWWAs have led to the development of silvicultural manipulations aimed at benefiting the species. At Chickasaw National Wildlife Refuge in Tennessee, these insights may find application in an experimental manipulation as part of the forest management plan of the refuge (Hamel, this volume). Similar implementation of insights gained through work on CERW has led to implementation of a comparison of a standard silvicultural prescription with a prescription similar to Hamel (this volume) on property managed by Anderson Tully Co. (P. Hamel, M. Staten, and R. Wishard, pers. obs.). An experimental forest management prescription designed to benefit CERWs and other forest-interior songbirds also has been implemented on Tennessee National Wildlife Refuge (R. Wheat, pers. comm.).

Clear association of GWWAs with periodically disturbed and maintained shrubby powerline rights of way indicates that management for that species is critical to habitat maintenance (Confer 1992). Association of GWWAs in the Cumberland Mountains of Tennessee with abandoned strip-mine benches undergoing succession has led to an opportunity to maintain experimentally some of these areas in early-successional habitats and evaluate the population response of the birds to the disturbance of the vegetation (D. Buehler, unpublished work in progress).

(5) What is known about the relative importance of breeding versus wintering habitat to population trends of the two species?

Definitive studies have not been conducted that test the sensitivity of CERW or GWWA populations to limiting factors on breeding vs. wintering grounds. Limited evidence suggests, however, that it is not all one or the other. In expanding CERW populations in Ontario, where reproductive success appears to be good (Oliarnyk and Robertson 1996), breeding ground

conditions may be sufficient to overcome whatever limitations in survival being experienced on the wintering grounds. CERW populations in the Cumberland Mountains of Tennessee declined after several years of poor nest success related to cool-wet El Niño springs, again suggestive of sensitivity to breeding grounds effects (Nicholson 2003). Studies on other species, like Black-throated Blue Warblers (*Dendroica caerulescens*) (e.g., Sillett and Holmes 2002), suggest that even within a given species, populations may be limited under some circumstances by breeding grounds events and under other circumstances, by wintering ground events. Historical patterns of GWWA breeding range contraction and expansion correlate closely with documented patterns of human land use practices and changes in those practices (Confer et al. 2003). These changes occurred before recent habitat changes in GWWA wintering grounds.

Some data are beginning to appear on the topic of winter habitat, e.g. Jones et al. (2000) for CERW. Habitat destruction on the winter grounds likely is detrimental to all species of interest, including residents and migrants. This is not always true, however. In Jamaica (Confer and Holmes 1995) as well as other regions, peak densities of Neotropical migratory birds occur in slightly to moderately disturbed sites. Effects of disturbance are species-specific, with carrying capacity for some species enhanced and that for others hurt by habitat modifications. We have little information on the effects of management on bird populations in winter habitats, many of which have in past experienced extreme variations in effects of human populations on the extent of forest in the landscape. We will need such data in the future.

Discussion

Pro- versus anti-management arguments

Central to developing avian conservation strategies is the notion that habitat for each species can be described as a vector of vegetation structural characteristics (James 1971). We assume that structure is a sufficient surrogate for the occurrence of the other needs for food, safety, and space to conduct the actions of life history successfully. In this view, structure proceeds through a dependable sequence as time progresses, with various disturbances or perturbations pushing it back or sideways on the trajectory.

Clearly, early-, and later-successional forest stands cannot occur on the same acre at the same time, so at each instant, a decision to create early-successional habitat on a particular plot retards the development of later-successional conditions, just as a decision to permit the progress of succession precludes the maintenance of early-successional conditions. In general, early-successional habitat can be created in a short time period, whereas later-successional habitat may take many decades to develop. We, then, pose the question, "Can structure for an early-successional species be maintained on the same land that contains habitat structured for a later-successional species?"

Some would answer this question, "No!" and proceed to develop means of providing areas of one successional condition and different areas of another successional condition (e.g., Hamel 1990). Suppose we call these people anti-management. Their belief is that our intervention cannot dependably create such a desired future condition. Providing habitat for an early- and a later-successional species must take place on separate areas in this view.

Others would answer this question, "Why not?" and proceed to develop means of controlling disturbance and perpetrating interventions that maintain that area of land in a combination structure, which includes the elements important to early-successional species and to later-successional species. Such a philosophy is apparent in Hamel (1992), Short et al. (2001), and well illustrated in the diagrams in Staten (1994). Suppose we call these people pro-management. Their belief is that purposeful management action can create a desired future condition that is beneficial to the species in question.

Both anti-management and pro-management viewpoints have merit. Anti-management opinion respects the essential incompleteness of our knowledge of the habitats of species of interest, which may lead to unwanted elimination of desirable species through management action, or to unwanted increase of undesirable species. Pro-management opinion recognizes the inevitability of vegetation change with time (Hamel et al. 2001). In a certain sense, the limitation of each of these viewpoints is the strength of the other. A consideration we offer to the reader is the following. Time will hurt us all if we don't work with it, for vegetation change beyond the conditions suitable for a particular species may be very difficult to reverse. Similarly, time is a major ally when interventions take advantage of what it provides, in a sense harnessing successional processes to achieve specific goals.

Will an integrated, multi-species approach to habitat conservation work?

The integrated, multi-species approach to conservation is at the heart of the PIF process. As a mechanism to coordinate human efforts, such as through the North American Bird Conservation Initiative (U.S. NABCI Committee 2000, Bird Studies Canada 2002), it has already proven its effectiveness. With respect to management action on the ground, a multi-species ap-

proach must work as well, because we have no other realistic alternative. Nevertheless, actions directed toward improving habitat for one species do not always produce benefits for other species of similar ecological characteristics (Block et al. 1986).

Absent specific manipulations to create a particular disturbance, natural disturbance regimes will produce changes in vegetation on a haphazard basis at unpredictable times and in unpredictable locations. Natural disturbances affect lands and landscapes irrespective of their community content of birds; all the species are, in a sense, stuck with the results.

Considerable interest in the potential effects of mountain top removal surface mining for coal exists in relation to these two species. Evidence in Tennessee and West Virginia suggests that some successional conditions resulting from older mining practices before the Surface Mining Control and Reclamation Act of 1977 (Public Law 95-87; Office of Surface Mining 2002) appear to support CERWs on the slopes and GWWAs on the abandoned benches (Yahner and Howell 1975; Nicholson 1979, 1980; M. Welton, pers. obs.; D. Buehler, pers. obs.). Modern mining practices have not been shown to duplicate these vegetation conditions.

The Take Home Message

Reconciling the needs of early- and later-successional species is a key consideration in conservation planning and action. Management activities for GWWA and CERW might be conducted on the same sites, or perhaps more likely where space is less a limitation, on separate tracts within a larger jurisdictional unit, such as a state park, national forest, or managed industrial forest. The two species provide an opportunity for the bird conservation community to address head-on issues related to management of multiple species, as well as to confront legitimate concerns of stakeholders skeptical of intervention activities in forest habitats. One important consideration in management is that an activity must be clearly defined; otherwise normal humans cannot carry it out. Because this is so, following an adaptive approach to management of habitats for these and other species is a useful course.

Finally, the cost of management must be borne by someone, and this expense often is not trivial. Where it is possible for forest products to underwrite the costs of the habitat improvements obtained in the process, it would appear prudent to promote suitable timber harvest practices.

Summary and Conclusion

Through a series of questions and answers, focused on the conflicting biological and concordant conservation needs of two warblers of high conservation concern, issues related to management of species of high conservation concern are addressed. GWWA and CERW are species of wide distribution, acute conservation concern, and divergent habitat needs.

The modicum of information we have indicates that each of these birds is associated with canopy disturbance in some way. GWWAs are often associated with an opening in the forest, whose dominant vegetation is herbaceous with some woody plants, and trees nearby. Without disturbance, such openings rapidly succeed to forest. CERWs are believed by many to be associated with canopy gaps. These may be natural gaps created by windthrow or storms; or they may be anthropogenic gaps resulting from a harvest manipulation such as shelterwood or group selection harvesting, or some other activity. These openings also close rapidly as the vegetation responds to the increased light levels reaching the lower stories.

Managing both of these warblers on the same acre without intervention of some sort is likely impossible. Without action, the future of the early-successional GWWA is made more uncertain. Lack of experimental evidence of the effect of manipulations on the future development of habitat for the later-successional CERW prescribes caution in conduct of management activities. Following a deliberate middle course between these simultaneous benefits and risks is the essence of adaptive management.

Ultimately, bird conservation in broadleaf forest habitats means more than just locking away expanses of undisturbed mature forest. Temporal as well as spatial dynamics of disturbance are important to bird conservation in forest habitats. How natural and anthropogenic disturbances are managed in the landscape is key to maintaining mature forest as well as early-successional forest in today's landscape.

Acknowledgments

We are grateful to D. Demarest and C. Hunter for their urging that we undertake this task. J. Woehr provided a critical review, which has been an important stimulus to this manuscript. J. Confer has been an insightful participant in the development of this work, both during initial discussions about its form, and later as a reviewer. His contrasting views have made this a better work, even though he does not entirely agree with our approach. T. Dell and B. Wigley provided a critical review of an earlier draft of the work as well. We are indebted to the clear thinking of an anonymous reviewer for pointing out opportunities to clarify a number of points in the manuscript, and to T. Rich for thoughtful and rigorous editing. We must acknowledge gratefully the patience and

attention to detail of those valiant souls who have conducted the Breeding Bird Survey routes.

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Does Habitat Matter in an Urbanized Landscape? The Birds of the Garry Oak (*Quercus garryana*) Ecosystem of Southeastern Vancouver Island, British Columbia[1]

Richard E. Feldman[2] and Pam G. Krannitz[3]

Introduction

The Garry oak (*Quercus garryana*) ecosystem was once a dominant habitat type on southeastern Vancouver Island, British Columbia, but urbanization has lead to massive habitat loss and fragmentation (Hebda 1993). Most bird species are expected to respond negatively to urbanization because of increased patch isolation, increased predation pressure, and negative edge effects (Marzluff and Ewing 2001). On southeastern Vancouver Island, Garry oak remnants form a mosaic along with coastal Douglas-fir (*Pseudotsuga menziesii*) forests. Since the two ecosystems differ in habitat structure and composition, there is an *a priori* expectation that their bird communities differ. However, urbanization may have fragmented the landscape to the extent that only generalist species use both habitat types. This study tests whether bird abundance in patches of Garry oak and Douglas-fir is related to habitat type or patch size and/or urbanization in the landscape. It also compares bird community composition of Garry oak patches surrounded by urbanization to those patches surrounded by Douglas-fir forest.

Methods

Bird surveys were conducted in May and June 2000, at seven Garry oak patches and four adjacent Douglas-fir patches. Two transects of 400 m each were surveyed in each patch. Five-minute counts were made at stations every 50 m; each site was visited 4 to 5 times. Bird territory densities were delineated through territory mapping (Bibby et al. 1992). Habitat type was measured as Garry oak stem volume (oakvol), which was calculated for randomly chosen trees along the transects. Patch size (area) was measured via GIS and urbanization was measured as as human population density surrounding the patch (humans). Relationships between environmental variables and abundance of 16 species of birds were inferred by selecting the best linear regression model by Akaike Information Criterion.

Results

Human population density, our measure of urbanization in the landscape, was the most common factor associated with bird species abundance. For American Robins, Brown Creepers, Chestnut-backed Chickadees, Dark-eyed Juncos, Golden-crowned Kinglets, Orange-crowned Warblers, Townsend's Warblers, and Winter Wrens there was evidence for a negative relationship between abundance and human population density (*table 1*). Anna's Hummingbirds and Spotted Towhees, on the other hand, preferred urbanized patches. The Red-breasted Nuthatch was the only species for which patch size was the most important variable associated with abundance.

For seven species the best model as chosen by AIC included Garry oak stem volume. Brown-headed Cowbirds, Chipping Sparrows and Orange-crowned Warblers were positively associated with Garry oak, while Brown Creepers, Chestnut-backed Chickadees, Golden-crowned Kinglets and Winter Wrens were negatively associated with Garry oak (*table 1*). A null model describes the situation where abundance is equivalent across patches and not related to any of the environmental variables. The null model was selected for Bewick's Wrens, Pacific-slope Flycatchers, and overall species richness.

The abundances of 15 species were compared between Garry oak patches surrounded by coniferous forest to Garry oak patches surrounded by urbanization (*table 2*). Only the House Finch was consistently more abundant in Garry oak patches surrounded by urbanization. In fact, it was not found in Garry oak surrounded by forest. Eight species (Brown Creepers, Chipping Sparrows, Dark-eyed Juncos, House Wrens, Northern Flickers, Pacific-slope Flycatchers, Townsend's Warblers, and White-crowned Sparrows) were found only in Garry oak patches surrounded by forest. An additional species, the Orange-crowned Warbler, was consistently more abundant in Garry oak surrounded by forest than Garry oak surrounded by urbanization. The remaining five species (American Robins, Bewick's Wrens, Brown-headed Cowbirds, Chestnut-backed Chickadees, and Spotted Towhees) had similar abundances in the Garry oak patches surrounded by both habitat types.

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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Table 1— *The best linear regression equations describing the relationship between bird abundance and environmental variables. The best model was selected from a model set and chosen as the model with the minimum AIC value. For some species, multiple models are depicted because more than one model had similar AIC values and model weights. Parameter estimates for terms used in the final model were calculated along with the unconditional 95% confidence interval (Anderson et al. 2000). Equations without regression coefficients correspond to a null relationship.*

Best approximating models	(Intercept ± 95% conf. int.) + (estimate ± 95% conf. int.) parameter
American Robins	(0.200 ± 0.092) - (0.044 ± 0.056) humans
Anna's Hummingbirds	(-0.015 ± 0.078) + (0.051 ± 0.064) humans
Bewick's Wrens	0.105 ± 0.091
Brown-headed Cowbirds	(0.023 ± 0.193) + (0.100 ± 0.073) oakvol
Brown Creepers	(0.333 ± 0.194) - (0.134 ± 0.076) oakvol - (0.160 ± 0.109) humans
Chestnut-backed Chickadees	(0.330 ± 0.103) - (0.041 ± 0.005) oakvol - (0.074 ± 0.036) humans
Chipping Sparrows	(0.012 ± 0.012) + (0.023 ± 0.035) oakvol
	(0.069 ± 0.094) - (0.033 ± 0.059) area
Dark-eyed Juncos	(0.131 ± 0.017) - (0.107 ± 0.106) humans
Golden-crowned Kinglets	(0.279 ± 0.183) - (0.099 ± 0.071) oakvol - (0.132 ± 0.102) humans
Orange-crowned Warblers	(0.136 ± 0.122) - (0.109 ± 0.090) humans
	(0.135 ± 0.023) - (0.109 ± 0.090) humans + (0.023 ± 0.036) oakvol
Pacific-slope Flycatchers	0.156 ± 0.116
Red-breasted Nuthatches	(-0.056 ± 0.080) + (0.080 ± 0.059) area
Spotted Towhees	(0.200 ± 0.179) + (0.200 ± 0.173) humans
Townsend's Warblers	(0.110 ± 0.089) - (0.104 ± 0.086) humans
Winter Wrens	(0.251 ± 0.194) - (0.100 ± 0.079) oakvol - (0.093 ± 0.092) humans
Species Richness	17.09 ± 3.28

Table 2— *Abundances in territories ha^{-1} (mean ± 95% confidence interval) of 17 species in Garry oak patches surrounded by urbanization (N = 3) and in Garry oak patches surrounded by coniferous forest (N = 4)*

	Surrounded by urbanization			Surrounded by coniferous forest			
Species	Highrock	Mt. Tolmie	Uplands	Mt. Douglas	Rocky Point	Thetis Lake	Mary Hill
American Robin	0.400	0.750	0.375	0.375	0.714	0.875	0.875
Bewick's Wren	0.400	0.375	1.875	0.625	0.143	0	0.250
Brown-headed Cowbird	0.200	0.500	0.625	0.125	0.714	0.125	0.875
Brown Creeper	0	0	0	0.125	0.429	0.125	0
Chestnut-backed Chickadee	0.600	0.125	0.500	0.625	0.571	1.250	0.875
Chipping Sparrow	0	0	0	0.500	0.143	0.375	0.500
Dark-eyed Junco	0	0	0	0	0.286	1.000	0.125
House Finch	0.200	0.125	0	0	0	0	0
House Wren	0	0	0	0.125	0.429	0.250	0
Northern Flicker	0	0	0	0	0.143	0.375	0.250
Orange-crowned Warbler	0	0.250	0	0.375	0.429	0.500	1.125
Pacific-slope Flycatcher	0	0	0	0.250	0.714	0	0.625
Spotted Towhee	0.400	1.500	3.000	1.500	0.143	1.125	0.250
Townsend's Warbler	0	0	0	0.125	0.571	0.375	0
White-crowned Sparrow	0	0	0	0.250	0.143	0	0.875

Conclusions

Most birds analyzed in this study were negatively associated with the urbanization of British Columbia's Garry oak ecosystem. This was further supported by the fact that some species were consistently more abundant in Garry oak patches surrounded by forest than in Garry oak patches surrounded by urbanization. These species included common forest birds (e.g. Brown Creepers, Pacific-slope Flycatchers) but also open woodland species (e.g. Chipping Sparrows, White-crowned Sparrows). Urban Victoria was not an inhospitable environment for all species. Anna's Hummingbirds, House Finches and Spotted Towhees were positively associated with urbanization, possibly due to the proliferation of feeders and other supplemental resources.

While it is unlikely that any species is obligate on Garry Oak ecosystems, some were more strongly associated with oak than with coniferous forest. Furthermore, most woodland species were not found in Garry oak surrounded by urbanization. This result could be due to landscape and habitat factors. Surrounding forest may act as a buffer against negative urban edge effects such as cat predation. Garry oak patches surrounded by forest have more shrub cover and more conifer trees than Garry oak surrounded by urbanization (Feldman 2002). It is possible that further conifer encroachment into Garry oak patches will lead to declines in open woodland species as has been shown in Oregon (Hagar and Stern 2001). Further study is needed on the effects of conifer encroachment on bird community composition in this region.

Since the majority of birds analyzed in this study are associated with urbanization and there are relatively fewer differences in composition between Garry oak and coniferous forest patches (see also Feldman 2002), management for most birds should be done at the landscape-scale and consider oak and forest habitats together. Site-level management may be required to maintain the open woodland bird assemblage. More importantly, restoring Garry oak woodlands to a savanna is a necessary first step for the conservation of endangered coastal grassland species: (Lewis' Woodpeckers [*Melanerpes lewis*, Georgia Depression Population], Western Meadowlarks [*Sturnella neglecta*, Georgia Depression Population], Western Bluebirds [*Sialia mexicana*, Georgia Depression Population], Vesper Sparrows [*Pooecetes gramineus affinis*] and Streaked Horned Larks [*Eremophilia alpestris strigata*]), most of which are extirpated from Vancouver Island.

Acknowledgments

This project was funded by the Georgia Basin Ecosystem Initiative of Environment Canada. Access to sites was provided by the Saanich, Oak Bay, Esquimalt, and Capital Regional District parks departments and A. Robinson and G. Usipck of the Canadian Forest Service and Department of National Defence. Thank you to K. Christie for her tremendous help with field work in 2000.

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Early Impacts of Residential Development on Wood Thrushes in an Urbanizing Forest[1]

L. E. Friesen[2], E. D. Cheskey[3], M. D. Cadman[4], V. E. Martin[5], and R. J. MacKay[6]

Abstract

Environmental protection policies sometimes protect forests along an advancing suburban front although many of the forests may be brought into close proximity to residential housing. Research suggests that even when forests are physically preserved, their bird communities are simplified as the surroundings become urbanized. However, little is known of the time required for these changes to appear or of the mechanisms that drive them. We obtained population measures on the Wood Thrush (*Hylocichla mustelina*), an urban-sensitive woodland species in at least portions of its breeding range, before, during, and after development occurred alongside a large (140 ha) upland deciduous forest in Waterloo, Ontario, and compared these measures with those from rural control sites. From 1998 to 2001, the number of houses within 500 m of the urbanizing forest increased from 24 to 470. We detected no significant differences between the relative abundance of Wood Thrushes in the urbanizing and rural control sites, nor was there any significant difference in levels of nesting success, productivity, and brood parasitism. We did not detect any significant changes in successive nest locations of individual banded birds in response to encroaching development. These results suggest that the anticipated impacts of development on Wood Thrushes, and perhaps other forest birds, in adjacent woodlands may not be immediate but, rather, they may require a number of years to manifest. The high return rate (59 percent) of adult females on the urbanizing site in 2001 suggests pronounced site tenacity that may offset any aversion to nesting near houses.

Key words: housing, Neotropical migrants, residential development, urbanization, Wood Thrush.

Introduction

Deciduous forests in eastern North America have undergone a considerable resurgence since the 1930s, mainly because of the abandonment and regeneration of marginal farmland (Martin 1988, McKibbon 1995). But now there are growing concerns that the pace of urban growth is beginning to outstrip that of forest regrowth. In many regions, sprawling land development accounts for the greatest amount of land use change and threatens forests, wetlands, and croplands on an accelerating scale (Mitchell 2001).

The result of urban sprawl can be the loss of older, established forests, as in York Region in the Greater Toronto Area, Canada, where upland deciduous forest cover dropped from 18 percent in 1991 to 14 percent in 2000 (L. Munt, pers. comm.). Or forests may be preserved along an advancing suburban front although their condition is altered. For example, forest cover in the Halton area along Ontario's Niagara Escarpment increased slightly, from 43 to 44 percent, from 1976 to 1995 (Braid and Ramsay 2000). At the same time, the forests became more fragmented, in part because of a proliferating intrusion of rural residences into the forests (Braid and Ramsay 2000).

A growing body of research across eastern North America suggests that even when forests are retained, their bird communities change as the matrix becomes more urbanized. Habitat specialists, many of them Neotropical migrant species, usually decrease or disappear in the presence of nearby housing. Supporting evidence comes from studies that have focused on the following:

1. A single site through time as the surrounding area became more urbanized (Holt 2000)

2. A number of sites in a single landscape having differing intensities of adjacent residential development (Dowd 1992, Friesen et al. 1995, Mancke and Gavin 2000, Dawson et al. 2001)

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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3. Sites in two or more landscape types having different housing densities (Nilon et al. 1995, Kluza et al. 2000)

Results from Ontario are illustrative of the emerging pattern, if not the details, documented by these studies; there, 4-ha woodlots without adjacent development contained a higher abundance and diversity of Neotropical migrants than 25-ha urban woodlots (Friesen et al. 1995). Of the nine most common Neotropical species recorded in this study, the Wood Thrush showed the most dramatic response to development: while common in rural forests, it practically disappeared in urban forests of similar size (Friesen et al. 1995).

The ecological impacts of land use adjacent to forests evidently add to the effects of fragmentation per se (Saunders et al. 1991) and contribute to profound changes within the Neotropical forest bird community. However, little is known of how much time is required for these changes to appear after the advent of development: Are they immediate, gradual, or do they occur suddenly after a certain interval of time? Similarly, little is known of the mechanisms that drive and shape the changes: Are they linked to poor nesting success resulting from a higher abundance of urban-adapted predators and/or Brown-headed Cowbirds (*Molothrus ater*)? Low adult return rates?

We attempted to answer these questions by obtaining population measures on the Wood Thrush, an urban-sensitive woodland species in at least parts of its breeding range (Friesen et al. 1995, Kluza et al. 2000, but see Mancke and Gavin 2000). Long-term demographic studies of sensitive species have been identified as one of the highest avian research priorities in urbanizing areas, particularly as they help to identify source/sink populations (Marzluff et al. 2001a). Our research was conducted before, during, and several years after development occurred alongside a large upland deciduous forest in the City of Waterloo, Ontario, Canada (*fig. 1*). The population measures from the urbanizing forest were compared with those from rural control sites to distinguish between local and regional effects.

Study Area and Methods

The Regional Municipality of Waterloo in southern Ontario, Canada is a fragmented urban/agricultural landscape with 14 percent forest cover that varies locally from 10 to 25 percent (see Friesen et al. 1999 for a general description of the landscape). Forested Hills (140 ha), an urbanizing forest, is an Environmentally Sensitive Policy Area, a designation that effectively precludes development within its borders (Regional Municipality of Waterloo 1995). The forest is situated on the western edge of the City of Waterloo, which had a population of 102,300 in 2001, representing a 3.5 percent increase over the previous year (Regional Municipality of Waterloo 2002). Rapid growth is expected to continue, especially in this neighborhood, with Forested Hills becoming completely encircled by housing between 2007 and 2012.

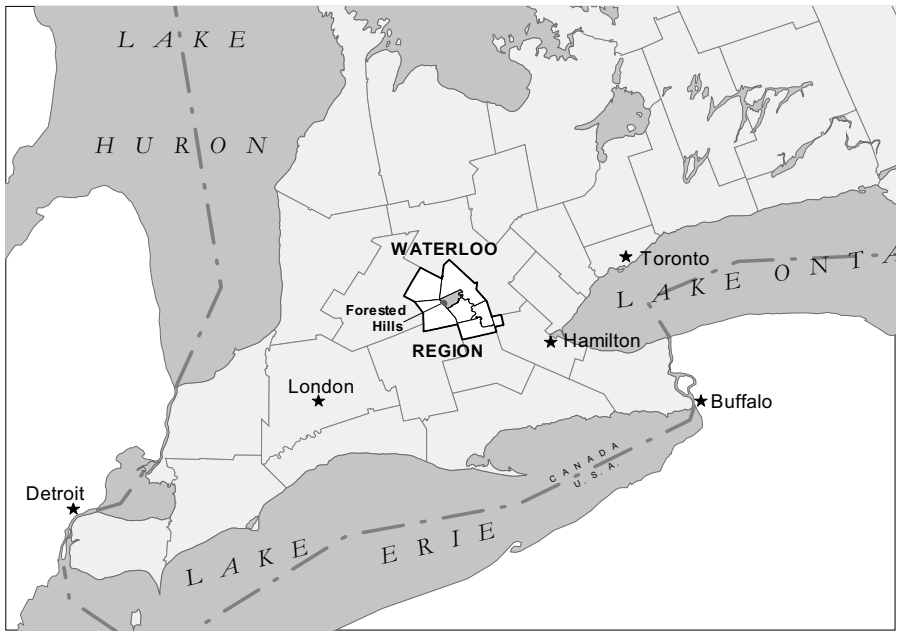

Figure 1— Location of study area in southern Ontario, Canada.

Point Counts

In a separate study to monitor avian population changes in response to increased housing density, point counts were established within Forested Hills and neighboring rural forests. Data for Wood Thrushes were summarized from 18 point-count stations within Forested Hills and nine point-count stations in four control forests located within 1 km of Forested Hills but lying outside of the designated development zone. The purpose of the controls was to deal with year-to-year variation within the Wood Thrush population due to causes other than development pressure. There was no matching of control and Forested Hill stations for vegetative or spatial features. All 27 stations were monitored from 1998 to 2001 by the same observer, using, two or three 10-minute point counts. To account for the varying number of visits (2 vs. 3), the average abundance of Wood Thrushes per station was calculated over visits in a given year.

Demographic Study

Field research on Wood Thrushes' demography was conducted from 1997 to 2001 in Forested Hills on six rural woodlots, sized 3 to 24 ha (*fig. 2;* see Friesen et al. 2000 for more details of these study sites). Note that these sites were different than the control sites used in the point-count study. One of the six rural sites was situated 1 km from Forested Hills; the other five were 10 to 20 km from Forested Hills. All six control woodlots were in rural landscapes where agriculture, primarily corn and soybean production, was the predominant land-use. Primary habitat at all study sites was upland deciduous forest dominated by sugar maple (*Acer saccharum*), American beech (*Fagus grandifolia*), and white ash (*Fraxinus americana*).

At the outset of the study, the land surrounding Forested Hills consisted of fields that were either actively cropped or were lying fallow awaiting development. We used property assessment and building permit data from the Regional Municipality of Waterloo to determine the extent of development before and during our study.

We located Wood Thrush nests and monitored them every 2 or 3 days using a mirror attached to a telescoping pole (see Friesen et al. 1999 for details). Nesting success was estimated using the Mayfield (1975) method, based on a 25-day nesting cycle. A nest was considered successful if host or cowbird fledglings survived to at least 10 days of age, when fledging is known to occur (Roth et al. 1996). Parasitism rates were calculated as the proportion of nests found during the incubation stage that contained cowbird eggs. We mist-netted and banded adults at their nests throughout the breeding season to determine incidences of double-brooding and renesting among females (see Friesen et al. 2000 for details); this information is needed to accurately assess productivity and population viability. Adult annual return rates were calculated as the proportion of birds captured and banded in one year and recaptured and/or resighted the following year.

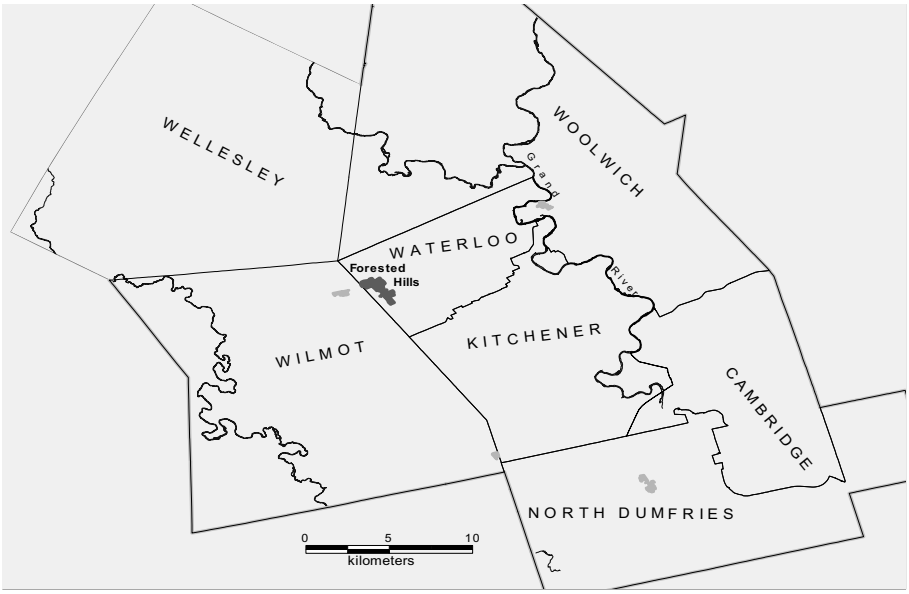

Figure 2— Location of Forested Hills and rural control sites in the Regional Municipality of Waterloo, Ontario, Canada.

We adopted "conservative" and "optimistic" survival rates for adult and juvenile Wood Thrushes to estimate whether the production of young Wood Thrushes was sufficient to support a self-sustaining population. Published estimates of annual adult survival of Wood Thrushes range from 0.58 to 0.70 (Roth et al. 1996); juvenile survival rates range from 0.29 to 0.35 (Trine 1998). We determined that 0.86 female young per pair were required annually to maintain a viable population if the highest estimated adult and juvenile survival rates were used; 1.45 female young were needed if the lowest estimated survival rates were used. Our fecundity model (see Donovan et al. 1995 for details) incorporated nesting values derived from our study population, i.e., Wood Thrushes were double-brooded (Friesen et al. 2000) and 15 percent attempted three nests in a season (L. Friesen, unpubl. data).

Mapping and Spatial Analysis

A GPS unit was used to gather positional data on each nest in the study, to an estimated accuracy of +/- 5 m. GPS coordinates were brought into MapInfo® (GIS software from MapInfo Corporation) for mapping and analysis. Points representing the nests were created and overlaid on digital imagery to verify the accuracy of the nest locations.

Various comparative measures of the location of successive nests were possible. Our primary interest was in detecting responses to urbanization pressures, and our focus, therefore, was on the measurement of a hypothesized drift in nest locations relative to the source of those pressures. We speculated that individual Wood Thrushes might respond to encroaching development by moving successive nests away (i.e., in a westerly direction) from the source of the disturbance, which was concentrated along the eastern side of the forest. We, therefore, measured changes in successive nest locations of individual banded birds to determine whether there was a shift in location away from the residential development. This was done by calculating the net change in x (easting) coordinates for successive nests. The control group consisted of all successive nests from the control sites, plus 1998 and 1999 nests from Forested Hills. The latter were included with the control group because in those years development remained well removed from the study site (the closest encroachment to any nest at that time was approximately 250 m).

Statistical Analyses

An analysis of variance (Sokal and Rohlf 1981) was used to test the hypothesis of a difference in population trend over years between Forested Hills and the control sites; the average number of Wood Thrushes detected per year at each station was used as the response. The multiple comparison method (Sauer and Williams 1989) was used to test whether the Mayfield estimates of daily survival of Wood Thrushes differed among years and woodlot size classes. Standard chi-squared procedures (Sokal and Rohlf 1981) were used to examine differences in parasitism rates among the woodlot size classes and between years. We pooled data across years, unless noted otherwise, and considered results significant if $P \leq 0.05$. For purposes of analysis of the movement of nests, the nests were divided into a control group and a study group, and we hypothesized that the means from each group were equal against a two-sided alternative (two sample t-test).

Results

In 1997, 24 houses were located within 500 m of Forested Hills (*fig. 3*). Residential construction associated with the new development began in 1998. By 2001, the number of houses within 500 m of the eastern edge of the forest had increased to 470 (*figs. 4-6*). The number of houses within 50 m of the forest increased from 5 in 1997 to 55 in 2001.

Point Count Data

There was no evidence of a difference ($P = 0.60$) or a trend ($P = 0.75$) on the relative abundance of Wood Thrushes between Forested Hills and the control sites (*fig. 7*).

Nesting Success, Productivity, Population Viability, and Adult Return Rates

Two hundred and thirty-nine Wood Thrush nests were monitored across the study sites from 1997-2001 (*table 1*). There was no significant difference ($\chi^2 = 0.268$, df = 1, $P = 0.604$) in nesting success between Forested Hills (51 percent, N = 102) and the control sites (47 percent, N = 137). Similarly, there was no significant difference ($\chi^2 = 2.83$, df = 1, $P > 0.701$) in parasitism rates between Forested Hills (34 percent) and the control sites (46 percent) for all five years combined.

Productivity at all of our study sites surpassed the source-sink threshold if we assumed optimistic survival rates for adults and juveniles (70 percent and 35 percent respectively; *fig. 8*). When we assumed conservative survival rates for adults and juveniles (58 percent and 29 percent respectively), Forested Hills but not the control sites surpassed the source-sink threshold. In either case, we detected no significant difference in fecundity levels between Forested Hills and the control sites.

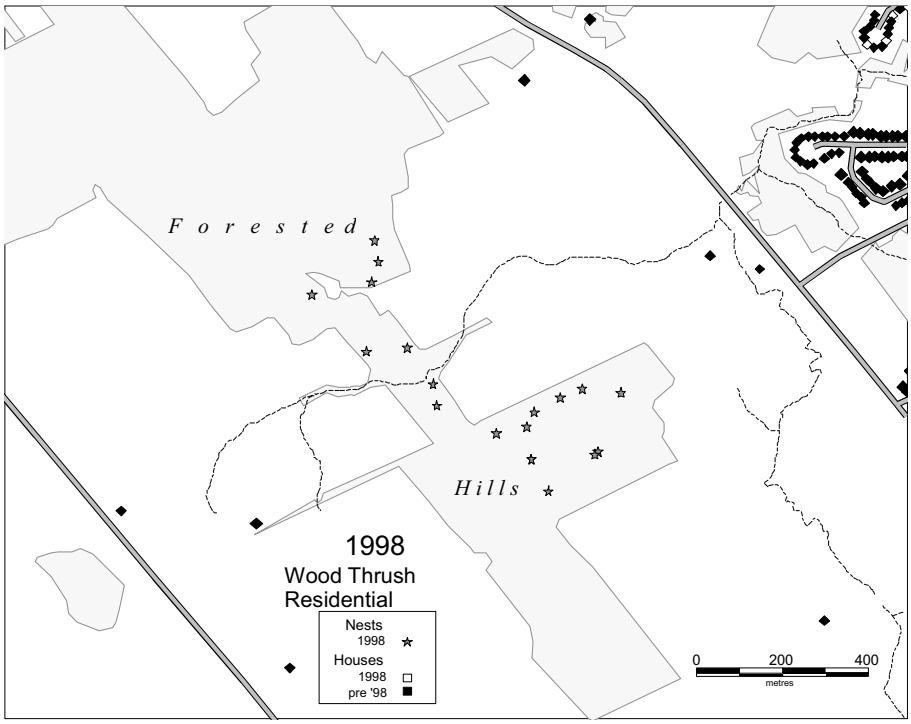

Figure 3— Location of nests and residential housing around Forested Hills in the Regional Municipality of Waterloo, Ontario, Canada.

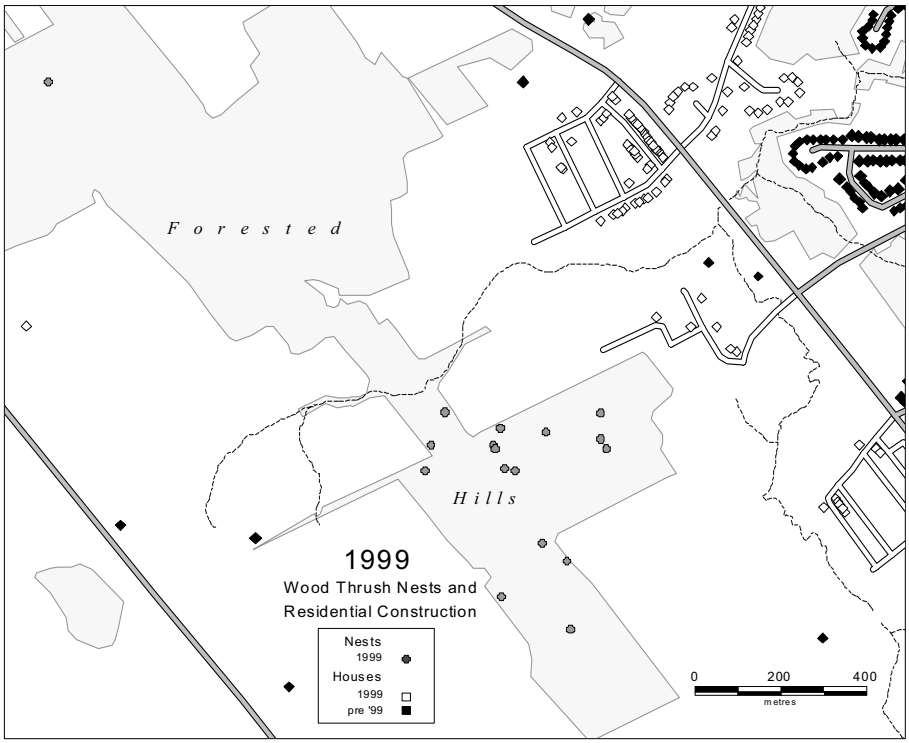

Figure 4— Location of nests and residential housing around Forested Hills in the Regional Municipality of Waterloo, Ontario, Canada.

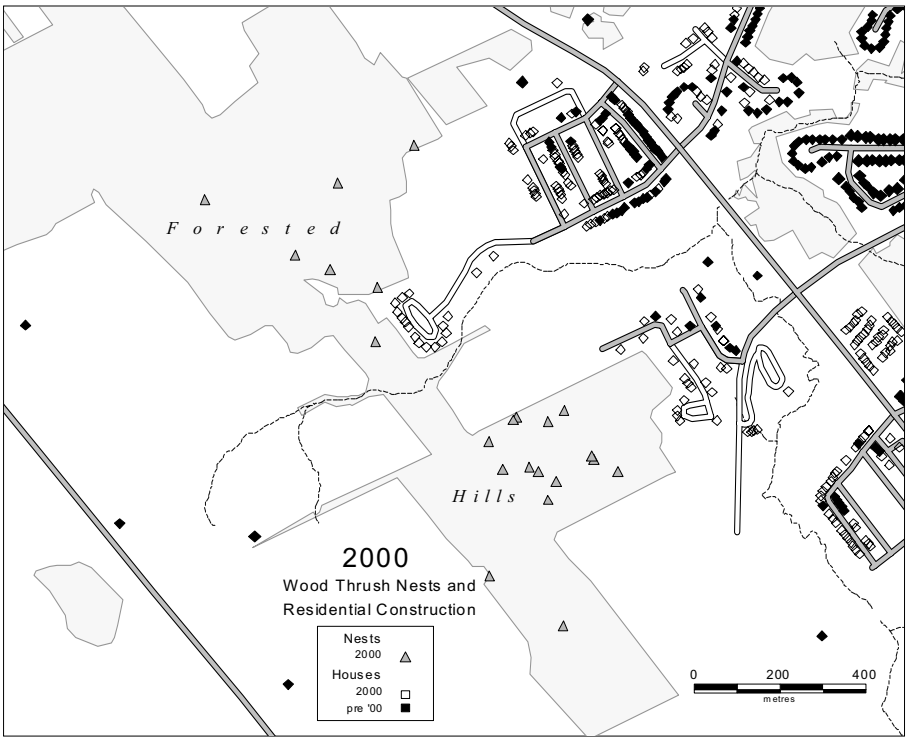

Figure 5— Location of nests and residential housing around Forested Hills in the Regional Municipality of Waterloo, Ontario, Canada.

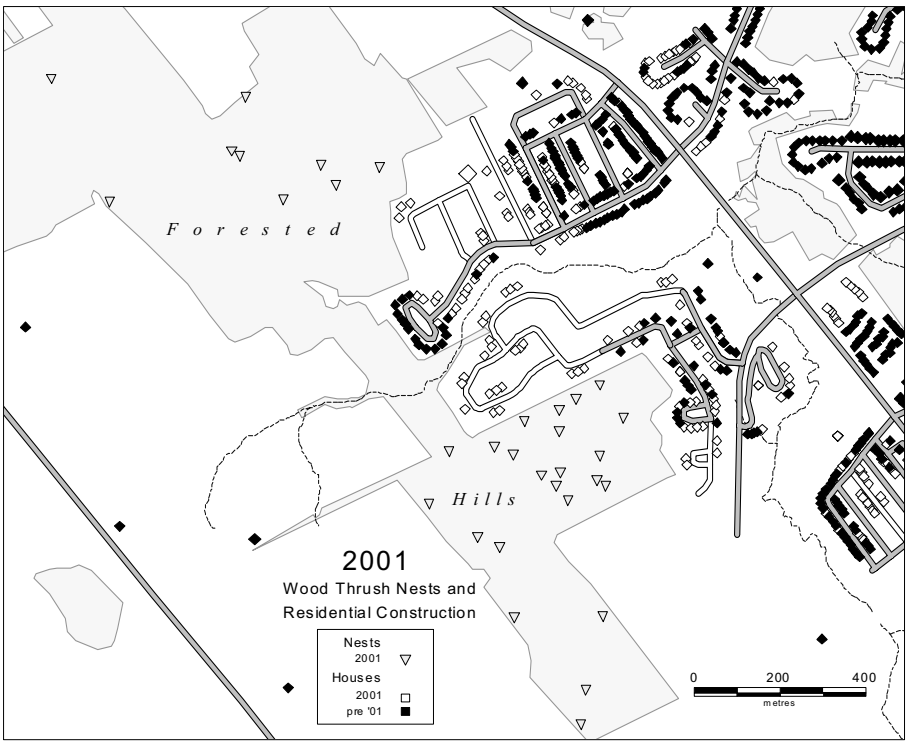

Figure 6— Location of nests and residential housing around Forested Hills in the Regional Municipality of Waterloo, Ontario, Canada.

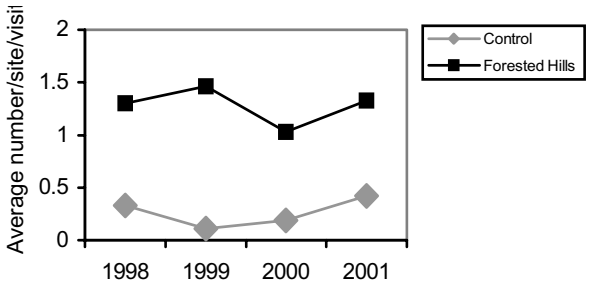

Figure 7— Average abundance of Wood Thrushes per point count station in Forested Hills and surrounding control sites in the Regional Municipality of Waterloo, Ontario, Canada.

Fifty-nine percent (N = 10) of the females and 31 percent (N = 5) of the males that were banded at Forested Hills in 2000 returned to that site in 2001. By comparison, 22 percent (N = 4) of the females and 35 percent (N = 6) of the males that were banded in the control sites in 2000 were recaptured or resighted in 2001.

Nest location

Eighty-two nests were available for spatial analysis; 27 were from Forested Hills and 55 made up a control group composed of the rural control sites as well as the first two years (predevelopment) of data from Forested Hills. Our analysis of the nest-to-nest movement of banded individuals did not detect any significant shift of nests away from the encroaching development ($t = 0.914$, $p = 0.360$).

Discussion

Considerable evidence exists to suggest that housing developments can have a profound ecological effect on adjacent forests. These effects include changes in vegetation structure (Matlack 1993) and bird composition (reviewed in Marzluff et al. 2001a). However, our results suggest that the anticipated impacts of development on the abundance of Wood Thrushes, and perhaps other Neotropical migrant species in adjacent woodlands, may not be an immediate effect but instead require years to manifest themselves.

Sometimes, when habitat is fragmented or the surrounding matrix is altered, there is a time lag during which populations initially show few, if any, ill effects but then decline, either in a sudden drop or gradually over a period of many years (Knick and Rotenberry 2000). Red-shouldered Hawks (*Buteo lineatus*), for example, were the most common Buteo species in Waterloo Region in the 1920s (Soper 1923), remained common in the 1940s (Knechetel 1945). They declined steadily thereafter (Weir 1987) and by the 1970s persisted only in small numbers although they still nested at that time in several urbanizing forests in the City of Waterloo (Craig Campbell, pers. comm.). By 1991, the hawk had disappeared from the region (Cheskey 1991). The relationship between bird species' presence and the age of urban habitat fragments has been noted for other habitat types. Soulè et al. (1988) observed that in chaparral habitat in southern California, species' loss was, in part, a function of fragment age; the longer a patch was isolated by urban development, the greater the species' loss until a new equilibrium was reached.

Table 1— *Nesting success and parasitism of Wood Thrushes in the Regional Municipality of Waterloo, Ontario, Canada*

Site	Year	Number of nests	Nesting success (%)[a]	Wood Thrush young[b]	Nest parasitism (%)
Forested Hills	1997	13	32	2.4	46
	1998	19	63	2.4	32
	1999	17	60	3.1	24
	2000	21	53	2.8	14
	2001	32	44	2.1	50
	All years	102	51	2.5	34
Control sites	1997	30	53	2.1	50
	1998	25	46	1.9	76
	1999	26	44	2.4	50
	2000	32	38	2.8	22
	2001	24	55	2.4	38
	All years	137	47	2.3	46

[a] Proportion of nests expected to fledge young based on the Mayfield (1975) estimate.
[b] Average number of Wood Thrush nestlings fledged from nests that produced at least one Wood Thrush and/or Brown-headed Cowbird.

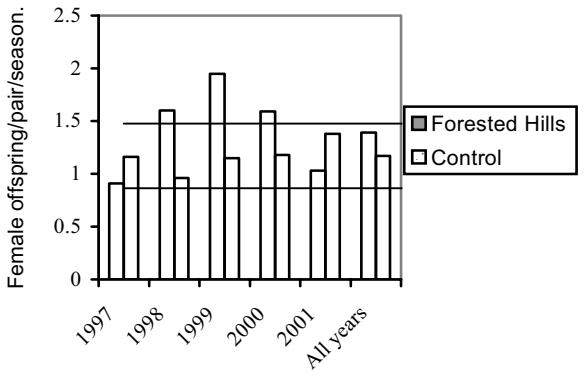

Figure 8— Annual female fledgling productivity of Wood Thrush pairs in Forested Hills and the control sites. Upper solid line is the level of productivity needed for a sustainable population, using the lowest estimated survival rates of adults and juveniles (58% and 29% respectively). Lower solid line is the level of productivity needed for a sustainable population using the highest estimated survival rates of adults and juveniles (70% and 35% respectively).

A higher abundance of potential nest predators in urban woodlots might explain why some bird species disappear or have lower densities near buildings (Kluza et al. 2000). Populations of raccoons (*Procyon lotor*), jays, crows, grackles, and squirrels can be substantially higher in suburban/urban areas than in rural areas (Riley et al. 1998; Haskell et al. 2001, Marzluff et al. 2001b). If predator abundance had increased in Forested Hills along with development, one might expect Wood Thrush nesting success to be lower there than in the rural control sites. However, nesting success was not significantly different in the urbanizing forest than at the other study sites, suggesting that the predator community, or at least its effect, was similar in all the areas.

The identity of these predators in our study area remains unknown, for despite regular nest monitoring, no act of nest predation has ever been witnessed. Raccoons, however, are frequently observed and were the only predator recorded at every site in an artificial nest/camera study conducted in 2001 (L. Friesen, unpubl. data). Few domestic cats have been sighted at any of our study sites. Cats have been identified as a predator whose effects are most pronounced in urban/suburban areas (Barratt 1998). Cats could directly influence Wood Thrush nesting success by killing adult birds during the breeding season (probably not a common occurrence in our study, given the low incidence of nest abandonment) and they would have difficulty accessing the nests themselves, which often are located in thin-stemmed saplings. Cats may become a more prominent presence at Forested Hills as housing density increases and if homeowners permit their pets to roam freely. At this point, raccoons and Blue Jays (*Cyanocitta cristata*) likely pose a far greater threat to Wood Thrush nests than cats owing to their higher abundance in the forest and their ability to access almost any nest they find.

Residential development around Forested Hills is still in its early stages and further monitoring is needed to better assess the impact of predators that exploit urban and suburban habitats. It may be that the availability of human refuse (i.e., compost heaps, garbage cans) and food from bird feeders subsidizes a suite of urban predators including raccoons, crows, grackles, and squirrels that in turn may increase pressures on nesting birds in nearby forests. On the other hand, it may be that potential nest predators alter their behavior in urban environments to the benefit of nesting birds, e.g., scavenging at compost heaps might draw potential predators, such as raccoons, away from songbird nests (Haskell et al. 2001). Ecologists have only recently begun to examine the relationship between potential urban predators and songbird nesting success (e.g., Mazluff et al. 2001b). What they have learned so far suggests that the relationship is complex and resistant to easy generalizations.

Contrary to our hypothesis, the mapped locations of nests at Forested Hills (*figs. 3 to 6*) suggested no obvious movement of nests away from the intensifying development over years. Any movement to this effect, if present, was too subtle for us to detect at this juncture.

Many of the banded birds in our study revealed high site tenacity between years, as evidenced by the 59 percent return rate for females at Forested Hills in 2001. Older birds may be compelled by habit and/or instinct to return to previous nesting sites, regardless of changes to the surrounding landscape. Potential immigrants, especially young birds, are not bound by such commitment and might reject a site such as Forested Hills for a less urbanized forest. If this were the case, then changes to the Wood Thrush community would become evident only after the original population disappeared through natural attrition, a process requiring 5 to 10 years. Once gone, new recruits might not replace the original population.

Acknowledgments

This project was generously supported by the Canadian Wildlife Service, Environment Canada, Ontario Region; the City of Waterloo, Ontario; the Environmental Conservation Branch, Environment Canada, Ontario Region; the Federation of Ontario Naturalists; Human Resources Development Canada, Ontario Region; the Science Horizons Youth Internship Program, Environment Canada, Ontario Region; and the Regional

Municipality of Waterloo. We are grateful to the landowners who permitted access to their lands and indebted to the many field assistants who participated in the project over the years. Special thanks to L. Campbell for help with preparation of this document, L. Munt for information on forest cover loss in York Region, and Craig Campbell for information on birds in Waterloo Region. We thank T. Rich, C. Hunter, D. Demarest, and an anonymous reviewer for their perceptive and constructive comments on the manuscript.

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Accommodating Birds in Managed Forests of North America: A Review of Bird-Forestry Relationships[1]

Rex Sallabanks[2] and Edward B. Arnett[3]

Abstract

Managed forests of North America provide important breeding and wintering habitat for many bird species. It is therefore essential that we understand all aspects of bird-forestry relationships if forest managers are to balance the needs of birds with timber harvest objectives. To help meet this need, here we provide a review of 116 research articles, dating from 1960 to 2002, which have examined bird-forestry relationships in managed forests across North America. We emphasize patterns in response of birds to silviculture, discuss how forestry practices might be used to enhance habitat for birds, synthesize management recommendations, and offer suggestions for future research. The majority of studies reviewed occurred in northeastern (27 percent) or northwestern (19 percent) North America. Clearcutting (72 percent of studies) has been examined more than any other silvicultural technique. Studies have primarily focused on breeding songbirds (67 percent) and have mostly collected data on relative avian abundance (65 percent); avian demographics (e.g., nest success or productivity) have rarely been studied (13 percent). The response of birds to forestry practices has been mixed and highly species-specific, but in general, net change in community richness following timber harvest was negligible. Among silvicultural practices, uneven-aged management (e.g., selection harvest) appears to be the most favorable for birds. In contrast, snag removal was highly deleterious, with >80 percent of studies reporting net species loss; net gain was never reported. Short-term effects (0–5 years) were more commonly found than no effect, with bird population decreases being reported more often than increases. In contrast, long-term effects (10+ years) were mostly negligible, but when effects were identified, they tended to be more beneficial than deleterious. Reports of severe deleterious effects were both rare and temporary. Causal mechanisms that might drive observed patterns between birds and forestry were deductively inferred in 72 percent of studies. Management recommendations were not made in the majority of cases (69 percent). Our review suggests that opportunities to enhance habitat for birds through forestry will vary from species to species. Management objectives, in addition to being compatible with ownership objectives, should be prioritized based upon those bird species that are sensitive to forestry and showing sharp declines. Future research on bird-forestry relationships needs to be more mechanistic, manipulative, and long-term. What is ultimately needed are resourceful ways to integrate stand- and landscape-level features created by forestry with those required by birds for sustained avian population health and viability.

Key words: causal mechanisms, cavity-nesting birds, community response, forest management, forestry practices, research needs, silviculture, songbirds, timber harvest

Introduction

North American forests provide important breeding and wintering habitat for many bird species (DeGraaf et al. 1991a, Rappole 1996). These forests are not only important to birds, but also provide wood products for an ever-expanding human population. Given increasing demands for such products, management of forests is inevitable and widespread. Approximately one-third of the U.S. land area is forested (298 million ha; Powell et al. 1993). Forests considered commercial timberlands capable of management for commodity extraction (henceforth "managed forests") comprise approximately 198 million ha, or two-thirds of all forest land in the U.S. Seventy-three percent (145 million ha) of these timberlands are privately owned and managed (116 million ha owned by non-industry landowners; 29 million ha owned by the forest products industry), while the remaining 27 percent are managed by public land-management agencies (Powell et al. 1993). Thus, it is crucial to understand bird responses to silviculture throughout managed forests of the U.S.

Research efforts to understand general relationships between forestry practices and bird populations have increased throughout the past quarter century (Sallabanks et al. 2000). These efforts have perhaps

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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been driven by reports of declines in some migratory songbird populations (e.g., Robbins et al. 1989, Peterjohn et al. 1995). Research on bird-forestry relationships may be especially critical considering that approximately one-third of all migratory bird species are forest-dependent during one or more phases of their life cycle (Rappole 1996). Furthermore, permanent resident species may be even more dependent on managed forests than many Neotropical migrants because of their year-round use of such habitat. Indeed, evidence suggests that permanent residents, as a group, may be more strongly influenced by forestry practices than migratory species (Hejl et al. 1995).

We conducted a continent-wide review of studies that have examined bird-forestry relationships in managed forests across North America. Sallabanks et al. (2000) provided an evaluation of research on the effects of timber harvest on bird populations that focused on the kind of research that has been conducted, a critical assessment of its effectiveness, and suggested future directions. Here, we also characterize the nature of such studies (e.g., where conducted, in what habitats, which silvicultural techniques, and experimental design), but focus more on the response of birds to silviculture, examine relationships between birds and habitat features created by forestry, and synthesize management recommendations. Our review summarizes previous research, identifies key findings and trends, presents some unifying principles, and highlights information gaps and future research needs. Finally, we discuss how forestry practices might be used to enhance habitat for birds and offer suggestions on how avian conservation and timber production might become more complimentary.

Methods

We used two techniques to identify as many studies as possible that addressed relationships between forestry practices and bird populations in North America: (1) an extensive literature search which provided published studies in refereed scientific journals, USDA Forest Service publications (e.g., General Technical Reports, Research Papers, and Research Notes), and symposium proceedings; and (2) a letter sent to 23 forest products companies requesting reprints, submitted manuscripts, annual reports, and study proposals which yielded information on past studies, as well as those that were still ongoing or even planned for the near future. To be included in our review, studies must have been conducted within North America (48 contiguous United States, Alaska, Canada, and Mexico) and specifically address relationships between silvicultural practices and birds. University dissertations and theses were not considered. We did not include studies of forest fragmentation, patch size, or edge effects unless recent (last 25–30 years) silvicultural techniques were involved and well described (e.g., Schmiegelow et al. 1997). These topics have been recently reviewed elsewhere (e.g., Paton 1994, Faaborg et al. 1998). Neither did we include studies that described general bird-habitat relationships or behavior (e.g., foraging; Conner and Crawford 1974, Franzreb 1983), even if conducted in managed forests, unless direct references to forestry were discussed or implied. Modeling efforts that described simulated responses of birds to forestry practices also were omitted (e.g., Hansen et al. 1993, 1995a; Thompson 1993).

Our objective was to focus primarily on common breeding birds, especially passerines and cavity-nesters. We excluded studies of species listed as Threatened or Endangered, such as the Northern Spotted Owl (*Strix occidentalis*; Irwin et al. 1991, Meyer et al. 1998), Marbled Murrelet (*Brachyramphus marmoratus*; Courtney 1995, Nelson and Sealy 1995, Ralph et al. 1995), Northern Goshawk (*Accipiter gentilis*; Crocker-Bedford 1990, Finn et al. 1997), and Red-cockaded Woodpecker (*Picoides borealis*; Wood et al. 1985, Conner and Rudolph 1991; Conner et al. 1991, 1995). Finally, although they are silvicultural practices, we did not include studies of regeneration, site preparation, or animal damage control in our review. Instead, we chose to focus on those silvicultural techniques that involve manipulation of stand density and distribution. Studies of birds that involve forestry practices other than tree removal are rare (e.g., effects of herbicide and fertilizer treatments; see McComb and Rumsey 1983, Thiel 1987) and we urge that more focus be put on this important topic in the future.

All articles in our review were first classified by each of 22 study criteria and "scored" using a variety of classification "fields" (*table 1*). In most cases, the appropriate classification field was gleaned directly from the article being reviewed; in others, a simple reanalysis of available data was required, such as when calculating overall avian community response (*table 1*, *criteria no. 14*) if this had not been done by the original author(s). Usually, only one classification field could be listed per review criterion (e.g., the study was conducted in the northwest, but not in the northwest and the southeast). In some cases, however, multiple classification fields could be applied to the same study (e.g., studies that examined a variety of silvicultural techniques); in such cases, all fields that were appropriate were included in our analyses (see *Appendix 1* for a summary of field scores for all studies included in our review).

Table 1—*List of criteria used to classify literature on the effects of forestry practices on bird populations in managed forests of North America.*

No.	Review criteria	Classification fields
1	Geographical region of study	north (AB, MI, MN, NS, ON, WI); northwest (AK, BC, ID, MT, OR, WA); west (CA, CO, UT, WY); southwest (AZ); south (AR, TX); southeast (AL, FL, NC, SC); east (KY, MD, VA, WV); northeast (MA, ME, NH, NY, PA, PQ, VT); Midwest (MO)
2	Forest habitat	coniferous; hardwood; mixed coniferous-hardwood
3	Silvicultural prescription[1]	clearcut; group selection; shelterwood; single-tree selection; (pre)commercial thin; snag removal/retention; salvage logging
4	Prescription category	even-aged; uneven-aged; snag removal
5	Spatial scale of study	edge; stand; landscape/watershed
6	Study duration	number of years study was conducted (field seasons of data)
7	Pre-/post-treatment data	yes; no
8	Degree of replication	mean number of replicate experimental units per silvicultural treatment
9	Type of study	mensurative (i.e., observational/correlative); manipulative experiment
10	Bird species or nest type studied	breeding birds; wintering birds; year-round birds; cavity nesters; single species; real nest success; artificial nest predation
11	Data type collected	relative abundance; density; demographics (e.g., nest success, mist-netting, artificial nest studies)
12	Effects on avian abundance[2]	abundance increased; abundance decreased; no effect (no difference/change); mixed (e.g., breeding bird patterns ≠ winter bird patterns or relationships changed over time)
13	Effects on species richness ("richness" defined as number of species)[2]	richness increased; richness decreased; no effect (no difference/change); mixed (e.g., breeding bird patterns ≠ winter bird patterns or relationships changed over time)
14	Overall community response[2]	the number of species that increased in abundance > those that decreased; the number of species that increased in abundance < those that decreased; the number of species that increased in abundance = those that decreased
15	Effects on nest survival[2]	nest success increased; nest success decreased; no effect (no difference/change)
16	General effects of forestry[3]	minor; moderate; major
17	Short-term (0–5 years) effects[2]	increase in parameter measured (i.e., avian abundance, species richness, or nest success); decrease in parameter measured; no effect (no difference/change)
18	Long-term (10+ years) effects[2]	increase in parameter measured (i.e., avian abundance, species richness, or nest success); decrease in parameter measured; no effect (no difference/change)
19	Causal mechanisms identified	none; habitat features (e.g., snag density, understory structure, canopy cover); predators; food resources; physical features; landscape features
20	Vegetation data collected	yes; no
21	Bird-habitat relationships	yes; no
22	Management recommendations made	none; specific recommendations (e.g., leave snags, maintain light overstory, incorporate old growth features)

[1] "Single-tree selection" included "selective logging" and "best management practice cuts"; "(pre)commercial thinning" included "overstory removal", "understory removal", and "two-age" or "two-story cutting". All other types of silviculture were as listed.

[2] Results include scores for only those studies where these criteria were applicable and/or analyzed.

[3] The general effects of forestry practices were determined by interpreting the magnitude of effects reported in each article, relative to all other articles included in the review (e.g., based upon the number of species responding to silvicultural treatments); this particular criterion is therefore a subjective, qualitative, and relative measure.

Results

Studies on Forestry Practices and Bird Populations

We reviewed 116 research articles dating from 1960–2002 that addressed effects of forestry practices on bird populations (*Appendix 1*). Studies were conducted throughout North America, but almost half occurred in either the northeast or the northwest (northeast, 27 percent [*n* = 31]; northwest, 19 percent [n = 22]; southeast, 11 percent [n = 13]; north, 10 percent [n = 12]; southwest, 9 percent [n = 10]; east, 9 percent [n = 10]; west, 9 percent [n = 10]; south, 4 percent [n = 5]; Midwest, 2 percent [n = 2]). Effects of management in coniferous forest (39 percent [*n* = 45]) have been studied more frequently than in hardwoods (32 percent [n = 37]) or mixed coniferous-hardwood forest (29 percent [n = 34]). The most common silvicultural system studied has been clearcutting, with 84 (54 percent) studies reviewed having some component that examined this particular method of timber harvest. Other silvicultural practices that have been examined include commercial thinning (21 percent [n = 33]), single-tree selection (11 percent [n = 17]), snag management (6 percent [n = 10]), group selection (5 percent [n = 7]), shelterwood cuts (2 percent [n = 3]), and salvage logging (1 percent [n = 1]). The spatial scale of studies was typically small, either being limited to the stand level (87 percent, n = 106) or forest edges (5 percent, n = 6). Landscape-level studies, where effects of forestry were examined at larger scales (e.g., watersheds), were rare (8 percent, n = 10), and have occurred relatively recently (all 10 studies were published since 1995).

Studies on bird-forestry relationships typically have lasted 1–2 years (expressed as the number of field seasons in which data were collected; for all studies, mean ± 1 SE = 2.35 ± 0.14); only six studies (5 percent) in our review reported data collected in more than four field seasons. The majority of studies were retrospective (i.e., data were not collected prior to timber harvest; 78 percent, n = 91); pre- and post-treatment comparisons were therefore limited (22 percent, n = 25). Replication of experimental units was low. Most studies (26 percent, n = 30) had only one replicate per treatment (for all studies, mean ± 1 SE = 5.55 ± 1.49). All studies in our review were mensurative (observational or correlational); none incorporated a manipulative experimental design where treatments were randomly assigned to experimental units (Hurlbert 1984).

With respect to which species of bird were typically studied, breeding birds (primarily songbirds) were the norm (67 percent [n = 80]). Others included year-round residents (13 percent [n = 15]), artificial nests (7 percent [n = 8]), real nest success (4 percent [5]), cavity nesters (4 percent [5]), single species (3 percent [n = 3]), and wintering birds (2 percent [n = 2]). Finally, the majority of studies on bird-forestry relationships collected data on relative avian abundance (primarily using point counts; 65 percent, n = 78), rather than density estimates (primarily from spot-mapping; 22 percent, n = 27) or demographics such as nest success, rates of nest depredation, or productivity (primarily from nest monitoring, artificial nest experiments, or mist-netting; 13 percent, n = 16).

Effects of Forestry Practices on Birds

Avian Abundance

Seventy-nine percent (n = 92) of studies provided data that allowed us to classify them with respect to effects of forestry practices on avian abundance (typically measured as relative abundance or density, but basically reflecting numbers of individual birds). In general, all forestry practices considered together tended to result in more decreases in avian abundance (32 percent, *n* = 29 studies) than increases (24 percent, n = 22 studies). Twenty-six percent (n = 24) of studies found no changes in abundance; eighteen percent (n = 17) of studies found "mixed effects" (e.g., abundance increased for breeding birds, but decreased for wintering birds). When the silvicultural method being studied was snag removal (n = 5), decreases in abundance always were reported.

Species Richness and Compositional Changes

Seventy-four percent of studies (n = 86) reported changes in species richness (numbers of species) in response to forestry practices. Richness decreased in 33 percent (n = 28) of studies, increased in 27 percent (n = 23), and remained unchanged in 26 percent (n = 22). In 15 percent of studies (n = 13), response of species richness to forestry practices was mixed (i.e., breeding bird responses differed from wintering bird responses and/or responses changed over time). Overall avian community response (number of species increasing in abundance vs. number decreasing) to forestry practices was determined for 78 percent (n = 91) of studies. Although 43 percent (n = 39) of studies found more species decreased than increased, an equal number (42 percent, n = 38) found more species increased than decreased; 15 percent (n = 14) found the number of species increased to be equal to the number decreased. When analyzed with respect to silvicultural method, overall community response was negligible for even-aged management, more species increased than decreased for uneven-aged management, and many more species decreased than increased for snag removal.

Nesting Success

Relationships between nest success (or predation rate) and forestry could be assessed for 14 of 16 studies that collected demographic data. In response to forestry, reduced rates of nest success were more commonly reported (42 percent, n = 6) than increased rates (29 percent, n = 4) or no effects (29 percent, n = 4). Approximately half of the studies that examined nest success did so using artificial nest experiments which have been criticized in the scientific literature (see Discussion). With respect to responses to forest practices, however, results from artificial nest experiments were qualitatively the same as those from studies of real nests.

Magnitude of Effects

General effects of forestry practices were determined by interpreting the magnitude of effects reported in each article, relative to all other articles included in our review; this particular criterion is therefore a subjective, qualitative, and relative measure. If, for example, relatively few species were affected, or changes in avian abundance, richness, community composition, or nest success were relatively minimal, general effects of forestry were scored as being "minor." If, on the other hand, relatively large numbers of species were affected or changes were relatively severe (e.g., some species disappeared altogether), general effects were scored as "major", and so on. In this way, we found most studies to report "moderate" (48 percent, n = 56) to "minor" (44 percent, n = 51) effects; "major" effects were rarely reported (8 percent, n = 9). For nine studies classified as having "major" effects, most (n = 6) documented decreases in the avian population parameter being measured; half of these (n = 3) were in relation to intermediate cutting prescriptions (again, snag removal *per se*).

Duration of Effects

Short-term (0–5 years) vs. long-term (10+ years) effects of forestry practices on bird populations were assessed for 38 percent (n = 44) of studies; some examined short- or long-term effects, and some both. The majority of these results are based on reported changes in bird abundance and species richness (only four studies of nest success addressed short- vs. long-term effects). Short-term effects were found more commonly than no effect, with population decreases ("deleterious" effects; 50 percent, n = 23) being reported more often than increases ("beneficial" effects; 33 percent, n = 18). In contrast, long-term effects were mostly negligible (62 percent, n = 23), but when effects were identified, they were more beneficial (24 percent, n = 9) than deleterious (14 percent, n = 5).

Mechanisms Driving Bird-Forestry Relationships

Causal mechanisms (proximate factors) that might drive observed relationships between birds and forestry were deductively inferred in 72 percent (n = 84) of studies included in our review. Proximate factors (e.g., habitat structures) are assumed to lead to changes in ultimate factors (e.g., nest site or food availability) that can directly influence population viability of birds. Habitat structure, such as understory cover or tree stocking density, do not directly affect avian productivity (i.e., number of young produced per nest) and are therefore considered proximate factors or mechanisms. On the other hand, predator density and food availability, which may be driven by habitat structure, clearly have the potential to directly influence avian fitness and are therefore considered ultimate factors or mechanisms. Ultimate factors are rarely discussed in studies of bird-forestry relationships. In our review, the most frequently suggested proximate mechanism for bird responses to forestry was change in habitat structure (53 percent, n = 64). Of those studies that did list habitat structure as the reason for changes or responses of birds to forestry practices, 42 percent (n = 27) did not give measured details on specific variables. Of those that did, snag density (18 percent, n = 16), understory structure (16 percent, n = 15), and canopy cover (9 percent, n = 8) ranked highly. Many studies (60 percent, n = 70) did collect data on habitat characteristics, yet only a subset of these (22 percent, n = 25) used the data to interpret bird-forestry relationships.

Management Recommendations

Specific management recommendations were not reported in the majority of cases (69 percent, n = 80). When management recommendations were suggested, they were highly variable and case-specific. The most common recommendations were to leave and/or create snags (24 percent, n = 15), leave uncut reserves and maintain residual old growth clumps (13 percent, n = 8), incorporate features of old growth forest into younger stands (8 percent, n = 5), enhance vegetative diversity (especially in the understory) by creating light gaps (8 percent, n = 5), and retain large contiguous forest tracts with few openings (i.e., minimize forest fragmentation; 8 percent, n = 5).

Discussion

Much has been learned about relationships between birds and forestry since research began on this subject almost four decades ago with the work of Hagar (1960). Studies have occurred in all major forest types (coniferous, hardwoods, and mixed coniferous-hard-

wood), and most efforts have focused in the northeastern and northwestern regions of North America. Overwhelmingly, effects of clearcut harvesting on birds have been studied more than any other form of forest management. Moreover, these studies have been short-term and conducted at the stand level. Historically, clearcutting has been the predominant method by which to harvest timber. Whereas the current trend is a decline in use of clearcut harvesting on federal lands (G. Lettman, Oregon Dept. Forestry, pers. comm.), this silvicultural practice will likely continue to be very important on private lands, which comprise the bulk of managed forest in the U. S. (Powell et al. 1993). To continue conducting research that is of highest relevance to forest managers, it is important to consider which silvicultural techniques are currently being practiced when designing research projects. One way to ensure that experimental treatments being studied will have relevance to current forest management is to include managers during development of research projects (Finch and Patton-Mallory 1993, Arnett and Sallabanks 1998).

Effects of Forestry Practices on Bird Populations

Combining results from all studies (i.e., disregarding the silvicultural prescription examined), effects of forestry practices on birds have been very mixed, but generally have resulted in few net changes in either avian abundance (number of birds) or species richness (number of species). Approximately one-quarter of studies report no response. Because most silvicultural treatments will benefit some species and not others, management for high avian "biodiversity" may be a hollow goal (Hansen et al. 1995b). Thus, it seems prudent that management objectives to enhance habitat for birds should be specific and driven by the highest priority species in the region. Partners in Flight (PIF) priority species scores (Carter et al. 2000) could possibly be used to identify focal species. To facilitate their implementation, avian conservation strategies should consider perspectives and management objectives of private landowners as well as public land-management agencies.

Effects of forestry on birds therefore appear to be more meaningfully evaluated if done at the species level rather than the community level. Without exception, all studies included in our review reported mixed results with respect to individual species' responses: some birds either increased post-harvest or were more abundant in logged habitat, others either decreased post-harvest or were less abundant in logged habitat, while still others were unaffected. The magnitude and direction of these relationships varied across studies, even within species, often depending upon the forestry practices employed, region and habitats examined, duration, and season of study. In order to summarize these relationships, the number of species increasing was compared to the number decreasing for all possible studies. The results were almost identical and suggest that for every species negatively impacted by forestry, one is positively impacted, and vice versa. This result further emphasizes the need for species-specific management strategies in combination with general efforts to improve forest habitat for all birds. In addition, these results suggest that a variety of habitats, or a wide range of variation in key habitat structures, is necessary to support entire bird communities. Our review also demonstrated that effects at one spatial scale can be quite different from those at another. Thus, while stand-level abundance can decrease for a species, forest managers actually might have opportunities to increase abundance for that species at a larger spatial scale.

Although our review indicates that no forestry technique will benefit all species, uneven-aged management practices (i.e., single- and group-tree selection) did result in a greater number of species showing population increases than decreases, as compared with even-aged prescriptions such as clearcutting and shelterwood cuts. What seems to be particularly detrimental to forest avifauna is removal of snags. When prescriptions involved manipulation of snag densities, either by removing (Kilgore 1971, Scott 1979, Dingledine and Haufler 1983, Scott and Oldemeyer 1983, Schreiber and deCalesta 1992), retaining (Dickson et al. 1983, Zarnowitz and Manuwal 1985, Stribling et al. 1990, Schreiber and deCalesta 1992, Welsh et al. 1992), or creating (McPeek et al. 1987) snags, bird numbers were typically found to be positively correlated with snag density. Unlike even-aged and uneven-aged management practices, removal of snags never resulted in more species increasing in abundance than decreasing. The importance of snags to birds is well-known (Davis et al. 1983 and references therein, Bull et al. 1997, references above), not only to cavity nesters, but also songbirds (Sallabanks et al. 2002) that may use snags for nesting, perching, foraging, singing, and scanning for predators.

Effects of Forestry Practices on Bird Species

Species-specific responses to forestry are obviously highly variable and difficult to summarize given the broad geographical range of studies included in our review. Using representative studies, however, here we offer some generalizations about which species exhibited significant responses to a variety of silvicultural techniques. In Maine, for example, Derleth et al.

(1989) found the White-throated Sparrow (*Zonotrichia albicollis*), Common Yellowthroat (*Geothylpis trichas*), American Robin (*Turdus migratorius*), and Common Grackle (*Quiscalus quiscula*) to be more abundant in clearcut areas than the surrounding forest edge. These are species well-known to use patchy or early successional habitat (see also Webb et al. 1977 and Titterington et al. 1979). The Red-breasted Nuthatch (*Sitta canadensis*) and Cape May Warbler (*Dendroica tigrina*) were two species found to be intolerant of forest openings and adjacent forest edges in Maine (Derleth et al. 1989). Like Townsend's Warbler (*Dendroica townsendi*) in the west (Sallabanks et al. 2002), these species appear to favor dense forest stands with closed canopies.

In response to fuelwood cutting in southern New England, the Ovenbird (*Seiurus aurocapillus*), Hermit Thrush (*Catharus guttatus*), and Wood Thrush (*Hylocichla mustelina*) decreased in number (Chadwick et al. 1986). More species were found in cut stands than uncut stands, however, and included the Spotted Towhee (*Pipilo erythrophthalmus*), Common Yellowthroat, Blue Jay (*Cyanocitta cristata*), Black-and-white Warbler (*Mniotilta varia*), and Chestnut-sided Warbler (*Dendroica pensylvanica*). Bird communities of uncut stands were dominated by species that prefer mature, closed-canopy forests and by cavity nesters (Chadwick et al. 1986).

In the southwest, Szaro and Balda (1979) found species such as the White-breasted Nuthatch (*Sitta carolinensis*), Grace's Warbler (*Dendroica graciae*), Chipping Sparrow (*Spizella passerina*), Broad-tailed Hummingbird (*Selasphorus platycercus*), and Western Bluebird (*Sialia mexicana*) to have their highest population densities in treated plots, indicating density increases in response to openness. In contrast, numbers of Red-faced Warbler (*Cardellina rubrifrons*), Pygmy Nuthatch (*Sitta pygmaea*), Cordilleran Flycatcher (*Empidonax occidentalis*), Violet-green Swallow (*Tachycineta thalassina*), and Black-headed Grosbeak (*Pheucticus melanocephalus*) were significantly reduced as intensity of timber harvest increased (e.g., heavily thinned and clearcut treatments).

In the Douglas-fir (*Pseudostuga menziesii*) region of northwestern California, Hagar (1960) found the following seed-eating birds to increase in number in response to clearcutting: Dark-eyed Junco (*Junco hyemalis oreganus*), Spotted Towhee, Mountain Quail (*Oreortyx pictus*), Golden-crowned Sparrow (*Zonotrichia atricapilla*), and Fox Sparrow (*Passerella iliaca*). Edges were used by the Red-breasted Nuthatch and Chestnut-backed Chickadee (*Parus rufescens*) although these species responded negatively to cutting practices in general. Other species found to have lower abundance in "cutovers" compared with old growth forest included the Hermit Thrush, Golden-crowned Kinglet (*Regulus satrapa*), and Pileated Woodpecker (*Dryocopus pileatus*).

Several studies that specifically addressed snag manipulations identified several cavity-nesting birds that had lower numbers in areas without snags. In Arizona, these included the Northern Flicker (*Colaptes auratus*), Violet-green Swallow, and Pygmy Nuthatch (Scott 1979, Scott and Oldemeyer 1983); in Texas, these included the Great Crested Flycatcher (*Myiarchus crinitus*), Red-headed Woodpecker (*Melanerpes erythrocephalus*), Downy Woodpecker (*Picoides pubescens*), Red-bellied Woodpecker (*Melanerpes carolinus*), Hairy Woodpecker (*Picoides villosus*), and Carolina Chickadee (*Parus carolinensis*) (Dickson et al. 1983). Clearly, dependency of cavity nesters on snags is one reason why silvicultural methods that include prescriptions for snag removal have more profound effects on birds than others that do not target snags *per se*.

Due to the high degree of species-specific variability in relationships with forestry, guild-level responses (although variable themselves) may be a more useful way to summarize which species are likely to benefit and which are not. Among foraging guilds, for example, granivorous and ground-gleaning species are likely to benefit from forestry practices because of the general increase in ground cover and associated food resources (Franzreb and Ohmart 1978, Szaro and Balda 1979, Maurer et al. 1981, Blake 1982, DeGraaf et al. 1991b, Tobalske et al. 1991). Aerial feeders also may benefit due to an increased ability to maneuver beneath forest canopies (Franzreb and Ohmart 1978, Szaro and Balda 1979; but see Maurer et al. 1981, Scott et al. 1982). Foliage- and timber-gleaners are likely to be the most adversely affected by forestry, presumably due to a reduction in foraging substrates (leaves and bark, respectively) and therefore fewer insects (Franzreb and Ohmart 1978, Maurer et al. 1981, Scott et al. 1982, Medin 1985, Medin and Booth 1989, Tobalske et al. 1991, Probst et al. 1992; but see Szaro and Balda 1979, McPeek et al. 1987, Norton and Hannon 1997).

Analyses of nesting guilds clearly show cavity nesters to respond negatively to logging, especially snag removal (Scott 1979, Szaro and Balda 1979, Scott and Oldemeyer 1983, Medin 1985, Zarnowitz and Manuwal 1985, Medin and Booth 1989, Johnson and Brown 1990, Greenberg et al. 1995; but see McComb et al. 1989, Welsh et al. 1992). Shrub nesting species are more likely to benefit from forestry practices that create light gaps, open up the overstory, and promote development of the herbaceous layer (Hallock 1989–1990; but see Norton and Hannon 1997). Results for ground (Medin 1985, Hallock 1989–1990, Tobalske et

al. 1991, Norton and Hannon 1997) and canopy (Szaro and Balda 1979, Greenberg et al. 1995, Norton and Hannon 1997) nesters appear to vary with management intensity.

Effects of Forestry Practices on Avian Reproductive Success

Forestry practices appear to have a greater impact on bird populations when nest success is considered rather than relative avian abundance or density. All studies (n = 16) of nest success included, at least in part, an examination of effects of clearcut harvesting. Because few nest studies have been conducted, however, our synthesis of results from this research should be treated cautiously. Moreover, half (n = 8) of the "nest success" studies included in our analyses were studies of artificial nests rather than real nests (Yahner and Scott 1988, Yahner et al. 1989, DeGraaf and Angelstam 1993, Rudnicky and Hunter 1993, DeGraaf 1995, Yahner and Mahan 1996a, Darveau et al. 1997, and Manolis et al. 2000). Results from such studies, while certainly of high utility, may not reflect true rates of nest success and may provide misleading information with respect to predation rates and predator identification for several reasons (Wilson et al. 1998). For example, artificial nests lack parental defense of eggs and young. Moreover, all of the above eight studies used either chicken, Common Quail (*Coturnix coturnix*), or Northern Bobwhite (*Colinus virginianus*) eggs in their artificial nest experiments. Use of large, artificial eggs has been criticized because they may be too large for certain nest predators (small mammals such as mice, squirrels, and chipmunks) to handle (Reitsma et al. 1990; Roper 1992; Haskell 1995a, 1995b; DeGraaf and Maier 1996; Yahner and Mahan 1996b).

In future research on this important topic, we encourage use of smaller eggs, such as those of the House Sparrow (*Passer domesticus*), that more realistically mimic egg size of ground and low-shrub nesting songbirds. Of eight artificial nest studies conducted, four found nest success to be lower in harvested plots (Yahner and Scott 1988, Yahner and Mahan 1996a, Darveau et al. 1997, Manolis et al. 2000), and three found negligible differences (Yahner et al. 1989, DeGraaf and Angelstam 1993, DeGraaf 1995). The only exception was the study of Rudnicky and Hunter (1993), who found success rates to be lower for nests placed in the forest compared with those placed in young, regenerating stands that were clearcut harvested 3–10 years prior to data collection.

When real nests were monitored, impacts of forestry practices on nest success were again found to be variable. Barber et al. (2001) found that only three of nine species differed with respect to nesting success among silvicultural treatments in managed forests of the Ouachita Mountains, central Arkansas. In general, many species had nest success rates equal to or greater than those in previously published studies (most of which had occurred in unmanaged forests). Barber et al. (2001) found nesting success to be lowest in thinned stands (3–7 years post-thinned; 17–23 years old) for most nesting guilds due to high predation rates. This result could potentially be due to an abundant understory, which might support mammalian and reptilian predators. Thinned stands also had been pruned of lower limbs, therefore resulting in copious open space between the understory and the bottom of tree crowns. This could potentially have aided avian predators in their hunting and/or Brown-headed Cowbirds (*Molothrus ater*) in their searching.

Similar to Barber et al. (2001), Manolis et al. (2000) found thinned, even-aged, regenerating stands (mean age = 11.3 years) had greater nest predation rates. While Duguay et al. (2000) also found nest success to be higher in unharvested forest stands, no differences were found between clearcut (even-aged, regenerating stands, approximately 15 years old) and two-age (deferment) harvesting prescriptions. King et al. (2001) found no differences between clearcut and group selection prescriptions, but did report high survival rates in plots that had been clearcut harvested (4–5 years prior to data collection). In Oregon, Arnett et al. (2001) found that nest success in general was similar in salvage-logged stands of lodgepole pine (*Pinus contorta*) compared to unmanaged stands. Finally, Yahner (1991) found nest success to be independent of stand age (time since clearcut) and distance from clearcut edge.

Differences between results of studies relying upon artificial nest experiments and those monitoring real nests may exist if predator assemblages between harvested and unharvested forest also differ. If for example, relative to numbers of avian predators, small mammals (e.g., squirrels) are more abundant in forested habitats than regenerating stands, artificial nest experiments may find higher predation rates in the latter and erroneously conclude that clearcutting is deleterious with respect to songbird populations. Clearly, more studies of effects of forestry practices on avian reproductive success and population viability are needed.

Mechanistic Relationships

To improve habitat for birds via forestry requires that we understand why a factor (e.g., overstory removal) causes a response (e.g., change in avian nest success); such processes are determined by mechanistic relationships (Marzluff et al. 2000). There are both prox-

imate and ultimate mechanisms that may drive changes in bird populations responding to forestry practices and distinguishing between these two is important for making accurate management recommendations. Nest-site availability (Martin 1993a, 1993b, 1995) and food availability (Martin 1987, 1995) are two ultimate mechanisms influencing health and viability of bird populations. Both of these forces will be driven by proximate mechanisms, such as changes in forest structure and/or landscape composition. Timber harvest will change forest stand structure in specific ways (e.g., reduction of overstory, reduction in total basal area, changes in stand structural heterogeneity, short-term reduction of understory vegetation, and long-term increase in understory vegetation) that may influence availability of safe nest sites for songbirds and/or cause changes in resident insect populations (the primary food for forest-breeding bird species; see Duguay et al. 2000). Changes in nest-site availability may lead to changes in nest predation rates and, therefore, avian fitness. Similarly, changes in insect populations may drive concurrent avian fitness changes if food availability is a more important mechanism than safe nest-site availability in determining nest success (e.g., Burke and Nol 1998, Robinson 1998). In many cases, it may be difficult to identify factors or mechanisms directly influencing effects of forestry on bird populations. Numerous studies, for example, have found correlations between seral stage and avian abundance or species richness, and then used these relationships to discuss causal effects. Unfortunately, cause and correlation are not the same thing, and indirect factors apparently influencing bird populations have limited use, especially when making predictive statements about effects of a proposed harvest prescription.

Unless direct mechanisms (both proximate and ultimate) are identified, causal relationships cannot be understood and management recommendations will be severely limited (Marzluff et al. 2000). Our review indicated that potential mechanisms were deductively inferred in most cases (72 percent), but many constituted general statements about habitat structure (27 out of 64 articles). Specific habitat features were not described in many cases, which again offers little to forest managers. When specific structural characteristics were mentioned, snag density and features of the understory were most frequently cited. We remain somewhat perplexed as to why most researchers took time to collect habitat data (60 percent), but then rarely (22 percent) used them to better interpret bird-habitat relationships.

In only a few cases were specific bird-habitat relationships modeled using statistical procedures such as multiple regression (e.g., Titterington et al. 1979; Monthey 1983; Yahner 1986, 1987a; Hagar et al. 1996; Karriker 1996; Rogers et al. 1996). Such models are useful for identifying specific causal mechanisms and developing subsequent management guidelines. It is important to note that numerous studies that were not included in this review, because they were primarily concerned with describing bird-habitat relationships and not effects of forestry practices *per se*, also provide information which is highly pertinent to this discussion (e.g., Conner et al. 1975, Crawford et al. 1981, Kerlinger and Doremus 1981, Briggs et al. 1982, Niemi and Hanowski 1984, DeGraaf and Chadwick 1987, Dessecker and Yahner 1987, Yahner 1987b, Raphael 1991, Adams and Morrison 1993, Hansen et al. 1995b, and Bosakowski 1997).

Opportunities for Creating Habitat for Birds

Forest management practices and changing land-use patterns have reduced the abundance, distribution, and recruitment of snags in managed forests in several regions of the U.S. (e.g., Thomas et al. 1979, Cline et al. 1980, McComb et al. 1986, Land et al. 1989, Ohmann et al. 1994, Lewis 1998). To comply with State forest practices laws, coupled with the advent of habitat conservation planning as outlined in section 10 of the Endangered Species Act (Lewis 1998) and other landscape habitat management planning efforts (e.g., Sustainable Forestry Initiative, American Forest and Paper Association), landowners and land management agencies have undertaken efforts to maintain and create snags, or provide future snag resources through green-tree retention. Numerous methods for creating snags and wildlife trees exist and could provide suitable habitat for cavity- and snag-using wildlife (Lewis 1998). Chambers et al. (1997) suggested that creating snags by topping may retain or increase populations of cavity nesters in areas with low natural snag density. Green-tree retention strategies have advanced to include prescriptions that can vary the level and spatial pattern of retained trees to achieve specific objectives, such as mimicking the effects of natural disturbance (Lehmkuhl et al. 1999). Since large remnant snags and "defective" residual green trees provide much of the snag habitat for cavity-nesters in early- to mid-successional stands, particularly on private lands (Ohmann et al. 1994), retention of these structures will be important for maintaining populations of cavity- and snag-using avian species in managed forests. Snag retention and/or creation were the most commonly listed management recommendations from studies included in our review. We concur that leaving snags wherever possible is another important way that foresters can improve or maintain avian habitat quality within managed forest landscapes. We recommend additional research to un-

derstand avian response to snag densities and distributions (at both stand and landscape scales) to maintain viable populations of avian species, particularly cavity-nesters. Furthermore, studies addressing effectiveness of snag creation (e.g., Chambers et al. 1997, Arnett 1998), foraging habitat requirements (Weikel and Hayes 1999), and green-tree retention strategies (e.g., Lehmkuhl et al. 1999) are warranted.

Fuelwood cutting has not been found to adversely affect songbird populations, but may be detrimental to cavity nesters (Dingledine and Haufler 1983, Chadwick et al. 1986). Instances of large-scale snag removal occur primarily in the form of salvage logging following stand-replacement wildfire. Salvage logging typically influences vegetative structure by removing snags and down wood, and can represent either even-aged (i.e., most or all trees removed from a stand; e.g., Saab and Dudley 1998) or uneven-aged (i.e., retention of varying densities of snags and/or green trees; e.g., Arnett et al. 2001). Relationships between forest avifauna and salvage logging are poorly understood and limited to only a few studies (Overturf 1979, Moeur and Guthrie 1984, Arnett et al. 2001, R. Sallabanks, unpubl. data). Bird response to different approaches to salvage logging and opportunities to maintain habitat structure for birds warrants further investigation.

Shrub abundance is known to be directly influenced by forestry practices (Beck 1985), yet most studies in our review paid little attention to this potentially important source of structural variation within managed forest stands. In the Pacific Northwest, shrub cover has been found to be extremely important to forest songbirds, especially Neotropical migrants; over 80 percent of shrub-nesters in this region are migrants (Bunnell et al. 1997). Forestry practices directly alter overstory conditions, which in turn influence dynamics of the understory, as light and moisture gradients change. Most researchers, when studying effects of forestry on birds, therefore tend to focus on collecting overstory habitat data, at the expense of data on understory structure and composition. We are concerned that vegetation sampling may lack sufficient rigor and intensity to adequately describe understory conditions for birds. Measures of shrub patch dynamics, height and layering of understory canopies, species identification of shrubs, forbs, and grasses, and even canopy cover by major understory strata are rarely made. To significantly improve our understanding of relationships between birds and forestry, we conclude that additional research is needed on overstory-understory dynamics (e.g., Johnson et al. 1993), and the interactions between these dynamics and shrub-nesting birds in managed forests.

Many studies, especially those that did not describe potential causal mechanisms, such as habitat structure, simply did not collect data necessary for specific management implications to be assessed. In the future, we encourage authors to end research articles with a discussion of management implications derived from their work. We stress that such discussion should take the form of potential implications and relevance for management opportunities to maintain or create habitat structure for birds, rather than listing specific management recommendations *per se*. Quite often, researchers are tempted to make recommendations beyond the scope of their data, which can be counterproductive. Most studies (69 percent) did not make specific management recommendations. Understandably, when recommendations were made, they were very case-specific and perhaps only relevant to the forests and birds in question. Generalized guidelines are difficult to make and may even be dangerous if applied elsewhere to other systems (Young and Varland 1998). For these same reasons, our ability to offer specific management recommendations based upon results of our review is limited. We caution that, because of the breadth of our review, which included all forest types, all forestry practices, and all regions of North America, our suggestions on how to enhance bird habitats through forestry also are broad.

Suggestions for Future Research

Study Design Considerations

Designing and implementing rigorous field experiments (i.e., those that are well-replicated, include treatment groups randomly assigned to experimental units, and gather pre- and post-treatment data; Hurlbert 1984) is notoriously difficult to accomplish (Underwood 1997), and research on effects of forestry practices on bird populations is no exception. To the extent possible, future studies of relationships between timber harvest and bird populations need to be more mechanistic, manipulative, and long-term in their approach. Sallabanks et al. (2000) provided a critical review of studies addressing effects of forestry practices on birds and offered suggestions for future research. Here, we synthesize key concepts and approaches for researchers to consider when designing studies to address the effects of forestry practices on birds.

Most studies in our review were not rigorously designed (i.e., they were descriptive, observational, appeared to have low statistical power [Steidl et al. 1997, Gerard et al. 1998]), and inferences about specific effects of forestry were limited and deductive at best. By incorporating more rigor to experimental design (e.g., replication, randomization), researchers can reduce or eliminate such factors affecting the interpretation of

findings. Studies of bird-forestry relationships with little replication have low statistical power (Cohen 1988) and therefore are prone to concluding that a particular silvicultural treatment did not have an effect when in fact it did (Type II error; Zar 1996). Few studies in our review had more than four replicates per treatment, with the majority having only one. With only one replicate in a treatment, researchers have no way of knowing whether results that they report are representative of that treatment or not. Other local factors (e.g., aspect, slope, elevation, or juxtaposition with other forest stands) may have more bearing on bird communities found on a site than silvicultural treatments in question (e.g., Irwin 1998). Studies with only one replicate per treatment very likely were guilty of pseudoreplication (Hurlbert 1984), and interpretations from these studies should be viewed cautiously.

Few (22 percent) studies in our review incorporated pre- and post-treatment data (i.e., they were retrospective), and all studies were mensurative, where treatment groups were not randomly assigned to experimental units (replicates). Snag creation research (Arnett 1998), green tree retention (Lemkuhl et al. 1999), and bird response to thinning in Douglas-fir forests (Hayes et al. 2003) are the only manipulative studies we are currently aware of. An inherent problem associated with "observational" or "correlative" studies is that statistical inference is limited simply to differences among physical locations or points in time and is not relative to treatment effect (Hurlbert 1984, Heffner et al. 1996). Because observational studies provide only deductive and indirect inferences about relationships between forestry and birds, causal mechanisms underlying changes in bird communities following timber harvest cannot be directly determined. Studies in our review that suggested cause-and-effect relationships did so based on correlations. Romesburg (1981) noted that the history of science is replete with strong pronouncements of cause-and-effect based entirely on correlations. We agree with Romesburg (1981) that those studies where correlations are the sole evidence offer weak support for determining causal mechanisms relative to treatment effects. Forest managers need reliable information about mechanisms if they are to improve forest habitat for birds (Marzluff et al. 2000).

We suggest that future research on effects of forestry practices on bird populations utilize the hypothetico-deductive scientific method described by Romesburg (1981), and incorporate manipulative experiments where treatments are randomly assigned to experimental units. Random assignment of treatment provides an "unbiased" experiment that generally guarantees independent distribution of errors, thereby allowing for objective statistical testing of treatment effects (Hurlbert 1984). Furthermore, recent articles suggest the use of more informative and practical analytical methods such as confidence intervals or Bayesian methods (Steidl et al. 1997, Gerard et al. 1998). These approaches may offer greater insight to the practical importance and magnitude of a potential treatment effect than traditional hypothesis testing and, thus, may better guide management decisions (Steidl et al. 1997). Information-theoretic approaches to modeling (e.g., Burnham and Anderson 1998) have become popular in recent years and appear useful toward developing more meaningful models that reduce the potential for spurious results (Anderson et al. 2001). We therefore encourage researchers to explore these approaches when designing studies of bird-forestry relationships.

Temporal and Spatial Scale

If birds are found to respond to forestry, it seems imperative that we understand how long these effects remain. Studies in our review also were short-term, however, with data often only being collected during one to two field seasons. By far the longest study has been that of Webb et al. (1977), who surveyed breeding bird populations in a northern hardwood forest subjected to different logging intensities for ten consecutive seasons. Effects of forestry may be long-lasting (20+ years), or short-term (one to three years), but will remain ambiguous without studies that last longer than one to two years. Past research is characterized not only by small temporal scales, but small spatial scales as well. Landscape-level studies were rare and have been a relatively recent phenomenon (e.g., Hagan et al. 1995, 1996, 1997; Tappe 1996; Schmiegelow et al. 1997).

Response of Birds to Forestry Practices

Based upon results from our review, studies have focused heavily on relationships between forestry practices and breeding songbirds; wintering bird populations (i.e., permanent resident species) were surveyed in only 14 percent (n = 17) of studies. This result is biased by our decision to exclude studies of certain species (e.g., Threatened or Endangered species) from our review, but nevertheless illustrates the relative focus on breeding populations compared to wintering populations. Several factors have likely contributed to this bias: (1) relative to wintering birds, breeding songbirds are more easily sampled using standard point count surveys (Ralph et al. 1993); (2) field conditions are generally more conducive to collecting field data during spring and summer months; (3) more species are typically present during the breeding season, thereby seeming more cost-effective than sampling depauperate avian communities in winter; and (4) analyses of Breeding Bird Survey (BBS) data suggest

that some migratory species, those only present during the breeding season in temperate North America, may be in decline (e.g., Robbins et al. 1989, Peterjohn et al. 1995). The lack of studies on wintering birds is rather alarming, especially in light of recent analyses by Hejl et al. (1995) that suggest permanent resident species in the northern Rocky Mountains are more adversely affected by silviculture than Neotropical migrants. The effects of forestry on migrating birds have received even less attention. To our knowledge, only one study examined relationships between silvicultural practices (hardwood removal and prescribed burning) and birds during spring and fall migration (Michael and Thornburgh 1971). Additional research on effects of forestry on permanent resident species and the use of managed forests as stopover sites for migrating birds is clearly needed.

Also of concern is that most (65 percent, n = 78) of our interpretations of forestry effects on bird populations are based upon measures of relative avian abundance, collected using point counts. Studies of species-habitat associations are known to be limited for numerous reasons (Wolff 1995), yet few researchers have critically questioned relationships between factors typically measured (i.e., relative abundance) and habitat quality (as might be better indicated by reproductive success, for example). Again, there are obvious reasons why abundance data are so commonly relied upon: point counts are simple and cost-efficient relative to alternative sampling methods. There are, however, some fundamental problems associated with use of abundance data as the only method to measure avian populations. Numerous studies, mostly on birds, have noted that density is not necessarily an accurate indicator of habitat quality (Krebs 1971, Van Horne 1983, Pulliam 1988, Robbins et al. 1989, Gibbs and Faaborg 1990, Blake 1991, Martin 1992, Vickery et al. 1992, Hagan et al. 1996, R. Sallabanks, unpubl. data). Inferences about actual quality of habitat can only be indirectly deduced from correlational and often poorly replicated bird surveys. Yet such studies are the norm.

Research should be directed more toward measuring avian fitness components and identifying critical structural characteristics of forests that influence nesting success, depredation rates, survivorship, and dispersal. Of course, others have recognized similar needs (e.g., Martin 1992), and studies that investigate population parameters have become more common in recent years (King et al. 1996, Machtans et al. 1996, Annand and Thompson 1997). Machtans et al. (1996) is the only published study to conduct sampling protocols related to songbird demographics (in this case, mist-netting) pre- and post-timber harvest. To our knowledge, there is yet to be a single published study of passerines that tests for treatment effects experimentally and measures direct changes in nest success in relation to timber harvest (i.e., experimental manipulations of forest structure where treatments and reference stands are randomly assigned and data are collected pre- and post-treatment).

Conclusions

One conclusion from our review is that forestry, in most cases, does not result in community-wide bird declines. On the contrary, we have found that managed forests support abundant, rich, diverse, and productive bird communities. There are obviously some species that favor old forest conditions and these conditions would clearly be altered by timber harvest. For example, Townsend's Warbler (Matsuoka et al. 1997, Sallabanks et al. 2002), Pileated Woodpecker (Bull and Holthausen 1993), and Brown Creeper (*Certhia americana*; Mariani and Manuwal 1990, Adams and Morrison 1993) are all species known to be associated with closed canopy forest and large-diameter trees, particularly snags. We do not dispute that such species are likely to be negatively impacted by certain forestry practices (e.g., clearcutting), at least at the stand level and over the short-term. On the other hand, there are just as many species that require forest habitat created by forestry, such as the Dark-eyed Junco, Dusky Flycatcher (*Empidonax oberholseri*), Orange-crowned Warbler (*Vermivora celata*), Chipping Sparrow, House Wren (*Troglodytes aedon*), and Mountain Bluebird (*Sialia currucoides*; Sallabanks et al. 2002). In order to maintain viable populations of all species on the landscape, a mix of all forest conditions, from clearcuts to old growth, is required. In reality, stand-level changes that cause species' declines may actually be required to maintain those species at the landscape scale (e.g., in order to maintain stand structures that are resistant to catastrophic disturbance). Several studies in our review suggested varying the amount of timber removed from stands during logging operations (e.g., Chadwick et al. 1986, Hagar et al. 1996). We agree, but also suggest applying this recommendation to broader spatial scales (e.g., Annand and Thompson 1997). If forest stands exist as a patchwork mosaic of different structural stages across broad landscapes, all but the most wide-ranging bird species should have adequate foraging and nesting sites. Perhaps one of the biggest questions left unanswered is "How much of each structural stage is required (and in what arrangement) on the landscape to successfully blend avian conservation with timber production?" This question is not easy to answer, but advanced modeling efforts combined with field tests of model predictions might be one approach for the future (e.g., Hansen et al. 1993, 1995a; Brooks 1997).

We also feel strongly that while having the landscape be comprised of a range of seral stages is important, maintaining and creating essential structural attributes is more critical. By leaving down logs, snags, patches or trees, old residual trees, and adequate shrub cover, managers can maintain species that may be dependent on structure rather than stand age or seral stage. In short, results from our review suggest that managing for structural features may be more important than managing for seral stage *per se*.

If management is to occur, our results indicate that uneven-aged methods will lead to fewer species' decreases compared with even-aged methods. Of course, this conclusion is largely driven by our unavoidable focus on short-term, stand-level results. At the stand level, uneven-aged management alters forest structure less dramatically than even-aged prescriptions. Thus, it is not surprising that uneven-aged management would have a less dramatic short-term, stand-level effect on bird communities. As we have documented here, response of bird communities differs little between the two harvesting systems when considered at larger spatial and temporal scales. Again, we see the need for variation on the landscape, both within and among forest stands. Following our review, there were no clear trends as to which specific forestry technique (e.g., single-tree selection or group selection) might be more conducive to maintaining high quality habitat for birds.

Avian research always will face trade-offs and compromises, often driven by logistical and financial constraints that prevent us from collecting the full complement of demographic data in an experimental, long-term framework. Such "Utopian" research will be challenging to develop and implement (Marzluff and Sallabanks 1998). Individual studies must have their own strengths that, when combined with those of others, will begin to complete the puzzle and fill information gaps. The past 40 years have produced some quality work that has greatly improved our understanding of effects of timber harvest on bird populations. To improve effectiveness, however, we urge that future research take some new directions. We encourage researchers to design and implement manipulative field studies wherever possible. To minimize confounding factors inherent to observational studies, we suggest increasing experimental rigor through: (1) inclusion of references (controls); (2) better replication in both space and time; (3) randomized selection of experimental units (replicates); (4) interspersion of experimental units across the study area (Hurlbert 1984); (5) gathering pre- and post-treatment data; and (6) lengthening study duration. With these recommendations in mind, and as long as the needs of forest managers are kept clearly in view, we believe that future research on the relationships between timber harvest and bird populations will continue to make both novel and significant contributions to this critical area of study. To achieve such studies, careful, insightful planning and involvement of forest managers from a project's inception will be required (Arnett and Sallabanks 1998). To increase power and experimental rigor of such studies, we also encourage researchers to coordinate and implement large-scale cooperative research programs involving multiple organizations and resources.

In conclusion, we echo our earlier comments that opportunities to enhance habitat for birds through forestry will vary from species to species. Management objectives must be prioritized based upon those bird species that are sensitive to forestry and showing sharp declines, as well as being compatible with ownership objectives. Continued research, especially that which incorporates information needs identified in this review, will help tell us which species these are and why they might be at risk. Attempts to improve habitat for all species by managing for maximum avian biodiversity have limited utility. What is needed are resourceful ways to integrate stand- and landscape-level features created by forestry with those required by birds for sustained avian population health and viability.

Acknowledgments

We thank the following for sending reprints, government publications, unpublished annual reports, and study proposals: J. D. Brawn, M. Darveau, R. M. DeGraaf, B. Fledderman, M. R. Houser, R. A. Lancia, W. C. McComb, M. A. Melchoirs, P. A. Tappe, F. R. Thompson, III, D. E. Varland, and W. L. Webb. Funding for this project was provided by the National Council for Air and Stream Improvement and Weyerhaeuser Company. This review would not have been possible without the efforts of Weyerhaeuser librarian D. Louchs and her staff, J. Scott and L. Keeley. L. Knelly assisted with screening publications and entering data. For constructive comments on a previous version of this paper, we thank T. B. Wigley, L. L. Irwin, and C. J. Ralph.

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Appendix 1. *Descriptive criteria for 116 studies of bird-forestry relationships included in our review. Space limitations prohibit the inclusion of actual results from each study. See footnotes for column definitions. Studies are listed in alphabetical order by primary author.*

No.	Reg[1]	State	Hab[2]	Pres[3]	Cat[4]	Scl[5]	Dur[6]	BvA[7]	Rep[8]	Type[9]	Birds[10]	Data[11]	Veg[12]	B-H[13]	Mgt[14]	Reference
1	W	MO	C	CC, SW, GS, ST	M	S	2	N	12	M	BB	RA, FT	Y	N	Y	Annand and Thompson (1997)
2	NW	OR	C	SL	U	S	2	Y	6	M	BB	RA	Y	N	N	Arnett et al. (2001)
3	W	UT	C	CC	E	S	1	N	1	M	BB	RA	N	N	N	Austin and Perry (1979)
4	E	KY	M	TA, CC	M	S	3	Y	4	M	BB	RA	Y	N	N	Baker and Lacki (1997)
5	S	AR	M	CC, ST	M	S	3	N	6	M	RN	FT	N	N	N	Barber et al. (2001)
6	SW	AZ	C	PC, CC	M	S	1	N	1	M	WB	RA	Y	Y	N	Blake (1982)
7	SW	AZ	C	CC, CT	M	S	3	N	1	M	BB	DN	N	N	N	Brawn and Balda (1988)
8	NW	OR	C	ST	U	S	1	N	1	M	BB	RA	N	N	N	Bull et al. (1995)
9	NE	MA	H	FC	U	S	2	N	16	M	BB	RA	Y	Y	Y	Chadwick et al. (1986)
10	NW	OR	C	GS, TA, CC	M	S	1	N	3	M	WB	RA	N	N	Y	Chambers and McComb (1997)
11	E	VA	H	CC	E	S	1	N	1	M	BB	RA	Y	N	Y	Conner and Adkisson (1975)
12	E	VA	M	CC	E	S	1	N	4	M	YB	RA	N	N	N	Conner et al. (1979)
13	NE	QC	C	CC	E	S	2	Y	20	M	BB	DN	N	N	N	Darveau et al. (1995)
14	NE	QC	C	CC	E	S	4	N	5	M	AN	FT	N	N	N	Darveau et al. (1997)
15	W	UT	H	CC	E	S	4	Y	1	M	BB	DN	N	N	N	Debyle (1981)
16	NE	NH	H	CC	E	E	3	N	6	M	BB	RA	Y	N	N	DeGraaf (1992)

Appendix 1. *Continued.*

No.	Reg[1]	State	Hab[2]	Pres[3]	Cat[4]	Scl[5]	Dur[6]	BvA[7]	Rep[8]	Type[9]	Birds[10]	Data[11]	Veg[12]	B-H[13]	Mgt[14]	Reference
17	NE	NH	H	CC, CT	M	S	1	N	3	M	AN	FT	Y	N	N	DeGraaf (1995)
18	NE	NH	H	CC	E	S	1	N	14	M	AN	FT	N	N	N	DeGraaf and Angelstam (1993)
19	NE	MA	H	ST	U	S	3	N	3	M	BB	RA	Y	N	N	DeGraaf et al. (1991b)
20	N	MI	H	CC	E	S	1	N	-	M	SS	RA	Y	N	Y	Dellasala and Rabe (1987)
21	NW	AK	C	CC, CT, GS	M	S	2	N	5	M	YB	RA	Y	Y	Y	Dellasala et al. (1996)
22	NE	ME	M	CC	E	S	4	N	10	M	BB	RA	Y	N	N	Derleth et al. (1989)
23	N	TX	H	SR	S	S	5	N	4	M	BB	RA	Y	N	Y	Dickson et al. (1983)
24	N	MI	H	SR	S	S	2	Y	3	M	BB	DN	Y	N	N	Dingledine and Haufler (1983)
25	E	WV	H	TA, CC	M	S	2	N	18	M	RN	FT	N	N	Y	Duguay et al. (1999)
26	NW	BC	C	CC	E	S	1	N	2	M	BB	RA	N	N	N	Eckert et al. (1992)
27	N	AB	C	CC	E	S	1	N	3	M	BB	RA	N	N	N	Farr (1992)
28	SW	AZ	C	OR	U	S	2	N	1	M	BB	DN	Y	Y	Y	Franzreb (1977)
29	SW	AZ	C	OR	U	S	2	N	1	M	BB	DN	Y	Y	N	Franzreb (1978)
30	SW	AZ	C	ST	U	S	2	N	1	M	BB	RA, DN	Y	N	N	Franzreb and Ohmart (1978)
31	N	NS	H	CC, CT	M	S	1	N	2	M	BB	DN	Y	N	N	Freedman et al. (1981)
32	NE	VT	H	CC	E	S	2	N	3	M	BB	RA	Y	N	N	Germaine et al. (1997)
33	SE	FL	M	CC	E	S	2	N	3	M	YB	RA	Y	N	N	Greenberg et al. (1995)
34	NE	ME	H	CC, CT	M	S, L	2	N	11	M	BB	RA	N	N	Y	Hagan et al. (1995)
35	NE	ME	H	CC	E	L	1	N	-	M	BB, SS	RA, FT	Y	N	Y	Hagan et al. (1996)

Appendix 1. *Continued.*

No.	Reg[1]	State	Hab[2]	Pres[3]	Cat[4]	Scl[5]	Dur[6]	BvA[7]	Rep[8]	Type[9]	Birds[10]	Data[11]	Veg[12]	B-H[13]	Mgt[14]	Reference
36	NE	ME	H	CC, CT	M	S, L	2	N	11	M	BB	RA	N	N	Y	Hagan et al. (1997)
37	W	CA	C	CC	E	S	3	N	7	M	BB	RA	N	N	N	Hagar (1960)
38	NW	OR	C	CT	U	S	2	N	8	M	YB	RA	Y	Y	Y	Hagar et al. (1996)
39	W	CO	C	CC, CT	M	S	2	N	1	M	YB	RA	Y	N	N	Hallock (1989–90)
40	SE	NC	H	CC	E	S	2	N	1	M	BB	DN	N	N	N	Horn (1984)
41	NE	ME	M	CC, ST	M	S	2	N	2	M	BB	DN	Y	Y	Y	Johnson and Brown (1990)
42	SE	NC	M	CC, CT	M	S	2	N	3	M	YB	RA	Y	Y	Y	Karriker (1996)
43	W	WY	C	CC	E	S	2	N	7	M	BB	RA	Y	N	N	Keller and Anderson (1992)
44	NW	AK	C	CC	E	S	1	N	2	M	BB	RA	Y	N	N	Kessler (1979)
45	W	CA	C	UR, SR	S	S	4	Y	2	M	BB	RA	Y	Y	N	Kilgore (1971)
46	NE	NH	H	CC	E	S	2	N	3	M	SS	FT	Y	N	Y	King et al. (1996)
47	NE	NH	H	CC	E	E	2	N	4	M	BB	DN	Y	N	N	King et al. (1997)
48	NE	NH	H	CC, GS	M	S, L	2	N	3	M	RN	FT	N	N	N	King et al. (2001)
49	SE	SC	M	CC	E	L	1	N	8	M	BB	RA	N	N	N	Lancia et al. (1996a)
50	SE	SC	M	CC	E	S	1	N	3	M	BB	RA	Y	N	N	Lancia et al. (1996b)
51	SE	SC	M	CC	E	L	2	Y	9	M	BB	RA	N	N	N	Lancia et al. (1997)
52	NE	VT	H	CC, ST	M	S	2	N	1	M	BB	RA, DN	Y	Y	N	Lent and Capen (1995)
53	N	AB	M	CC	E	S	3	Y	3	M	BB, MN	DN, FT	N	N	N	Machtans et al. (1996)
54	NW	OR	C	CT	U	S	3	N	4	M	BB	RA	Y	Y	Y	Mannan and Meslow (1984)
55	N	MN	H	CC	E	E	2	N	3	M	AN,	FT	N	N	Y	Manolis et al.

Appendix 1. *Continued.*

No.	Reg[1]	State	Hab[2]	Pres[3]	Cat[4]	Scl[5]	Dur[6]	BvA[7]	Rep[8]	Type[9]	Birds[10]	Data[11]	Veg[12]	B-H[13]	Mgt[14]	Reference
											RN					(2000)
56	E	VA	H	CC, ST	M	S	2	N	1	M	BB	RA	N	N	N	Maurer et al. (1981)
57	NW	MT	C	SW, GS, CC	M	S	6	N	2	M	CN	RA	Y	N	Y	McClelland (1980)
58	E	KY	M	CC	E	S	2	N	3	M	YB	RA	Y	N	N	McComb and Rumsey (1983)
59	E	KY	M	CT	U	S	4	Y	1	M	YB	RA	Y	N	N	McComb et al. (1989)
60	E	KY	M	SR	S	S	4	Y	1	M	YB	RA	Y	N	N	McPeek et al. (1987)
61	NW	ID	C	CT	U	S	4	Y	3	M	BB	DN	Y	N	N	Medin (1985)
62	NW	ID	C	ST	U	S	5	Y	2	M	BB	DN	N	N	N	Medin and Booth (1989)
63	S	TX	M	PC	U	S	2	N	1	M	YB	RA	N	N	N	Michael and Thorneburgh (1971)
64	SE	AL	H	CC	E	S	1	N	1	M	BB	RA	N	N	N	Mitchell and Lancia (1990)
65	SE	SC	H	CC	E	S	1	N	1	M	BB	RA	N	N	Y	Mitchell et al. (1991)
66	NW	OR	C	CC	E	S	1	N	2	M	BB	RA	Y	Y	N	Monthey (1983)
67	W	CA	M	CC, PC	M	S	4	N	1	M	BB	RA	Y	N	N	Morrison (1992)
68	N	AB	M	PC, CC	M	S	2	Y	3	M	BB	RA	Y	N	Y	Norton and Hannon (1997)
69	SE	FL	M	CC	E	S	6	Y	1	M	YB	DN	N	N	Y	O'Meara et al. (1985)
70	N	MI, MN	H	CC	E	S	8	Y	4	M	BB	DN	Y	N	N	Probst et al. (1992)
71	SE	FL	C	CC	E	S	1	N	3	M	YB	RA	Y	N	N	Repenning and Labisky (1985)
72	N	MI	C	CC	E	S	2	N	5	M	BB	RA	Y	Y	Y	Rogers et al. (1996)

Appendix 1. *Continued.*

No.	Reg[1]	State	Hab[2]	Pres[3]	Cat[4]	Scl[5]	Dur[6]	BvA[7]	Rep[8]	Type[9]	Birds[10]	Data[11]	Veg[12]	B-H[13]	Mgt[14]	Reference
73	SE	FL	M	CC, CT	M	S	4	Y	1	M	BB	RA	N	N	N	Rowse and Marion (1981)
74	NE	ME	M	CC	E	E	2	N	-	M	AN	FT	Y	N	N	Rudnicky and Hunter (1993)
75	NW	OR	C	CT	U	S	1	N	20	M	BB	RA	Y	Y	N	Sallabanks (1994)
76	NW	OR	C	CT	U	S	1	N	12	M	BB	RA	Y	Y	Y	Sallabanks (1995)
77	NW	ID	C	CT	U	S	3	Y	8	M	BB	RA	Y	Y	N	Sallabanks (1996)
78	NW	ID	C	CT	U	S	4	Y	8	M	BB	RA	N	N	N	Sallabanks (1997)
79	NW	OR	C	CT	U	S	3	N	12	M	BB	RA	Y	Y	Y	Sallabanks et al. (2002)
80	NW	ID	C	CC, CT	M	S	2	N	4	M	BB	RA	N	N	N	Sallabanks et al. (submitted ms)
81	S	AR	M	PC, CC	M	S, W	1	N	-	M	BB	RA	Y	N	N	Sams (1995)
82	N	AB	M	CC	E	S, L	3	Y	3	M	BB	RA	Y	N	N	Schmiegelow et al. (1997)
83	NW	OR	C	SR	S	S	2	N	3	M	CN	DN	Y	Y	Y	Schreiber and deCalesta (1992)
84	SW	AZ	C	SR	S	S	4	Y	1	M	BB	DN	Y	N	Y	Scott (1979)
85	W	CO	H	CC	E	S	1	N	4	M	BB	RA	N	N	N	Scott and Crouch (1987)
86	W	CO	H	CC	E	S	1	N	10	M	BB	RA	N	N	N	Scott and Crouch (1988)
87	SW	AZ	C	CC	E	S	4	Y	2	M	BB	DN	N	N	N	Scott et al. (1982)
88	SW	AZ	C	ST, GS, CC	M	S	4	Y	1	M	BB	RA	Y	N	Y	Scott and Gottfried (1983)
89	SW	AZ	C	SR	S	S	4	Y	1	M	CN	DN	Y	N	Y	Scott and Oldemeyer (1983)

Appendix 1. *Continued.*

No.	Reg[1]	State	Hab[2]	Pres[3]	Cat[4]	Scl[5]	Dur[6]	BvA[7]	Rep[8]	Type[9]	Birds[10]	Data[11]	Veg[12]	B-H[13]	Mgt[14]	Reference
90	N	WI	H	CC	E	S	2	N	1	M	BB	RA	Y	N	N	Steffen (1985)
91	S	TX	M	CC	E	E	1	N	4	M	BB	RA	Y	N	Y	Strelke and Dickson (1980)
92	NE	PA	H	CT, SR	U	S	1	N	2	M	BB	RA	Y	Y	Y	Stribling et al. (1990)
93	SW	AZ	C	CT, SW	U	S	2	N	1	M	BB	DN	Y	N	Y	Szaro and Balda (1979)
94	SW	AZ	C	CC, PC	M	S	3	N	1	M	BB	DN	Y	Y	N	Szaro and Balda (1986)
95	S	AR	M	PC, CC	U	S, W	2	N	1	M	BB	RA	N	N	N	Tappe (1996)
96	NE	VT	H	CC, PC	M	S	2	N	6	M	BB	RA	Y		Y	Thompson and Capen (1988)
97	MW	MO	H	CC	E	S	4	Y	3	M	BB	RA	Y	N	N	Thompson and Fritzell (1990)
98	MW	MO	M	CC	E	S	2	N	9	M	BB	DN	N	N	N	Thompson et al. (1992)
99	NE	ME	C	CC	E	S	1	N	3	M	BB	DN	Y	Y	N	Titterington et al. (1979)
100	NW	MT	C	CC, PC	M	S	2	N	4	M	BB	RA	Y	N	Y	Tobalske et al. (1991)
101	E	KY	M	CC, PC	M	S	2	Y	2	M	BB	RA	N	N	Y	Triquet et al. (1990)
102	NE	NY	H	CC, PC	M	S	10	N	1	M	BB	RA	N	N	N	Webb et al. (1977)
103	N	ON	M	ST	U	S	1	N	-	M	BB	DN	N	N	N	Welsh (1987)
104	NE	NH	H	CC	E	S	2	N	3	M	BB	RA	Y	N	N	Welsh and Healy (1993)
105	NE	MA	H	ST, SR	U	S	2	N	4	M	CN	RA	Y	N	Y	Welsh et al. (1992)
106	NW	BC	C	CC	E	S	1	N	4	M	BB	RA	N	N	N	Wetmore et al. (1985)
107	E	MD	H	ST	U	S	2	N	1	M	BB	RA	N	N	N	Whitcomb et al. (1977)
108	SE	NC	H	CT	U	S	1	N	6	M	BB	RA	Y	Y	N	Wilson and Watts (1988)
109	NE	PA	M	CC	E	S	3	N	3	M	YB	RA	Y	Y	N	Yahner (1986)

Appendix 1. *Continued.*

No.	Reg[1]	State	Hab[2]	Pres[3]	Cat[4]	Scl[5]	Dur[6]	BvA[7]	Rep[8]	Type[9]	Birds[10]	Data[11]	Veg[12]	B-H[13]	Mgt[14]	Reference
110	NE	PA	M	CC	E	S	4	N	3	M	YB	RA	Y	Y	N	Yahner (1987a)
111	NE	PA	M	CC	E	S	3	N	5	M	RN	FT	N	N	N	Yahner (1991)
112	NE	PA	M	CC	E	S	2	N	10	M	YB	RA	N	N	N	Yahner (1993)
113	NE	PA	M	CC	E	S	1	N	10	M	AN	FT	N	N	N	Yahner and Mahan (1996a)
114	NE	PA	M	CC	E	S	1	N	10	M	AN	FT	N	N	N	Yahner and Scott (1988)
115	NE	PA	M	CC	E	E	1	N	15	M	AN	FT	Y	N	N	Yahner et al. (1989)
116	NW	WA	C	CC, PC, SR	M	S	2	N	2	M	CN	DN	Y	Y	Y	Zarnowitz and Manuwal (1985)

[1] Reg = Geographical region of study (E = East, MW = Midwest, N = North, NE = Northeast, NW = Northwest, S = South, SE = Southeast, SW = Southwest, W = West)
[2] Hab = Forest habitat (C = Coniferous, H = Hardwoods, M = Mixed);
[3] Pres = Silvicultural prescription studied (CC = Clearcut, CT = Commercial thin, FC = Fuelwood cutting, GS = Group selection, OR = Overstory removal, PC = Partial cut, SL = Salvage logging, SR = Snag removal/retention, ST = Single-tree selection, SW = Shelterwood, TA = Two-age cut, UR = Understory removal);
[4] Cat = Prescription category (E = Even-aged, M = Mix of even- and uneven-aged, U = Uneven-aged);
[5] Scl = Spatial scale of study (E = Edge effects study, L = Landscape-level, S = Stand-level, W = Watershed-level);
[6] Dur = Study duration (number of field seasons that data were collected);
[7] BvA = Before vs. after treatment data were collected and compared (Y = Yes, N = No);
[8] Rep = Degree of replication (mean no. replicate stands or plots studied per treatment);
[9] Type = Type of study (M = Mensurative or correlational, E = Manipulative experiment);
[10] Birds = Bird species or nest type studied (AN = Artificial nests, BB = Breeding birds, CN = Cavity nesters, RN = Real nests, SS = Single species, WB = Wintering birds, YB = Year-round birds);
[11] Data = Data type collected (DN = Density estimates, FT = Fitness parameters [e.g., nest success, productivity], RA = Relative abundance);
[12] Veg = Vegetation or habitat data collected (Y = Yes, N = No);
[13] B-H = Bird-habitat relationships examined and identified (Y = Yes, N = No);
[14] Mgt = Management recommendations made (Y = Yes, N = No).

Forest Management Under Uncertainty for Multiple Bird Population Objectives[1]

Clinton T. Moore[2], W. Todd Plummer[3], and Michael J. Conroy[4]

Abstract

We advocate adaptive programs of decision making and monitoring for the management of forest birds when responses by populations to management, and particularly management trade-offs among populations, are uncertain. Models are necessary components of adaptive management. Under this approach, uncertainty about the behavior of a managed system is explicitly captured in a set of alternative models. The models generate testable predictions about the response of populations to management, and monitoring data provide the basis for assessing these predictions and informing future management decisions. To illustrate these principles, we examine forest management at the Piedmont National Wildlife Refuge, where management attention is focused on the recovery of the Red-cockaded Woodpecker (*Picoides borealis*) population. However, managers are also sensitive to the habitat needs of many non-target organisms, including Wood Thrushes (*Hylocichla mustelina*) and other forest interior Neotropical migratory birds. By simulating several management policies on a set of alternative forest and bird models, we found a decision policy that maximized a composite response by woodpeckers and Wood Thrushes despite our complete uncertainty regarding system behavior. Furthermore, we used monitoring data to update our measure of belief in each alternative model following one cycle of forest management. This reduction of uncertainty translates into a reallocation of model influence on the choice of optimal decision action at the next decision opportunity.

Key words: adaptive management, forest management, *Hylocichla mustelina*, models, *Picoides borealis*, Piedmont National Wildlife Refuge, Red-cockaded Woodpecker, uncertainty, Wood Thrush.

Introduction

The management of forests for bird conservation objectives is often complicated by uncertainty about the responses of bird populations to silvicultural actions (Thompson 1993, Marzluff et al. 2000). Uncertainty implies that trade-offs in management outcomes are impossible to forecast prior to the decision action.

For example, consider a simple situation in which the responses (e.g., density) by two bird populations to a single type of forest management action (e.g., frequency of prescribed burning) are of interest, and we will assume that responses to management by the populations are known (*fig. 1A*). If the objective of management is to maximize a composite measure of these responses (average density, perhaps), then selection of a level of action that achieves this objective is straightforward, requiring no special accommodation of uncertainty (*fig. 1A*).

More realistically however, we will not know the nature of the population response. In particular, stakeholders to the decision may vehemently disagree over population response and therefore the appropriate course of management (e.g., management of forests in the range of the Northern Spotted Owl [*Strix occidentalis caurina*]; Noon and McKelvey 1996). For example, if some parties believe that management has a highly pronounced effect on one of our hypothetical populations, then their opinion of correct management choice will be far different from the choice in the first case *fig. 1B*). Thus, the choice between which actions are optimal is not clear and may be highly controversial (Conroy 2000b). Managers therefore confront the possibility of choosing an action that is inappropriate for the true response and risking unnecessary harm to one of the resources.

Of course, bird population dynamics, management objectives, and decision alternatives are usually more complex than in these simple examples. Landscape heterogeneity and distribution of food and nesting resources often imply that birds respond to the distribution of treatments throughout the forest as well as to the total area affected (Pulliam et al. 1992, Dunning et al. 1995). Stochastic processes affect how closely the realized management action resembles the intended action, and they affect population dynamics and responses by birds to those actions (Nichols et al. 1995, Williams 1997, Regan et al. 2002).

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California**.

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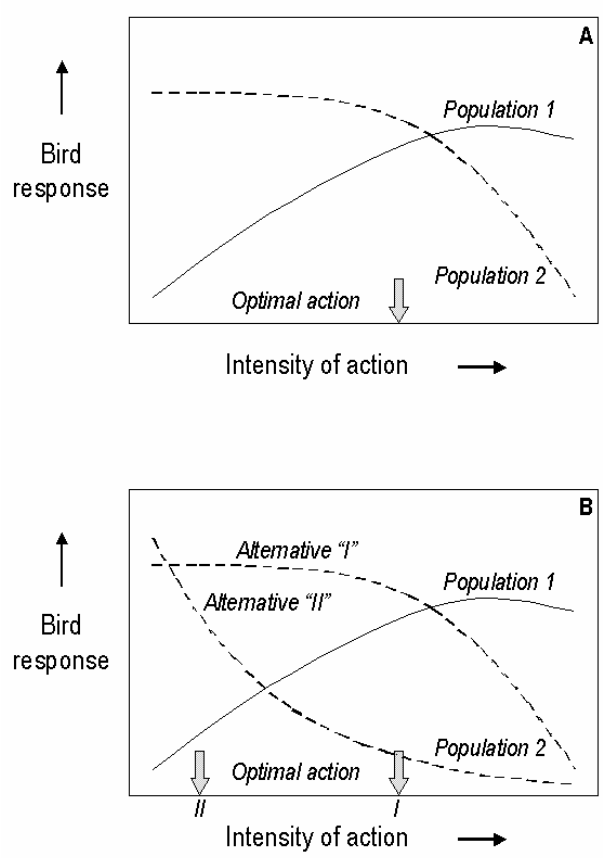


Figure 1— Response to management by two hypothetical bird populations. Where responses by both species are assumed to be known (A), selection of an optimal action that maximizes some joint response of both populations is fairly straightforward. Where there is uncertainty about the response by one of the populations (B), selection of the optimal action is unclear and may be contentious among stakeholders because it depends on belief in alternative I or II as the appropriate model of population response.

Faced with these challenges in designing forest management for conservation objectives, managers need tools and new approaches for decision making under uncertainty. We advocate the use of model-based decision making in an adaptive context, in circumstances of ecological uncertainty or risk, for the conservation management of forest bird populations. We first present some principles in optimal decision making, and we describe the use of adaptive management when the response to management is uncertain. We also present a case study in which we applied these principles to forest management at the U.S. Fish and Wildlife Service Piedmont National Wildlife Refuge (Georgia, USA), where management of the pine (*Pinus* spp.) hardwood forest is directed both toward recovery of the endangered Red-cockaded Woodpecker (*Picoides borealis*) and to the maintenance of many populations of forest-interior wildlife species. Our interest centered on responses by the Wood Thrush (*Hylocichla mustelina*), a Neotropical migrant associated with closed-canopy and shrubby understory forest conditions, to woodpecker-focused management, in which intensive silviculture is applied to counter these conditions.

Optimal Decision Making and Adaptive Management

Any decision-making problem has three ingredients: a quantitative statement of management objectives (i.e., an objective function), a set of decision actions from which one action will be chosen, and a model describing the response of the objective function to each action (Walters and Hilborn 1978, Williams 1989). Furthermore, as forest management involves repeated opportunities for decision making through time, the model should also forecast the state of the resource system at the next decision opportunity (Williams 1989). The system state is the set of important attributes that describes the system at any time: average basal area, distribution of old trees, and total number of breeding bird pairs are examples of state components. The optimal decision action is that which maximizes the objective reward value.

Uncertainty about the managed system implies that more than one model plausibly describes the response of the system to any single management decision (Walters 1986:160). The decision identified as best for a given system state is dependent on the distribution of belief that a manager places among the uncertain models.

Adaptive management offers a formal means of acquiring information and applying it to the reduction of uncertainty in decision making (Walters and Hilborn 1978, Walters 1986, Williams 1996). The focus of adaptive management is on improving long-term management performance. That is, reduction of uncertainty is valued only to the extent that it improves management performance (Johnson et al. 1993, Williams and Johnson 1995). Under adaptive management, uncertainty is expressed in a set of models, each capable of generating a prediction about the system response to a given management action. For example, one model may be offered that challenges some traditional or baseline notion of how the resource responds to management. However, both models in this example must provide quantitative predictions about the response of the resource and consequent satisfaction of management objectives. The generation of alternative model predictions provides the means by which degree of belief in each model, and therefore the best action for a given system-state, may be revised in light of system feedback following the management action (Johnson et al. 1993, Conroy 2000b, Conroy and Moore 2002). Thus, management serves as a real-time experiment in which model predictions are compared to data collected on the system.

Adaptive management has three requisite ingredients (Nichols et al. 1995, Williams 1997). The first is a set

of models that captures uncertainty about a system. In the simple example portrayed earlier (*fig. 1B*), the extreme plausible responses for species B could be captured in two alternative models. The second ingredient is a probabilistic expression of relative degree of belief in each model. Again, using the earlier example, belief weight of 0.5 assigned to each model suggests equal uncertainty with regard to the two models. It is these belief weights that adaptive management seeks to modify over time. A belief weight of 1.0 assigned to any model in a set (and consequently 0.0 assigned to all others in the set) implies certainty with regard to behavior of the system. Lastly, a program of system monitoring is requisite, as it provides the information needed to assess model predictions and to therefore modify the belief weights.

The implication of the above is that, under adaptive management, we keep track of an "information state" as well as a physical system state (Walters 1986:200-202, Johnson et al. 1993). The information state tells us at any point in time the status of our knowledge about the system. Given our current state of knowledge about the system, we can make a good management decision for a given status of the resource. Furthermore, at later decision opportunities, our best decision for the same resource status should "adapt" with gain in system knowledge (Johnson and Williams 1999). Thus, adaptive management follows a cyclic pattern of decision making, system measurement, and updating of the information state (Johnson et al. 1993, Johnson and Williams 1999). Bayes' Rule (Lindley 1985:43, Johnson et al. 1993, Conroy 2000b) is the mechanism that reconciles model predictions against monitoring data and updates the information state.

Finally, whereas adaptive management provides a means for moving forward on difficult decisions characterized by uncertainty, we are aware of no decision procedure, including adaptive management, that operates without identification of decision objectives. Thus, adaptive management provides no help at all if parties are simply unable to first agree on resource objectives.

Case Study: Forest Management at the Piedmont National Wildlife Refuge

We applied principles of adaptive management to forest decision making on the Piedmont National Wildlife Refuge, a 14,000-ha, mostly forested area on the southern edge of the Piedmont physiographic province in central Georgia. Much of the management focus at the refuge is on growth of approximately 40 Red-cockaded Woodpecker breeding groups. However, managers are also charged with maintaining populations of co-occurring migratory birds, including those which nest in the substrate that is targeted for removal under woodpecker management.

Red-cockaded Woodpecker habitat at the refuge is characterized by a sparse, mature pine (*P. taeda* or *P. echinata*) overstory, an herbaceous understory, and a nearly absent midstory (Lennartz and Heckel 1987, Loeb et al. 1992). These conditions are maintained by aggressive programs of thinning, burning, and midstory removal (Jones 1993, Powell et al. 2000, U.S. Fish and Wildlife Service 2000). In contrast, the Wood Thrush is associated with dense midstory and closed canopy conditions (Roth et al. 1996, Powell et al. 2000).

The degree to which management for the Red-cockaded Woodpecker and Wood Thrush may be compatible is unknown. Previous work on the refuge found no strong evidence that Wood Thrush densities, survival, or productivity were reduced by woodpecker management (Powell et al. 2000). However, the study was somewhat limited in range of treatment (relative to those practiced elsewhere in the woodpecker's range and to those contemplated in future refuge operations) and in statistical power (Powell et al. 2000). The findings of the study could not preclude the possibility that, at some level, woodpecker-oriented management is incompatible with Wood Thrush population maintenance (Powell et al. 2000).

Similarly, many uncertainties exist regarding spatial dynamics of Red-cockaded Woodpecker populations and population response to forest management. Because the woodpecker's social structure is complex and its life history is so closely tied to a rare and ephemeral type of habitat (Walters 1991), many have recently proposed the incorporation of spatial structure in forest management models (Letcher et al. 1998, Walters et al. 2002).

Refuge managers carry out annual burning, thinning, and regeneration activities in selected stands throughout the forest. For management purposes, the forest is divided into 34 compartments, and compartments are assigned to eight groups of 4-5 noncontiguous compartments each. One group of compartments is visited annually for cutting treatments, but burning treatments may occur anywhere in the refuge. Stands are selected for thinning, regeneration, and burning on the basis of guidelines provided by the U.S. Fish and Wildlife Service (U.S. Fish and Wildlife Service 2000). The guidelines also prescribe number and location of woodpecker artificial recruitment clusters to establish each year.

Model Development and Simulation

Though the guidelines dictate the type, timing, and distribution of many of the forest management activities, managers have latitude in some areas of forest planning. We used simulation modeling to forecast bird population growth under two levels of prescribed burning and four alternative arrangements of compartments into management groups (Moore 2002). The prescribed burning alternatives contrasted high-frequency burning (each compartment burned approximately every 2 years) to low-frequency treatment (approximately every 5 years). The alternative compartment arrangements either maximized or minimized inter-compartment distances both within groups and among groups treated in successive years (*fig. 2*). The combination of these options yielded eight alternative management scenarios or policies.

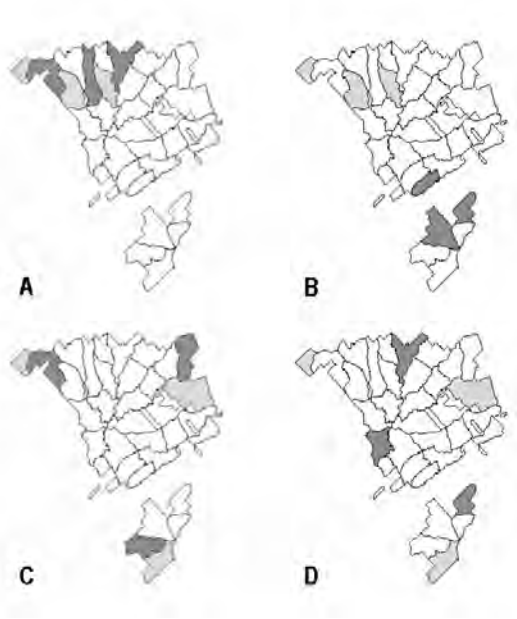


Figure 2—Examples of alternative arrangements of six refuge compartments into two management groups. Compartments of the same shade are treated in the same year; those of different shades are treated in successive years. In cases A and B, compartments treated in the same year are clustered closely but non-contiguously; in cases C and D, within-year compartments are widely spaced. In cases A and C, compartments treated in successive years are positioned next to each other; in cases B and D, successive-year compartments are widely spaced.

We built a set of 12 models that expressed critical uncertainties regarding forest structure dynamics and bird response to forest conditions. The alternative models proposed that forest succession from pine to hardwood occurred (1) slowly, (2) moderately, or (3) rapidly; that woodpecker recruitment was either (1) not sensitive or (2) positively related to the amount of foraging habitat; and that the logarithm of Wood Thrush density responded to forest conditions either (1) linearly (i.e., without bound) or (2) subject to asymptotic lower and upper limits (Moore 2002).

Given one of the eight management policies, the models simulated forest growth dynamics in each of 3,840 landscape cells. We modeled the woodpecker population in a spatially explicit, breeding-cluster-based representation. Woodpecker breeding groups either colonized new clusters, remained in existing clusters, or abandoned their clusters according to estimated forest midstory conditions that were controlled through management. Breeding groups were either nonproductive or produced one or more recruits per year. Depending on the model used, the rate of productivity was also controllable through management. Dispersal of recruits was the mechanism for the colonization of nearby clusters. In contrast, we modeled Wood Thrush density only in a habitat-correlative fashion. Pine basal area, canopy closure, and time since burning were predictor variables in the Wood Thrush models. Several features of each model were stochastic, including forest disturbance events, rate of hardwood succession, woodpecker cluster occupation, and woodpecker recruitment.

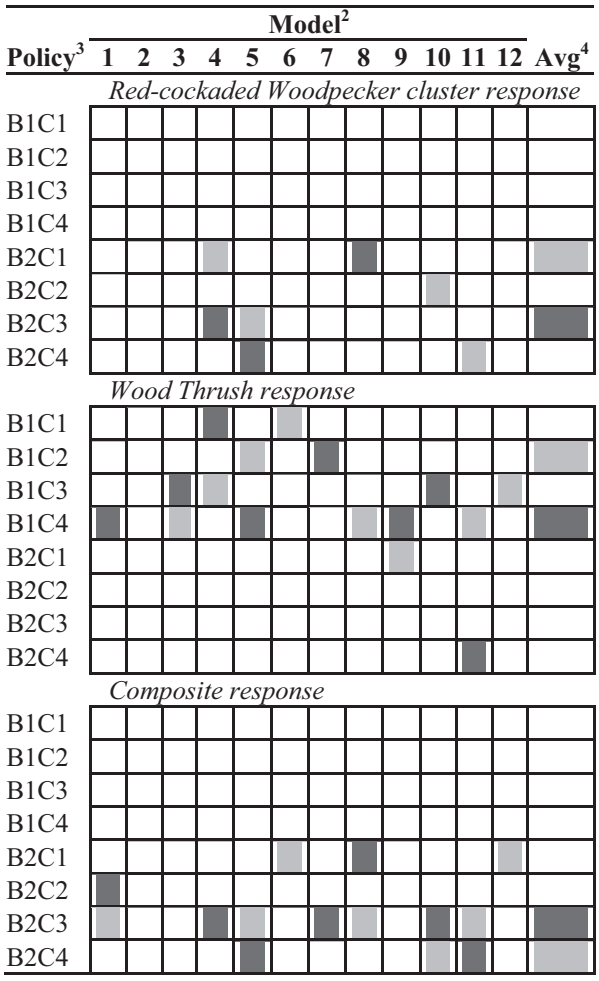
We had very little data for model construction. Our own field data provided information for parameterization of the Wood Thrush habitat models. The refuge provided us with data for modeling woodpecker productivity, but other parameters of our woodpecker model were either derived from the literature or were guessed. Parameters of the forest dynamics model were subjectively chosen, but most had some empirical support from the literature.

We simulated each model over a 100-year time horizon under each alternative policy. Because the models were stochastic, we replicated each simulation 20 times. We calculated the average number of active woodpecker clusters and average density of Wood Thrush for each set of replicates. We obtained a composite average of the two outcomes after scaling each outcome by its standard error.

Results

Each response—average number of active clusters, average Wood Thrush density, and composite score—was highly sensitive to the choice of management policy (*table 1*). In general, high frequency burning, compartment arrangements that maximized within-year compartment dispersion, and arrangements that minimized compartment dispersion in successive years yielded the greatest average woodpecker response. Low frequency burning and maximum separation of compartments both within years and between successive years generally maximized the Wood Thrush response. Because of unequal variation in the constituent responses, patterns in the composite response closely resembled that of the woodpecker response.

Table 1— *Optimal decision policies[1], by forest resource model and expected across models, for each of three resource responses at the Piedmont National Wildlife Refuge, Georgia*



[1]Dark-shaded cells indicate the policy receiving the greatest outcome rank for a model, and the light-shaded cells indicate the second-ranked policy. Cells with no shading represent the policy receiving an outcome ranked third or greater.

[2]Key to model types: hardwood succession rate either intermediate (1-4), rapid (5-8), or slow (9-12); woodpecker productivity either non-responsive (1, 2, 5, 6, 9, 10) or responding positively (3, 4, 7, 8, 11, 12) to amount of foraging habitat around the cluster; and Wood Thrush density response to habitat either linear (1, 3, 5, 7, 9, 11) or nonlinear (2, 4, 6, 8, 10, 12).

[3]Key to policy types: average periodicity of compartment burning either 5 years (B1) or 2 years (B2); and compartment arrangement of type C1 (*fig. 2A*), C2 (*fig. 2B*), C3 (*fig. 2C*), or C4 (*fig. 2D*).

[4]Policy ranks obtained by assigning prior probability of 1/12 to each model and computing the expected outcome over all models.

These patterns were mostly, but not entirely, consistent among all 12 models. However, because of stochasticity of outcomes, a greater degree of consistency in optimal policy among models may be more likely than was apparent.

Monitoring and the Reduction of Uncertainty

When faced with alternative choices of appropriate resource model and alternative indications of which policy is optimal, a reasonable approach for a manager is to choose that policy that yields the maximum expected return across the uncertain models (Conroy 2000a, 2000b). In our case, we assigned equal probability weight of $P_0 = 1/12$ to each model, and we computed outcomes for each policy expected over all models (*table 1*). Thus, despite uncertainty regarding choice of resource model, we nevertheless found policies that were optimal conditional on this uncertainty.

The great benefit of adaptive management is the ability to modify these probability weights through the acquisition of resource data and to thus re-direct future management in response to the gain of information. We used our models to simulate the change in forest and bird state between years 2000 and 2001 following management actions that were carried out during the winter of 2000-2001. Each model provided a prediction of Red-cockaded Woodpecker cluster status in each cell of the landscape. We compared these predictions against cluster status data collected by refuge personnel during the breeding season of 2001. Using Bayes' Rule to combine calculations of conditional likelihoods (a product of Poisson probabilities) with the "prior" model weights ($P_0 = 1/12$ for each model), we computed "posterior" weights that reflected the relative performance by each of these models in predicting future state of the system. To the extent that we can use this approach to accumulate evidence to support or refute these models, we can begin to make management decisions that reflect the increasing state of knowledge about the system and increase management performance.

All of the models over-predicted (range of $\bar{x}$ abundance = 42.6 - 42.9) the abundance (N = 39) of active woodpecker clusters in year 2001. However, the more accurate predictions corresponded to certain hypotheses codified in specific models (*table 1*). Models that proposed a positive association between woodpecker recruitment and foraging habitat received a greater share of posterior probability than those that did not. Similarly, models that proposed a relatively rapid rate of pine succession to hardwood received a greater share of posterior probability than either of the two that proposed a slower rate.

As a consequence of model weight updating, we see that the updated model probabilities now range between 0.0771 and 0.0896 (*table 2*). By comparing each updated value to the prior value of 0.0833, we notice that some models gained credibility and others did not. These adjustments are small, but they are not unreasonable given the fact that we simulated only a single time step. Another iteration of

management could then use this updated information, exactly in the manner as before, to select a management policy that is optimal for the revised state of uncertainty. That new policy will reflect the slightly greater influence offered by the better-predicting resource models.

Discussion

Although we observed that responses were sensitive to simulated management policies, we also found that the optimal policy for each response was mostly insensitive to choice of simulation model. This implies that the resolution of uncertainty provides little practical benefit insofar as management performance is concerned.

However, we stress that this conclusion is dependent on whether critical uncertainties were suitably expressed through this set of models and whether our set of simulated management policies in fact represented the true range of decision alternatives likely available to refuge managers. Despite the detail in our models, we believe that they are nevertheless lacking in the simulation of forest disturbances and succession, in the cluster activity and dispersal dynamics of woodpeckers, and in the set of habitat variables chosen for the prediction of Wood Thrush density. Perhaps more troublesome is our doubt that we were able to successfully portray, through a set of fixed behavior rules, the entire spatially and temporally-explicit pattern of forest cutting and burning actions that would be realized under any given policy option. Prior to starting our work, we were aware that the strategic forest management policies of the refuge are rarely implemented in a predictable way due to limited resources or to short-term shifts in priorities. Though we feel that there is still much to do in improving our models and decision structures, our work has provided us a starting point for finding these improvements and implementing them through time. More importantly, the models, despite their flaws, do represent our best knowledge of the system and, as such, they serve as the most objective basis for charting a course of forest management today.

Although we cannot state with certainty the trade-off between woodpeckers and Wood Thrushes that is implied by any single management policy, by representing uncertainty through a set of resource models, we have obtained a range of trade-offs to consider. For example, the trade-off between the two species ranges from very great (most models in *table 1*) to very slight (models 9 and 11 in *table 1*). Given a statement of the relative degree of belief in each of the models, we can then place bounds on the trade-off implicit for any given decision policy.

Table 2— *Likelihood values ($\mathscr{L}$) and posterior probabilities[1] (P_1), conditional on year 2001 observed abundances of active woodpecker clusters and prior probabilities (P_0), for alternative forest and bird simulation models.*

Model[2]						
Number	**Hardwood**	**RCW**	**WT**	$\mathbf{P_0}$	$\mathscr{L}$[3]	$\mathbf{P_1}$
1	I	N	L	0.0833	8.74×10^{-14}	0.0808
2	I	N	N	0.0833	8.87×10^{-14}	0.0820
3	I	R	L	0.0833	9.17×10^{-14}	0.0848
4	I	R	N	0.0833	9.15×10^{-14}	0.0846
5	R	N	L	0.0833	8.34×10^{-14}	0.0771
6	R	N	N	0.0833	9.47×10^{-14}	0.0876
7	R	R	L	0.0833	9.28×10^{-14}	0.0858
8	R	R	N	0.0833	9.69×10^{-14}	0.0896
9	S	N	L	0.0833	9.00×10^{-14}	0.0832
10	S	N	N	0.0833	8.66×10^{-14}	0.0801
11	S	R	L	0.0833	8.88×10^{-14}	0.0821
12	S	R	N	0.0833	8.90×10^{-14}	0.0823

[1]Posterior probability for each model *i* computed through application of Bayes' Rule:

$$P_{1i} \quad \frac{P_{0i}\mathscr{L}_i}{\sum_{j\ 1}^{12} P_{0j}\mathscr{L}_j}$$

[2]Key to models: hardwood succession either intermediate (I), rapid (R), or slow (S); woodpecker (RCW) productivity either non-responsive (N) or positively responsive (R) to amount of foraging habitat around the cluster; and Wood Thrush (WT) density response to habitat either linear (L) or nonlinear (N).

[3]Counts of active woodpecker clusters in each compartment assumed to follow a Poisson distribution, conditional on prediction model mean.

The most glaring deficiency in our work and the greatest impediment to implementing adaptive management on the refuge is the lack of a systematic, sufficiently detailed, and computer-retrievable program of forest monitoring (Conroy 2000a). Data collected from such a program would substantially contribute to the development of better models and to more accurately record the history of management actions. The program would provide observations against which model predictions could be compared and would serve as the basis for adjusting model belief weights. The woodpecker data described above are currently the only data collected and recorded at any useful resolution for reconciling model predictions to data.

Implications of Adaptive Management for Bird Conservation

We advocate model-based, adaptive approaches to the conservation of bird populations when responses by birds to management are uncertain. This approach requires managers to explicitly state their management objectives, to frame their uncertainty in a set of alternative decision models, and to implement a program of monitoring that measures responses to actions and informs the manager about the relative performance of each model (Conroy 2000a). The first of these requirements cannot be overemphasized: where a management dispute centers on disagreement over objectives, no formal decision making approach is likely to be helpful without first finding a political solution to the impasse.

Under this approach, and as exemplified by our case study, objective decisions may be made in the face of complete uncertainty. The promise of improved management performance is the motivation to reduce uncertainty through the collection of monitoring data. Because models are the basis for decision-making, and because models can be proposed without the aid of data, adaptive management can proceed in data-poor environments as long as a commitment to follow-up monitoring is delivered.

In many other situations, however, we have an abundance of spatial data and have available a number of advanced techniques (Conroy 2000b) to uncover correlations between patterns of bird distribution and habitats. Discussion often ensues on whether such models are "valid" or "invalid" and on their trustworthiness regarding their use for management. Adaptive management places the issue of model validation in a clear and unambiguous context (Conroy and Moore 2002): models are valid to the extent that the quality of their predictions surpasses that offered by any reasonable competitor in repeated application. Thus, without making any absolute and illusory distinction between "valid" and "invalid" models, adaptive management provides a vehicle for making bird conservation decisions under uncertainty with respect to all plausible models. At the same time, however, adaptive management maintains a focus on reducing that uncertainty.

Acknowledgments

Funding and support for our work came from the USGS Patuxent Wildlife Research Center, the U.S. Environmental Protection Agency STAR Fellowship Program (Fellowship U-915424-01-0), the USGS Georgia Cooperative Fish and Wildlife Research Unit (Work Order #34, Coop. Agreement #14-16-0009-1551), and the University of Georgia Warnell School of Forest Resources. We thank the staff of the Piedmont National Wildlife Refuge for their assistance and advice. We also appreciate the invitation by Dan Casey to present our work at the International Partners in Flight Conference. We lastly thank T. D. Rich and J. B. Buchanan who provided helpful comments on our manuscript.

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Effects of Selective Logging on Birds in the Sierra de Coalcomán, Sierra Madre del Sur, Michoacán, Western Mexico[1]

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Abstract

In order to determine the effects of selective logging on pine-oak forest's bird communities in central-western Mexico, we gathered information through 10-min point counts in plots without wood extraction and sites logged at different times in the past (1, 4, and 8 years). We did not find evidences to argue for effects of logging on bird communities; the study plots showed very similar diversity values, and similarity index values among them were high. Feeding guild groups showed different patterns after logging, and particular resident species were the most affected. Migrants as a group did not show a negative effect; none showed significant differences among treatments, and some species were detected more frequently in logged sites.

Introduction

Selective logging is one the most frequently applied silvicultural techniques in the world for the extraction of forest resources. "Sustainable forest management" practices are intended to maintain biodiversity as well as the ecosystem functions and ecological processes of the forests. Selective logging is one of the sustainable methods applied, attempting to emulate the dynamics of natural processes such as the establishment of openings and natural ecological succession (Pearce et al. 2003). In Mexico, as in many other Latin American countries, its implementation has not been completely appropriate and has promoted the deterioration of the forest's structure. With the decrease in habitat's quality, it is logical to expect the impoverishment of the native wildlife communities.

Most of the research on the effects of selective logging on animal communities has been carried out in temperate forests of the United States and Canada (e.g. Sallabanks et al. 2000), as well as in tropical areas of the world such as Belize (Whitman et al. 1998), Brazil (Johns 1991, Aleixo 1999), Ghana (Holbech 1992), Uganda (Sekercioglu 2002), Guiana (Thiollay 1992), and areas of the South Pacific like Borneo (Lambert 1992), Indonesia (Wilson and Johns 1982), and Malaysia (Wong 1986, Johns 1996). According to Sekercioglu (2002), even though 3 to 10 percent of the trees in a selectively logged area are removed for commercial use, 40 to 80 percent of the trees are destroyed as a result of the creation of logging roads, trees falling over neighboring trees, and the activity of machinery used in the process. Basal area, canopy cover, and canopy height are reduced while average gap size and distance between trees increase. Changes in vegetation structure modify the microclimatic conditions by altering temperature, humidity, and light. On one hand, soil desiccation increases seed mortality and lowers tree recruitment, and on the other, rapidly growing shrubs frequently become dominant as a result of higher light incidence near the ground. In general, the findings suggest the existence of important changes in the composition of animal communities and the distribution and abundance of food resources (Johns 1988).

Animal groups that have been frequently used as indicators to determine the effects of selective logging are birds (e.g. Thiollay 1997, Sallabanks et al. 2000), small mammal species and primates (e.g. Kasenene 1984, Crome and Richards 1988, Plumptre and Reynolds 1994, Laurance and Laurance 1996, Ochoa 2000), amphibians (e.g. Messere and Ducey 1998, Lemckert 1999), butterflies and other insect groups (e.g. Atlegrim et al. 1997, Willot 1999, Vasconcelos et al. 2000, Wagner 2000, Willot et al. 2000, Lewis 2001, Summerville and Crist 2002), and reptiles (e.g. Lima et al. 2001).

Particularly for bird populations, the results of studies show a variety of responses. Some studies have detected negative effects, such as the collapse of densities in some bird guilds that are more abundant in forests without harvesting (such as large species, frugivores, and terrestrial and understory insectivores); the decrease has been estimated between 20 to 100 percent of the number of individuals in the groups inhabiting the affected area (Wong 1986; Johns 1988, 1991, 1996; Lambert 1992; Thiollay 1999). Another group of studies has found positive effects, such as an increase in the local abundance of those bird species that adapt very fast to the new conditions, such as hummingbirds, upper-canopy frugivores, omnivores, and gap, edge or low second-growth specialists (Johns 1992; Thiollay 1992, 1999). Additionally, another set of investigations

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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did not find clear and significant effects on bird communities, but considered that species richness and diversity were similar in places with and without selective logging (Holbech 1992, Johns 1992, Whitman et al. 1998, Aleixo 1999).

In the area of the Sierra de Coalcomán, Mexico, selective logging practices have been applied for wood extraction since the 1960s, by "Maderas de Coalcomán" (MADECO) and more recently by "Maderas Preciosas y Derivados" (MAPREyDE), companies that have followed the guidelines of the method known as "Ordenación de Bosques Irregulares". For this method, the volume of wood to be extracted depends on the total number of potentially exploitable trees; the removal of one third of those trees is permitted, and after extraction the plot is allowed to rest for a minimum period of 10 years for the regeneration of the tree cover and the restitution of the forest structure. The criteria of selection for those individual trees to extract are their diameter, age, and general condition (Molina 1997).

Considering the importance of the forest in this section of the Sierra Madre del Sur in Mexico, and that we are not aware of any attempt to determine the effects of selective logging on birds in any forest within Mexico, the objective of this study was to assess the effect of selective logging on the bird communities of a temperate pine-oak forest in central-western Mexico, by determining (1) the diversity of birds in plots without wood extraction and sites logged at different times in the past, (2) the degree of similarity among those plots, and (3) the species richness and abundance of species within the feeding guilds in the plots studied.

Methods

The study area is located in the Sierra de Coalcomán, in the southwestern portion of the state of Michoacán, Mexico, within the municipalities of Coalcomán and Aguililla. The area has a vegetative cover of coniferous forests (pine-oak-fir-juniper) and some cloud forest restricted to protected and more humid areas, at an elevation between 1,700 and 2,500 meters above sea level. To assess the effects of selective logging we selected a control plot that was maintained without extraction at least during the twenty previous years (non-replicated because other non-logged sites were unavailable), and three pairs of plots representing three treatments: (1) one year, (2) four years, and (3) eight years after selective logging. To sample bird communities we performed standard 10-minute point counts (Hutto et al. 1986), in permanent transects in those plots during seven repeated visits, and recorded resident as well as migratory species between December 1999 and December 2000. Bird species were assigned to six foraging guilds according to De Graff (1985): carnivores, granivores, nectarivores, frugivores, insectivores (canopy, understory, aerial, trunk, and terrestrial), and omnivores. Values of diversity were calculated through the Shannon Index [$H'=-\Sigma(p_i*\log_2 p_i)$], and the species abundance distribution by the evenness index

$$[H'/ H'_{max} \text{ where } H'_{max} = \log_2 S];$$

similarity among plots was determined by the use of both, the Sorensen qualitative Index and the Morisita quantitative Index (Magurran 1988); significant differences in the abundance of feeding guilds individuals and the most common species among treatments were determined by one-way ANOVA.

Table 1— *Number of bird species and individuals, and mean number of species and individuals per count, diversity (Shannon Index, H') and evenness (e) for each of the treatment sites at Sierra de Coalcomán, Mexico. n=number of counts.*

Treatments: Years after logging (sample size)	Number of species	Number of individuals	Mean number of species per count	Mean number of individuals per count	H'	e
Control (1 site) (n = 69)	77	854	9.8	12.4	3.9	0.90
1 (2 sites) (n = 138)	89	1,929	9.6	14.0	3.7	0.83
4 (2 sites) (n = 157)	91	2,160	8.9	13.8	3.8	0.84
8 (2 sites) (n = 157)	89	1,962	9.4	12.5	3.8	0.85
Totals (7 sites) (n = 521)	110	6,905	9.4	13.2		

Results

We obtained information from a total of 521 counts, in which 6,905 individuals of 110 species were detected (86 residents and 24 migrants). In general, we did not find significant differences in the mean number of species detected per count (mean = 9.4 [8.9 - 9.8], F = 1.27, p = 0.28), nor in the number of individuals per count (mean = 13.2 [12.4 – 14.0], F = 1.87, p = 0.13) among treatments (*table 1*). With regard to the diversity calculated through the Shannon index, the values were very similar (3.7 to 3.9), as well as the evenness values (0.83 to 0.90). See *table 1*.

When comparing how similar the bird communities were within the treatment plots, it is remarkable that all comparisons resulted in very high coefficients, with a lowest value of 78 percent similarity between the most dissimilar sites (*table 2*). If we consider only information on presence/absence data, the most similar sites are those with one and four years after logging, and the most different being surprisingly the control site and the eight years site. When applying the Morisita Quantitative Index, the sites after one year and after eight years are the most similar, while the control site and the one-year site are the most dissimilar (*table 2*). However, the differences are too small to argue for strong effects.

Table 2— *Comparison between the study sites according to qualitative and quantitative community indexes in the Sierra de Coalcomán, Mexico.*

Treatments	4 year	8 year	Control
Qualitative Index: Sorensen			
1 year	0.91	0.88	0.80
4 year		0.86	0.83
8 year			0.78
Quantitative Index: Morisita			
1 year	0.88	0.94	0.79
4 year		0.93	0.81
8 year			0.87

With respect to the feeding guilds, the insectivores were the most abundant guild, including 53 species, followed by the omnivores (21), frugivores (12), granivores (10), nectarivores (9), and carnivores (5). The non-insectivorous guilds comprised 52 percent of all species, and 41.5 percent of all individuals recorded. Insectivores comprised 48 percent of the species, and 58.5 percent of the individuals recorded. Understory insectivores were the most abundant group with 1,359 individuals, followed by canopy (977), aerial (931), trunk (689), and terrestrial insectivores (83).

With regard to the treatments, guilds showed different responses to harvesting (*fig. 1*). Nectarivores and omnivores increased after opening of the forest and decreased in subsequent years. The carnivores' guild diminished with the logging activities and increased subsequently in the four and eight years after treatment. Frugivores showed a response to the productivity of the forest plants, and had an initial increase that diminishes with time after logging. Seed-eating species showed an initial increase, diminishing in subsequent phases and increasing in the eight years after treatment.

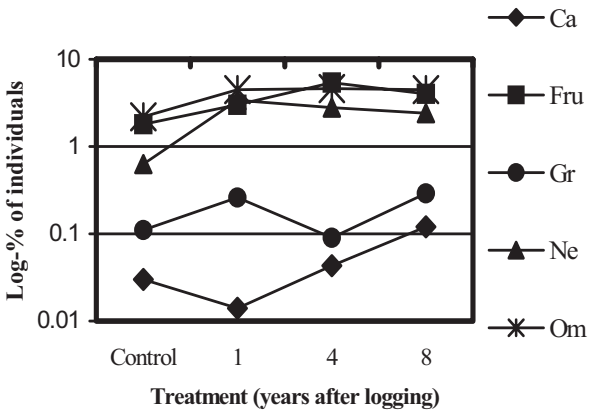

Figure 1— Log-percentage of the number of bird individuals recorded per feeding guild in each treatment, in the Sierra de Coalcomán, Mexico. Feeding guilds: Ca= Carnivores, Fru=Frugivores, Gr= Granivores, Ne= Nectarivores, Om=Omnivores.

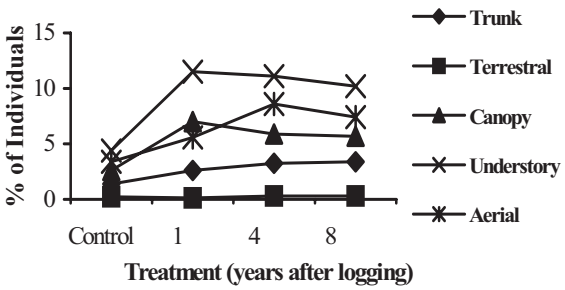

Figure 2— Percentage of the number of insectivore individuals recorded in each treatment at Sierra de Coalcomán, Mexico.

Except for the terrestrial insectivores that showed a decrease in abundance, all other insectivores apparently showed at least a slight increase after selective logging; detections of understory and canopy insectivores went up more than twice one year after logging and decreased gradually afterwards. Trunk insectivores increased slowly to reach the highest numbers at the eight-year treatment, to decrease once again in the nonlogged site (control). Aerial insectivores reached the highest values at the four-year treatment and decreased afterwards (*fig. 2*).

When considering individual species, out of the 54 species with more than 20 detections, 27 (50 percent) showed significant differences in their abundances among treat-

ments (*appendix 1*): among the resident species, 18 decreased and 11 increased; among the neotropical migrant species, none showed significant decreases, and 5 increased their abundances ($\chi^2 = 8.52$, df = 1, P = 0.0035). These figures suggest that there are important differential effects of selective logging on resident and migrant species. Among those affected by selective logging we can include the following species (see *appendix 1* for scientific names): West Mexican Chachalaca, Elegant Trogon, Acorn woodpecker, Happy Wren, Greater Pewee, Grace's Warbler, and Black-headed Oriole. Among the species being favored by logging activities are the White-eared Hummingbird, Broad-tailed Hummingbird*, Western Flycatcher, Cedar Waxwing*, Nashville Warbler*, Townsend's Warbler*, and Hermit Warbler* [* = migrant species].

Discussion

In places where logging activities have been practiced for a considerable period of time in the past, we have different forest successional stages currently represented. Our results did not show evidence of clear trends in any of the diversity and evenness values for the study sites. They were, however, slightly greater in the control site without recent forest extraction, as found by Thiollay (1999) in a tropical rain forest of French Guiana, where the overall effect of selective logging caused only a difference of 6 percent in the diversity and evenness values.

The variation in the composition of the communities, although small, may be caused by changes in the dynamics of the productivity of the forest; the opening of the vegetation could promote the temporary appearance of resources used by different sets of species, and the establishment of different interactions between bird species. The different patterns resulting from selective logging could be the result of various factors involved at different scales. On the other hand, the migratory species as a group did not show evidence of negative effects caused by logging in the forests where they winter, similar to previous studies in western Mexico (Hutto 1992, Hutto 1995, Villaseñor and Hutto 1995). However, individual species were apparently affected. This implies that each species reacts differently to habitat changes caused by logging activities, and those effects are not necessarily detected at the level of guilds. We should devote special attention to those species that are more sensitive to forest modification.

Clear general effects of selective logging on the bird communities of the Sierra de Coalcomán could also be lacking because of confounding effects such as (1) high environmental heterogeneity in the study area, (2) the history of logging in the study sites is complex and not clearly known, and (3) uncertainty of the intensity of the extraction during the previous logging activities.

Marzluff et al. (2000) indicate that two of the main problems of most studies are their limited temporal and spatial scales, as well as the lack of rigorous experimental design. In this sense, very often research is limited by the extant conditions of the study sites and logistical problems, mostly when funding is limited in time, and the design has to take the form of short-term pseudo experimental studies; our study is not an exception to the general picture. Because of these kinds of problems, dispersal and metapopulation effects could be involved making it hard to determine the population dynamics and the real responses of given species. This is stressed in an interesting review of timber harvest effects on bird populations in North America presented by Sallabanks et al. (2000).

Given that selective logging is practiced widely in the world, what are the aspects that we should consider in future research?

- Studies should consider the environmental heterogeneity of the areas,
- Long-term research would help us understand the recovery dynamics of the forests,
- Studies should monitor variables which may be closely related to population demographics, especially for species which are relatively easy to age and sex,
- Studies should identify metapopulation processes occurring in these fragmented, timber harvest landscapes.

Acknowledgments

This study was possible thanks to the support of the Comisión Nacional para el Uso y Conocimiento de la Biodiversidad (CONABIO FB63/R215/98), the Association of Field Ornithologists (AFO) through a Latin American E. Alexander Bergstrom Research Award (1999-Neyra Sosa Gutiérrez), and the Coordinación de Investigación Científica of Universidad Michoacana de San Nicolás de Hidalgo (UMSNH-CIC Project 7.2 / 1998-1999). We thank the staff at the UMSNH Ornithology Lab who were amazingly valuable in the fieldwork, especially F. Martinez, F. R. Pineda, F. J. Torres, A. Blanco, P. Marti, and L. Villaseñor. We deeply appreciate all the comments and suggestions made by reviewers C. J. Ralph, A. D. Cuarón, C. Tena, and T. Bateridge.

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Appendix 1— *Bird species recorded in the Sierra de Coalcomán, Michoacán, Mexico. Total of individuals detected (n), mean of number of individuals per count for each treatment (T1, T4, T8, Control), and the derived significance value from One-way ANOVA (p)*

			Years after treatment				
Species	**English Name**	**n**	**T1**	**T4**	**T8**	**Control**	**p**
Ortalis poliocephala	West Mexican Chachalaca	38	0.107	0.026	0.026	0.232	0.002
Accipiter striatus	Sharp-shinned Hawk	6	0.000	0.000	0.038	0.000	ns
Buteo jamaicensis	Red-tailed Hawk	5	0.007	0.013	0.006	0.015	ns
Falco sparverius	American Kestrel	1	0.000	0.006	0.000	0.000	ns
Patagioenas fasciata	Band-tailed Pigeon	13	0.065	0.000	0.026	0.000	ns
Zenaida asiatica	White-winged Dove	11	0.015	0.013	0.045	0.000	ns
Columbina inca	Inca Dove	1	0.000	0.000	0.006	0.000	ns
Leptotila verreauxi	White-tipped Dove	19	0.029	0.019	0.051	0.058	ns
Piaya cayana	Squirrel Cuckoo	3	0.000	0.000	0.000	0.044	0.000
Geococcyx velox	Lesser Roadrunner	1	0.000	0.000	0.006	0.000	ns
Glaucidium brasilianum	Ferruginous Pygmy-Owl	1	0.000	0.000	0.000	0.015	ns
Colibri thalassinus	Green Violet-ear	9	0.007	0.045	0.006	0.000	0.042
Hylocharis leucotis	White-eared Hummingbird	400	0.966	0.809	0.771	0.290	0.003
Amazilia beryllina	Berylline Hummingbird	11	0.044	0.006	0.000	0.058	0.040
Lampornis amethystinus	Amethyst-throated Hummingbird	141	0.449	0.261	0.185	0.130	0.001
Eugenes fulgens	Magnificent Hummingbird	14	0.022	0.026	0.045	0.000	ns
Atthis heloisa	Bumblebee Hummingbird	5	0.000	0.000	0.000	0.073	ns
Selasphorus platycercus	Broad-tailed Hummingbird	33	0.101	0.070	0.013	0.087	0.027
Selasphorus rufus	Rufous Hummingbird	14	0.087	0.006	0.006	0.000	0.005
Trogon mexicanus	Mountain Trogon	144	0.384	0.210	0.338	0.073	0.000
Trogon elegans	Elegant Trogon	26	0.015	0.032	0.038	0.188	0.000
Euptilotis neoxenus	Eared Quetzal	2	0.000	0.000	0.013	0.000	ns
Melanerpes formicivorus	Acorn Woodpecker	64	0.217	0.115	0.083	0.435	0.000
Sphyrapicus varius	Yellow-bellied Sapsucker	4	0.007	0.013	0.006	0.000	ns
Picoides scalaris	Ladder-backed Woodpecker	18	0.007	0.032	0.057	0.044	ns
Picoides stricklandi	Strickland's Woodpecker	55	0.080	0.121	0.115	0.101	ns
Veniliornis fumigatus	Smoky-brown Woodpecker	5	0.015	0.006	0.006	0.015	ns
Colaptes auratus	Northern Flicker	50	0.087	0.115	0.057	0.159	ns
Campephilus guatemalensis	Pale-billed Woodpecker	1	0.007	0.000	0.000	0.000	ns
Sittasomus griseicapillus	Olivaceous Woodcreeper	6	0.000	0.000	0.038	0.000	3.553
Lepidocolaptes leucogaster	White-striped Woodcreeper	234	0.522	0.529	0.395	0.246	0.002
Camptostoma imberbe	Northern Beardless-Tyrannulet	3	0.015	0.006	0.000	0.000	ns
Myiopagis viridicata	Greenish Elaenia	8	0.022	0.022	0.006	0.029	ns
Mitrephanes phaeocercus	Tufted Flycatcher	322	0.464	0.605	0.745	0.667	0.011
Contopus pertinax	Greater Pewee	132	0.116	0.172	0.344	0.507	0.000

Appendix 1, *continued*

Species	English Name	n	Years after treatment T1	T4	T8	Control	p
Empidonax hammondii	Hammond's Flycatcher	10	0.145	0.026	0.013	0.029	ns
Empidonax occidentalis	Cordilleran Flycatcher	199	0.493	0.369	0.360	0.246	0.041
Empidonax fulvifrons	Buff-breasted Flycatcher	8	0.051	0.006	0.000	0.000	ns
Attila spadieus	Bright-rumped Attila	21	0.007	0.019	0.076	0.073	0.008
Myiarchus tuberculifer	Dusky-capped Flycatcher	222	0.515	0.446	0.357	0.362	ns
Pachyramphus major	Gray-collared Becard	6	0.007	0.013	0.006	0.029	ns
Pachyramphus aglaiae	Rose-throated Becard	3	0.015	0.006	0.000	0.000	ns
Vireo plumbeus	Plumbeous Vireo	11	0.015	0.013	0.032	0.029	ns
Vireo huttoni	Hutton's Vireo	106	0.217	0.239	0.140	0.142	0.025
Vireo gilvus	Warbling Vireo	67	0.130	0.134	0.083	0.217	ns
Vireolanius melitophrys	Chestnut-sided Shrike-Vireo	8	0.044	0.006	0.000	0.015	0.039
Cyanocitta stelleri	Steller's Jay	159	0.413	0.248	0.299	0.232	ns
Corvus corax	Common Raven	2	0.000	0.006	0.006	0.000	ns
Poecile sclateri	Mexican Chickadee	9	0.000	0.019	0.038	0.000	ns
Psaltriparus minimus	Bushtit	177	0.275	0.459	0.369	0.130	ns
Sitta carolinensis	White-breasted Nuthatch	43	0.029	0.096	0.153	0.000	0.000
Sitta pygmaea	Pygmy Nuthatch	82	0.232	0.089	0.159	0.159	ns
Certhia americana	Brown Creeper	169	0.283	0.312	0.414	0.232	ns
Campylorhynchus megalopterus	Gray-barred Wren	155	0.370	0.293	0.306	0.145	ns
Catherpes mexicanus	Canyon Wren	1	0.000	0.000	0.000	0.015	ns
Thryothorus felix	Happy Wren	32	0.029	0.032	0.028	0.246	0.043
Troglodytes aedon brunneicollis	House Wren	231	0.754	0.261	0.369	0.406	0.000
Henicorhina leucophrys	Gray-breasted Wood-Wren	23	0.029	0.446	0.038	0.087	ns
Sialia sialis	Eastern Bluebird	32	0.036	0.076	0.064	0.073	ns
Myadestes occidentalis	Brown-backed Solitaire	323	0.601	0.599	0.713	0.493	ns
Catharus aurantiirostris	Orange-billed Nightingale-Thrush	5	0.007	0.006	0.006	0.029	ns
Catharus occidentalis	Russet Nightingale-Thrush	127	0.210	0.248	0.191	0.420	0.018
Catharus franzii	Ruddy-capped Nightingale-Thrush	2	0.000	0.013	0.000	0.000	ns
Catharus guttatus	Hermit Thrush	9	0.007	0.026	0.026	0.000	ns
Turdus assimilis	White-throated Robin	56	0.029	0.104	0.159	0.145	ns
Turdus migratorius	American Robin	88	0.219	0.198	0.121	0.116	ns
Ridgwayia pinicola	Aztec Thrush	95	0.007	0.535	0.051	0.029	ns
Melanotis caerulescens	Blue Mockingbird	58	0.145	0.076	0.076	0.203	0.043
Bombycilla cedrorum	Cedar Waxwing	86	0.000	0.535	0.000	0.029	0.017
Ptilogonys cinereus	Gray Silky-flycatcher	225	0.159	0.707	0.414	0.391	0.011
Peucedramus taeniatus	Olive Warbler	323	0.688	0.701	0.490	0.594	ns

Appendix 1, *continued*

Species	English Name	n	Years after treatment T1	T4	T8	Control	p
Vermivora celata	Orange-crowned Warbler	6	0.007	0.019	0.006	0.015	ns
Vermivora ruficapilla	Nashville Warbler	21	0.022	0.064	0.045	0.015	ns
Vermivora crissalis	Colima Warbler	1	0.000	0.000	0.006	0.000	ns
Parula superciliosa	Crescent-chested Warbler	216	0.558	0.497	0.331	0.130	0.004
Dendroica coronata	Yellow-rumped Warbler	16	0.015	0.045	0.045	0.000	ns
Dendroica nigrescens	Black-throated Gray Warbler	2	0.000	0.000	0.000	0.029	0.004
Dendroica townsendi	Townsend's Warbler	126	0.384	0.166	0.204	0.217	0.041
Dendroica occidentalis	Hermit Warbler	73	0.268	0.083	0.121	0.058	0.030
Dendroica graciae	Grace's Warbler	64	0.022	0.096	0.172	0.275	0.001
Mniotilta varia	Black-and-white Warbler	8	0.007	0.000	0.019	0.058	0.009
Oporornis tolmiei	MacGillivray's Warbler	8	0.051	0.000	0.006	0.000	ns
Wilsonia pusilla	Wilson's Warbler	159	0.268	0.363	0.306	0.246	ns
Cardellina rubrifrons	Red-faced Warbler	43	0.051	0.089	0.089	0.116	ns
Ergaticus ruber	Red Warbler	15	0.015	0.057	0.026	0.000	ns
Myioborus pictus	Painted Redstart	5	0.000	0.006	0.006	0.044	0.018
Myioborus miniatus	Slate-throated Redstart	419	0.841	0.822	0.822	0.652	ns
Basileuterus rufifrons	Rufous-capped Warbler	14	0.000	0.038	0.000	0.116	0.001
Basileuterus belli	Golden-browed Warbler	149	0.457	0.185	0.344	0.044	0.000
Piranga flava	Hepatic Tanager	134	0.297	0.293	0.217	0.188	ns
Piranga rubra	Summer Tanager	9	0.000	0.026	0.032	0.000	ns
Piranga ludoviciana	Western Tanager	3	0.007	0.006	0.000	0.015	ns
Piranga bidentata	Flame-colored Tanager	99	0.261	0.102	0.172	0.290	0.008
Piranga erythrocephala	Red-headed Tanager	10	0.022	0.000	0.019	0.058	ns
Diglossa baritula	Cinnamon-bellied Flowerpiercer	6	0.015	0.013	0.013	0.000	ns
Atlapetes pileatus	Rufous-capped Brush-Finch	46	0.138	0.108	0.064	0.000	ns
Buarremon virenticeps	Green-striped Brush-Finch	74	0.297	0.057	0.147	0.015	0.000
Pipilo ocai	Collared Towhee	31	0.065	0.070	0.064	0.015	ns
Aimophila ruficeps	Rufous-crowned Sparrow	6	0.007	0.006	0.000	0.058	0.001
Chondestes grammacus	Lark Sparrow	2	0.015	0.000	0.000	0.000	ns
Junco phaeonotus	Yellow-eyed Junco	6	0.015	0.026	0.000	0.000	ns
Pheucticus melanocephalus	Black-headed Grosbeak	23	0.065	0.064	0.026	0.000	ns
Passerina versicolor	Varied Bunting	2	0.007	0.000	0.006	0.000	ns
Icterus graduacauda	Audubon's Oriole	18	0.000	0.006	0.019	0.203	0.000
Icterus galbula	Baltimore Oriole	24	0.015	0.076	0.045	0.044	ns
Icterus parisorum	Scott's Oriole	7	0.007	0.026	0.013	0.000	ns
Euphonia elegantissima	Elegant Euphonia	18	0.015	0.032	0.000	0.159	0.012

Appendix 1, *continued*

Species	English Name	n	Years after treatment			Control	p
			T1	T4	T8		
Loxia curvirostra	Red Crossbill	4	0.000	0.000	0.000	0.058	0.001
Carduelis pinus	Pine Siskin	32	0.065	0.019	0.051	0.174	0.026
Carduelis notata	Black-headed Siskin	33	0.029	0.022	0.026	0.333	0.000

Restoring High Priority Habitats for Birds: Aspen and Pine in the Interior West[1]

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Abstract

This paper describes a long-term habitat restoration project in the Blue Mountains ecoregion, northeast Oregon, that we initiated in May 2000. We focused our restoration activities on two habitats previously identified as being high priority for birds: quaking aspen (*Populus tremuloides*) and ponderosa pine (*Pinus ponderosa*). In the interior West, these two habitats have become heavily degraded as a result of ungulate herbivory, fire exclusion, and logging associated with Euro-American settlement. To begin to restore these important habitats, we established 12 permanent study sites, initiated restoration treatments (fence building and conifer removal in aspen; prescribed burning in pine), and collected baseline ecological data (birds and habitat) to describe reference conditions. In two years (2000–2001), we built approximately 7 km of fence around existing aspen stands, burned 400 ha of pine, monitored 816 nests of 46 bird species, and intensively sampled vegetative characteristics at a variety of scales. In 2002, we added another 0.75 km of fence, built 180 protective cages around individual aspen trees, and burned another 400 ha of pine. In this paper, we describe our study area, monitoring techniques, restoration activities, brief summaries of breeding bird abundance and nesting success, project progress to date, and future plans.

Key words: avifauna, Blue Mountains, fire, grazing, habitat degradation, nest monitoring, point counts, ponderosa pine, quaking aspen, restoration.

Introduction

Grazing, fire exclusion, and logging associated with Euro-American settlement have brought about substantial changes to forest conditions throughout the inland West, including the Blue Mountains ecoregion of northeast Oregon (Sallabanks et al. 2001). In particular, the exclusion of natural fires has led to increased tree densities and associated shifts in ecosystem structure, fire hazard, disturbance regimes, and wildlife habitat (Covington and Moore 1994, Agee 1999). To remedy these problems and restore "Eastside" forests to more natural conditions requires immediate action on the behalf of researchers and land managers.

Because of their limited distribution and degraded condition, two habitats have been identified as high priority for nongame landbirds by recent Partners in Flight conservation planning efforts for coniferous forests of the northern Rocky Mountains in Oregon and Washington (Altman 2000): riparian habitat, especially quaking aspen (*Populus tremuloides*), and dry forest, especially ponderosa pine (*Pinus ponderosa*). Both habitats occur extensively throughout the Blue Mountains ecoregion, including the Wallowa Mountains, which is where our restoration efforts are currently focused. Settlement, the introduction of domestic livestock, management for timber, and changes to historical fire regimes have significantly affected both aspen and pine, and both are high priorities for restoration by managers.

Eastside riparian habitat is complex, and includes both low elevation streamside vegetation as well as upland stands of aspen (Chappell et al. 2001). Aspen stands are restricted to present occupation because current grazing pressure (from both wild and domestic herbivores) limits natural regeneration by seedling establishment. As a result, the only way to retain aspen as a component in Eastside forests is to reinvigorate existing stands. Restoration of riparian habitat requires fencing (to exclude herbivory), oftentimes in combination with prescribed burning (especially for aspen, which is fire maintained), and selective vegetation management (i.e., mechanical removal and culling of competing tree species, especially conifers). High priority bird species such as the Red-naped Sapsucker (*Sphyrapicus nuchalis*), Williamson's Sapsucker (*Sphyrapicus thyroideus*), Veery (*Catharus fuscescens*), Red-eyed Vireo (*Vireo olivaceus*), and Yellow Warbler (*Dendroica petechia*) may benefit from this type of management. Many other species, such as the Warbling

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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Vireo (*Vireo gilvus*), Mountain Bluebird (*Sialia currucoides*), and Hairy Woodpecker (*Picoides villosus*), also frequently use aspen woodlands for foraging and nesting habitat (Sallabanks 2000a, 2001).

Within dry forests, managers seek to restore open, park-like stands of mature ponderosa pine using a combination of prescribed burning and selective vegetation management (Covington et al. 1999). Returning this habitat to a more historical condition likely will benefit several high priority bird species, such as the White-headed Woodpecker (*Picoides albolarvatus*), White-breasted Nuthatch (*Sitta carolinensis*), and Flammulated Owl (*Otus flammeolus*). Other species that regularly use pine for nesting and foraging include Hammond's Flycatcher (*Empidonax hammondii*), Chipping Sparrow (*Spizella passerina*), and Pygmy Nuthatch (*Sitta pygmaea*; Sallabanks 2000a, 2001).

To address these management needs, we initiated a habitat restoration project in May 2000 that included a bird-monitoring component (Sallabanks 2000b). Our specific short-term (2-year) study objectives were four-fold:

(1) To locate, map, and establish permanent long-term (minimum of 10 yr) study sites in six aspen stands and six ponderosa pine/Douglas-fir (*Pseudostuga menziesii*) stands in the Wallowa Mountains of northeast Oregon

(2) To build fences around the six selected aspen stands. Exclosures were to initially range from 8 to 16 ha in size, depending on the size of the existing aspen stands (currently 2 to 8 ha). Our goal during the 10-yr period 2000 to 2010 was to create at least six aspen patches >16 ha in size

(3) To initiate burning and selective vegetation management prescriptions in a subset of the selected aspen stands (not all aspen stands will needed burning, for example) and in all six selected ponderosa pine/Douglas-fir stands (pine stands were >200 ha in size)

(4) To establish an extensive monitoring program in all 12 selected study sites to provide a baseline assessment of avian community composition and vegetation composition. This also would include an assessment of avian structure population viability in a subset (8) of the study sites. These assessments would serve as a basis against which to measure future changes in habitat features and bird populations as restoration efforts take effect.

Our long-term (minimum of 10 yr) study objectives were three-fold:

(1) To maintain fences around all aspen stands and conduct some re-burning and selective vegetation management in selected stands in subsequent years

(2) To monitor changes in avian community composition and population viability, as well as habitat structure and plant species composition, as restoration efforts continue through at least 2010

(3) To expand our study to include restoration of additional aspen and pine habitat.

In this paper, we describe our study area, restoration activities, monitoring techniques, and provide an overview of project progress during the first three years, 2000 to 2002. Preliminary summaries of avian community composition, birds caught and banded, nests found, and fledging success also are provided.

Methods

Study Area

Our study occurred within the Sheep Creeks/Imnaha Collaborative Stewardship Initiative (SCICSI) planning area in the Wallowa Mountains, northeast Oregon, which form part of the Blue Mountains ecoregion. The SCICSI planning area is located in Wallowa County, approximately 20 km northeast of the town of Enterprise and just southwest of the small community of Imnaha. The planning area encompasses approximately 80,000 ha of mid-elevation (1,500 to 1,600 m asl) forest and grassland habitat within the Imnaha subwatershed of the Snake River drainage. The Imnaha River and the ridgeline above Little Sheep Creek form the east and west boundaries, respectively. The confluence of Little Sheep Creek and the Imnaha River forms the north-end of the planning area near Imnaha. The Eagle Cap Wilderness Area forms the south boundary. Several major ridges and associated canyons run north and south through the planning area, separated by Big and Little Sheep Creeks and the Imnaha River. These include Clear Lake, Deadhorse, and Beeler Ridges.

Ridge tops in the planning area are dominated by native bunchgrass communities of Idaho fescue (*Festuca idahoensis*), with bluebunch wheatgrass (*Elytrigia spicata*) and Junegrass (*Koeleria nitida*) also common. Sandberg's bluegrass (*Poa sandbergii*) is common on scablands and other areas of shallow soil. These grassland communities provide habitat for a wide range of wildlife species including deer (both mule [*Odocoileus hemionus hemionus*] and white-tailed [*O. virginianus ochrourus*]) and Rocky Mountain elk (*Cervus elaphus nelsoni*), raptors such as the Prairie Falcon (*Falco mexicanus*) and Ferruginous Hawk

(*Buteo regalis*), and rare birds such as the Upland Sandpiper (*Bartramia longicauda*) and Columbian Sharp-tailed Grouse (*Tympanuchus phasianellus columbianus*). Due to the low, open road density on Clear Lake and Deadhorse Ridges, elk can often be found using this open grassland habitat year-round. A resident herd of over 350 elk can be found on the Clear Lake/Deadhorse Ridge section alone. More than 1,000 elk use the planning area as winter and transitory range during spring and fall. The timbered slopes create a classic, grass-tree mosaic habitat with mixed conifer stands of pine and fir. Ponderosa pine is dominant in the numerous draws. At the heads and in the bottoms of these draws are substantial remnant hardwood communities of aspen, hawthorn (*Crataegus* spp.), upland willows (*Salix* spp.), mountain ash (*Sorbus scopulina*), and serviceberry (*Amelanchier alnifolia*). Approximately 100 aspen clones are known to occur within the planning area totaling approximately 100 ha. Some of these clones are within existing exclosures (built during the 1970s) or have received other treatments, but the majority are in fair-to-poor condition and exposed to grazing. The upper elevations in the south portion of the planning area have mixed conifer communities of lodgepole pine (*Pinus contorta*), western larch (*Larix occidentalis*), Douglas-fir, and true firs near the wilderness boundary. In the bottom of Devil's and Bear Gulches are relatively intact riparian zones of cottonwood (*Populus* spp.), aspen, alder (*Alnus* spp.), and birch (*Betula* spp.), providing excellent habitat for a wide variety of Neotropical migratory songbirds including the Red-eyed Vireo and Veery, as well as Ruffed (*Bonasa umbellus*) and Blue (*Dendragapus obscurus*) Grouse, Wild Turkey (*Meleagris gallopavo*), and Mountain Quail (*Oreortyx pictus*).

A unique feature to the planning area is the high-elevation, natural playa lakes that give Clear Lake Ridge its name. These small lakes and ponds total approximately 84 surface ha of water and emergent habitats. The largest of these is Downy Lake, which covers over 40 ha in years of average precipitation. Sensitive amphibians such as the Columbia spotted frog (*Rana luteiventris*) inhabit the lake and many species of bats, including the sensitive pale western big-eared bat (*Corynorhinus townsendii ingens*), catch insects over the lakes in the summer months.

The riparian and wetland vegetation surrounding these small lakes provides habitat for a variety of waterfowl and shorebirds, including many species of ducks and geese, Horned (*Podiceps auritus*) and Eared (*P. nigricollis*) Grebes, and Trumpeter Swans (*Cygnus buccinator*). Downy Lake has the only nesting colony of Yellow-headed Blackbirds (*Xanthocephalus xanthocephalus*) within at least 80 km and used to be the only known nesting area in the lower 48 states for the Greater Yellowlegs (*Tringa melanoleuca*); whether yellowlegs still breed there today remains unconfirmed.

This vegetation zone also provides habitat for several rare, sensitive plant species including Spalding's Silene or Catchfly (*Siliene spaldingi*) and Henderson's Ricegrass (*Oryzopsis hendersonii*). The lakes provide a ridgetop water supply for livestock and native ungulates. All lands lying between Little Sheep Creek and the Imnaha River also are historic Rocky Mountain Bighorn Sheep (*Ovis canadensis canadensis*) range and lie adjacent to the Hells Canyon Bighorn Sheep Initiative Area to the east.

The planning area is divided into a number of private, state, and federal ownerships as follows:

(1) U.S. Forest Service (USFS), approximately 70 percent

(2) private ranches, approximately, 20 percent

(3) U.S. Bureau of Land Management <10 percent

(4) Oregon Department of Fish and Wildlife, <5 percent

(5) Oregon Nature Conservancy (ONC), approximately 2 percent.

Within the SCICSI planning area, we proposed to focus our initial restoration efforts on USFS and private lands during 2000–2001. Specifically, we targeted degraded stands of quaking aspen and ponderosa pine along Beeler Ridge. Over the course of our long-term study, however, we anticipate expanding restoration activities to include the natural playa lakes and other important wetland habitats within the planning area. As a result, we hope all landowners will eventually become involved as habitat restoration occurs on other lands. By mid-summer 2000, 11 permanent study sites had been established within the planning area: 5 in aspen habitat and 6 in ponderosa pine habitat. During the 2001 season, a sixth aspen study site was added to the project (*table 1*).

Monitoring Techniques

During the 2000 and 2001 avian breeding seasons, we collected several different types of data, as outlined below.

Table 1— *Study sites selected for a long-term habitat restoration project in the Wallowa Mountains, northeast Oregon, 2000–2001.*

Habitat	Site name	Plot size	Ownership	Lat-long (deg., min. sec)
Aspen	Target Springs	13 ha	FS (WVRD)	N45° 14.475′, W117° 04.623′
	Marr Flat	16 ha	FS (WVRD)	N45° 19.366′, W116° 53.591′
	Road Canyon	18 ha	FS (WVRD)	N45° 17.920′, W116° 55.577′
	Bristow Flat	16 ha	FS (WVRD)	N45° 23.015′, W116° 50.436′
	Marks	24 ha	Private	N45° 18.470′, W116° 57.127′
	Timber Creek	20 ha	Private/FS (WVRD)	Lat-long not recorded
Pine	Hidden Springs	25 ha	FS (HCNRA)	N45° 06.919′, W116° 58.902′
	Indian Crossing	25 ha	FS (HCNRA)	N45° 06.899′, W117° 00.338′
	Ollokot	25 ha	FS (HCNRA)	N45° 08.411′, W116° 52.990′
	Evergreen	25 ha	FS (HCNRA)	N45° 06.815′, W116° 59.742′
	Sierra Flat	25 ha	FS (HCNRA)	N45° 06.794′, W116° 54.607′
	Imnaha	25 ha	FS (HCNRA)	N45° 08.813′, W116° 52.850′

Notes: FS (WVRD) = U.S. Forest Service (Wallowa Valley Ranger District); FS (HCNRA) = U.S. Forest Service (Hells Canyon National Recreation Area). Timber Creek site added in 2001.

Relative avian abundance

We measured relative breeding bird abundance at all sites using the standard fixed-radius (50 m) point-count censusing technique in both years (Ralph et al. 1993). With one exception, six point-count stations, at least 150 m apart, were established at each site; one aspen stand, Target Springs (*table 1*), was only large enough to accommodate five stations. We visited each station three times, except for Timber Creek, which was added to the study in 2001 and only visited twice (*table 1*) during the period of 12 May through 14 July 2000 and 2 June through 1 July 2001. During counts, all vocal and visual avian detections were identified to species. Birds flying above the canopy were recorded as such, and birds known or suspected to have been recorded at a previous count station within the survey area were ignored.

Nest success and fledging rates

We conducted nest searching and monitoring at five aspen sites (all except Timber Creek) and at three pine sites (Hidden Springs, Indian Crossing, and Ollokot) using standardized techniques in both years (Martin and Geupel 1993). Eight sites are all that we could effectively monitor given available funding and associated field personnel. All nests found were monitored every 3 to 4 d and their fate recorded (i.e., successful, deserted, depredated, parasitized by cowbirds, or fate unknown). Where possible, numbers of eggs laid, eggs hatched, and young fledged were recorded for all nests monitored.

Mist netting and color banding

We used mist nets and leg bands to catch and mark birds following protocols of the national Monitoring Avian Productivity and Survivorship Program (MAPS; DeSante 1992), with some modifications. Establishing a population of marked birds is useful for long-term demographic studies and also would facilitate the assessment of within-season reproductive success of individual pairs of birds. Over the 2-yr period, mist netting and banding occurred at all aspen sites with the exception of Timber Creek; MAPS protocols were followed most stringently at Marr Flat (see below), with more selective targeted mist-netting occurring at the remaining sites. No banding occurred at Target Springs in 2001 because of the driving distance to the site. In addition to standard USFWS metal bands, which were placed on all caught birds, we used color bands to uniquely identify a subset of species. Species selected for color banding represented those that were relatively common and for which we were able to find and accurately monitor nests. We did not want to color band birds unnecessarily, such as species for which we would rarely find nests or that nested in the canopy where we could not monitor them. In both years, we conducted intensive banding at Marr Flat, where ten 12-m nets were opened for 6 hr (0600–Noon) 1 d every 10 d for a 100-d period beginning in late May. Pyle (1997) was used to identify species and make detailed recordings of plumage, age, sex, body weight, molt, fat, and reproductive status (if appropriate); for a more detailed description of the data collected, refer to Ralph et al. (1993).

GPS surveys

With the exception of Timber Creek (see *table 1*), which wasn't added to the study until 2001, we surveyed all point-count station locations using a Global Positioning System unit in 2000 for later downloading into a U.S. Forest Service Geographical Information System database. Mapping study sites in this way will facilitate the repeated location of count stations throughout the duration of restoration efforts, even following burning events, as well as allow for landscape-level analyses of variation in bird population parameters and study site juxtaposition.

Restoration Activities

During 2000–2001, we built five different kinds of fence that varied in construction costs and herbivore-control objectives. To exclude cattle only, we built four-strand barbed wire fence (*fig. 1A*). To exclude cattle and small ungulates (e.g., deer), we built four-strand barbed wire fence fitted with outriggers of two or three strands of 8-gauge smooth wire or white electric tape (*fig. 1B*). To exclude all ungulates, including elk, we built three fence types: (1) 2.4 m woven wire (*fig. 1C*); (2) welded-wire stock panels and pole top (*fig. 1D*); and (3) buck and pole (*fig. 1E*). One of our interests was to compare the different fence types in terms of their ability to exclude ungulate herbivores. Another was to compare the cost-effectiveness of the different fence types to protect aspen from herbivory and, therefore, promote restoration. Hence the reason for building a variety of fence types, even for fence with the same ungulate exclusion objectives. Where possible, we used conifers (primarily lodgepole pine) removed from aspen stands to build the fences (e.g., *fig. 1D*).

During the summer and fall of 2000, we initiated a combination of fence removal (old fences that were no longer excluding herbivores), fence building, and selective conifer removal at one aspen site (Target Springs). We removed 1.3 km of old fence and built 0.58 km of new fence (0.45 km of four-strand barbed wire and 0.13 km of welded-wire stock panels and pole top). In 2001, we expanded restoration efforts to all other aspen sites included in our study (with the exception of Timber Creek), constructing a total of 6.2 km of new exclosure fencing. The majority of fence built in 2001 consisted of four-strand barbed wire fence designed to exclude domestic cattle. These fences were built as large, single exclosures that encompassed all aspen trees included in our monitoring. Most recently (spring and summer 2002), we added another 0.75 km of buck and pole fence and constructed 180 stock panel cages (*fig. 1F*) around individual clumps of regenerating aspen within the larger exclosures at Marr Flat (84 cages), Road Canyon (67 cages), Bristow Flat (17 cages), and Target Springs (12 cages). These cages were designed to exclude all herbivory, including by deer and elk. In addition, we have repaired fences at Target Springs and Bristow Flat that were damaged by snow, fallen trees, and/or elk. Finally, although not part of our monitoring project, approximately 0.3 km of new buck and pole fence has been constructed on ONC land near Findley Buttes in partnership with Wallowa Ranch Camp and Oregon Youth Conservation Corps.

Prescribed burns totaling approximately 400 ha were ignited at two ponderosa pine sites (Imnaha and Ollokot) over a 2-d period beginning on 7 October 2000. Steeper upslope sections of the burn units were "black-lined" by hand-crews using drip-torches; downslope sections were ignited using a plastic sphere dispenser (PSD or "ping-pong" machine) mounted to a light helicopter. Multiple passes were made with the helicopter in an attempt to establish fire in several stringers of Douglas-fir. Except for building firelines, there was no pretreatment of fuels prior to ignition. At the time of the burn, relative humidity was in the range of 22 to 30 percent and temperatures were between 15 to 20 ºC. Winds were mostly out of the south at speeds of 5 to 10 km/hr, with occasional gusts to 20 km/hr. As fire crews worked downslope from the top of the units, flame lengths increased from 0.3 m to 0.6–1.0 m. Throughout both sites, fuels did not burn well, primarily because of moisture from heavy rains approximately one month prior to burning. As a result, objectives were not met for either fuels consumed (fuels were measured before and after burning) or mortality achieved in the understory saplings. Target fuels for these burns were in the 0 to 7.6 cm diameter range. Direct tree mortality was minimal and large wood consumption, for the most part, was moderate for a fall prescribed burn. Two years post-burn (i.e., October 2002), there were signs of secondary fire effects such as large-diameter ponderosa pine and Douglas-fir being attacked by bark beetles (compared to adjacent unburned stands).

Burning of the remaining pine sites was scheduled for fall 2001, but unfavorable environmental conditions prevented any treatments from occurring. On 10 October 2002, however, three additional sites (Hidden Springs, Evergreen, and Indian Crossing) were burned (total area = 400 ha). These burns also were implemented using a combination of hand-crew and helicopter ignitions. In general, conditions were considerably drier than described above for 2000. As a result, prescribed burns implemented in 2002 were considered "textbook" in terms of meeting prescription objectives. Average flame lengths were in the 1.0 to 1.2 m range, and the fire continued to consume large fuels for two weeks following ignition. Our remaining pine site (Sierra Flat) currently is scheduled for burning in 2003.

Results

In 2000, we detected 3,083 individual birds representing 75 different species; in 2001, this number increased to 3,177 individuals, but representing only 71 species. Combining count data from both years of study, we detected 3,234 individual birds representing 71 species in aspen and 3,026 birds representing 60 species in pine (*table 2*). Many species were detected with similar frequency in 2001 as they were in 2000, although there were some exceptions (e.g., Dark-eyed Junco [*Junco hyemalis oreganus*], European Starling [*Sturnus vulgaris*], Pine Siskin [*Carduelis pinus*], and Western Wood-pewee [*Contopus sordidulus*]). Species closely associated with aspen included Downy Woodpecker (*Picoides pubescens*), Dusky Flycatcher (*Empidonax oberholseri*), Common Raven (*Corvus corax*), House Wren

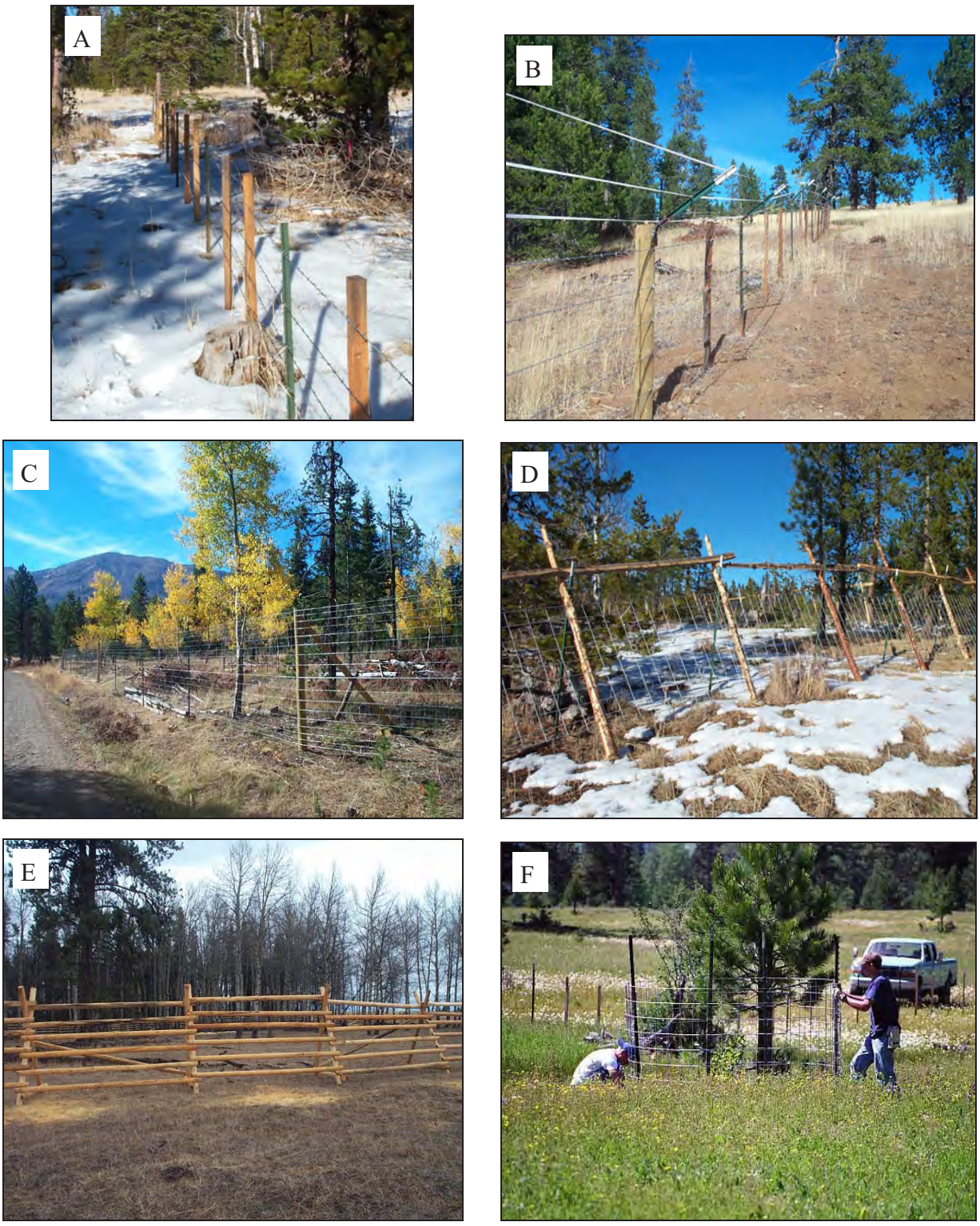

Figure 1— Six different kinds of fence built around aspen as part of a long-term habitat restoration project in the Wallowa Mountains, northeast Oregon, 2000–2001: (A) four-strand barbed wire (excludes cattle), (B) four-strand barbed wire with outriggers having two or three strands of 8-guage smooth wire or white electric tape (excludes cattle and small ungulates, such as deer), (C) 2.4 m woven wire (excludes all ungulates, including elk), (D) welded-wire stock panels and pole top (excludes all ungulates), (E) buck and pole (excludes all ungulates), and (F) stock panel cages built around individual clumps of regenerating aspen (excludes all ungulates). Photos by Nils Christoffersen.

Table 2— *Numbers of birds detected (regardless of distance from observers), summarized by habitat and year, as part of a long-term habitat restoration project in the Wallowa Mountains, northeast Oregon, 2000–2001.*

		Numbers of birds detected in each habitat						
		Aspen			Pine			Grand
Common name	Scientific name	2000	2001	Total	2000	2001	Total	total
American Goldfinch	*Carduelis tristis*	0	2	2	0	6	6	8
American Kestrel	*Falco sparverius*	0	0	0	1	0	1	1
American Robin	*Turdus migratorius*	107	129	236	166	153	319	555
Belted Kingfisher	*Ceryle alcyon*	0	0	0	1	0	1	1
Black-backed Woodpecker	*Picoides arcticus*	0	0	0	3	3	6	6
Black-headed Grosbeak	*Pheucticus melanocephalus*	1	1	2	3	1	4	6
Blue Grouse	*Dendragapus obscurus*	0	0	0	2	0	2	2
Brewer's Blackbird	*Euphagus cyanocephalus*	2	0	2	0	0	0	2
Brewer's Sparrow	*Spizella breweri*	6	6	12	0	0	0	12
Brown Creeper	*Certhia americana*	4	0	4	6	5	11	15
Brown-headed Cowbird	*Molothrus ater*	22	29	51	0	2	2	53
California Quail	*Callipepla californica*	0	4	4	0	0	0	4
Calliope Hummingbird	*Stellula calliope*	6	3	9	1	1	2	11
Canyon Wren	*Catherpes mexicanus*	0	0	0	1	0	1	1
Cassin's Finch	*Carpodacus cassinii*	41	57	98	28	61	89	187
Cassin's Vireo	*Vireo cassinii*	5	1	6	44	27	71	77
Cedar Waxwing	*Bombycilla cedrorum*	1	0	1	6	1	7	8
Chipping Sparrow	*Spizella passerina*	75	92	167	88	115	203	370
Clark's Nutcracker	*Nucifraga columbiana*	4	3	7	0	0	0	7
Common Nighthawk	*Chordeiles minor*	1	0	1	0	0	0	1
Common Raven	*Corvus corax*	32	25	57	7	3	10	67
Common Snipe	*Gallinago gallinago*	1	1	2	0	0	0	2
Cooper's Hawk	*Accipiter cooperii*	0	0	0	1	0	1	1
Dark-eyed Junco	*Junco hyemalis oreganos*	108	67	175	127	62	189	364
Downy Woodpecker	*Picoides pubescens*	5	12	17	0	0	0	17
Dusky Flycatcher	*Empidonax oberholseri*	67	98	165	4	0	4	169
European Starling	*Sturnus vulgaris*	42	120	162	0	0	0	162
Evening Grosbeak	*Coccothraustes vespertina*	0	0	0	14	4	18	18
Golden-crowned Kinglet	*Regulus satrapa*	6	5	11	25	21	46	57
Gray Jay	*Perisoreus canadensis*	2	4	6	1	1	2	8
Hairy Woodpecker	*Picoides villosus*	30	31	61	14	9	23	84
Hammond's Flycatcher	*Empidonax hammondii*	17	2	19	154	175	329	348
Hermit Thrush	*Catharus guttatus*	15	12	27	8	7	15	42
House Wren	*Troglodytes aedon*	104	144	248	0	0	0	248
Killdeer	*Charadrius vociferous*	0	3	3	0	0	0	3
Lazuli Bunting	*Passerina amoena*	1	2	3	1	3	4	7
Lincoln's Sparrow	*Melospiza lincolnii*	20	12	32	0	0	0	32
MacGillivray's Warbler	*Oporornis tolmiei*	18	28	46	42	28	70	116
Mountain Bluebird	*Sialia currucoides*	12	14	26	0	0	0	26
Mountain Chickadee	*Parus gambeli*	82	58	140	79	93	172	312
Mountain Quail	*Oreortyx pictus*	0	8	8	0	0	0	8
Nashville Warbler	*Vermivora ruficapilla*	0	0	0	2	0	2	2
Northern Flicker	*Colaptes auratus*	47	42	89	30	28	58	147
Northern Goshawk	*Accipiter gentilis*	0	0	0	0	1	1	1
Northern Pygmy-owl	*Glaucidium gnoma*	0	2	2	0	1	1	3
Olive-sided Flycatcher	*Contopus borealis*	1	1	2	4	3	7	9

Table 2— *continued.*

Common name	Scientific name	Numbers of birds detected in each habitat						
		Aspen			Pine			Grand
		2000	2001	Total	2000	2001	Total	total
Orange-crowned Warbler	*Vermivora celata*	6	21	27	5	11	16	43
Pileated Woodpecker	*Dryocopus pileatus*	4	4	8	8	8	16	24
Pine Siskin	*Carduelis pinus*	106	52	158	62	69	131	289
Prairie Falcon	*Falco mexicanus*	0	1	1	0	0	0	1
Pygmy Nuthatch	*Sitta pygmaea*	24	20	44	0	0	0	44
Red Crossbill	*Loxia curvirostra*	28	34	62	44	14	58	120
Red-breasted Nuthatch	*Sitta canadensis*	33	48	81	130	92	222	303
Red-naped Sapsucker	*Sphyrapicus nuchalis*	16	31	47	1	1	2	49
Red-tailed Hawk	*Buteo jamaicensis*	4	2	6	0	5	5	11
Red-winged Blackbird	*Agelaius phoeniceus*	18	47	65	0	0	0	65
Rock Wren	*Salpinctes obsoletus*	0	0	0	2	2	4	4
Ruby-crowned Kinglet	*Regulus calendula*	40	26	66	0	8	8	74
Ruffed Grouse	*Bonasa umbellus*	0	1	1	7	9	16	17
Rufous Hummingbird	*Selasphorus rufus*	3	2	5	0	0	0	5
Sharp-shinned Hawk	*Accipiter striatus*	1	0	1	0	0	0	1
Song Sparrow	*Melospiza melodia*	1	0	1	8	2	10	11
Spotted Sandpiper	*Actitis macularia*	0	0	0	1	1	2	2
Spotted Towhee	*Pipilo maculates*	1	2	3	0	0	0	3
Steller's Jay	*Cyanocitta stelleri*	4	7	11	11	15	26	37
Swainson's Thrush	*Catharus ustulatus*	1	0	1	51	33	84	85
Townsend's Solitaire	*Myadestes townsendi*	1	0	1	2	1	3	4
Townsend's Warbler	*Dendroica townsendi*	3	0	3	2	7	9	12
Tree Swallow	*Tachycineta bicolor*	23	27	50	0	0	0	50
Varied Thrush	*Ixoreus naevius*	0	0	0	1	0	1	1
Vaux's Swift	*Chaetura vauxi*	0	1	1	0	2	2	3
Warbling Vireo	*Vireo gilvus*	77	109	186	34	46	80	266
Western Bluebird	*Sialia mexicana*	35	56	91	1	1	2	93
Western Meadowlark	*Sturnella neglecta*	21	37	58	0	0	0	58
Western Tanager	*Piranga ludoviciana*	26	16	42	134	77	211	253
Western Wood-pewee	*Contopus sordidulus*	43	80	123	11	8	19	142
White-breasted Nuthatch	*Sitta carolinensis*	12	9	21	3	2	5	26
White-crowned Sparrow	*Zonotrichia leucophrys*	6	0	6	0	0	0	6
White-headed Woodpecker	*Picoides albolarvatus*	2	1	3	8	0	8	11
Williamson's Sapsucker	*Sphyrapicus thyroideus*	11	4	15	0	0	0	15
Wilson's Warbler	*Wilsonia citrina*	1	3	4	0	1	1	5
Yellow Warbler	*Dendroica petechia*	2	0	2	1	0	1	3
Yellow-rumped Warbler	*Dendroica coronata*	56	81	137	199	208	407	544

(*Troglodytes aedon*), Mountain Bluebird, Tree Swallow (*Tachycineta bicolor*), and Williamson's Sapsucker. Species closely associated with pine included Evening Grosbeak (*Coccothraustes vespertina*), Golden-crowned Kinglet (*Regulus satrapa*), Hammond's Flycatcher, Swainson's Thrush (*Catharus ustulatus*), and Western Tanager (*Piranga ludoviciana*) (*table 2*).

Nest searching yielded a total of 389 monitored nests of 39 species in 2000 and 427 nests of 37 species in 2001. Combining nests from both years, we monitored 637 nests of 39 species in aspen and 179 nests of 24 species in pine (*table 3*). Nest success was lower in aspen in 2001 (mean ± SE = 47.96 ± 2.70 percent of nests successful) than 2000 (63.85 ± 2.62; *fig. 2*).

Although a useful index of reproductive output, estimates of nest success do not address the production of young (which is presumably an even better measure of habitat quality). Combining data from both years, we therefore calculated productivity (mean no. young fledged per nest) and found birds nesting at Bristow Flat to be the most productive. In contrast, birds nesting at Target Springs were the least productive (*fig. 3*).

Table 3— *Numbers of bird nests found and monitored (scientific names in* Table 2*), summarized by habitat and year, as part of a long-term habitat restoration project in the Wallowa Mountains, northeast Oregon, 2000–2001.*

	Numbers of nests found in each habitat						
	Aspen			Pine			
Common name	2000	2001	Total	2000	2001	Total	Grand total
American Kestrel	1	0	1	0	0	0	1
American Robin	9	37	46	9	16	25	71
Black-backed Woodpecker	0	0	0	0	1	1	1
Brewer's Blackbird	1	0	1	0	0	0	1
Brown Creeper	1	0	1	0	0	0	1
Calliope Hummingbird	0	1	1	0	1	1	2
Cassin's Finch	0	7	7	0	1	1	8
Cassin's Vireo	0	0	0	3	4	7	7
Chipping Sparrow	13	19	32	10	12	22	54
Common Snipe	1	0	1	0	0	0	1
Dark-eyed Junco	20	8	28	12	5	17	45
Downy Woodpecker	3	4	7	0	0	0	7
Dusky Flycatcher	30	29	59	0	0	0	59
European Starling	17	20	37	0	0	0	37
Fox Sparrow	2	0	2	0	0	0	2
Hairy Woodpecker	6	9	15	1	1	2	17
Hammond's Flycatcher	0	1	1	16	12	28	29
Hermit Thrush	0	0	0	0	1	1	1
House Wren	26	37	63	0	0	0	63
Lincoln's Sparrow	2	4	6	0	0	0	6
MacGillivray's Warbler	2	3	5	1	1	2	7
Mountain Bluebird	7	7	14	0	0	0	14
Mountain Chickadee	15	15	30	3	5	8	38
Northern Flicker	17	10	27	0	1	1	28
Northern Saw-whet Owl	0	1	1	0	0	0	1
Orange-crowned Warbler	0	0	0	0	1	1	1
Pileated Woodpecker	2	0	2	0	1	1	3
Pine Siskin	2	0	2	0	0	0	2
Pygmy Nuthatch	7	11	18	0	0	0	18
Red-breasted Nuthatch	4	7	11	9	5	14	25
Red-naped Sapsucker	13	11	24	0	0	0	24
Red-tailed Hawk	1	0	1	0	0	0	1
Red-winged Blackbird	10	13	23	0	0	0	23
Ruby-crowned Kinglet	2	0	2	0	0	0	2
Ruffed Grouse	0	0	0	2	0	2	2
Swainson's Thrush	0	0	0	2	2	4	4
Townsend's Warbler	0	0	0	0	1	1	1
Tree Swallow	9	11	20	0	0	0	20
Warbling Vireo	23	19	42	3	3	6	48
Western Bluebird	19	27	46	0	0	0	46
Western Tanager	2	1	3	10	9	19	22
Western Wood-pewee	11	13	24	0	0	0	24
White-breasted Nuthatch	5	3	8	0	1	1	9
White-headed Woodpecker	3	2	5	1	0	1	6
Williamson's Sapsucker	6	2	8	0	0	0	8
Yellow-rumped Warbler	7	6	13	8	5	13	26
Totals	299	338	637	90	89	179	816

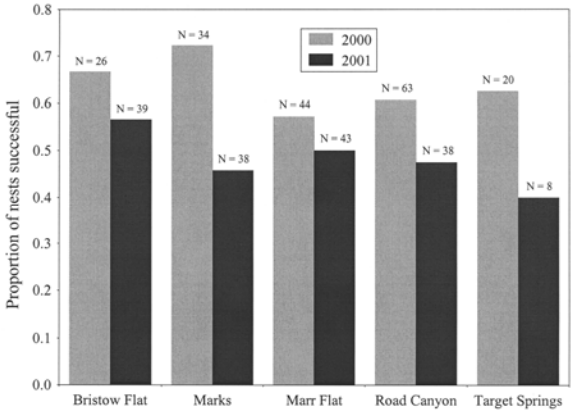

Figure 2— Success rates (proportion of nests successful) of nests found in aspen habitat in the Wallowa Mountains, northeast Oregon, 2000–2001. Numbers of successful nests are provided above each bar for each of five study sites.

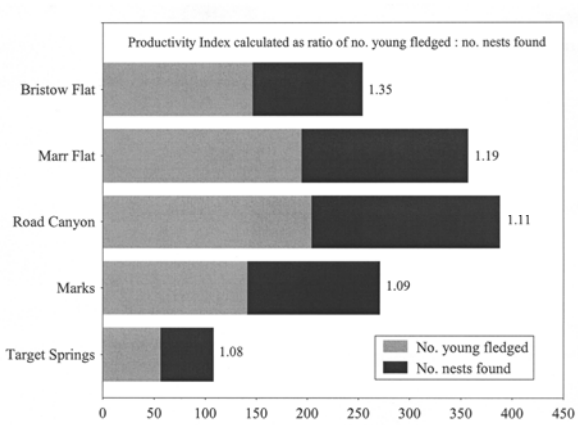

Figure 3— Productivity Index, calculated as the ratio of no. young fledged:no. nests found (i.e., no. young fledged per nest), for five study sites in aspen habitat in the Wallowa Mountains, northeast Oregon. Data have been pooled across years (2000–2001). Sites are ranked in descending order of Productivity Index, which is provided at the end of each bar for each site.

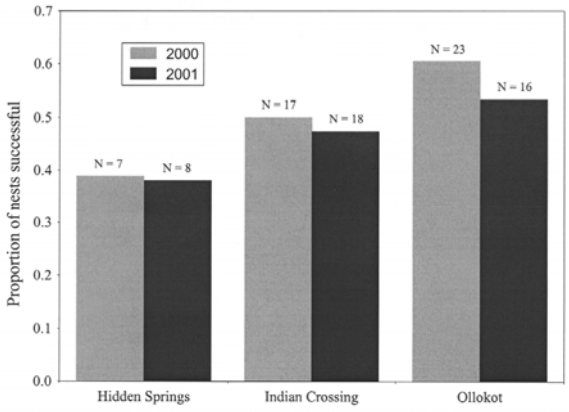

Figure 4— Success rates (proportion of nests successful) of nests found in pine habitat in the Wallowa Mountains, northeast Oregon, 2000–2001. Numbers of successful nests are provided above each bar for each of three study sites.

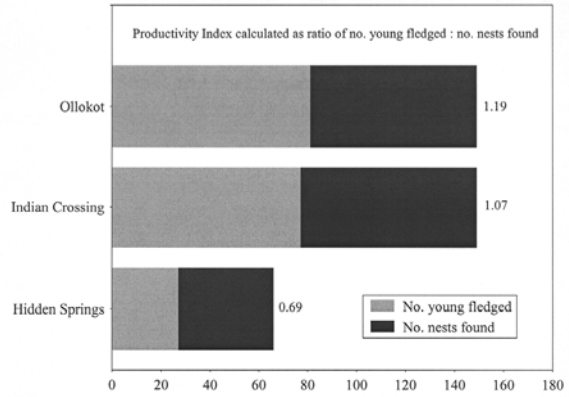

Figure 5— Productivity Index, calculated as the ratio of no. young fledged:no. nests found (i.e., no. young fledged per nest), for three study sites in pine habitat in the Wallowa Mountains, northeast Oregon. Data have been pooled across years (2000–2001). Sites are ranked in descending order of Productivity Index, which is provided at the end of each bar for each site.

Differences in rates of nest success between 2000 (49.81 ± 6.25) and 2001 (46.27 ± 4.44) were negligible among ponderosa pine sites (*fig. 4*). However, while birds nesting at Ollokot and Indian Crossing were equally productive, fledging success for birds nesting at Hidden Springs was extremely low (*fig. 5*).

Banding efforts resulted in 140 banded birds of 29 species in 2000 and 144 birds of 30 species in 2001. Of those birds banded in 2000, 92 individuals of 18 species also were color banded. This number increased to 111 individuals of 18 species in 2001. Species most frequently caught and banded include American Robin (*Turdus migratorius*), Chipping Sparrow, Dark-eyed Junco, Dusky Flycatcher, House Wren, MacGillivray's Warbler (*Oporornis tolmiei*), Warbling Vireo, and Western Bluebird (*Sialia mexicana*). Mist-netting operations were focused on Road Canyon and Marr Flat in 2000, and on Marr Flat, Bristow Flat, and Marks in 2001. After two years of banding, we have marked 284 birds (36 species) with USFWS metal leg-bands and 203 birds (21 species) with auxiliary color leg-bands. Three male Warbling Vireos, one male Red-naped Sapsucker, and one male House Wren that were banded in 2000 were recaptured in 2001; numerous other individuals of several species were resighted but not recaptured.

Discussion

According to Covington et al. (1999), far too many ecological restoration projects have been started without clear definition of restoration goals and with little attempt to evaluate success quantitatively. Heeding

these words, we have taken a scientific approach to ecological restoration of degraded stands of aspen and pine in the SCICSI planning area of Wallowa County. As recommended by Bradshaw (1993), such an approach implies that we will: (1) be aware of other relevant work; (2) carry out experiments to test ideas; (3) monitor key indicator parameters (in our case, forest avifauna and plant species composition and structure); (4) design further experiments and tests based on results of monitoring; and (5) publish peer reviewed results and conclusions in scientific journals (the first of which is represented by this paper). To help us achieve these goals, as well as provide some guidance on future activities, we adopted a stepwise systems analytic approach to the design of ecosystem restoration experiments developed by Covington et al. (1999; see *table 4*). Most of the steps outlined in such an approach have either been completed or are actively in progress.

Our results are intended to summarize baseline data collected at the beginning of a long-term restoration effort in two high priority habitats in the interior West. Our data were not collected to examine the direct effects of restoration activities on existing breeding bird communities, nor for comparing avian responses to different restoration approaches (e.g., building different types of fence). Rather, our intent is that data summarized here will serve as a basis against which to compare future assessments of the breeding aspen and ponderosa pine avifauna in our study area. We simply chose to use birds, rather than any other taxa, as a tool with which to monitor ecosystem conditions and evaluate hypotheses. Only in this way will we have a mechanism by which to judge the ecological impacts of our restoration efforts (Covington et al. 1999). Although we have no data to support it, our initial impression is that the four-strand barbed wire fence, in combination with some additional stock panel caging around individual clumps of regenerating aspen within the fence perimeter, will provide the most cost-effective protection. Only through additional bird monitoring, in combination with habitat assessments, will we know for sure.

Our results do suggest that aspen habitat in Wallowa County, Oregon, supported a richer breeding bird community compared with ponderosa pine. This finding contrasts with Sallabanks et al. (2001) who analyzed species-habitat associations in Eastside forests of Oregon and Washington. In that review, 77 bird species were associated with upland aspen and 131 species were associated with ponderosa pine. Our results also indicate that bird communities in aspen forests of Wallowa County were richer than other aspen in the interior West (e.g., DeByle 1981, DeByle et al. 1987). One possible reason for the relatively high number of species detected is that the aspen we studied did not occur as pure stands of climax forest but rather as mixed seral forest including ponderosa pine, grand fir, lodgepole pine, and western larch. Indeed, the lack of large tracts of pure aspen is one indication of the degree to which this habitat in our study area has become degraded by conifer encroachment. Increased habitat heterogeneity would presumably support a more diverse bird community. As a result, bird species that are not typically considered aspen associates were abundant at our aspen study sites (e.g., Chipping Sparrow and Pine Siskin). Consequently, birds known to be aspen specialists (e.g., Red-naped and Williamson's Sapsuckers) may suffer negatively from increased competition with other species for resources. Regardless of the reason for the apparent richness of the breeding aspen avifauna in Wallowa County, our data nevertheless confirm the importance of aspen to birds, justify its classification as a high priority habitat by Partners in Flight (Altman 2000), and reiterate the need for our restoration efforts.

Table 4— *A stepwise systems analytic approach to the design of ecosystem restoration experiments (modified from Covington et al. 1999), with the progress of our aspen/pine project in the Wallowa Mountains, northeast Oregon, summarized.*

	Recommended step	Aspen/pine project status
1	Clearly diagnose the symptoms and causes of the ecosystem health problem (i.e., what are the symptoms of degradation and what are the underlying mechanisms?)	Completed
2	Determine reference conditions (i.e., what was the condition of the ecosystem before degradation?)	In progress
3	Set measurable ecological restoration goals (i.e., how close to reference conditions do you intend to get? How will you know if you are moving in the right direction?)	In progress
4	What factors are most limiting to the restoration process?	In progress
5	Develop alternative ecosystem restoration hypotheses	Completed
6	Design restoration treatments that will allow you to test the alternative hypotheses	Completed
7	Implement restoration treatments defined in Step 6	In progress
8	Monitor ecosystem conditions and evaluate hypotheses	In progress
9	Feed the results back into the design and implementation of restoration experiments	Results pending

Abundance of several species differed between years. Such annual variation is typical (Franzreb and Ohmart 1978, Szaro and Balda 1979, Hejl et al. 1988), with numbers often responding to weather-related migration patterns, annual differences in immigration rates from, or emigration rates to, surrounding landscapes, and reproductive success in previous years. In particular, the Dark-eyed Junco and Pine Siskin were more abundant in 2000 whereas the European Starling and Western Wood-pewee were more abundant in 2001. Among these, the Pine Siskin, in particular, is known for sporadic changes in abundance and foraging behavior and has shown significant interactions between habitat use and year elsewhere in the inland west (Tobalske et al. 1991).

In general, average rates of nest success were comparable between aspen and pine, as well as with other published studies (e.g., Martin 1992). Unfortunately, because demographic studies of birds in aspen and pine habitats of the interior West have not been previously conducted, more specific comparisons are not possible. Within our study, rates of nest success and estimates of productivity were highly variable among study sites. These data might reflect habitat quality, suggesting that there was a considerable range in the degree to which aspen and pine stands were degraded in our study area. Indeed, local resource managers readily recognized that aspen at Target Springs were in poorer health than those at other sites included in our sample, which is one reason why we initiated restoration treatments there before moving on to less degraded stands. The extremely low production reported for the Hidden Springs pine stand is suggestive of sink habitat, and again may reflect the severely degraded condition of this particular forest. Additional data and more thorough analyses that incorporate micro- and macro-habitat features are likely needed to interpret why birds at Hidden Springs appear to be doing so poorly.

Recapture and resighting of previously banded birds suggested high site fidelity by several species. In particular, we caught several male Warbling Vireos that had been banded the previous summer. This Neotropical migrant is known to be highly site-faithful from one breeding season to the next (Gardali and Ballard 2000), and aspen stands in Wallowa County appear to be no exception. One male House Wren and one male Red-naped Sapsucker, both long-distance migrants (but not strictly Neotropical migrants), also returned to breed in the same territory in 2001 as they did the year before. These observations, although clearly preliminary, indicate the importance of maintaining existing aspen stands as available breeding habitat for numerous species. Before we can use our marked birds to estimate annual survivorship, however, additional banding in subsequent years will need to occur.

Several years into our long-term restoration project, we believe that significant progress has been made toward the goals and objectives established in 2000. To date, approximately 8 km of fence have been built around aspen stands, 250 ha of aspen habitat have been protected, and approximately 800 ha of pine have been burned as part of our restoration project. With the exception of some prescribed burning in one of our pine sites, all of our short-term goals have been successfully realized. Many project partners have become actively engaged in the restoration process, including private land owners. To date, approximately 18 partners (e.g., foundations, agencies, private individuals) have played a role in implementing this project. Momentum is building toward increased funding and in-kind support for additional treatments, and the potential to at least double the amount of aspen fenced and the amount of pine burned during the 2003–2004 seasons is very realistic. As we have illustrated by presenting brief summaries in this paper, the avian monitoring component of our study also was very successful, yielding a considerable amount of data on nesting success and community composition that has not previously been described for aspen and pine in the interior West. Overall, we are confident that we have sufficient bird and habitat data (habitat data were collected, but not summarized in this paper) to accurately represent baseline conditions and describe bird-habitat relationships.

Monitoring of ecosystem conditions (plant and avian community structure, as well as the productivity of breeding bird species) needs to continue for several years, pending sufficient funding. Such monitoring is critical for gauging habitat recovery, restoration progress, and ultimately therefore, project success. The first of several planned analyses will be to describe the current composition and population health of breeding bird communities in degraded stands of aspen and pine in Wallowa County. Subsequent analyses will focus on the short-term (3 to 5 yr) response of plant and bird communities to fence building and burning in aspen and pine, respectively. Following our initial period of data collection (2000–2001), monitoring does not need to occur on an annual basis, but perhaps only every other year for vegetation and every 3 to 5 years for birds. For example, in 2002, we did not collect any bird data but did revisit all aspen stands and collect habitat data as done previously in 2000; pine stands will be resampled pending additional burning in the fall. Alternatively, we might envision a series of short-term monitoring periods, each of which lasts 2 years, occurring in 2005, 2010, 2015, etc. Such a schedule would allow us to monitor ecosystem changes over time, but without the added burden of finding funding on an annual basis.

Acknowledgments

Support for this project to date has been provided by the National Fish and Wildlife, Packard, Ford, LaSalle-

Adams, and Oregon Community Foundations; the American Bird Conservancy; the USDA Forest Service; Rocky Mountain Elk Foundation; Blue Mountains Elk Initiative; Oregon Nature Conservancy; Oregon Department of Fish and Wildlife, Wallowa Resources; and the Sustainable Ecosystems Institute. We are especially grateful to private landowners Don Marks and Don Buhler for allowing us access to their land to conduct bird monitoring and initiate restoration activities. Nick Nolte of the Wallowa Fire Zone provided information on the fall prescribed burns. The Oregon Youth Conservation Corps and Wallowa Ranch Camp kindly assisted with the construction of fences, clearance of competing conifers, and vegetation monitoring. Bob Altman and Terry Rich provided valuable comments on a previous version of this paper. We also thank the following for collecting bird and habitat data during field seasons 2000–2001: Ben Flemer, Craig Fosdick, River Gates, Eric Hallingstad, Jason Meyer, Courtney Sherwood, and Kevin Warner.

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Monitoring for Adaptive Management in Coniferous Forests of the Northern Rockies[1]

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Abstract

Monitoring can and should be much more than the effort to track population trends; it can be a proactive effort to understand the effects of human activities on bird populations. It should be an integral part of the adaptive management process. With this in mind, the Northern Region Landbird Monitoring Program has a dual focus: (1) to monitor long-term bird population trends, and (2) to study bird-habitat relationships and management effects. By conducting permanent, long-term monitoring transects every other year, we are free to use the intervening years to study the effects of specific management activities. The coordination and funding is in place to achieve an impressive degree of replication in such studies. These alternate-year monitoring efforts have great potential to get management-oriented results into the hands of managers in the short term, so planning can be improved before long-term trends might reveal a problem. We have conducted several such projects, including the effects of partial-cut logging in coniferous forests, and the effects of grazing on willow-riparian bird communities. We discuss here another such project that we initiated in 2001, on bird responses to dry-forest restoration in the northern Rockies. Ponderosa pine (*Pinus ponderosa*) stands have been greatly altered from historical conditions due to logging and fire suppression. Active treatment of ponderosa pine forests to reverse historical trends is a recent management direction involving well-financed, regionally coordinated restoration efforts. The widespread distribution and abundance of planned treatments provided a unique opportunity for a controlled research design (with high replication), including pre- and post-treatment surveys. We present some preliminary results and discuss their relevance to adaptive management.

Key words: forest, habitat relationships, management, monitoring, restoration

Introduction

"*Monitoring is thus the cornerstone of adaptive management; without monitoring we cannot learn and cannot adapt*." Noss and Cooperrider (1994, p. 300).

The goal of bird conservation requires at least three major processes that are integral to the Partners in Flight agenda: To increase our knowledge of the ecological requirements of bird species, to use this knowledge to implement appropriate management and restoration activities, and to monitor the effects of those activities. A program that integrates these elements into one collaborative process can be said to be practicing adaptive management (Walters 1986, Lee 1993).

Adaptive management has been defined in many ways and used in many contexts (Gray 2000). It often refers to policy decisions covering multiple resources and balancing the needs of multiple stakeholders over large-scale management areas (e.g., Stankey and Shindler 1997). Here we use the term *adaptive management* on a smaller scale, referring to any process that monitors the effects of management practices and uses that information in future management decisions.

In developing the Forest Service's Northern Region Landbird Monitoring Program (NRLMP), we have felt from the beginning that a monitoring program should involve both the tracking of long-term population trends and the description of habitat associations and land-use effects (Hutto and Young 2002). A program that relies entirely on the monitoring of long-term population trends will always be reactive. The monitoring of long-term trends is useful for discovering whether populations are in decline, but not very useful for discovering the reasons behind such declines. Monitoring can and should be much more than the effort to track population trends; it can be a much more proactive effort to understand the effects of human activities that may persist or increase in intensity or extent over time. Habitat association data can help us move beyond long-term population trend monitoring, which most of us equate with the word "monitoring." Perhaps most importantly, habitat association data can be used to anticipate problems, thereby allowing an agency to modify its activities through a process of adaptive management.

The NRLMP involves breeding-season monitoring of all diurnal (primarily forest) landbird species that can be

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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detected through a single (point-count) methodology. The dual focus of the NRLMP is to produce short-term results on habitat relationships and management effects as well as long-term population trend data. By conducting permanent, long-term monitoring transects on an alternate-year basis, we are free to use the intervening years to study the effects of management activities. The coordination and funding is in place to efficiently survey a large number of sites across the region—a level of replication almost never achieved in published studies (see summary of the usual levels of replication in Sallabanks et al. 2000). These alternate-year monitoring efforts have the potential to be a very powerful way to get management-oriented results into the hands of managers in the short term, so planning can be improved before long-term trends might reveal a problem.

As an example of one of the alternate-year studies of management effects, we discuss here a study we initiated in 2001 on avian species' responses to dry-forest restoration in the northern Rockies. Dry forest habitat types historically and currently represent a major forest cover type in Montana and the American west. Dry forest types are distributed widely throughout the interior west, and are found at lower to middle elevations on both public and private lands. Forest stands dominated by ponderosa pine (*Pinus ponderosa*) represent approximately 35 percent of the commercial forestland in the American west, or about 12 million ha (Barrett 1979). Timbered, dry sites comprise two million out of 10 million total ha in Forest Service Region One.

Prior to European settlement, fire intervals in the dry forest types of Montana ranged from 5 to 45 yrs depending on elevation, local climate, and the extent of fire initiation by Native Americans (Fischer and Bradley 1987, Arno 2000). These frequent fires were usually of low intensity and promoted a forest structure of open, uneven-aged stands dominated by large ponderosa pines by selectively killing the more fire-sensitive young Douglas-fir (*Pseudotsuga menziesii*). Understory development was dominated by grass species with shrub undergrowth generally sparse (Arno et al. 1997). Stands of large ponderosa pine historically dominated most dry forest sites in western Montana. It should be noted, however, that it is still not known how much variation existed in tree densities and fire regimes on these sites (Baker and Ehle 2001).

Human intervention in the form of fire suppression has had a dramatic effect on existing vegetation, allowing forest succession to progress unimpeded toward climax vegetation. The absence of fire has permitted relatively shade-tolerant and fire-vulnerable Douglas-fir and grand fir (*Abies grandis*) to become a significant portion of the species composition of many of these sites (Fischer and Bradley 1987). The major change common to most dry forest types (especially ponderosa pine) in Montana and elsewhere in the American west is a profound alteration in age-class structure, physical structure, tree density, and tree species composition as a result of logging and fire suppression (Arno et al. 1997, Covington and Moore 1994). Stands that were largely dominated by mature and old-growth trees in an open-parkland setting have been changed to abnormally dense stands dominated by younger trees. Douglas-fir regeneration in the understory has created a fire ladder, greatly increasing the potential of stand-replacement crown fires (Fischer and Bradley 1987; Saab and Rich 1997).

Active treatment of ponderosa pine forests to reverse historical trends is a recent phenomenon. From 1997 to 1998, the area treated with logging and understory burning increased in Forest Service Region One from approximately 18,000 to 24,000 ha. Under a tentative two-decade plan (USDA Forest Service 1998), the area to be treated with both logging and understory burning will rise to 70,000 ha annually in Region One, with an additional 30,000 ha to undergo solely mechanical treatment. Under the tentative plan, approximately half of the estimated 1.7 million dry-forest ha on Forest Service land in Montana would be treated to restore historic conditions during a 20-yr cycle. These major restoration activities in Montana and northern Idaho complement similarly well-financed and regionally coordinated efforts in Regions 2, 5, and 6 (Colorado, California, Washington, and Oregon). The extreme forest fire seasons of 2000 and 2002, when millions of acres burned throughout the western United States, have greatly increased the perception that we need active management of dry forests and have virtually assured increased funding for such activities (USDA Forest Service and Department of the Interior 2000, U.S. Office of the President 2002).

The goal of this project is to collect and develop information on avian species' response to guide management of dry forests in Region One and the west. By combining survey efforts across the multiple national forests and other land types in Region One, we can gain important insight into the health of dry forests, identify universal and site-specific features to guide restoration, and identify the most effective techniques for active land management and the conservation of avian habitats. Specific objectives are to

1) compare the effects on bird populations of dry-forest restoration treatments and the naturally-caused low-to-moderate-severity fires they are intended to mimic

2) determine the relationship of vegetation structure and plant species composition to bird populations within and among untreated, treated, and naturally-burned sites

3) compare vegetation structure, components, and plant species composition among treatment types

Methods

We selected study sites in stands of mature forest that contained ponderosa pine mixed with Douglas-fir or grand fir. Habitat types were represented by dry Douglas-fir and grand fir habitat types that contain ponderosa pine as the major seral or climax associate. Western larch (*Larix occidentalis*) is potentially a co-dominant on some sites under consideration. We chose three categories of sites for comparison in this study: 1) 30 control sites, slated for future treatment, containing either significant fire-ladder fuels or encroachment by medium- or smaller-diameter trees; 2) 11 treated sites that had been logged, underburned, or a combination of logging and underburning to reduce fuels and approximate the more open structural conditions that existed historically; and 3) 19 sites that were naturally underburned during the 2000 fire season.

The study design was developed to maximize opportunities for statistical comparison for a single field season or for multiple field seasons. All untreated sites are targeted for treatment within the next few years, and at least half will be treated before the final bird surveys. Statistical analyses will allow us to compare bird responses to 1) different treatment categories within one year, 2) pre- and post-treatment conditions at the same sites in multiple years, and 3) continuous variables within and among treatment types

A controlled experimental design, especially one utilizing pre- and post-treatment testing (BACI), minimizes the potential effect of confounding variables due to differences in environmental conditions among sites and the surrounding landscapes.

The bird survey design we used on this and other impact assessment studies is a little more intensive than the single-visit methods we use for the long-term monitoring. We surveyed multiple points per site (usually five) and visited each site three times per year, a design similar to the habitat-based protocol of Huff et al. (2000). The multiple-visit protocol improves the accuracy of habitat association analyses by increasing the probability of detecting an individual when it is present (Thompson and Schwalbach 1995). We placed most of the survey points away from roads, and we also collected more extensive habitat data.

The bird survey technique followed recommendations established by participants in the national point count workshop (Ralph et al. 1995). A description of the point count method also can be found in Hutto et al. (1986). Field technicians conducted 10-minute point counts at each of the sampling points in a site, recording all birds seen or heard within the count period. We use 10-minute counts to decrease variability due to observer skill levels and bird detectability (Hutto and Young 2002). They surveyed each site three times (occasionally two) during the breeding season from the third week of May through the second week of July, in the first five hours after sunrise, and not when there was continuous rain or high winds.

Results

We surveyed 60 sites: 19 were natural underburns, 11 had received recent restoration treatments, and 30 were untreated dry forest sites that are to be treated in the future. We anticipate that at least 9 or 10 of those sites will be treated before we survey them again in 2003 and 2005.

We detected 75 bird species, with 43 species detected on at least six (10 percent) of the sites (*table 1*). The canopy cover was reduced by about the same amount (relative to the controls) in the restoration treatments as in the natural underburns (*fig. 1a*). The understory cover, especially of deciduous shrubs, was lowest in the natural underburns (*fig.1b*). Species that typically respond negatively to thinning of the tree canopy, such as Townsend's Warbler (*Dendroica townsendi*; *fig. 2a*) and Golden-crowned Kinglet (*Regulus satrapa*), had a negative response to both treatments in this study. Most of the species that differed in abundance between the restoration treatment and the natural underburns were species associated with shrubs, such as Swainson's Thrush (*Catharus ustulatus*; *fig. 2b*), MacGillivray's Warbler (*Oporornis tolmiei*), and Warbling Vireo (*Vireo gilvus*). These were probably responding to the lower shrub cover in the natural burns (*fig. 1b*).

Discussion

Preliminary results showed that the responses of most species were similar to those found in other data on the effects of forest thinning from the NRLMP (Young and Hutto 2002). There was some indication that the restoration treatments provided similar habitat to the natural underburns that they are intended to mimic. This suggests that the restoration treatment may be at least superficially successful as a management practice.

The lower coverage of understory shrubs in the natural underburns may have accounted for most of the differences in bird populations between the treatments. The surveys in the natural underburns were conducted less than a year after the fires occurred, so the understory vegetation had no chance to recover. As the understory recovers, the differences between the treatments (both birds and vegetation) may lessen. On the other hand, the open understory in the first couple of years after a natural underburn may be critical for such ground-foraging species as the Townsend's Solitaire, which was the only species that was significantly more abundant on natural underburns than on restoration treatments.

Table 1— *Relative abundances of birds among dry-forest controls, restoration treatments, and natural underburns in the northern Rockies. This table includes the 43 species (in taxonomic order) that were detected on at least 6 (10 percent) of the sites in 2001.*

	Abundance per 100 points		
Species	**Control**	**Treated**	**Natural**
Ruffed Grouse, *Bonasa umbellus*	3	0	2
Williamson's Sapsucker, *Sphyrapicus thyroideus*	2	3	3
Red-naped Sapsucker, *Sphyrapicus nuchalis*	2	9	1
Hairy Woodpecker, *Picoides villosus*	4	11	7
Northern Flicker, *Colaptes auratus*	7	17	16
Pileated Woodpecker, *Dryocopus pileatus*	6	1	3
Hammond's Flycatcher, *Empidonax hammondii*	14	66	23
Dusky Flycatcher, *Empidonax oberholseri*	7	12	6
Cassin's Vireo, *Vireo cassinii*	36	5	4
Warbling Vireo, *Vireo gilvus*	3	18	10
Gray Jay, *Perisoreus canadensis*	10	3	6
Steller's Jay, *Cyanocitta stelleri*	1	1	3
Clark's Nutcracker, *Nucifraga columbiana*	53	18	7
Common Raven, *Corvus corax*	3	3	1
Black-capped Chickadee, *Poecile atricapillus*	26	48	8
Mountain Chickadee, *Poecile gambeli*	23	48	36
Chestnut-backed Chickadee, *Poecile rufescens*	4	0	0
Red-breasted Nuthatch, *Sitta canadensis*	112	122	59
Brown Creeper, *Certhia Americana*	6	8	2
Winter Wren, *Troglodytes troglodytes*	3	1	3
Golden-crowned Kinglet, *Regulus satrapa*	14	4	5
Ruby-crowned Kinglet, *Regulus calendula*	19	26	23
Townsend's Solitaire, *Myadestes townsendi*	5	13	22
Swainson's Thrush, *Catharus ustulatus*	52	38	17
Hermit Thrush, *Catharus guttatus*	0	0	7
American Robin, *Turdus migratorius*	27	72	39
Cedar Waxwing, *Bombycilla cedrorum*	3	14	0
Orange-crowned Warbler, *Vermivora celata*	13	9	7
Nashville Warbler, *Vermivora ruficapilla*	7	8	1
Yellow-rumped Warbler, *Dendroica coronata*	99	98	87
Townsend's Warbler, *Dendroica townsendi*	50	20	18
MacGillivray's Warbler, *Oporornis tolmiei*	18	7	8
Western Tanager, *Piranga ludoviciana*	75	87	75
Spotted Towhee, *Pipilo maculatus*	4	12	4
Chipping Sparrow, *Spizella passerina*	47	57	59
Dark-eyed Junco, *Junco hyemalis*	54	81	77
Black-headed Grosbeak, *Pheucticus melanocephalus*	6	1	1
Lazuli Bunting, *Passerina amoena*	1	0	9
Brown-headed Cowbird, *Molothrus ater*	11	20	1
Cassin's Finch, *Carpodacus cassinii*	0	1	3
Red Crossbill, *Loxia curvirostra*	23	79	13
Pine Siskin, *Carduelis pinus*	24	80	27
Evening Grosbeak, *Coccothraustes vespertinus*	8	5	0

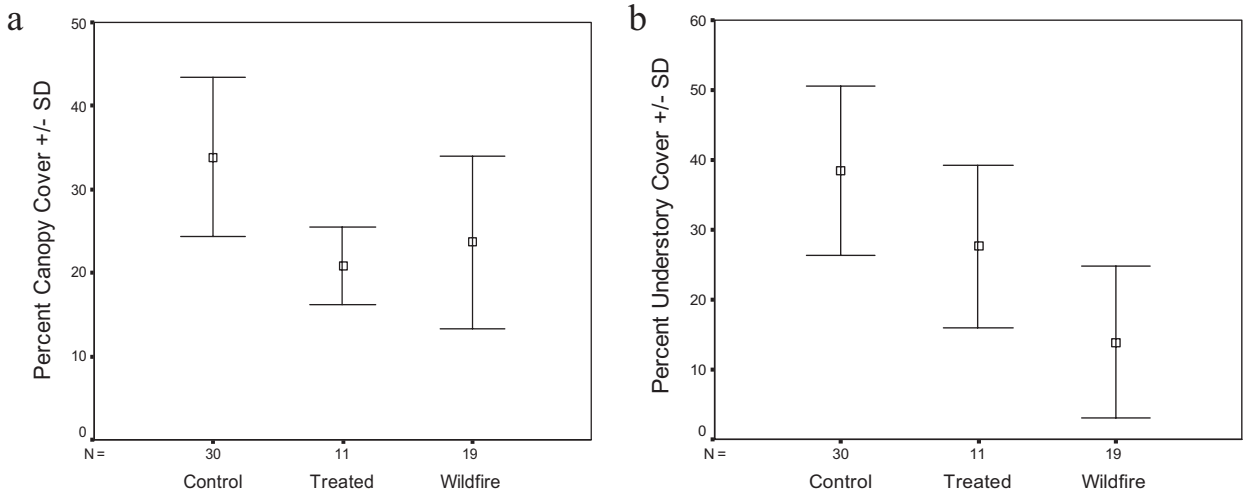

Figure 1— Means and standard deviations of ocular estimates for the percent cover of vegetation in dry-forest controls, restoration treatments, and natural underburns in the northern Rockies in 2001: a) tree canopy cover, b) total shrub and sapling understory cover.

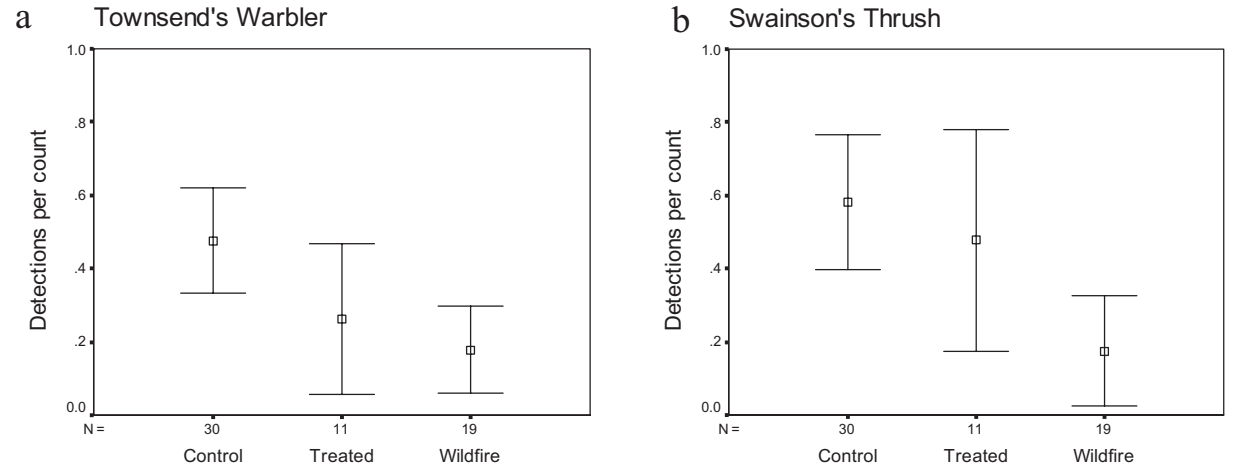

Figure 2— Means and 95 percent Confidence Intervals of the number of detections per count in dry-forest controls, restoration treatments, and natural underburns in the northern Rockies in 2001: a) Townsend's Warbler; b) Swainson's Thrush.

Bird species typically associated with denser, more mesic conifer forests were negatively affected by restoration treatments. However, treatments applied to dry forests should not greatly reduce the overall populations of these species, the bulk of which occur in those mesic forests. On the other hand, if thinning and other fuels-reduction treatments were applied to those more mesic forests as well as to the drier, lower elevation forests, then such activity would begin to negatively affect many bird species that need the denser forests.

Any conclusions should wait for the completion of the study, however. We hope to be able to get before-and-after data on at least 10 sites that are scheduled for treatment in the next couple of years. We will survey all of the sites again in 2003 and probably at a later date as well. Further data collection also will help to clear up immediate post-treatment complications such as site fidelity and vegetation recovery.

We feel that incorporating impact assessment studies into monitoring programs in this way greatly strengthens the scientific worth of, and political support for, the program. It allows anticipation of problems and, therefore, is proactive and fulfills some of the promise of adaptive management (McLain and Lee 1996). Such studies can be done separately, but under our design the coordination and funding are in place to efficiently survey many replicates across the region. It also turns out to be the strongest selling point for the program in many cases, interesting agencies in participating that would be reluctant to sign on to a purely long-term monitoring scheme.

We recognize that we have not yet achieved the full process of adaptive management. We have meetings in which biologists and managers determine management activities in need of evaluation. However, for the most part we are monitoring the effects of management treatments that are already planned. We also are not explicitly comparing different ways of reaching the management goal. Most importantly, however, we do not have a formal process by which the results of the study are applied directly toward planning of future management activities.

If there is one weakness associated with adaptive management in practice, it is the lack of a formal involvement of monitoring participants in the adaptive management loop, where participants have a chance to present results that might bear on future land-use plans. Although "monitoring is at the core of adaptive management and essentially synonymous with effective decision making" (Mulder and Palmer 1999; p. 6), our monitoring results are not yet formally integrated into the decision-making process. Instead, most of our findings that have influenced policy have done so because the information filtered informally into management circles. Even worse, we observe way too often that environmental impact statements and subsequent management decisions are clearly made without all of the available scientific information.

There needs to be a more formalized method for direct communication between the actual decision-makers and reputable biologists with access to the latest research and monitoring data. Ultimately, monitoring should be part of an adaptive management cycle that involves

1) gathering data on long-term population trends and short-term land-use effects

2) informing planners of results

3) discussing whether results merit a change in land-use plans

The last step could be in the form of interdisciplinary team meetings or some other process. We do not know what the best method will turn out to be, but we believe that this issue must be addressed if we are to fulfill the promise of adaptive management and conservation biology.

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Developing a Bird Conservation Plan for the Diverse Coniferous Forests of California[1]

John C. Robinson[2]

Abstract

Bird conservation plans represent one of the pillars of the National Partners in Flight (PIF) bird conservation strategy known as the Flight Plan. The Flight Plan provides the framework for bird conservation plans that, in turn, set conservation priorities and specific objectives for bird populations and habitat for each state or eco-region in the nation. Many of California's birds and other wildlife depend upon coniferous forests. In 1998, the California PIF partners identified a need for a comprehensive bird conservation plan for the coniferous forests of California. In order to develop the plan, initial meetings focused on identifying the focal bird species and categorizing the forested habitats that were perceived as most integral to completing the plan. Responsibility for drafting several of the more important chapters was delegated to Forest Service and Point Reyes Bird Observatory (PRBO) staff and, later, to the Klamath Bird Observatory; there were advantages and disadvantages to each method. Eight conservation objectives included within the plan are described and briefly discussed; and six implementation tasks are identified.

Key words: Bird Conservation Plan, California, coniferous forest, Partners in Flight.

Introduction

In March 1998, the California PIF (CPIF) cooperators identified a need for a comprehensive bird conservation plan for the coniferous forests of California. It was envisioned that such a plan would address all coniferous forest habitats in California and an initial list of 21 bird species which show an affinity to coniferous forests was identified.

Bird conservation plans represent one of the pillars of the national PIF bird conservation strategy known as the Flight Plan (Partners in Flight 2001, 2002). The Flight Plan provides the framework for bird conservation plans that, in turn, will set conservation priorities and specific objectives for bird populations and habitat for each state or ecoregion in the nation. The ultimate goal of PIF land bird conservation planning, as expressed through the bird conservation plans, is to sustain healthy populations of native land birds over the long-term. Bird conservation plans are generally prepared (Partners in Flight 2001) using a four-step process:

a) identifying the species and habitats most in need of conservation;

b) describing desired conditions for those habitats;

c) developing biological objectives consistent with the desired conditions; and

d) identifying recommended conservation actions that would achieve the biological objectives.

While many bird conservation plans prepared under the Flight Plan's vision address birds at a physiographic area or ecoregion level, the bird conservation plans in California have instead mostly been habitat-based (e.g., the Riparian Bird Conservation Plan (RHJV 2000)).

Many of California's birds and other wildlife depend upon coniferous forests. A large array of such forests exists within the state, encompassing a number of habitat types (Robinson and Alexander 2002). Associated bird communities are also quite varied, with some species quite specialized in the forest type required for breeding, and others that are generalists and can be found in numerous coniferous forest habitats across the state. Approximately 45 percent of California's land mass is covered with coniferous forests (Davis et al. 1998); yet, a century of intensive resource extraction and forest management has led to major changes in the amount and quality of coniferous forest habitat. Problems that the forests have faced include loss of habitat to logging, lack of replacement of old growth stands due to rotations of insufficient length in time; fire suppression; elimination of snags and dead trees, and fragmentation. Bird and other wildlife populations have subsequently been altered by such changes; declines and extirpations have been observed in a number of species, some of which are now afforded

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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special status at the federal or state level. Others will likely require such protection in the future, if efforts are not employed to curb these declines.

The objectives of this paper are to:

a) Describe and comment on the process used to develop California's coniferous forest bird conservation plan;

b) Identify and briefly describe the conservation objectives included in the coniferous forest bird conservation plan; and

c) Identify and briefly discuss the implementation tasks contained within the coniferous forest bird conservation plan.

Materials and Methods

In May 1999, the Regional Forester for the Pacific Southwest Region of the USDA Forest Service announced that he would work with Point Reyes Bird Observatory (PRBO) to develop a bird conservation plan for the coniferous forests of California. PRBO is a non-profit membership organization founded in 1965 that works to conserve birds, other wildlife and their ecosystems through innovative scientific research and outreach. The Forest Service had agreed to take the lead in the development of this conservation plan because of the many coniferous-forested lands in California that were in Forest Service ownership.

A Coniferous Forest Bird Conservation Plan Working Group was formed to identify potential focus bird species that would be included as part of the conservation plan. The group also identified the types of coniferous-forested habitats that would be addressed within the conservation plan.

The draft list of focal species included a Primary List of bird species that would receive detailed species accounts in the final conservation plan; a Secondary List of species that would receive a species account summary (i.e., a shortened version of a detailed species account); and a list of species that would be addressed in the conservation plan via the use of "Bio-regional Notes" - that is, the species would be mentioned within the context of certain bio-regions where their conservation needs are of importance.

During FY 2000, the Regional Forester funded the Forest Service efforts to assist PRBO in organizing all comments received, helping to assign authors to various bird species, and preparing initial drafts of the chapters that would be part of the bird conservation plan. Later, a partnership with the Klamath Bird Observatory was funded to complete the plan. Compensation was provided to authors who were enlisted to develop the remaining detailed species accounts.

Conservation objectives and implementation tasks that are included in the conservation plan were identified by reviewing the detailed species accounts, research papers dealing with the conservation of birds in coniferous forests, and the state of Oregon's Coniferous Forest Bird Conservation Plan (Altman 1999).

Results and Discussion

Eight people attended the initial meeting of the Coniferous Forest Bird Conservation Plan Working Group in August 1999. The primary objective of this meeting was to develop a focal species list (*table 1*). Focal bird species, as used here, are those species whose requirements represent a spectrum of habitat characteristics and types (Chase and Geupel, this volume). Conservation planners have found it useful to concentrate on a few "focal" species because these species help define which spatial and compositional attributes characterize a healthy ecosystem and guide the development of appropriate management regimes. A landscape designed and managed to meet the focal species' needs encompasses the requirements of other species (Lambeck 1997).

The Working Group grappled with some of the difficulties (*table 2*) involved with developing a conservation plan for a broad array of habitat types, such as those found in the coniferous forests of California.

After several iterations, the Working Group arrived at a decision to categorize coniferous forests into six conifer habitat types. These conifer habitat types are described and cross-referenced using three widely accepted vegetation classification schemes: the Society of American Foresters Forest Cover Types (Eyre 1980); California Wildlife Habitat Relationships habitat types (Mayer and Laudenslayer 1988), and vegetation series described by Sawyer and Keeler-Wolf (1995). Each Society of American Foresters conifer habitat type is made up of one or more vegetation series as described in Sawyer and Keeler-Wolf (1995). In turn, each of these vegetation series is cross-referenced with corresponding Wildlife Habitat Relationships habitat types (e.g., *table 3*).

The California PIF web site and the USDA Forest Service's mailing lists were used to solicit comments on the focal species list and to recruit authors for the various species accounts. However, little progress was made between October 1999 and October 2000, primarily as a result of conflicting work priorities and other barriers. The difficulties that were experienced may be summarized as follows:

Table 1— *List of focal species for the Coniferous Forest Bird Conservation Plan.*

Species list category	Species included in this category
Primary species list (species which will receive a detailed species account in the conservation plan)	Black-backed Woodpecker (*Picoides arcticus*), Black-throated Gray Warbler (*Dendroica nigrescens*), Brown Creeper (*Certhia americana*), Dark-eyed Junco (*Junco hyemalis*), Flammulated Owl (*Otus flammeolus*), Fox Sparrow (*Passerella iliaca*), Golden-crowned Kinglet (*Regulus satrapa*), MacGillivray's Warbler (*Oporornis tolmiei*), Olive-sided Flycatcher (*Contopus cooperi*), Pileated Woodpecker (*Dryocopus pileatus*), Red-breasted Nuthatch (*Sitta canadensis*), Vaux's Swift (*Chaetura vauxi*), and Western Tanager (*Piranga ludoviciana*)
Secondary species list (species which will receive a species account summary)	Yellow-rumped Warbler (*Dendroica coronata*), Steller's Jay (*Cyanocitta stelleri*), Spotted Owl (*Strix occidentalis*), Cassin's Finch (*Carpodacus cassinii*), Clark's Nutcracker (*Nucifraga columbiana*), Gray Jay (*Perisoreus canadensis*), Gray Flycatcher (*Empidonax wrightii*), Mountain Quail (*Oreortyx pictus*), Purple Finch (*Carpodacus purpureus*), and Chipping Sparrow (*Spizella passerina*)
Bio-regional notes species (species which will be mentioned in the text as appropriate)	Varied Thrush (*Ixoreus naevius*), Townsend's Solitaire (*Myadestes townsendi*), Pinyon Jay (*Gymnorhinus cyanocephalus*), Great Gray Owl (*Strix nebulosa*), Plumbeous Vireo (*Vireo plumbeus*), and Marbled Murrelet (*Brachyramphus marmoratus*)

Table 2— *Summary of the difficulties encountered by the Coniferous Forest Bird Conservation Plan Working Group during the development of the Conservation Plan.*

Description of problem	Brief discussion for why this was a problem
Selecting species representative of various seral stages/types of conifer habitats	A great diversity exists in the types of coniferous forests found in California; and for each habitat type, different bird species may be present depending on the age of the forest
How young can a forest be and still be a forest?	At what age does a forest begin? Are small openings within a forested landscape also part of the forest?
Do we include pinyon/juniper?	Some members of the Working Group were not sure if pinyon/juniper habitat would be covered in a separate bird conservation plan for California
Over 50 species were included on the initial focal species list	Preparing a detailed species account for over 50 species would quickly exceed the resources that were available to complete the conservation plan

Table 3— *Example of the relationships between the three vegetation classification schemes used in the coniferous forest bird conservation plan.*

SAF Major Forest Type Group: Douglas-fir		
Applicable Sawyer-Keeler-Wolf Vegetation Series	**Society of American Foresters Forest Cover Type**	**WHR Habitat Type**
Douglas-fir	Interior Douglas-fir, Pacific Douglas-fir, Douglas-fir/western hemlock	Sierra mixed conifer, Klamath Mixed Conifer, Douglas-fir
Douglas-fir/Ponderosa Pine	Pacific Ponderosa pine/Douglas-fir	Douglas-fir
Douglas-fir/tanoak	Douglas-fir/tanoak/Pacific Madrone	Montane hardwood conifer, Douglas-fir
Bigcone Douglas-fir, Bigcone Douglas-fir/canyon live oak		Douglas-fir

- Conflicting Work Priorities. The Forest Service staff person assigned to prepare the initial draft of the coniferous forest bird conservation plan found it difficult to simultaneously perform her regular duties, respond to emergency fires, and take on the task of preparing the coniferous forest bird conservation plan.

- Communication Barriers. Communication between people may be affected by social, age, language, and political/economic barriers (Scott et al 2000: 417).

These barriers also affect communication between agencies, where problems may arise due to language differences, the number of people who have a need to communicate with one another, and the number of protocols that govern how communication may actually take place. In the case of the coniferous forest bird conservation plan, the large number of authors (many of whom work for different agencies or institutions), combined with the issue of conflicting work priorities noted above, contributed to creating barriers to effective communication both within and between agencies. For example, it was not until September 2000 that all parties involved in the development of the coniferous forest bird conservation plan realized that a significant part of the document still needed to be written.

In December 2000, the Regional Forester established an additional fund to accomplish all remaining work on the conservation plan. This money was used to establish a partnership with the Klamath Bird Observatory to prepare several of the conservation plan's more important chapters and to pay Forest Service biologists or contractors to prepare the remaining detailed species accounts. In addition, a more frequent schedule of communication was established between all agencies and institutions charged with preparing the various components of the conservation plan.

Conservation Objectives

Forty-three specific recommendations (e.g., *table 4*) for coniferous forest habitat activities throughout California were developed across five "conservation need" categories. Within each conservation need category, one or more conservation objectives were identified.

All of the conservation recommendations documented in the plan were developed within each of the five conservation need categories by combining information from the most recent scientific data and analyses available with input from conservation organizations, agencies, scientific researchers, and the public. Essentially, all of these recommendations seek to reverse the current declines of many coniferous forest-associated bird populations, and to maintain stable conditions of others.

Conservation objectives developed under the Habitat Protection category are aimed at identifying multiple avenues for prioritizing the protection of coniferous forests across a diverse landscape involving multiple ownerships.

Conservation objectives developed under the Habitat Management and Restoration categories remind us that effective management of coniferous forest habitats is crucial to the survival and recovery of coniferous forest associated land birds. Proper management increases habitat value to wildlife, arrests species declines, and contributes to the recovery of declining bird populations.

In order to successfully protect and expand native bird populations, managers must have the most recent data available on populations and their habitat needs. Conservation objectives developed for Monitoring and Research are aimed at standardizing the scientific monitoring of populations and providing decision makers with the population data and habitat needs that are necessary for making informed decisions.

Policy conservation objectives recognize that conservation efforts will make little headway without effective policy development. This mechanism anticipates the need for policy makers to examine and appropriately amend statutory and regulatory programs that endanger native habitats or that unnecessarily impede restoration actions.

Implementation Tasks

Six implementation tasks were identified within the coniferous forest bird conservation plan (*table 5*). The tasks identified here are but one part of the overall implementation plan being developed for the coniferous forest bird conservation plan. These tasks, and the implementation plan they are a part of, will ultimately provide a framework for land managers and partners to set bio-regional coniferous forest habitat conservation priorities that benefit coniferous forest-associated bird species. A brief description of each implementation task is provided (*table 5*).

Table 4—Sample of the conservation recommendations included in the Coniferous Forest Bird Conservation Plan.

Conservation need category	Conservation objective	Recommendation example
Habitat protection	Prioritize coniferous forest sites for protection	Prioritize the protection of existing old-growth/late successional coniferous forest habitats
Habitat management	Manage for old-growth/late successional conditions	Manage for large trees
	Management should ensure that the diversity of coniferous forest types, processes, and characteristics in California are represented	Revise fire management regimes to mimic natural fire patterns wherever possible
Restoration	Implement and time land management activities in coniferous forests to increase avian reproductive success and enhance populations	Limit restoration or management activities (e.g., prescribed fire or firewood removal) to the non-breeding season
Monitoring and research	Provide data on pressing conservation issues affecting birds	Consider reproductive success and survival rates when monitoring populations, assessing habitat value, and developing conservation plans
	Maximize the effectiveness of ongoing monitoring and management efforts	Increase communication and coordination between land managers and specialists hired to implement specific projects or conduct monitoring
	Use information gathered in avian monitoring programs to test specific coniferous forest habitat needs for bird species, and the effects of management practices	Conduct replicate studies on the impacts of long-term grazing on bird communities in coniferous forests
Policy recommendations	Encourage regulatory and land management agencies to recognize that avian productivity is a prime criterion for determining protected status of specific habitats, mitigation requirements for environmental impacts, and preferred land management practices	Consider avian population parameters (such as reproductive success) as important criteria when designating priority or special-status sites such as Research Natural Areas

Conclusion and Recommendations

Preparation of a well-researched and useful bird conservation plan for a physiographic province or a broad habitat category (such as coniferous forests) is a complex, long-term process requiring input from many people. Based on our experiences with the coniferous forest bird conservation plan the following recommendations are made for future authors who aspire to prepare a bird conservation plan:

1. Clearly Defined Roles. To ensure that practical, well-researched conservation plans are prepared on time and within budget, everyone involved in the effort must have clearly defined roles and know what their responsibilities are. It must be remembered that bird conservation plans are large, complex documents where multiple people are assigned the task for working on various parts of the final product. In such an environment, it becomes easy for one or more people to feel that their role(s) are not clearly defined. Roles should be clearly defined in writing as early in the process as possible.

2. Dedicated Time. The persons who are actually charged with authorship of major sections of the conservation plan must be granted major blocks of uninterrupted time that are dedicated to that task. Although well qualified to perform this work, employees of state or federal agencies often have an existing workload of sufficient size that precludes them from spending the time needed to prepare a well-researched bird conservation plan. Hiring a temporary, full-time position or contracting the work out are two solutions that address this problem, and both of these options may sometimes cost less money than assigning this work to a permanent, full-time employee who can only afford to work intermittently on the project.

Table 5—*Implementation Tasks identified in the Coniferous Forest Bird Conservation Plan.*

Name of implementation task	Brief description
Interface with other conservation and planning efforts	Conservation objectives can be used in the development of site-specific conservation plans, such as state and private Habitat Conservation Plans. Other conservation objectives may be met via parallel conservation efforts on state, federal, or private lands.
Community communication workshops	Three community communication workshops are planned in California to provide Forest Service managers an opportunity to become familiar with the contents of the plan and to identify opportunities where the plan could be integrated into ongoing or planned activities.
Briefing for Regional Forester and PSW Station Director	A briefing of this plan for the Regional Forester and Station Director provides yet another opportunity to place institutional commitment to the PIF program at various levels of the Forest Service.
Include coniferous forest bird conservation goals into Forest Plan revision process	Over the next 5-10 yrs, many of the National Forests in CA will be revising their Land and Resource Management Plans (LMP), providing regional wildlife program managers an opportunity to emphasize the importance of the need to incorporate land bird interests into the LMP plan revisions.
Monitor the effectiveness of the coniferous forest bird conservation plan	Monitoring, and the closely related concept of adaptive management, are two elements of any plan's implementation.
Integrating with the North American Bird Conservation Initiative	Implementation of the coniferous forest bird conservation plan will be integrated with the larger North American Bird Conservation Initiative.

3. Frequent, Effective Communication. In addition, a protocol of frequent communication between everyone involved in bringing the document together must be established and maintained throughout the term of the project. Recognition of this need is critical, especially when one considers that 20 or more authors may contribute to the final product. It is recommended that one person from each lead agency or institution be responsible for maintaining an open line of communication and participating in all important decisions that need to be made.

Finally, it should be noted that conservation objectives and implementation plans are important components of any bird conservation plan. Conservation objectives outline one or more paths to successful habitat protection, management, or restoration and enable the monitoring that is needed to ensure that adaptive management processes can improve on existing conservation strategies. Implementation plans are designed to ensure that an effective, consistent message is communicated between land managers and partners which allows conservation priorities to be established on both local and regional scales. For example, a feedback form developed specifically for the coniferous forest bird conservation plan is now being used in a modified format on PRBO's Internet site (Point Reyes Bird Observatory 2002) to monitor and acquire information about all of the bird conservation plans currently in use in California.

Acknowledgments

I wish to thank all those persons, agencies, or institutions who were instrumental in the development of the Coniferous Forest Bird Conservation Plan. In particular, I express my thanks to: the USDA Forest Service, Klamath Bird Observatory, Point Reyes Bird Observatory, the David and Lucille Packard Foundation, the Bureau of Land Management, California Partners in Flight, and the Bureau of Reclamation. In addition, I wish to thank the various Species Account authors and those individuals who helped peer review selected species accounts. Special thanks goes to L. Fenwood, G. Geupel, J. Alexander, A. Holmes, G. Wilson, R. Burnett, D. Wallace, and S. Webb, all of whom were instrumental in writing, promoting, and producing this document.

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Challenges of Avian Conservation on Non-Federal Forests in the Pacific Northwest[1]

Joseph B. Buchanan[2]

Abstract

Conservation of species associated with mature forest habitats remains an important objective for non-federal lands in the Pacific Northwest. With few exceptions, state forest practices rules, a Washington state pilot landscape planning program, and federal Habitat Conservation Plans provide little functional habitat for species, like the Pileated Woodpecker (*Dryocopus pileatus*), that are associated with mature forest structures such as large-diameter snags and defective trees. At the beginning of the new millennium, millions of hectares of non-federal forest lands in western Washington and Oregon will be managed on 50-year rotations with no emphasis on using "new forestry" or adaptive management principles to benefit avian conservation. The economic philosophy of managing forests on relatively short rotations, is a major impediment to Partners in Flight conservation planning in the Pacific Northwest, and likely elsewhere. Solutions to this forest bird conservation dilemma may involve regulation, economic incentive programs (potentially including concepts like carbon sequestration and green certification), corporate and stockholder outreach and education regarding conservation needs, and alternatives to modern-day forest management practices (including ecologically-based forest management trusts). PIF should convene a national committee to work with non-federal land managers and stakeholders to identify the impediments to successful conservation, and develop and implement a strategic plan designed to bring about meaningful bird conservation on non-federal forests.

Key words: conservation, *Dryocopus pileatus*, forest management, implementation impediment, Pacific Northwest, Pileated Woodpecker.

Introduction

Conservation of species associated with mature forest habitats remains an important, but elusive, objective for non-federal lands in the Pacific Northwest. Managed forests in the region provide important habitats for many species, ranging from Neotropical migrants to state and federally listed species such as the Spotted Owl (*Strix occidentalis*) and Marbled Murrelet (*Brachyramphus marmoratus*). However, existing conservation provisions and forestry regulations generally do not fully address the needs of many species associated with mature coniferous forests. These provisions and regulations included, among others, forest practices rules in Washington and Oregon, Habitat Conservation Plans (Beatley 1994), and a pilot program in Washington, completed in 2000, that offered regulatory "protection" to forest landowners in exchange for retention, enhancement or creation of wildlife habitat for certain species (DeMoss et al. 2000).

The potential value of such management efforts is considerable because a substantial portion of the region is comprised of non-federal lands. Of the 8.5 million ha landbase within the range of the Spotted Owl in Washington, 53.4 percent, or 4.6 million ha, is non-federally-owned (Washington Department of Natural Resources 1997). Similarly, over 2.8 million ha out of 6 million ha (47 percent of the landbase) in western Oregon is owned by state or private entities (Oregon Department of Forestry 1998). Although portions of these non-federal areas in both states have been permanently converted to non-forest conditions, substantial areas remain forested. Importantly, significant portions of some species' ranges include private lands (Cassidy and Grue 2000), a common pattern across North America (Scott et al. 2001). Consequently, management of non-federal lands can greatly influence the distribution and abundance of forest bird species in the Pacific Northwest and elsewhere. This is particularly relevant given that many forest birds use snags, a limited resource in managed forests, for breeding habitat (Bunnell and Kremsater 1990).

Evaluation of the conservation and management conditions resulting from state forest practices regulations and the aforementioned planning processes provided a unique opportunity to understand some of the challenges associated with implementing Partners in Flight (PIF) conservation planning for forest bird species on non-federal lands. To better illuminate this challenge, I assessed the value of the regulations and proposed or adopted management strategies relative to the habitat requirements of the Pileated Woodpecker (*Dryocopus pileatus*) as indicated in the scientific literature and recommendations made in the regional PIF conservation plan (e.g., Altman 1999). This species was used in the

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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assessment because (a) it is a keystone species (Aubry and Raley 2002a), a species whose presence on the landscape influences the presence or abundance of other species (Mills et al. 1993); (b) it uses habitat attributes—large-diameter defective trees and snags—that have generally become limiting resources in managed forest landscapes (Spies and Cline 1988); and (c) it has declined in abundance over substantial portions of intensively managed forest landscapes (Raphael et al. 1988). The assessment concludes with recommendations for a strategy to improve conservation benefits on non-federal forestlands in the Pacific Northwest.

The Pileated Woodpecker

In western Washington and Oregon Pileated Woodpeckers are strongly associated with mature and old-growth coniferous forests. They are generally more abundant in forests of older age classes due to the greater abundance of large diameter snags and defective trees in those forests (Mannan et al. 1980, Nelson 1989, Carey et al. 1991, Ralph et al. 1991, McGarigal and McComb 1995). Pileated Woodpeckers use large snags and cavity trees for nesting, roosting and foraging (*table 1*). On the Olympic Peninsula in Washington, 88 percent of nests were in snags or live trees with dead tops and the majority of nest (96 percent) and roost locations (66 percent) were situated in or above the canopy, with a mean height to nest and roost cavities of 35.3 m and 23.0 m, respectively (Aubry and Raley 2002b).

Pileated Woodpeckers have very large home ranges that contain large numbers of snags. In the Oregon Coast Range, Pileated Woodpecker *summer* home range size was 478 ha, of which 65 percent (310 ha) was considered suitable habitat (Mellen et al. 1992). On the Olympic Peninsula, Washington, mean *annual* home range size was 863 ha for breeding pairs (Aubry and Raley 1995, 1996). These home ranges contained an average of 23.0 snags/ha (≥20 cm dbh) and 6.9 live trees with dead tops/ha (Aubry and Raley 1996), which equates to 25,804 snags or cavity trees per 863-ha home range.

Partners in Flight Recommendations

The PIF conservation plan for west-side coniferous forests in Washington and Oregon contained a number of conservation and management recommendations for the Pileated Woodpecker. The plan called for a population target of about 9 pairs per township (9.7/100 km^2), based on an average breeding-season home range of 600 ha (Altman 1999:36-37); using the annual home range size of 863 ha for the Olympic Peninsula (Aubry and Raley 1996), a comparable target could be adjusted to about 6 pairs per township (6.4/100 km^2) on the Olympic Peninsula. Habitat objectives included providing forest stands with specific structural conditions, with the following targets for snags of varying size classes, on a per ha basis: ≥18 that were 25-50 cm dbh, ≥8 that were 50-75 cm dbh, and ≥5 that were >76 cm dbh (Altman 1999).

Snags in Younger Forests

Managed second-growth conifer forests typically contain many fewer snags than older forests (Ohmann et al. 1994), particularly when the latter have regenerated following forest fires (Spies and Franklin 1991). The primary reason for this general age-related difference in snag abundance was that damaged trees and snags were carried over from a burned stand to the regenerated stand (Spies and Franklin 1991) whereas few snags and defective trees carry were retained in subsequent stands following timber harvest (Spies and Cline 1988). Most modern timber harvest practices include pre-commercial and/or commercial thinning, which are designed to increase tree vigor by reducing competition for sunlight and water; thinning generally reduces suppression mortality. These practices, as applied in 45-55-year harvest rotations, reduce the likelihood that large snags will be retained for the entire rotation or to successive stands (Wilhere 2003). Remaining snags often are removed for safety, operational, or economic considerations (Wilhere 2003).

Table 1— *Mean diameter at breast height (dbh) of trees and snags used for nesting, roosting, or foraging by Pileated Woodpeckers in the western portions of Washington and Oregon*

Dbh (cm)	Activity	Sample size	Location	Reference
101	Nest	25	Western Olympic Peninsula, Washington	Aubry and Raley 2002b
149	Roost	144	Western Olympic Peninsula, Washington	Aubry and Raley 2002b
103	Forage	31	Oregon Coast Range	Mannan et al. 1980
78	Nest	7	Oregon Coast Range	Mannan et al. 1980
69	Nest	15	Oregon Coast Range	Mellen 1987
112	Roost	15	Oregon Coast Range	Mellen et al. 1992
67	Nest	7	Oregon Coast Range	Nelson 1989

Forest Practices Rules

There currently are no forest practices rules for the Pileated Woodpecker in Washington or Oregon. Forestry regulations in Washington address snag retention to some extent, but these rules do not directly address the ecological requirements of the Pileated Woodpecker. In western Washington, for example, operators must retain 3 wildlife reserve trees and 2 green recruitment trees for every 0.4 ha in a harvest unit; wildlife reserve trees must be ≥3 m in height and ≥30 cm dbh, and green retention trees must be ≥25 cm dbh, ≥9.1 m tall, and with a crown ≥⅓ of the height of the tree (Washington Administrative Code 222-30-020 [11 (b)(c)]; Washington Department of Natural Resources 2002). In Oregon, an average of 2 snags or 2 green trees/0.4 ha that were ≥9.1 m tall and ≥28 cm dbh must be retained per 0.4 ha of harvest for those harvests over 10 ha in size (Oregon Revised Statutes 527.676 [1 (a)]; Oregon Legislative Counsel Committee 2001). New forest practices rules in Washington provided wider buffers along most forest streams (Washington Department of Natural Resources 2002). These rules did not specifically protect snags, and although some snag retention is likely, snag removal will occur for safety reasons. Additional snag retention may occur in unstable slope areas.

Planning Processes

Management for Pileated Woodpeckers under two non-federal planning processes, described here, will be evaluated below. Habitat Conservation Planning is a provision under the Endangered Species Act that allows non-federal landowners or land managers to legally impact, or "take," federally threatened species in exchange for a legally binding mitigation strategy (Bean et al. 1991, Beatley 1994, Noss et al. 1997). Although the Habitat Conservation Planning (HCP) process is controversial (Kareiva et al. 1999), a review of HCP issues is beyond the scope of this paper.

The other major planning initiative in the Pacific Northwest was the Landowner Landscape Planning pilot program in Washington (LLP). This program, enabled by Substitute House Bill 1985, allowed three state agencies—Natural Resources, Fish and Wildlife, and Ecology—to negotiate and approve landscape-level conservation plans with up to seven industrial forest landowners between 1997 and 2000. Resource management agencies, the wood products industry, and other stakeholders in the region supported the enabling legislation. The key component of the legislation was the stipulation that formal approval of a landowner's negotiated strategy to protect, enhance, or create habitat for specifically identified "species of special consideration" would provide the landowner with regulatory certainty—the conditions agreed to in the negotiated strategy—such that future state forest practices regulations for the particular species or its habitats would not apply in the pilot landscape for up to 50 years. The program was an incentive-based approach to encourage landowners to provide meaningful and proactive solutions to wildlife habitat management issues (DeMoss et al. 2000).

Results of Recent Planning Processes

Almost without exception, the multi-species HCPs proposed or approved for coniferous forests in the Pacific Northwest were based on strategies that would likely provide little, if any, functional habitat for Pileated Woodpeckers (*table 2*). Each HCP contained language indicating a willingness by the landowner to protect a certain number of snags or cavity trees when this could be done safely although secondarily to timber removal operations. Nearly all plans allowed for the removal of any snags that posed a safety hazard or interfered with harvest operations. In most plans, far fewer and smaller snags and/or cavity trees were recommended for retention than were thought to be appropriate for the Pileated Woodpecker, although incidental take permits were granted (or sought) for this species in each plan.

Most HCPs allowed substitution of green retention trees (GRTs) for unmet snag or cavity tree targets (*table 2*). Moreover, GRTs in all but one HCP could be smaller than the size of trees or snags used by the Pileated Woodpecker (*table 2*). Implementation of a GRT strategy for cavity-using species may be problematic because of uncertainty about future GRT functionality. This uncertainty is due to the possibility that (a) GRTs could be lost to windthrow, (b) GRTs could remain healthy live trees for decades or centuries, or (c) GRTs could be harvested after the term of the HCP had expired. Consequently, it is not clear whether passive attempts to compensate for snag shortages by retaining GRTs would be an effective conservation strategy.

Although there were no completed plans at the end of the LLP pilot project, three of the plans from western Washington had been negotiated to the point where the landowner's perspectives on habitat provisions for the Pileated Woodpecker were evident. One of the three landowners chose to shift from the LLP to the HCP process. A second landowner abandoned the LLP process during the negotiation phase. The third landowner committed to maintain 569 ha of woodpecker habitat, or 1.3 percent of the 42,898 ha planning area, in small patches distributed across the landscape.

Table 2— *Summary of habitat provisions proposed in or implemented according to multi-species Habitat Conservation Plans developed for state or private industrial timberlands in the western portions of Washington and Oregon.*

Habitat Conservation Plan	Location and size of planning area	Proposed or implemented conservation measures
Crown Pacific*	34,274 ha in the northwestern Cascade Mountains, Washington	Protect all snags ≥38 cm dbh where safe; retain 6 green trees at harvest (3 that were ≥25 cm dbh and 3 that were ≥38 cm dbh); one can be a hardwood tree. At year 20 snags would be created from the retained green trees (one ≥38 cm dbh and two ≥51 cm dbh per 0.4-ha). In Landscape B (about 1/5 of the planning area), retain 6 green trees of ≥38 cm dbh; at year 20 create ≥3 51 cm snags per 0.4 ha of harvest.
Longview Fibre*	8,903 ha in mid-Columbia Gorge, Washington	Retention of 3 wildlife reserve trees (≥3 m tall and ≥30 cm dbh) and 2 green trees (≥9 m tall and ≥25 cm dbh) per 0.4 ha of clearcut harvest. These would not be harvested during duration of HCP.
Murray Pacific	21,662 ha in the west-central Cascade Mountains, Washington	Retention of ≥4 live trees and 4 snags (if present) per 0.4 ha. All 4 trees ≥25 cm dbh; ≥2 of ≥46 cm dbh, and one dominant tree in stand that was harvested. If trees of these sizes not present, then largest trees present would be substituted. Snags will be ≥30 cm dbh and ≥3 m tall. Live trees ≥30 cm dbh may substitute (on a 1:1 basis) for any snags less than the target of 4.
Plum Creek	53,097 ha on east- and west-slopes of the central Cascade Mountains,Washington.	Retention of ≥3 snags or defective live trees ≥30 cm dbh and ≥3 m tall, 2 green retention trees ≥25 cm dbh and ≥9 m tall. Primary habitat would increase from 39% in 1996 to 46% in 2045.
Port Blakely	3,030 ha in southwestern Washington.	When present, maintain ≥4 hard snags/0.4 ha >38 cm dbh, of which 2 would be >51 cm dbh. Two green recruitment trees >15 or >22 cm dbh (for the snag target) would be substitute for each missing snag.
Simpson Timber Company	105,859 ha in western Washington	Retain snags within riparian buffers and certain forested wetlands that total about 12,950 ha. Retain 8 green trees/0.4 ha (4 dominant/codominant trees or snags and 4 others ≥10 cm dbh) after harvest on units within a Supplemental Wildlife Tree Conservation Program area of about 14,569 ha.
Washington Department of Natural Resources	a) Olympic Experimental State Forest = 107,474 ha on western Olympic Peninsula, Washington; b) five planning units in western Washington = 477,546 ha.	a) Average amount of submature and old forest habitat in 11 planning units would increase from 25% in 1996 to 36% in year 50 and 53% in year 100; b) 33,032 ha of forest with ≥3 snags or cavity trees/0.4 ha that were ≥51 cm dbh; dominant and co-dominant trees ≥26 m tall; ≥70% canopy closure; retention of an unspecified amount of marbled murrelet habitat; no entry or limited entry to 23,473 ha of riparian forest buffers.
Weyerhaeuser Willamette*	about 161,880 ha in central-western Oregon	Retain 3 green trees or snags per 0.4 ha of harvest (≥31 cm dbh or the largest available in stand); retain one 81+ cm dbh tree/8.1 ha (if unavailable, substitute more smaller green trees); retention in riparian reserve areas acceptable; no more than 244 m distance between any snag or green tree; removal of unsafe green trees without replacement.

Notes: Two HCPs completed for municipal watersheds in Washington were not included in the table. HCPs with asterisks were not implemented. References for HCPs, in the order of presentation, are as follows: Biota Pacific Environmental Services 1999, Longview Fibre Company 1995, Beak Consultants Incorporated 1994, USDI and USDC 1999, Beak Consultants Incorporated 1996, Simpson Timber Company 2000, Washington Department of Natural Resources 1997, Hampton Communications 1996.

New Forestry and Adaptive Management

New forestry and *adaptive management* are two concepts that were widely believed to be central to an impending change in modern forest management. For the purposes of this discussion, *new forestry* is broadly defined as *forest management practices that provide for a greater diversity of forest age classes and structural conditions than currently exist in managed forest landscapes* (see Franklin 1989 DeBell and Curtis 1993). It is commonly held that new forestry should be practiced at landscape levels to facilitate creation of a full range of habitat conditions at ecologically relevant spatial scales (McComb et al. 1993). New forestry may not account for all ecosystem processes and, therefore, additional management may be required to address any such shortcomings. *Adaptive management*, a process of using experiments and "feedback loops" to make improvements to management activities (Holling 1978, Walters 1986, Walters and Holling 1990), was envisioned as the primary means for making new forestry work (Irwin et al. 1989, Irwin and Wigley 1993).

How have new forestry and adaptive management changed the way that forest management is conducted on non-federal lands in the Pacific Northwest? Unfortunately, there has been negligible use of these concepts in management of non-federal lands in western Washington and Oregon. Discussions and negotiations with forest landowners and review of proposed or implemented HCPs indicated that millions of acres of non-federal forest lands in the region would continue to be managed on 45 to 55 year rotations (McComb et al. 1993), with almost no emphasis on using "new forestry" or adaptive management principles to benefit avian conservation where it is most needed—the habitat needs of snag-dependent species and those species associated with mature and older forests. Although adaptive management was mentioned in many HCPs, most "adaptive management" was little more than obligatory monitoring that typically lacks the requisite mechanism for altering management practices in response to new information (Buchanan 1997). Furthermore, other than a few small-scale experiments, there has been no implementation of snag-creation programs of any significance.

The Outlook for Future Forest Management

There appears to be a lack of consensus within the wood products industry as to the role of the industry in conservation of wildlife on private lands. An optimistic perspective from the wood products industry was reflected in the statement, based on the results of a survey of forest managers, that "protection of threatened and endangered wildlife constituted a proper role for private forestland owners" (Irwin and Wigley 1992). Conservation planning has been viewed as a valuable process, particularly if conducted at landscape or ecosystem scales and if flexibility was incorporated to address constraints imposed by forestry activities (Haufler and Irwin 1993, Irwin and Wigley 1992). On the other hand, a segment of the forest industry maintained that conservation of resource-limited wildlife on private lands was an unfair burden (see Loehle et al. 2001). The latter perspective appears to reflect present day forest management. A similar dilemma exists for state forestlands, where forest trust responsibilities have been debated.

The modern forest management paradigm in west-side forests of Washington and Oregon has changed little over the last half-century (DeBell and Curtis 1993). Forestry practices during this period have emphasized short rotations, clearcut harvesting, and replanting. Use of short rotations was a means to maximize the economic value of trees and to ensure adequate stocking needed to respond to changes in market conditions. For several decades, the predominant perspective was that trees should be harvested at a time when trajectories reflecting mean annual increment (MAI) and periodic annual increment intersected; this was thought to occur at relatively early stages of forest development (*fig. 1*; McArdle et al. 1961). These modeled values of MAI have been used, along with economic factors and policy considerations (Curtis and Marshall 1993), as the basis for modern harvest schedules. Recent information, however, indicated a later culmination of MAI in the forest development process, as trees continued to put on substantial growth beyond 50 years of age (*fig. 2*; Curtis 1995, Curtis and Carey 1996, Curtis and Marshall 1993,). Consequently, it has been argued that forest stands can be retained for greater time periods prior to final harvest while realizing substantial timber value.

Extending rotations and retaining or creating snags for nesting birds are not simple tasks. Of primary concern to landowners is the influence on short-term cash flow of extending rotations. Also, placing buffers around snags is expensive because the buffer must be large enough to meet logging safety standards, and this forest retention would result in reduced harvest volume. In the near term, recruitment of snags or defective live trees in an intensively managed forest would involve a snag creation program, at a 1997 cost of approximately $600 to $1200/ha for 12 snags/dead-topped trees/ha (Lewis 1998). Despite efforts to retain snags, providing this resource for Pileated Woodpeckers in managed forests will be difficult because natural snag decomposition and loss would necessitate either ongoing snag management or recruitment of large live trees that would function as habitat in future stands. In addition, a buffer-based approach may not be a flexible, sustainable, landscape-level strategy.

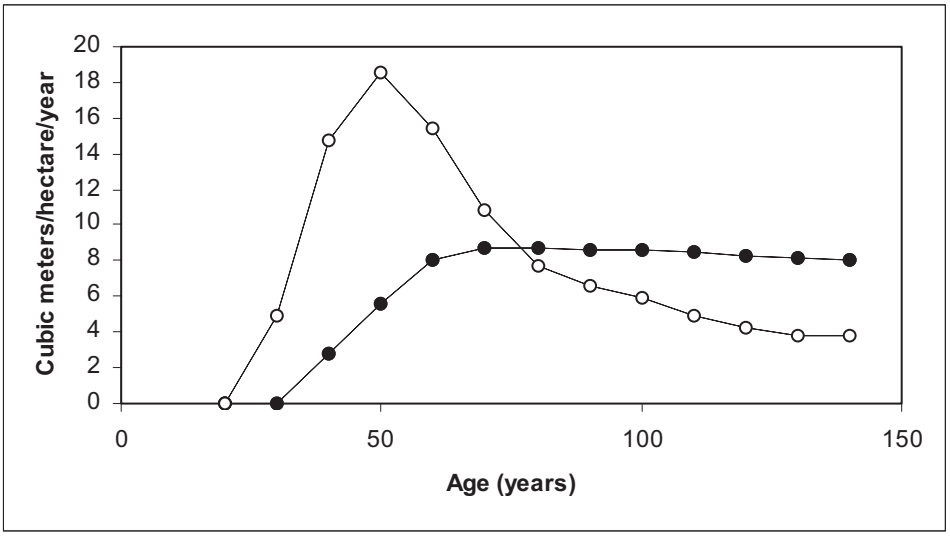

Figure 1— Generalized relationship between mean annual increment (●) and periodic annual increment (○) in Douglas-fir forests of the Pacific Northwest (McArdle et al. 1961; from Curtis and Carey 1996).

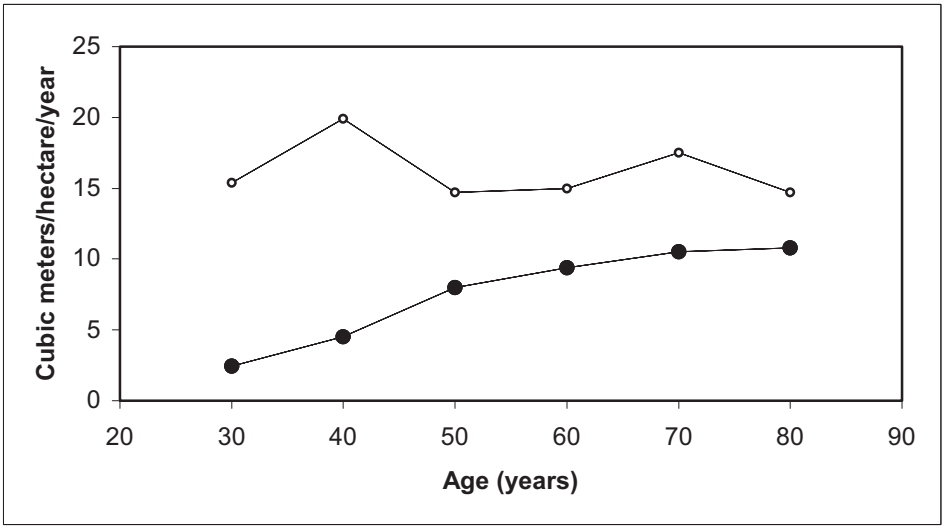

Figure 2— A more recent model of the relationship between mean annual increment (●) and periodic annual increment (○) in Douglas-fir forests of the Pacific Northwest (from Curtis and Carey 1996), indicating continued tree growth beyond 50 years.

Regulations that provided riparian buffers for salmon conservation were recently established in Washington (Washington Administrative Code 222-30-021; Washington Department of Natural Resources 2002). The value of these buffers for Pileated Woodpeckers in the near-term will likely be negligible because many buffers were intensively managed in the decades prior to the new regulations and would be snag deficient. As the forests in these buffers develop, snags will be recruited and the forests will provide habitat for some cavity users. The future value of these riparian buffers, particularly for a species with a very large home range, like the Pileated Woodpecker, is unknown. However, the highly linear nature of the riparian areas (*fig. 3*) suggests that high energetic costs associated with territory defense, foraging activities, and providing for young could be substantial. Additionally, landscapes with low stream densities will have less cumulative buffer and less potentially suitable habitat.

Improving Prospects for Conservation on Non-Federal Lands

Solutions to this wildlife habitat management quandary will not be easy and likely will involve a combination of numerous approaches. Some of these approaches may emphasize elements that deviate from the traditional economic view that holds the production of wood fiber as the only value derived from forest management.

Figure 3— Conceptual riparian buffer areas that would be protected under new forest practices rules in Washington. The inner circle represents the area of a Pileated Woodpecker home range (863 ha) in western Washington. The outer circle represents the amount of landscape (3228 ha) required to capture 863 ha within riparian buffers.

Alternative elements to consider include ecosystem function and resiliency, wildlife habitat, water quality, management of other forest products, aesthetics and recreation, and carbon sequestration. Recent studies indicated there are considerable profits associated with managing landscapes to meet a greater range of forest age-classes and ecological conditions (Lippke and Oliver 1993; Lippke et al. 1996; Marzluff et al., in press). Moreover, ecological resiliency, defined as the ability of an ecological system to maintain its inherent functions following a substantial disturbance (Holling and Gunderson 2002), more likely will be retained by managing forests on longer rotations. Stands managed on longer rotations will contain more trees of larger size and will undergo successional processes (Carey et al. 1999) that produce and retain snags and defective trees for Pileated Woodpeckers and other species. Processes for achieving a more functional landscape by altering site preparation practices (including maintenance of snags and other legacy features), using "biodiversity" thinnings to accelerate growth and development of the stand, and extending harvest rotations have been described (Carey and Curtis 1996, Carey et al. 1999). Potential reductions in present net value resulting from extended rotations (Lippke et al. 1996) could be minimized or offset by realizing greater value of larger-diameter trees available in future stands and "the enhancement of associated nontimber values" (Carey and Curtis 1996:617).

A new, effective forest management paradigm designed to provide wildlife value and ecological resiliency may build from a base of regulatory responsibility by the landowner, which might result in corporate and stockholder costs. Alternative tools that might be applied to enhance prospects for forest management include (1) economic incentives, (2) environmental assurance bonds in MCPs (Wilhere 2002), (3) implementation of carbon sequestration programs (Harmon et al. 1996), and (4) ecologically based green certification. Ecologically based forest management trusts, such as the New England Forestry Foundation (www.neforestry.org), may become an effective means to manage landscapes to provide greater ecosystem function.

The general lack of meaningful conservation value being provided for species associated with mature forest structures on non-federal lands is an impediment to Partners in Flight conservation planning in the Pacific Northwest and elsewhere. Partners in Flight should convene a national committee, with regional representation, to work with stakeholders to more clearly identify the impediments to successful conservation implementation on non-federal lands. This committee should develop a strategic plan that identifies, evaluates and implements a comprehensive suite of scenarios, including corporate and stockholder outreach, that may be applied to bring about meaningful bird conservation on non-federal lands.

Acknowledgments

I thank C. Rustay for helpful discussion, and T. Quinn and T. Rich for providing constructive comments that improved the manuscript.

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North American Wetlands Conservation Act: Contributions to Bird Conservation in Coastal Areas of the U.S.[1]

Keith McKnight,[2,3] Robert Ford,[4] and Jennifer Kross[2,5]

Abstract

The North American Wetlands Conservation Act (NAWCA) was passed in 1989, and has been instrumental in restoring, protecting, and enhancing 3.5 million has of wetland and associated habitats across North America. The objective of this study was to assess the extent to which NAWCA projects have addressed the priority habitat needs expressed by the North American Waterfowl Management Plan (NAWMP), Partners in Flight (PIF), and U.S. Shorebird Conservation Plan (USSCP) regional plans in coastal regions of the U.S., by comparing the habitat conservation activities described in approved NAWCA proposals with the habitat priorities outlined in the three bird plans. Assessment of 116 approved NAWCA proposals revealed a significant effect of bird initiative and geographic region on project scores, whereas time period (pre-2001, post-2001) had no effect. Several high priority habitat types, such as coastal wetlands (palustrine and estuarine), forest wetlands, flooded agricultural habitat, and diked marsh, were well represented in NAWCA projects. These habitats support a number of waterfowl, shorebird, songbird, and other species. Some habitats, however, were underrepresented by coastal NAWCA projects, including beach/barrier island habitats, tidal wetlands, riparian forest, and pocosins. Continued coordination and cooperation among bird conservation partners should help ensure that NAWCA continue and increase its contributions to wetland associated bird habitat conservation.

Key words: bird conservation, coastal habitats, NAWMP, NAWCA, North American Wetlands Conservation Act, PIF, USSCP.

Introduction

The North American Wetlands Conservation Act (NAWCA) was passed in 1989 to "conserve North American Wetland ecosystems and waterfowl and the other migratory birds and fish and wildlife that depend upon such systems" (16 USC 64). Since that time, NAWCA has provided over $462 million in federal funds, matched by more than $1.3 billion in partner funds to affect restoration, protection, and enhancement of 3.5 million has of wetland and associated habitats across North America.

The primary mechanism for distributing NAWCA funds in the U.S. is the U.S. Standard Grants program, which provides matching grants of between $50,000 and $1,000,000. Monies available for these grants come from several sources, the most important being NAWCA appropriations, interest from the Federal Aid in Wildlife Restoration Act (Pittman-Robertson Act), and Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA; 16 USC 3951-3956) funds. Coastal funds, as defined by CWPPRA, must be spent on projects located in "coastal watersheds" of the U.S., in states that border the Atlantic, Pacific, the Gulf of Mexico, and the Great Lakes (*fig. 1*; USFWS 2002).

Figure 1— Coastal regions of the United States used to delineate "coastal" NAWCA projects 1991-2003.

The North American Wetlands Conservation Council (Council) is mandated by the Act to provide recommendations for project funding as well as policy guidance for administration of the Act's objectives. Final approval of projects to receive NAWCA funding is given by the Migratory Bird Conservation Commission. Whereas NAWCA has traditionally served as a

[1]A version of this paper was presented at the **Third International Partners in Flight Conference**, **March 20-24, 2002, Asilomar Conference Grounds, California.**

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primary funding mechanism for the habitat conservation needs of the North American Waterfowl Management Plan (NAWMP; U.S. Department of the Interior and Environment Canada 1986), Council has expressed its intent that NAWCA contribute to the habitat needs of all wetland associated birds. This was most recently stated in December 2000 when "Council reaffirmed its intent that wetlands conservation projects provide conservation benefits to all wetland associated migratory birds, as well as other fish and wildlife that depend on these habitats" (NAWCC 2000).

Our objective here was to assess the extent to which NAWCA projects have addressed the priority coastal habitat needs expressed within the Plans of the NAWMP, Partners in Flight (PIF; Pashley et al. 2000), and U.S. Shorebird Conservation Plan (USSCP; Brown et al. 2001). To do this we compared the habitat conservation activities described in approved NAWCA proposals with the habitat priorities outlined in the three bird plans, using a simple scoring protocol for each proposal. We also were interested in determining if the availability of USSCP and PIF plans in recent years had an effect on the degree to which NAWCA projects addressed the habitat priorities of these initiatives.

Methods

Approved NAWCA coastal proposals were grouped into five geographic areas: Gulf Coast, North Pacific, South Pacific, North Atlantic, and South Atlantic (*fig. 1*). For the purposes of this analysis, we did not include the Great Lakes region, nor did we include unfunded proposals. Two time periods were considered as well: calendar years 1991-2000 and 2001-2003 (only approved projects for the first of two proposal submissions for 2003 were available for this study). Each NAWCA coastal proposal was evaluated for its contribution to the habitat area and activity goals within the physiographic plans of NAWMP, PIF, and USSCP ("Plans"). Summaries of these Plans were generated for each regional area in which a NAWCA project occurred. The Plan summaries elucidated priority habitats and their characteristics that are necessary to the conservation of bird species targeted in each planning region. Priority habitat characteristics included priority geographies, habitat quantity, and other relevant details. These Plan requirements were then used as a basis for scoring the NAWCA proposal.

Individual Proposal Evaluation

NAWCA coastal proposals were evaluated independently for contributions to each of the bird initiative Plans. The number of priority wetland and wetland associated habitat types varied among Plans by region and initiative (*table 1*).

First, habitat area was extracted and placed into the applicable priority habitat category identified by each Plan. The NAWCA proposal was scored for contributions to habitat objectives in three categories: 1) "Habitat Type"; consistency of habitat type and action with the priority habitats of the Plan, 2) "Geography"; consistency of geographic location with the Plan priorities, and 3) "Quantity"; significance of habitat quantity to the recommendations of the Plan. This scoring method was based on a 0-2 scale, where 0 was the lowest and 2 was the highest score a proposal could receive in a given category. The score for each category was determined as described below.

The NAWCA proposal received credit for Habitat Type only if the habitat listed in the proposal matched one of the habitat types and/or actions specified in a Plan. For each priority habitat, a proposal was given a Habitat Type score of 0 if that habitat was not addressed and a score of 2 if it was addressed. Consequently, if the Habitat Type score was 0, then the score for Geography and Quantity was 0. A score of 1 was assigned to Habitat Type where priority and non-priority habitat area was reported collectively.

The Geography score was based on the proposal's contributions to both "Local Geography" and "Broad Geography." Local Geography was defined as habitat improvements that contributed to an existing block of

Table 1— *Number of approved NAWCA projects, area (ha) conserved, and priority wetland and wetland associated habitats for three bird conservation initiatives among five coastal regions of the United States, 1991-2003.*

			Number of priority habitats		
Region	**Number of projects**	**Total ha conserved**	**USSCP**	**PIF**	**NAWMP**
Gulf Coast	22	83,804	7	5	5
South Atlantic	21	37,707	5	9	3
North Atlantic	42	61,648	3	7	4
South Pacific	9	29,344	6	3	3
North Pacific	22	34,287	6	4	5

priority habitat. A proposal received one point for this element if the proposed work added or protected habitat in a significant location relative to existing habitat, zero if not. Where local geography was not an important consideration (as is the case with many NAWMP and USSCP habitats), the proposal received one point for this element.

Broad Geography was defined as a regional priority area such as State Wildlife Management Areas, Wildlife Refuges, Bird Conservation Areas, and other coastal areas of special concern. One point was given if the proposed habitat work fell within one of the priority geographies listed in the Plan, zero if not. If the Plan did not list any priority geographies, then we assumed that all locations within the region were of equal importance and assigned a value of one to Broad Geography. If the Plan identified only one or two regional priority geographies for a given habitat type, and the NAWCA project was located in one of those select areas, the proposal received two points for the Broad Geography element. This essentially constituted a bonus point for activities located within a priority geography in planning regions with only a few (≤2) priority geographies.

The score for Quantity was based on the proportion of priority habitat the NAWCA project contributed to the objective listed in the Plan. Projects contributing less than 0.5 percent of the area called for in the Plan, 0.5-1 percent , and >1percent of priority habitat area scored 0, 1, and 2, respectively. When no priority habitat quantity was specified by the Plan, a score of 1 was assigned.

A subtotal of the points awarded to the NAWCA project under each priority habitat was calculated by combining the scores from the categories (Habitat Type, Geography, and Quantity; total possible score = 6). The final score for an individual NAWCA project was calculated by combining the subtotals (i.e. scores for each habitat type). The overall score was derived by dividing the total points for the project by the total possible points, as below:

$$\text{Overall score} = \sum_{i\ 1}^{n} = \mathrm{HP}_i + \mathrm{GP}_i + \mathrm{Q}_i \ / \ \sum_{i\ 1}^{n} = \mathrm{HPP}_i + \mathrm{GPP}_i + \mathrm{QP}_i$$

n = number of priority habitats listed by the Plan

HP = Habitat Type score for habitat i

GP = Geographic score for habitat i

Q = Quantity score for habitat i

HPP = Total possible Habitat Type score for habitat i

GPP = Total possible Geographic score for habitat i

QP = Total possible Quantity score for habitat i

Thus, the overall project score provided a measure of the percentage of habitat priorities of a given bird Plan within a physiographic region that were addressed by a single project.

Collective Proposal Evaluation

Whereas understanding the relative contribution of each project to individual bird initiatives is informative, the collective contribution of projects within a planning region is essential to an understanding of how NAWCA has contributed to bird conservation. To do this, we totaled the area of priority habitats of all approved NAWCA projects within each of the five geographic regions.

Statistical Analysis

We tested for effects of bird initiative, region, and time period on project score using analysis of variance and least squares means (SAS Institute Inc. 1997). Scores were arcsine transformed to meet assumptions of parametric tests (Sokal and Rohlf 1981). We used linear regression to test for relationship between project score and number of priority habitats.

Results

A total of 116 funded NAWCA Standard Grant projects were evaluated (*table 2*). Collectively, these projects conserved 246,790 ha of wetland and associated upland habitat in coastal areas of the United States. Four approved coastal projects were not included in this analysis due to inadequate information in the proposal.

Individual Project Scores

Project scores varied by Initiative ($P < 0.001$; $F = 59.4$; $df = 2$), Region ($P < 0.001$; $F = 17.0$; $df = 4$), and Initiative x Region ($P < 0.001$; $F = 6.1$; $df = 8$), but did not differ among Periods ($P > 0.05$) nor the interaction of Period with any other factors. NAWMP project scores were higher ($P < 0.05$) than the other two initiatives in the Gulf Coast, South Atlantic, and North Atlantic regions, whereas project scores for NAWMP did not differ ($P < 0.05$) from those for USSCP in the South Pacific, nor from those for PIF in the North Pacific region (*table 2*).

Table 2— *Least squares means of approved NAWCA project scores for North American Waterfowl Management Plan (NAWMP), U.S. Shorebird Conservation Plan (USSCP), and Partners in Flight (PIF) Plans in five coastal regions of the United States.*

	Region				
Initiative	**Gulf Coast**	**South Atlantic**	**North Atlantic**	**South Pacific**	**North Pacific**
NAWMP	0.50 A[1]	0.85 A	1.08 A	0.43 AB	1.00 A
USSCP	0.28 B	0.26 B	0.32 C	0.45 A	0.38 B
PIF	0.25 B	0.30 B	0.53 B	0.20 B	0.61 AB

[1]Means within columns followed by different letters differ ($P < 0.05$) according to least squares means analysis.

Table 3— *Least squares means of project scores for North American Waterfowl Management Plan (NAWMP), U.S. Shorebird Conservation Plan (USSCP), and Partners in Flight (PIF) Plans in five coastal regions of the United States.*

	Initiative		
Region	**NAWMP**	**USSCP**	**PIF**
Gulf Coast	0.50 C[1]	0.28 A	0.25 C
South Atlantic	0.85 B	0.26 A	0.30 BC
North Atlantic	1.08 A	0.32 A	0.53 A
South Pacific	0.43 C	0.45 A	0.20 C
North Pacific	1.00 AB	0.38 A	0.61 A

[1]Means within columns followed by different letters differ ($P < 0.05$) according to least squares means analysis.

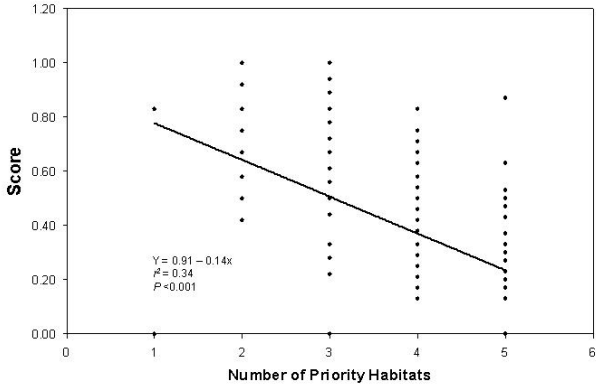

Figure 2— Relationship between project score and number of priority habitats in the Plan region, according to regression analysis for approved NAWCA projects in coastal areas of the United States, 1991-2003.

Scores for NAWMP priority habitats generally were highest ($P < 0.05$) in the North Atlantic and North Pacific regions, whereas NAWMP scores for the Gulf Coast and South Pacific were lower than in the other regions (*table 3*).

For USSCP, project scores did not differ ($P > 0.05$) among planning regions, although USSCP project scores in the North Atlantic region were lower ($P < 0.05$) than those for the other two initiatives (*table 2*). PIF priority habitat scores were greatest ($P < 0.05$) in the North Atlantic and North Pacific regions (*table 3*). Project scores were negatively related ($P < 0.05$; $df = 324$; $r^2 = 0.34$) to the number of priority habitats in the planning region (*fig. 2*).

Regional Project Contribution to Priority Habitats

Area of priority coastal habitat conserved by NAWCA projects since 1991 for NAWMP, USSCP, and PIF priorities were 183,990, 127,695, and 121,124 ha, respectively, with more priority habitat conserved since 2001, than prior to 2001 (*tables 4-6*). Note that area of priority habitats conserved relative to the three bird Plans is not additive. For example, "Coastal Marsh" accounts for 48,567 and 50,289 ha of priority habitat for both NAWMP and USSCP, respectively. Coastal Marsh (including saline, brackish, and fresh marsh), Forest Wetland, Flooded Agriculture, Seagrass Beds, and Upland Buffer comprised the majority of this area.

Priority habitat types consistently underrepresented in funded NAWCA projects were Riparian Forest and Tidal Wetland for NAWMP (*table 4*); Lacustrine Wetland, Beach, Shoreline and Rock Jetties, Tundra Meadows, and Salt Ponds for USSCP (*table 5*); and Pocosins, Pine Savannah, Sand Hill/Longleaf Pine, and Coastal Forest for PIF (*table 6*).

Discussion

NAWCA has contributed to the conservation of more than 200,000 ha of priority bird habitat in coastal regions of the United States through the Standard Grants program since its inception in 1991. These areas provide important habitat to a variety of bird taxa, and contribute significantly to regional habitat components of the three bird conservation initiatives we examined. Projects examined in this study contributed most consistently to the priority habitat objectives of the NAWMP. This was evident in both the individual project scores and the aggregate area (183,990 ha) of priority habitats.

Table 4— *Quantity (ha) of North American Waterfowl Management Plan priority habitats in NAWCA Standard Grant proposals funded in five coastal regions of the U.S. from 1991-2000 and 2001-2003.*

	Gulf Coast		South Atlantic		North Atlantic		South Pacific		North Pacific		Total	
Habitat type	**'91-'00**	**'01-'03**	**'91-'00**	**'01-'03**	**'91-'00**	**'01-'03**	**'91-'00**	**'01-'03**	**'91-'00**	**'01-'03**	**'91-'00**	**'01-'03**
Coastal Marsh	9,387	39,179	[1]-	-	-	-	-	-	-	-	9,387	39,179
Palustrine wetland	4,539	877	11,021	9,727	9,263	7,529	14,744	6,722	5,922	5,281	45,489	30,137
Estuarine wetland	-	-	1,464	1,133	8,856	2,003	-	-	1,076	2,280	11,396	5,416
Agriculture Habitat	2,047	1,012	-	-	-	-	142	0	0	0	2,189	1,012
Upland Buffer	-	-	150	40	841	21,681	-	-	-	-	991	21,722
Forested Wetland	1,824	162	-	-	-	-	-	-	-	-	1,824	162
Seagrass Bed	0	14,536	-	-	-	-	-	-	-	-	0	14,536
Shoreline	-	-	-	-	0	0	-	-	-	-	0	0
Riparian Forest	-	-	-	-	-	-	-	-	23	1	23	1
Tidal Wetland	-	-	-	-	-	-	-	-	0	85	0	85
Water	-	-	-	-	-	-	440	0	-	-	440	0
Total	17,797	55,766	12,635	10,901	18,961	31,214	14,886	6,722	7,021	7,647	71,300	112,250

[1]"-"Denotes habitat type was not a priority in this region.

Table 5-- *Quantity (ha) of U.S. Shorebird Conservation Plan priority habitats in NAWCA Standard Grant proposals funded in 5 coastal regions of the U.S. from 1991-2000 and 2001-2003.*

	Gulf Coast		South Atlantic		North Atlantic		South Pacific		North Pacific		Total	
Habitat Type	**'91-'00**	**'01-'03**	**'91-'00**	**'01-'03**	**'91-'00**	**'01-'03**	**'91-'00**	**'01-'03**	**'91-'00**	**'01-'03**	**'91-'00**	**'01-'03**
Coastal Marsh	10,290	39,999	[1]-	-	-	-	-	-	-	-	10,290	39,999
Freshwater Ponds	3,236	2,999	7,307	1,343	-	-	13,767	5,536	3,911	4,053	28,221	13,931
Esturine Intertidal	0	0	1,464	1,113	9,928	2,003	76	0	1,086	2,268	12,553	5,384
Flooded Agriculture	2,047	4,249	-	-	-	-	142	0	956	0	3,145	4,249
Barrier Island/Beach	0	879	0	0	25	0	-	-	0	0	25	879
Riverine Wetland	727	1,499	0	19	-	-	-	-	-	-	727	1,518
Lacustrine Wetland	0	0	6	59	-	-	-	-	-	-	6	59
Shoreline & Rock Jetties	-	-	-	-	*27	*10	-	-	*95	*45	95	
Diked Marsh	-	-	-	-	-	-	5,615	919	-	-	5,615	919
Tundra Meadows	-	-	-	-	-	-	-	-	80	0	80	0
Salt Ponds	-	-	-	-	-	-	0	0	-	-	0	0
Total	16,301	49,625	8,777	2,533	9,953	2,003	19,600	6,455	6,048	6,320	60,678	66,937

[1]"-"denotes habitat type was not a priority in this region.

*Expressed in kilometers.

Table 6— *Quantity (ha) of Partners in Flight priority habitats in NAWCA Standard Grant proposals funded in 5 coastal regions of the U.S. from 1991-2000 and 2001-2003.*

	Gulf Coast		South Atlantic		North Atlantic		South Pacific		North Pacific		Total	
Habitat type	**'91-'00**	**'01-'03**	**'91-'00**	**'01-'03**	**'91-'00**	**'01-'03**	**'91-'00**	**'01-'03**	**'91-'00**	**'01-'03**	**'91-'00**	**'01-'03**
Forested Wetland	6,881	5,215	3,090	8,244	5,299	4,473	-	-	-	-	15,270	17,931
Coastal Marsh	15,042	43,366	-	-	8,846	2,164	-	-	-	-	23,888	45,530
Salt Marsh	[1]-	-	424	36	-	-	-	-	-	-	424	36
Mangrove	-	-	6,243	0	-	-	-	-	-	-	6,243	0
Emergent Marsh	-	-	1,599	2,158	-	-	-	-	-	-	1,599	2,158
Barrier Island & Beach	-	-	449	360	0	0	-	-	-	-	449	360
Early Succession Scrub	373	0	172	0	57	148	0	0	0	15	602	162
Pocosins	-	-	0	0	-	-	-	-	-	-	0	0
Grassland	1,493	121	-	-	30	73	909	0	0	0	2,432	194
Pine Savanna	-	-	0	0	0	0	-	-	-	-	0	0
Sand Hill/Longleaf Pine	0	0	0	0	-	-	-	-	-	-	0	0
Coastal Forest	-	-	-	-	-	-	-	-	172	0	172	0
Migration Stopover	-	-	-	-	897	1,804	-	-	-	-	897	1,804
Riparian	-	-	-	-	-	-	213	418	192	149	405	566
Total	23,788	48,702	11,977	10,799	15,128	8,661	1,122	418	365	163	52,381	68,743

[1] "-" denotes habitat type was not a priority in this region.

Habitat Priorities Addressed by NAWCA Projects

NAWMP habitat objectives were met more consistently than habitat objectives in either PIF or USSCP Plans for at least two reasons. First, project partners have assembled and delivered NAWCA projects aimed at fulfilling primarily NAWMP habitat objectives, partially because bird conservation Plans from other initiatives have only recently been completed. Second, NAWMP has had a relatively simple classification of habitats in the implementation Plans. NAWMP habitat categories are relatively broad (e.g. palustrine wetland or estuarine wetland) compared to habitat categories used by the other initiatives. For our analysis, a project was more likely to have scored higher if the objectives were composed of relatively few, broad habitat categories. This assertion is supported by the negative relationship between project score and number of priority habitats (*fig. 2*) found in this study. As a Plan increased the number and narrowed the focus of priority habitat types, it became less likely that any single project addressed a significant number of them.

Nonetheless, NAWCA has provided notable habitat contributions to the objectives set forth in both PIF and USSCP Plans. Coastal marsh and forested wetland habitats, both PIF priority habitat types in at least two planning regions, were well addressed in the proposals examined. These habitats are important to a number of species, including Saltmarsh Sharp-tailed Sparrow (*Ammodramus caudacutus*) and Seaside Sparrow (*Ammodramus maritimus*) in coastal marsh, and Swallow-tailed Kite (*Elanoides forficatus*), Northern Parula (*Parula Americana*), and Swainson's Warbler (*Limnothlypis swainsonii*) in forested wetlands (Pashley et al. 2000). For shorebirds, coastal wetlands (palustrine and estuarine) were a priority in every planning region, and these habitats dominated the conservation activities in many projects. In addition to these, conservation of flooded agricultural habitats (Gulf Coast, North and South Pacific) and diked marsh (North Pacific) made up a substantial portion of the projects examined. These constitute important feeding habitats for many USSCP species of High Concern, including Dunlin, Red Knot, Greater Yellowlegs, Whimbrel, and Long-billed Curlew (Brown et al. 2001).

Meeting the needs of a variety of bird taxa is an advantage of a broader, habitat-based program such as NAWCA, compared to a narrowly focused, species-based program (Ford et al. 1995). Furthermore, local and regional delivery of projects through self-directed partnerships (e.g. Joint Ventures) contributes to the effectiveness of integrating different Plan objectives (Williams et al. 1999).

Habitat Priorities Poorly Addressed by NAWCA Projects

Some high priority bird habitats in each of the Plans we examined have received relatively little attention from NAWCA projects. Brown et al. (in press), in an independent evaluation of NAWCA performance for shorebirds in the North Atlantic, found that overlooked species are often specialists, and require habitats and/or microhabitats not addressed in the NAWCA projects. For shorebirds, the most notable habitat omissions in the present study were beach and rocky shoreline/jetties. Beach habitat is listed as priority in all but the South Atlantic region, whereas the rocky shoreline/jetties habitat is priority for North Atlantic and North Pacific shorebirds.

It is not clear why beach habitat was not included to a large extent in NAWCA projects. However, the relative high acquisition cost and limited suite of bird species that benefit from beach conservation may provide some explanation. Further, in most parts of the country beach habitat already is under public ownership, and opportunities for eligible NAWCA-funded activities (restoration, enhancement) likely are limited. Nonetheless, beach habitat conservation has increased in NAWCA projects in the Gulf Coastal region during the past few years (*table 5*).

For Partners in Flight priorities, a number of habitats have been largely absent from NAWCA projects, including barrier island/beach, early succession scrub, pocosins, pine savannah, sandhill/longleaf pine, coastal forest, and riparian habitat. Some of these habitats may be under estimated in our analysis because upland habitat generally was not well quantified or described in proposals. Also, most of these habitats are priority in only one or two regions, and are found within a relatively limited geographical extent. This is especially true with pocosin habitat, which occurs predominantly in North Carolina. The South Atlantic region had more priority (n = 10) and under-represented PIF priority habitats (n = 5) than any other region. Bogart (1996) noted relative under representation of riparian forest habitat in 14 NAWCA projects approved in the Central Valley of California prior to February 1995, which was attributed to the lack of riparian habitat in NAWMP Plan objectives for the Central Valley. It also should be noted that riparian forest vegetation typically occurs in relatively linear strips, even in undisturbed areas. Hence, measuring in hectares the impact of NAWCA regarding this habitat type may underestimate the biological impact of such conservation activities.

Priority habitats for NAWMP that were consistently under represented in NAWCA projects were shoreline, riparian forest, tidal wetland, and securement of water rights ("water"). All four of these habitats (or habitat

issues, in the case of "water") were priority in only one region, with two of them (riparian forest, and tidal wetland) occurring in the North Pacific. Shoreline habitat, tidal wetland, and water may have been underestimated in our study, as they were likely present in many projects, yet not adequately described in the proposals. In particular, shoreline habitat is inherently part of any wetland or aquatic habitat, but rarely described as such. Also, some of the wetland area classified as palustrine in North Pacific proposals likely were tidally influenced, and therefore "tidal wetlands", although they were not noted as such in the proposals.

Limitations of This Analysis

It is important to point out that our assessment of NAWCA is based on information available in project proposals, and not on inspection of project sites. Such an assessment would require substantial resources. Further field evaluations of NAWCA projects, combined with meetings with project directors (e.g. Brown et al. in press) would improve our knowledge of how NAWCA meets objectives for each of the bird Plans. However, our intent was to evaluate the NAWCA program based on the information available to decision makers when funding decisions are made. Whereas the final project certainly differs to some extent from the proposed project, it is our assumption that these differences are not of such magnitude as to change the general trends that emerge from the present analysis.

Other Factors Determining Funding for NAWCA

In response to the recent interest in NAWCA funding and projects spawned by maturation of initiative Plans and the North American Bird Conservation Initiative (NABCI 2000), we attempted to evaluate NAWCA actions relative to bird conservation priorities for three broad taxonomic groups. However, selection of NAWCA projects is not based solely on their contribution to bird conservation. In accordance with language in the law itself, NAWCA projects are selected based on the following factors in addition to bird habitat: (1) conservation of declining wetland types, (2) conservation of listed species (both floral and faunal), (3) contribution to long-term conservation, (4) partnership and non-federal cost-share, and (5) location within established Joint Venture geographies. It is likely no coincidence, then, that the habitat types most prevalent in coastal NAWCA projects (palustrine emergent, palustrine forested, estuarine) are important not only to bird conservation, but are (or were at the time of the project's selection) also declining wetland types.

Conclusions

NAWCA projects have contributed to the conservation of many bird species dependent on wetland and associated upland habitats in coastal regions of the United States. Results of this study clearly indicate that most of the NAWMP habitat objectives and many of the PIF and USSCP objectives for wetlands and associated habitats in coastal regions have been addressed by NAWCA. There were, however, some priority habitats that were not well represented in NAWCA projects. Whereas no single program or granting source can be expected to provide for all of the on-the-ground wetland and associated habitat needs of the existing bird initiatives, NAWCA certainly is poised to provide substantial assistance. Importantly, NAWCA can only fund projects that are proposed. The degree to which future projects include a wider array of priority habitats will depend to a large extent on the degree to which the partners involved in planning, design, and delivery of projects coordinate and collaborate, as suggested by Heitmeyer et al. (1996). Adoption of the objectives of the various bird conservation initiatives by many habitat Joint Ventures in recent years is resulting in improved integration of these objectives. As these efforts mature, it is more likely that quality wetland conservation projects assembled for consideration by NAWCA will contain more of these historically underrepresented habitats.

Acknowledgments

The authors wish to thank staff of the U.S. Fish and Wildlife Service Division of Bird Habitat Conservation for assistance in assembling the raw data and reviews of the manuscript. We also thank B. Andres, D. Demarest, and S. Mott for helpful comments and discussions regarding Plan summaries. The manuscript was greatly improved by reviews from D. Weaver and T. Rich.

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Partnerships to Deliver Bird Conservation along the Gulf Coast[1]

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Abstract

The Gulf of Mexico region contains much of the Western Hemisphere's most important stopover habitat. Long an important region for industry and agriculture, the near-shore maritime and wetland habitats are now highly threatened by habitat degradation and rapid urbanization. Because of the value placed on coastal property, acquisition is not always a viable conservation tool. The development of public and private partnerships has proven to be an excellent method to deliver cost-effective conservation in the maritime habitats of the western gulf coast. Here we describe accomplishments of four partnership programs spanning the gulf coast from Alabama to the Yucatan Peninsula: The Gulf Crossings Network, The Texas Prairie Wetlands Project, the Louisiana Waterfowl Project South, and the Mini-refuge Program. The Gulf Crossings Network includes 48 partner sites consisting of a diverse group of private and public landowners responsible for the management of 5.7 million acres of coastal habitat. The Gulf Coast Bird Observatory works to assist these partners with specific conservation efforts and also facilitates sister-site partnerships to share responsibilities and resources for similar habitat types and for shared avian species. Many en route migrants such as shorebirds, as well as wintering waterfowl and prairie grassland birds, benefit from the efforts of the Gulf Coast Joint Venture partnership and three private landowner programs. The Texas Prairie Wetlands Project, the Louisiana Waterfowl Project South, and the Mini-refuge Program each provide technical assistance and financial incentives to Texas and Louisiana landowners interested in creating or enhancing the status of wetlands on their property.

Key words: conservation partnerships, Gulf of Mexico, landowner incentives, nearctic-neotropical migrants, stopover habitat.

Gulf Crossings Network

The Gulf of Mexico, with its central position within the Americas, is a region of hemispheric importance to a great diversity of migratory bird species. More than 800 species of birds, including waterfowl, shorebirds, raptors, songbirds, and colonial waterbirds, use the shores of the gulf for breeding, over-wintering, and spring and fall migration staging areas.

About 300 of these species are nearctic-neotropical migrants that depend on stopover habitat in the gulf region to rest and refuel on their trans-gulf and circum-gulf journeys between breeding and wintering grounds. An important region for industry, tourism, and agriculture, the near-shore maritime and wetland habitats are increasingly threatened by coastal erosion, urbanization, and other land conversion activities.

In 1997 the Gulf Coast Bird Observatory (GCBO) began to address these issues by partnering with the stewards of important public and privately owned gulf coastal habitat via a network of partner sites in locations known to be of great importance during migration seasons. Specifically, the first site partners selected were well-known spring fall-out locations along the upper Texas and Louisiana coasts. The primary objective was to use the network concept to raise funds to acquire and protect these key stopover sites, then to expand the same principals of protection into all important coastal locations. End points of trans-gulf migration pathways (known fall-out sites) were the targeted properties. Beginning with eight key sites in 1997, the site-partner program was designed to recognize and assist landowners who wanted to protect and or provide stopover habitat for migratory landbirds. Each landowner had a strong interest in bird conservation and had existing, quality habitat located in the region of the trans-gulf flyway for migratory landbirds. The benefits to partners in the network include opportunities for international networking, increased site publicity, funding opportunities, and financial and technical assistance with on-the-ground projects such as habitat restoration, monitoring, and public use enhancements.

Today, the Observatory's Network includes 48 partner sites consisting of a diverse group of private and public landowners responsible for over 5.7 million acres of coastal habitat including maritime woodlands, marine and freshwater wetlands, and coastal prairies. To help fund the efforts of our partners, the Gulf Crossings

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California**.

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project was designed to assist these sites in their conservation efforts and to encourage cooperative action among them. Initial accomplishments of this project include the restoration of a coastal prairie in Texas, private lands conservation efforts in the Yucatan Peninsula, and the compilation of species and habitat data for each partner site. Currently, the Gulf Crossings project is involved in the acquisition of two important stopover habitats in coastal Texas, as well as conservation activities in the Yucatan Peninsula.

With site partners in five states in both the United States and Mexico, and one site in Cuba, the program has now expanded to include an all-bird focus. With the assistance of the partners, we are working to identify additional sites targeted for protection, develop action plans for habitat restoration at new as well as existing sites, and implement avian monitoring, education, and outreach programs at several sites.

The Gulf Crossings project of the GCBO has made significant achievements in land protection. Acquisition of valuable stopover habitat at Quintana Island and Mustang Island, Texas, were completed in 2001. Both sites were small privately owned woodlots in key migration zones and both were known (by birders) to be important stopover habitat. Each was threatened by increasing local development, and both acquisitions provided a unique opportunity to build new relationships between city officials interested in ecotourism and birders interested in new access to once-private property. Winning birding teams in the Texas Parks and Wildlife Birding Classic event provided the initial funding for these acquisitions. Gulf Crossings staff provided technical assistance to the city for enhancements, habitat management, and raising the remaining funds required to complete the land purchases. Gulf Crossings also assisted in raising funds for U.S. Fish and Wildlife Service (USFWS) acquisitions of three large tracts of riparian forest in the Columbia Bottomlands of coastal Texas. The Bird Pond tract (100 acres), the Hudson tract (1,093 acres), and the Bludworth tract (750 acres) all contain mature bottomland hardwood forests and freshwater wetlands that provide valuable habitat for migratory landbirds and waterfowl. All three tracts are managed as part of the USFWS Texas Mid-coast National Wildlife Refuge Complex. On another important coastal site, the Gulf Crossings project provided funds to restore 425 acres of coastal prairie. This prairie restoration, at The Nature Conservancy's Texas City Preserve, is expected to increase the habitat quality for the last wild population of the endangered Attwater's Prairie-Chicken (*Tymjpanuchus tupido Attwateri*).

The educational component of the Gulf Crossings project was initiated with a National Fish and Wildlife Foundation grant to provide annual funding to support a bird conservation/education specialist in Yucatan, Mexico. The Yucatan Conservation Coordinator is involved in a number of activities that have benefited the conservation of birds at the Mexico Gulf Crossings partner sites. The coordinator organized and taught a total of 17 bird identification and training workshops carried out in coastal communities. The workshops have had a significant impact on these communities as the participants have gained an understanding and appreciation of birds and their habitats. The benefits also have been seen in the increase of responsible and sustainable ecotourism practices, an important economic activity in the Yucatan. After only two years of funding, this position grew into a new full-time initiative and locally funded conservation effort, a first-of-its-kind Yucatan regional bird center, known as CAPY.

Sister-Site Partnerships

A new way in which Gulf Crossings is encouraging cooperation is through sister-site partnerships between sites within the larger network. Sister-site partnerships are mutually beneficial relationships between two sites with commonly shared features. The birds themselves are shared features, but sometimes there are also similar threats or management activities that the two sites can help each other with. Each site can benefit from the experiences and resources of the other, which translates into greater conservation results and efficiency. Using habitat and species data collected for each partner site, GCBO's Gulf Crossings staff selects those sites that share common traits, and approaches the site managers about their interest in a sister-site linkage. If the parties do have an interest, staff then facilitates the development of a formal Letter of Agreement with terms of benefit to both sites.

Gulf Crossings has established two such sister linkages. The partnership between Anahuac National Wildlife Refuge, in southeast Texas, and the Ria Lagartos Biosphere Reserve, in Yucatan, Mexico, is still in the planning stages, but it looks like a promising relationship because of the similarities in habitat and management strategies at these two reserves. A second linkage between the Houston Audubon Society and the Sian Ka'an Biosphere Reserve in Quintana Roo, Mexico is currently underway and has already met with success.

The Houston Audubon Society has provided much needed funds for conservation projects at Sian Ka'an. One of these projects consists of carrying out training workshops in the communities associated with this reserve. So far this year, nine training workshops have taken place in the Sian Ka'an associated communities of Chunyaxche, Punta Allen, and Xcalak. The workshops train community members in bird identification

and appreciation, the use of binoculars and field guides, and the skills and responsibilities for being an ecotourism guide. The participants are taught how to care for binoculars, how to avoid negatively impacting the birds and habitats, how to pronounce names of birds in English, and which species are endemic or most sought after by visiting birders. The workshops have been a remarkable success and have generated a spreading enthusiasm that has led some of the participants to begin bird watching for the pleasure of it—an uncommon activity in Mexico.

Another project funded through this sister-site partnership is the construction of a modest visitor center in the Sian Ka'an Biosphere Reserve. The center was built using traditional materials along a nature trail in the Maya archeological area near the indigenous forest community of Chunyaxche. The center is a simple and practical structure that serves as an environmental education facility as well as a station for staff and scientists at Sian Ka'an.

Staff exchanges are also encouraged between sister-sites. In January 2002, Barbara MacKinnon, the Founding President of Amigos de Sian Ka'an, traveled to Houston to give a presentation on the Sian Ka'an Biosphere Reserve at the Houston Audubon Society monthly meeting. In August, several representatives of the Houston Audubon Society traveled to the Yucatan Peninsula to visit with the Amigos de Sian Ka'an staff to see first hand the natural beauty and conservation work at this Biosphere Reserve. The sister-site partnership concept allows sites to focus their attention and energies on one other partner site within the broader network of sites that they are less closely involved with. This strategy increases the possibilities and the rate at which conservation results can be accomplished for birds and their habitats.

Like the Gulf Crossings project, our colleagues with the Gulf Coast Joint Venture (GCJV) work with partners along the shores of the Gulf of Mexico. In fact, the regions of work for both organizations overlap in four states. Both the GCBO and the GCJV keep apprised of each other's activities and share responsibilities for avian conservation in the region. The following three GCJV programs were each designed to use large expanses of active, idle, or abandoned agricultural lands in Texas and Louisiana. Since rice farming operations require 2- or 3-year crop rotations, this form of agriculture offers ample opportunity to provide seasonal habitat for wetland dependant bird species. Therefore, manipulated agricultural fields are the primary focus of these projects that benefit shorebirds, wintering waterfowl, wading birds, and even many wintering landbirds such as Sedge (*Cistothorus platensis*) and Marsh wrens (*C. palustris*), Common Yellowthroat (*Geothlypis trichas*), Yellow-rumped Warbler (*Dendroica coronata*), and Swamp Sparrow (*Melospiza georgiana*).

Texas Prairie Wetlands Project

Initiated in l991, the Texas Prairie Wetlands Project (TPWP) is a cooperative effort of the North American Waterfowl Management Plan and GCJV. The purpose of this program is to develop, restore, and enhance natural wetlands or seasonally flooded agricultural fields on private lands along the Texas coast. The goal is to address the wetland habitat needs of wintering waterfowl identified by the GCJV for private lands. Ducks Unlimited, Inc., Texas Parks and Wildlife Department, USFWS, and U.S. Department of Agriculture Natural Resources Conservation Service (NRCS) support the TPWP.

Strategies to meet the program's goal are the provision of technical assistance and financial incentives to landowners who are interested in improving the status of wetlands on their property. Financial cost-sharing for the restoration, enhancement, or creation of wetland habitat is provided to a landowner in exchange for an agreement to maintain and manage the area. Project agreements are for a period of not less than 10 years. In addition to waterfowl, many species of shorebirds, wading birds, songbirds, and other wetland-associated wildlife benefit from the quality wetland habitat effectively developed under the TPWP.

Over 26,000 acres of wetlands have been restored, enhanced, or created since the inception of the program. Project agreements have been established with 303 landowners for the development and management of approximately 550 wetland units. Seventy-one percent of the developed wetlands is categorized as flooded agricultural land and moist soil habitat (36 percent and 35 percent, respectively). The balance of the developed wetland acreage is categorized as either emergent marsh (25 percent) or lake/pond (4 percent).

Louisiana Waterfowl Project South

The Louisiana Waterfowl Project South (LWPS) focuses on the development of wetland habitat on private lands of southwestern and south central Louisiana. The LWPS is implemented in support of the North American Waterfowl Management Plan and GCJV. In addition to private landowners, key partners are Ducks Unlimited, Inc., the Louisiana Department of Wildlife and Fisheries, USFWS, and NRCS. Technical assistance and financial incentives are available to landowners interested in maintaining and managing off-season agricultural fields and other wetland areas as

waterfowl habitat. Project agreements are for a minimum of 10 years. The LWPS is similar to the TPWP but there are differences between the cost-share guidelines of the two programs. This newly established program has already developed over 3,500 acres of wetland habitat on private lands within the GCJV. Approximately 71 percent of the acreage is associated with agricultural lands. The remainder is divided among moist soil, scrub-shrub, and coastal marsh habitats.

Mini-Refuge Program

The southwest Louisiana mini-refuge program is a wetland habitat conservation partnership among the USFWS, Louisiana Department of Wildlife and Fisheries, and private landowners, initiated in 1988 under the auspices of the GCJV. The program is administered by USFWS from Lacassine National Wildlife Refuge. Under the program, private landowners provide a free lease to USFWS in exchange for trespass protection and the potential for reimbursement of some habitat management expenses. During the lease period, usually July through March of each year, enrolled properties become inviolate sanctuaries as part of the USFWS system. As funds are available, expenses for pumping water on agricultural fields and manipulating habitat are reimbursed to the landowner through annual agreements with USFWS.

The availability of funds to support this program has varied annually, resulting in unrealized habitat potential at some sites in some years. Consequently, new guidelines were established for this program in 1999 to more efficiently direct available funds. These guidelines are intended to improve habitat quality and distribution, while reducing the number of sites to accommodate funding limitations and improve program efficiency. The mini-refuge program is currently implemented in the portion of southwest Louisiana that is encompassed by the GCJV Chenier Plain Initiative Area, including the parishes of Cameron, Calcasieu, Jefferson Davis, Acadia, Vermilion, Allen, and Evangeline. Agriculture in this region is dominated by rice and rice-rotation crops. Louisiana's Chenier Plain Initiative Area is a continentally important region for wintering waterfowl, with midwinter population objectives of 4.5 million ducks and 340,000 geese. It is a particularly important area to wintering pintails, with midwinter population objectives of nearly 400,000. Northern Pintails (*Anas acuta*) are one of the few duck species that lag far behind their North American Waterfowl Management Plan population objective, so pintails are specifically targeted for management through the mini-refuge program. Habitat value to pintails may be reduced by a number of disturbance factors that increase energetic expenditures necessary to find foraging and roosting habitat. These high energetic costs (Cox and Afton 1998a) may interact with direct mortality factors to result in low overwinter survival of pintails, relative to those monitored in other regions (Cox et. al. 1998). One objective of the mini-refuge program is to provide sanctuary to pintails to partially mitigate the interaction between disturbance, energetic cost, and low survival.

Optimally managed mini-refuges serve as feeding and roosting sites for southwest Louisiana pintails and other ducks (Rave and Cordes 1993). An appropriate distribution of these sites will enhance ducks' access to surrounding agricultural foraging areas and decrease the energetic costs of lengthy transit and associated vulnerability to mortality. Researchers have estimated that 7 to 19 percent of daily energetic expenditures for southwest Louisiana pintails are due solely to one round-trip flight from a major daily roost site (Lacassine Pool) to nocturnal feeding areas, with one-way flight distance averages ranging from 5.4 to 15.2 miles (Cox and Afton 1996). Current guidelines for the spatial distribution of mini-refuges are, therefore, intended to provide diurnal roost sites that are no farther than 15 miles from other sanctuary.

The Lower Mississippi/Western Gulf Coast Regional Shorebird Plan has identified fall foraging habitat as a limiting factor to survival and/or condition of shorebird populations that utilize habitats in this region. Therefore, provision of late summer and fall shorebird foraging habitat is another objective of the mini-refuge program. Ideal mini-refuge sites are a minimum of 600 contiguous acres, with perimeter-to-area ratios as small as possible. This allows for a central core of flooding, surrounded by a protected buffer area. Eight sites were enrolled in the program during the fall/winter of 2001.

Waterfowl Management

Proper water management and habitat manipulation are critical to making sites attractive to feeding and/or roosting ducks. Pintails begin arriving in mid-September, while some Blue-winged Teal (*Anas discors*) arrive even earlier, usually in mid-August. This early fall period typically coincides with regionally dry habitat conditions. There is not as much incentive for the average landowner to flood early compared to later during fall and winter when hunting seasons are open. Providing early pumped water, especially when conditions are dry, is therefore an important focus of this program. Optimal flooding depths for pintails and other dabbling ducks are 3-6," with a maximum of 12." Flooding for waterfowl, whether pumped or collected from rainfall, is targeted to be at least 200 acres near the core of each site.

Idle fields have roughly 3 times the amount of waterfowl foods as harvested rice fields (Davis et al. 1960, Harmon et al. 1960), so flooding these moist-soil habitats is encouraged. In both field types, standing vegetation or stubble should be manipulated (i.e. rolled, lightly disked, or roller-chopped) to create visually opened areas attractive to pintails.

Shorebird Management

For those mini-refuge fields that are targeted for intensive shorebird management, shallow flooding of mudflats during late summer (mid-July through September) provides important foraging habitat for migrating shorebirds. Shallowly flooded, double-disked, rice rotation fields yield the type of mudflat attractive to most species of shorebirds. Subsequent mechanical manipulation is conducted to maintain a mudflat conducive to shorebird foraging.

Evaluating performance of mini-refuge sites is necessary to ensure an effective mini-refuge program. Performance is evaluated based on all stated objectives of the program, but provision of sanctuary to pintails and water during critical dry periods are the primary evaluation criteria. Aerial surveys ascertain diurnal waterfowl use by species once per month in October, November, and December. Ground surveys are conducted for each mini-refuge twice monthly. Guidelines for continuance in the program require that survey data demonstrate significant use by pintails or exceptional use by shorebirds. While this program has not yet realized its full potential, the successes of some specific sites are encouraging. Adherence to new guidelines and evaluation criteria, along with attainment of a stable funding source, should improve the program and increase benefits to migratory birds.

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Linking Shorebird Conservation and Education along Flyways: An Overview of the Shorebird Sister Schools Program[1]

Hilary Chapman[2] and Heather Johnson[2]

The Shorebird Sister Schools Program (SSSP) is an internet-based environmental education program that provides a forum for students, biologists, and shorebird enthusiasts to track shorebird migration and share observations along flyways. The program's vision is to engage public participation in the conservation of shorebirds and their wetland, grassland, and shoreline ecosystems along flyways. The target audiences are students and educators. However, facilitating interaction between biologists, students, and educators is an essential component of the program. In addition, numerous volunteer shorebird enthusiasts participate in the program and greatly enrich the information that is shared. Partnerships at the local, state, regional, national, and international levels are crucial for this program to function. Although the U.S. Fish and Wildlife Service (USFWS) is responsible for maintaining the primary program components that include a web site, list server, and K-12 curriculum, partner input into each component is essential.

The Shorebird Sister Schools Program (http://sssp.fws.gov) began in May of 1994 as a supplemental education program of the Kachemak Bay shorebird festival in Homer, Alaska. The Alaska Maritime National Wildlife Refuge, the local chamber of commerce, and local educators hosted the festival. During the first two years of the festival, 1992 and 1993, school field trips were planned to observe the thousands of shorebirds that stopped to rest and feed for two weeks before continuing to their artic breeding grounds. The birds' migration stops were predictable and viewing was easy because of a vast open stretch of water and mudflat. Local festival planners recognized that their conservation education efforts were only focused on the short time while the birds were in Homer, so they began looking for a way to make the phenomenon of migration more real to students.

A local teacher proposed the use of e-mail to build an information-sharing network among schools located along the Pacific flyway. Students from each stopover site monitored the progress of shorebird spring migration and reported their observations by e-mail to other schools participating in the project. In 1994, 17 schools from California to Alaska were connected using a basic Internet e-mail service.

At the start of the program the focus of the effort was to link schools along the United States portion of the Pacific flyway. The program has grown to include links between schools and partners along five flyways in the western and eastern hemispheres. The goal of SSSP is to increase awareness and knowledge and facilitate public participation in the conservation of shorebirds and the wetland, grassland, and shoreline ecosystems they depend on (Chapman et al. 2002b). This paper serves to provide an account of the SSSP development and current status.

In 1996, the program was transferred from the Alaska Maritime National Wildlife Refuge in Homer, Alaska to the USFWS Alaska Regional Office. From 1996 to 2000, the program grew to include a kindergarten to 12th-grade curriculum (De Zeeuw 1998), a World Wide Web site (http://sssp.fws.gov), and a faster and more convenient e-mail list server. The program also expanded its geographic coverage to include volunteer program coordinators for Mexico, South America, and Japan and, accordingly, the curriculum was translated into Spanish, Russian, and Japanese. Educator workshops for teachers and non-formal educators were held in Mexico, Argentina, Russia, and numerous places in the United States. The focus of this period was to expand the program along the entire Pacific Flyway and introduce the program to partners along the East-Asian Australasian Flyway. This was possible due to support from USFWS Alaska regional staff and the assignment of a dedicated education specialist who worked with biologists to further develop the program.

The current focus is to continue working along the Pacific Flyway and expand the program to the American Central and Atlantic Flyways through educator workshops, presentations, networking, and developing new partnerships (*fig. 1*). Education and outreach to communities living near and within important coastal and inland habitats that shorebirds depend on along these flyways is critical. In 2000, the SSSP moved to the USFWS National Conservation Training Center.

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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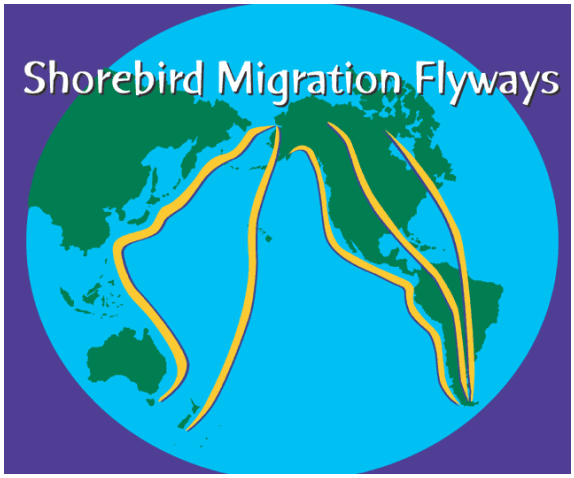

Figure 1— The five shorebird migration flyways for shorebirds breeding in northern North America.

The USFWS Alaska regional office continues to maintain the lead coordination for SSSP activities in Alaska and along the East Asian-Australasian and the central Pacific Flyways (Chapman 2002). Also, as part of national support for the program, SSSP receives cross-program support from a number of USFWS offices at the national and regional level, including the Division of International Conservation, the National Wildlife Refuge System, the National Conservation Training Center, and the Division of Migratory Birds. A vital part of national expansion is USFWS staff in each region who have accepted collateral duties as their region's SSSP coordinator. The World Wide Web site and curriculum are being revised to reflect all flyways in the Western Hemisphere and include, for the first time, non-artic nesting shorebirds.

SSSP curriculum, field trips, and workshops provide a foundation of awareness and knowledge about shorebirds and their habitat. The program goes the next step by providing opportunities for action. Action projects are vital for making the educational linkage to the larger conservation goal: ecosystem conservation along flyways. SSSP action projects include observing shorebirds in the local community and reporting their observations on the SSSP list server; becoming involved with community habitat conservation and nominating their community for a Shorebird Sister City award; learning about other communities along the flyway through pen-pal exchanges; and tracking shorebird migration as it is reported via the SSSP list server.

Students learn that habitats in their own communities are part of a chain of healthy habitats that shorebirds and other migratory species depend on. Expanding the possibilities for students to monitor, research, and participate is an important area of focus for the program. This type of inquiry learning is an important component of the National Science Education Standards (National Research Council 1996).

The tracking projects and other participatory projects engage students in real life science—the successes, challenges, and setbacks. Over the years, SSSP has collaborated with the Prince William Sound Science Center, the Point Reyes Bird Observatory, and the U.S. Geological Survey to provide the opportunity for students to track shorebird movements on-line, contribute data, and report banded birds.

In keeping with the program's vision, the SSSP must connect closely with research and management. A good example is a recent Buff-breasted Sandpiper (*Tryngites subruficollis*) project in which researchers from USGS teamed up with SSSP to involve students and shorebird enthusiasts (Johnson 2002). The U.S Shorebird Conservation Plan Council provides the link to a network of researchers and managers who work with educators to ensure that SSSP is integrated with shorebird conservation priorities. This strengthens the program's relevance and guides the program's expansion in the best direction. Moreover, the SSSP is a recommended education program in the United States Shorebird Conservation Plan (Brown et al. 2001).

Evaluation is crucial to determine if the program is meeting its vision and contributing to shorebird conservation goals. Educator evaluations, annual work plans, web site use, and list server interaction are all evaluation tools used by SSSP. The use of the SSSP web site grows every year and demonstrates a growing interest in the program. Since the web site was first established in 1996, the program has gone from several thousand hits on the web page during spring migration to over 100,000 hits in 2001 (*fig. 2*). Web site use also indicates which pages are of the most interest to users; program staff can then focus on improving and increasing attention on those topic areas. Evaluations from SSSP workshops, the curriculum, and other educational resources provide a guide for making program revisions. Feedback from teachers and their students is also very helpful. An evaluation of the program is completed on an annual basis (Chapman et al. 2002a).

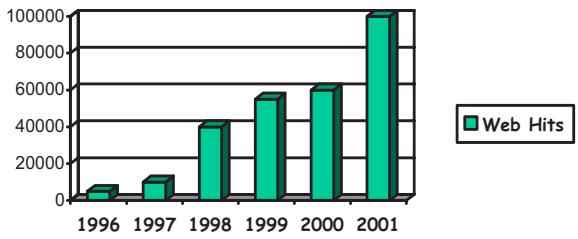

Figure 2— Number of visits ("hits") to the Shorebirds Sister School Program website from 1996-2001.

The SSSP would not exist with out partnerships. For example, a new partnership with National Estuarine Research Reserve sites designated by the National Oceanic Atmospheric Administration will help expand SSSP to key shorebird stopover and breeding areas along the Pacific, Atlantic, and Gulf coasts. Examples of partner projects include educator workshops, spring tracking projects, new product development, and distance learning broadcasts. In all aspects, state and federal agencies, non-government organizations, and universities work together to achieve shorebird conservation education. Because of these partnerships more can be accomplished for flyway conservation. In addition, partners help SSSP compete more effectively for grant money.

In the future, we would like to increase and strengthen our partnerships in the United States and internationally. We would also like to introduce a research project in which students can participate. We intend to expand our web site to include a new on-line registration system and electronic pen pals program in an effort to better connect people along flyways.

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Nariva Swamp Ramsar Site, Trinidad and Tobago (West Indies) Wetland Habitat Restoration Initiative[1]

Montserrat Carbonell[2] and Nadra Nathai-Gyan[3]

Introduction

Trinidad and Tobago, a twin island nation, is the most southerly of the Caribbean islands and lies just 11 km off the coast of Venezuela, near the Orinoco delta. Trinidad, the larger of the two islands, is approximately 5,000 km^2 and the Nariva Swamp is located on its eastern coast (*fig. 1*). In 1993, this site was designated as a wetland of international importance under the Ramsar Convention on Wetlands of International Importance (Ramsar Convention Bureau 1996) and received protection under national legislation in 1995.

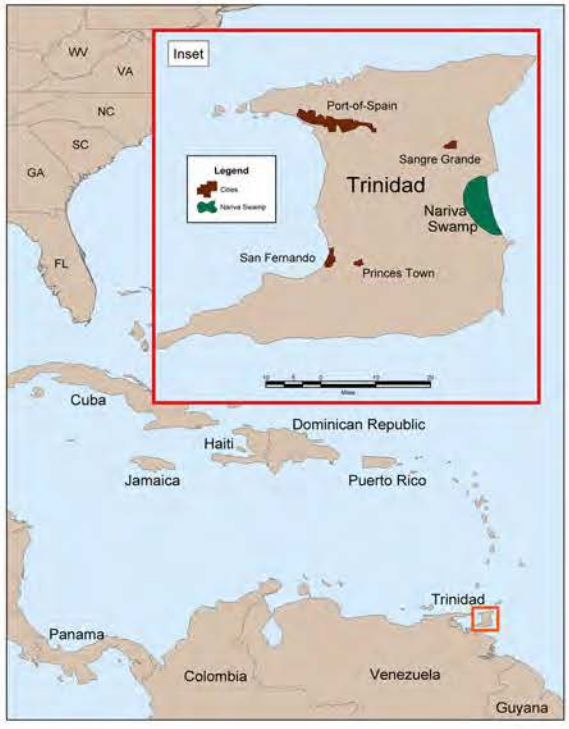

Figure 1— Location of Trinidad and Tobago, and Nariva Swamp.

Nariva Swamp is the largest fresh-water wetland in Trinidad and Tobago, covering almost 7,000 ha, and is one of the largest in the Caribbean. It is fed by a few rivers draining the Central Range, which runs in the middle of the island. Nariva Swamp drains into the ocean through the Nariva River but receives water from the ocean through seepage. The sand barrier that separates it from the ocean is mostly covered by a coconut plantation.

The Nariva Swamp includes a diverse mosaic of vegetation types: tropical forest, swamp forest, palm swamp forest, mangrove areas, marshland, and open waters (Bacon et al. 1979, James et al. 1986, James 1992). Agricultural areas add to the mosaic, and a small area at the northwestern tip was leased to local farmers. This area was illegally expanded through squatting by large rice farmers, and the negative impacts of this incursion will be explained below.

There are three small communities surrounding Nariva Swamp. Most of the inhabitants of these communities depend on the natural resources of the area for food, mainly the cascadura fish (*Hoplosternum littorale*), blue crab (*Cardisoma guanhumi*), and black conch (*Pomacea urceus*). These are highly valued by the local communities not only for subsistence but also for commercial purposes. Many people in the local communities also have gardens with annual crops such as peppers, cucumbers, watermelon, and rice.

The area is exceedingly rich in biological resources. There are over 175 species of birds recorded for Nariva Swamp (Bacon et al. 1979) out of the 433 total bird species for Trinidad and Tobago (ffrench 1980). The star is undoubtedly the Blue and Gold Macaw (*Ara ararauna*), the object of a venture with the Cincinnati Zoo for reintroduction to the area. Despite the diversity existing in Nariva swamp, no comprehensive bird studies or regular bird surveys have been conducted. It is hoped that with the implementation of the restoration work in the area, the development of a monitoring program based on the avifauna may become possible.

Problems

The greatest negative impact to Nariva Swamp was the illegal squatting by large rice farmers who came from the cities and used heavy machinery for their

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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operations. Their activity was originally detected in the early 1980s, and by the mid 1990s they had done untold damage. The farmers had dug canals to drain the wetland and set fires to forest and marsh in order to clear the accumulated organic matter for rice cultivation. Local farmers, too, have used fires in their fields, and, because wind direction can change suddenly, often times the fires have gone out of control and jumped into the forest or swamp. Fires are not a natural phenomenon here, so the damage is enormous.

Agrochemicals were heavily used by the illegal rice farmers, but the local farmers also use them. Other problems include the use of illegal fish traps and poaching. Mammals such as agouti (*Dasyprocta leporina*) are killed for meat, and birds such as Orange-winged (*Amazona amazonica*) and Cuban parrots (*A. leucocephala*) and the Red-bellied Macaw (*Ara manilata*) are caught for the pet trade. Both poachers and fishers set fire to the forest and the banks of streams, and again, they get out of control.

Solutions and Restoration

Trinidad and Tobago's Government interest in preserving the Nariva Swamp has become increasingly important. In 1994 the application of the Ramsar Advisory Mission (then known as Monitoring Procedure [MP]) was requested. In collaboration with the National Wetland Committee (NWC), national NGOs, the University of the West Indies (UWI), government personnel, and others, the Ramsar Convention Bureau prepared a report outlining the issues that needed urgent attention if the Nariva Swamp was to be saved. Before the report was published, the Government began to implement several of the recommendations included in it even though the country had gone through elections in the mean time. This was a clear sign of its strong commitment.

The first action the Government undertook was the removal of all squatters from Sector B, i.e. the large rice farmers, followed by the development of an environmental impact assessment (EIA) and a management plan. The Government and the Ramsar Convention Bureau provided the funding, and the Institute of Marine Affairs (IMA) was hired to carry out the task. In 1997 the Government, with partial assistance from the Ramsar Convention Bureau, also began to fill in the channels the large rice farmers had dug out and to carry out a fire fighting and prevention program that included training over 20 people from local communities.

In mid 1999, the Government invited Ducks Unlimited, Inc. (DU) and the USDA Forest Service (USFS) to visit Trinidad and Tobago in order to prepare in conjunction with national experts a "work plan" for the implementation of some of the recommendations made in the management plan and the EIA developed by the IMA. This work plan, and the implementation of the MP and the EIA, were to concentrate on the restoration of the hydrology and the aquatic vegetation, taking into account the role fires have played in the destruction of the site in the past and their use as a management tool in the future. During 2000 and 2003 a series of fire prevention and control workshops were organized to provide further training to local volunteer firefighters as well as Forestry Division personnel. The Government of Trinidad and Tobago has erected a fire control tower at the southern end of the Nariva Protected Area, to be manned by volunteer firefighters from the local communities and is planning to build a second one on the northern side of the swamp.

As of this date, the filling of canals dug out by the large rice farmers has stopped. It was realized that perhaps some of those canals were actually channelized rivers or creeks. Therefore, an analysis of changes occurred during the last 50 years using remotely sensed imagery was necessary before proceeding with the restoration. In 2002 a GIS work plan was developed in conjunction with government agencies, the IMA, and the UWI; financial support came from the USFS and DU. In 2003 the data processing and change analysis were carried out by colleagues in Trinidad and Tobago, and restoration models were discussed with the authorities. At the same time the hydrology was analyzed and carbon sequestration modeling initiated with the intention of developing a project to sell carbon credits to energy companies that will allow the restoration work to proceed on the ground at full scale.

Once the models that are being developed through change analysis and GIS are approved by the Government of Trinidad and Tobago, we will know exactly how much forest and grassland/marsh vegetation needs to be restored. However, we can anticipate that habitat restoration will cover approximately 3,600 ha, of which approximately half will be forest and half will be grassland/marsh vegetation. It is also estimated that restoration work on the ground will begin in 2004 with the involvement of hydrologists, topographers/land surveyors, engineers, and ecologists.

Trinidad and Tobago's legislation, unfortunately, does not include provisions to make those who damage the environment pay for restoration or mitigation of the impact they have caused. So, although the large farmers have been removed, the Government has assumed responsibility for finding a way to restore Nariva's original functions, values, and benefits. This by itself indicates the enormous dedication of the Government of this small nation to restore and protect its natural resources.

Communities

Until recently, there was another serious problem in the Nariva Swamp: unhappiness and unrest that had developed within local communities. It was felt that the government was doing nothing to defend their interests from the large illegal rice farmers' activities. The communities felt that the government was only interested in protecting wildlife. This began to change around 1995 when the Government of Trinidad and Tobago and a number of non-governmental organizations started to handle the situation differently. There were more interactions and the local people's problems and concerns were listened to. These issues were then addressed as part of an integrated approach to the conservation of Nariva Swamp. Slowly, mutual trust and respect was built, and together decisions are made to work collaboratively in the restoration of Nariva Swamp. After DU and the USFS came in, many objectives were achieved, but more needed to be done.

Conclusions

It can be said that the worst is behind us. The partnerships that have been built are strong both at national and international levels, and the volunteer firefighters nurtured by this initiative have become guardians of Nariva and true catalysts of the conservation process at the local level, having established their own Nariva Environmental Trust.

For many years, the Ramsar Convention has been urging Contracting Parties to take a range of actions in order to promote the restoration of wetlands. (e.g. Rec. 4.1, Rec. 6.15, Operational Objective 2.6 of the Strategic Plan 1996-2002, Res.VII.17). However, restoration had been considered a priority mainly by developed countries (e.g., Denmark, The Netherlands, United States), with little being done in less developed countries. In Latin America and the Caribbean, restoration has been or is being carried out, more or less successfully, at a number of other Ramsar sites (e.g., Santa Marta in Colombia and Palo Verde in Costa Rica).

However, these efforts have failed to address the situation in an integral and comprehensive way, not using to their advantage the many instruments available as Contracting Parties to the Ramsar Convention. On the other hand, Trinidad and Tobago not only has used the financial mechanisms available, but also much of the guidance provided through Resolutions and Recommendations adopted by the Conference of the Contracting Parties at their different meetings. Some of these include issues such as wetland policy formulation; revision of laws and institutional structure; involvement of local communities; promotion of communication, education and public awareness; development of environmental impact assessments and management plans; and monitoring of ecological character of wetlands.

Completion of the restoration work that will bring the Blue and Gold Macaw, the Blue-winged Teal (*Anas discors*), the Dickcissel (*Spiza americana*) and all the other 175-plus bird species back to the skies over Nariva is of paramount importance.

Acknowledgments

The work presented in this paper is the work of many colleagues and friends in Trinidad and Tobago as well as in the United States. The list is very long, and they should all be listed as co-authors. We apologize to those we have forgotten unintentionally, after more than 10 years working on this project with so many great people it is unavoidable that our memories should fail.

Special acknowledgement is due to P. Bacon (1938-2003) who led the wetland ecology research not only in Trinidad and Tobago but throughout the Caribbean and beyond. He was an inspiration to continue working in what we believe in, and a tireless ambassador of Nariva in Trinidad as well as at the Ramsar Convention forums.

Other colleagues in Trinidad and Tobago who have played and are playing key roles in implementing the restoration plans include: G. Alleng, A. Bartholomew (Permanent Secretary for the Ministry of Public Utilities and the Environment), D. Boodoo, K. Deonanan, S. Faizool (Director of Forestry Division), M. Gaskin, M. Lal, G. Lutchmedial, S. Poon, K. Shephard, R. Singh, S. Sookbir, and all the members of the National Wetlands Committee, who have always provided strong support and advice.

The office staff of the Wildlife Section deserves special thanks for their patience and for always taking on so many odd requests with big smiles on their faces. Fieldwork would not have been so pleasant without the hard work, hospitality, and love for the Nariva Swamp of the families in the communities of Plum-Mitan and Kernahan. Special thanks go to the Deonanan and the Jonas families and to the dedicated volunteer firefighters.

Special thanks also go to our friends in the U. S. Forest Service—J. Capp, B. Terry, W. Ebaugh, and D. Farnsworth—whose support has been invaluable during the last four years in carrying out our work, especially in those aspects related to fire prevention and control and the use of fires as a management tool.

S. Adair, C. Baker, and D. Kempka—DU colleagues—also are involved in the project, and their tremendous

expertise in wetland restoration and GIS/RS has proven to be key to the progress made in the last four years.

Finally, thanks to H. Raffaele, Head of the USFWS International Conservation Division, for the financial support provided to N. Nathai-Gyan to attend this meeting (Agreement No. 98210-2-G214).

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Coastal Forests of the Gulf of Mexico: A Description and Some Thoughts on Their Conservation[1]

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Abstract

Millions of Nearctic-Neotropical landbirds move through the coastal forests of the Gulf of Mexico each spring and autumn as they migrate across and around the gulf. Migration routes in the gulf region are not static—they shift year to year and season to season according to prevailing wind patterns. Given the dynamic nature of migration routes, coastal forests around the Gulf of Mexico potentially can provide important stopover habitat to *en route* migrants. The coastal forests from the Florida Keys to the Yucatan Peninsula include a wide range of habitat types that we have classified as 19 broad community types. From literature reviews, we determined that the majority of these coastal habitats have been lost or degraded due to the effects of development, agriculture, livestock grazing, timber industry activities, and the spread of exotic species. The continued loss and degradation of coastal forests pose a risk to migrating birds, and thus we need to develop a conservation strategy that maximizes the suitability of the remaining forested patches around the gulf. An effective conservation strategy will require considerations at the gulf-wide, regional, landscape and habitat levels. These considerations should include migrant movement and landfall patterns, migrant use of inland versus coastal fringe stopover sites, the creation of landscape mosaics that incorporate patch size and inter-patch distance, and the availability of within-habitat resources.

Key Words: coastal forest, conservation, Gulf of Mexico, landbird, migration, Nearctic-Neotropical migrant, stopover habitat.

Introduction

Each year millions of landbirds migrate across or near the coast of the Gulf of Mexico. During migration seasons, nearly all of the migratory landbird species of the eastern United States, as well as a strong representation of western species use the coastal plains of the western gulf (Lowery 1974, Barrow et al. 2001). The long journey that birds undergo between temperate and tropical areas is difficult, and mortality may be substantial (Wiedenfeld and Wiedenfeld 1995). Wooded vegetation situated along the gulf shores and up to distances of 100 km inland (Gauthreaux 1975) are stopover habitat that migrants use in spring to replenish energy and to sequester resources for the ensuing reproductive season. In autumn, the primary need is to store energy for continued migration and molt. Often these sites are precisely the most suitable for human development (Barrow et al. 2000). Human population growth along the coasts of the Gulf of Mexico is projected to increase rapidly over the next decade (Culliton et al. 1990).

Today, remnant forest patches are more common than intact coastal forest systems. As coastal stopover habitats are lost or degraded, there is likely to be a concomitant increase in risks posed to migrating birds (Moore et al. 1993). We should plan now to manage remaining patches of forest to maximize their suitability to migrating landbirds. Challenges to implementing a conservation strategy for migrant landbirds around the Gulf of Mexico include: 1) the large spatial scale where migration occurs, 2) the variety of habitats migrants interact with during passage, and 3) the inter- and intra-annual variation in the geographic locations where the majority of migrants stopover (e.g., coastal fringe vs. inland, western gulf vs. eastern gulf).

In this paper, we describe coastal forests around the Gulf of Mexico, discuss their status, and offer some thoughts to be considered when planning or implementing a conservation strategy for gulf coastal forests and the migratory birds that depend on them.

Coastal Forests of the Gulf of Mexico: Description and Status

Coastal forests around the Gulf of Mexico play an important role in bird migration by virtue of their

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California**.

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position along important migration pathways. We define coastal forests as wooded communities that develop within 100 km of the coast and usually occur on barrier islands, ridges, delta splays, and along river and bayou drainages. Coastal forests around the gulf encompass a wide range of habitat types that vary from estuarine systems like the mangroves in south Florida and Mexico to arid communities like the Tamaulipan thornscrub of south Texas and northern Mexico. The plant community composition and structure of these forests vary greatly due to the influence of factors such as precipitation, soil type and moisture, proximity to a river drainage, exposure to salt spray, and disturbance events (Pessin and Burleigh 1941, Gunter and Eleuterius 1973).

In *table 1*, we describe coastal-forest vegetation as 19 broad community types found in five regions around the gulf: east, northeast, northwest, west, and south. We used major river systems to delineate the five regions (*fig. 1*). The eastern region includes the gulf coast between the Florida Keys and the Apalachicola River. The northeast region is bounded by the Apalachicola and Mississippi Rivers, and the northwest region lies between the Mississippi and Colorado rivers. The western region includes the gulf coast from the Colorado River south to the Panuco River in Mexico, and the southern region includes the coastline south of the Panuco River to the tip of the Yucatan Peninsula.

A number of human-induced factors have contributed to the loss and degradation of the coastal forest communities summarized in *table 1*. We highlight a few of these factors in the following sections and provide examples from the five regions around the gulf.

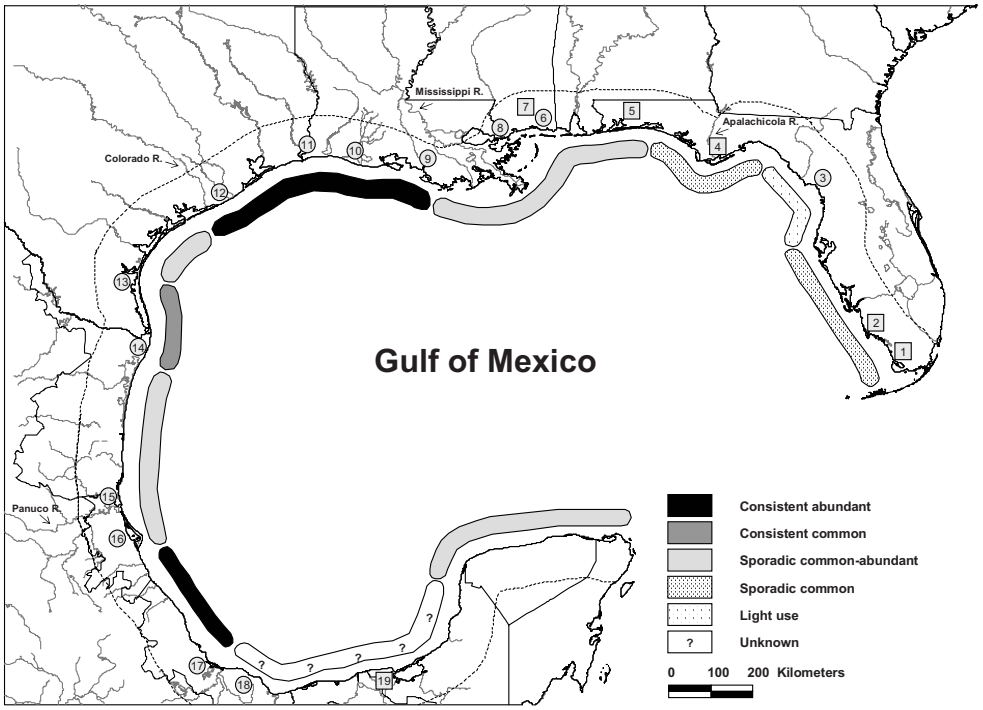

Figure 1— Geographic pattern of bird migration around the Gulf of Mexico and locations of remaining patches of extensive coastal forest. Pattern delineation is the result of literature review and the collective knowledge of authors. Migration landfalls (up to 100 km inland) are defined as: consistent abundant – area used by large numbers of migrants each year and season, consistent common – area used by a moderate number of migrants each year and season, sporadic common/ abundant – prevailing winds determine if area is used by moderate to large numbers of migrants, sporadic common – prevailing winds determine if area is used by a moderate number of migrants, light use – area used by a few migrants every year or season, unknown – use is unknown to the authors. Numbered squares represent protected forest and numbered circles represent unprotected or partially protected forest. Forest locations are as follows: 1 – Everglades National Park, 2 – Big Cypress National Preserve, 3 – Gulf Hammock, 4 – Apalachicola Bay (Apalachicola National Forest and surrounding public lands), 5 – Choctawhatchee and Escambia bays (Eglin Air Force Base, Blackwater River State Forest, and surrounding public lands), 6 – Lower Pascagoula River basin 7 – DeSoto National Forest, 8 – Lower Pearl River Basin, 9 – Atchafalaya River Basin, 10 – Mermentau River Basin and chenier forests, 11 – Big Thicket National Preserve and surrounding lands, 12 – Columbia Bottomlands, 13 - Live oak woodlands, 14 – Tamaulipan thornscrub, 15 – Humedales del Sur de Tamaulipas, 16 – Laguna de Tamiahua, 17 – Humedales de Alvarado, 18 – Los Tuxtlas, 19 – Pantanos de Centla.

Table 1— *Species composition and status of coastal forest community types around the Gulf of Mexico.*

Community type	Region	Common plant species	Status
Mangrove	East	black mangrove (*Avicennia germinans*) – red mangrove (*Rhizophora mangle*) – white mangrove (*Laguncularia racemosa*)	?
	Northwest	black mangrove	?
	West	black mangrove	threatened
	South	black mangrove – red mangrove – white mangrove	declining
Riparian	East	overcup oak (*Quercus lyrata*) – water hickory (*Carya aquatica*) – laurel oak (*Q. laurifolia*) – swamp chestnut oak (*Q. michauxii*) – sweetgum (*Liquidambar styraciflua*) – sweetbay (*Magnolia virginiana*)	?
	Northeast	overcup oak – water hickory – laurel oak – swamp chestnut oak – willow oak (*Q. phellos*) – green ash (*Fraxinus pennsylvanica*) – American elm (*Ulmus americana*) – sweetgum – hackberry (*Celtis laevigata*) – water oak (*Q. nigra*)	?
	Northwest	*Quercus* spp. – *Carya* spp. – american elm – winged elm (*U. alata*) – cedar elm (*U. crassifolia*) – green ash – yaupon (*Ilex vomitoria*) – deciduous holly (*Ilex decidua*) – box elder (*Acer negundo*) – dwarf palmetto (*Sabal minor*) – hackberry – red maple (*Acer rubrum*) – soapberry (*Sapindus drummondi*)	declining
	West	sweet acacia (*Acacia farnesiana*) – retama (*Parkinsonia aculeata*) – *Fraxinus* spp. – black willow (*Salix nigra*) – cedar elm – *Celtis* spp. – honey mesquite (*Prosopis glandulosa*) – Texas ebony (*Ebenopsis ebano*)	threatened
	South	guatope (*Inga* sp.) – ceibo (*Ceiba pentandra*) – Spanish cedar (*Cedrela odorata*) – capulin (*Muntingia calabura*) – maculis (*Tabebuia pentaphylla*) – Jobo (*Spondias mambin*)	?
Swamp	East	baldcypress (*Taxodium distichum*) – black gum (*Nyssa sylvatica*) – water tupelo (*Nyssa aquatica*) – *Fraxinus* spp., red maple, cabbage palm (*Sabal palmetto*)	?
	Northeast	baldcypress – black gum – water tupelo – buttonbush (*Cephalanthus occidentalis*) – black willow – red maple	?
	Northwest	baldcypress – water tupelo – black gum – red maple – black willow – dwarf palmetto – buttonbush – *Fraxinus* spp. – water-elm (*Planera aquatica*) – water locust (*Gleditsia aquatica*)	?
	South	Guiana chestnut *(Pachira aquatica)* – spiny bucida *(Bucida spinosa*) – black-olive *(Bucida buceras*) – logwood *(Haematoxylon campechianum*) – kancab'ché *(Erythroxylum confusum*) – muk *(Dalbergia glabra)* – botoncillo *(Conocarpus erecta)* - paurotis palm *(Acoelorrhaphe wrightii*)	?
Delta Splay	Northwest	black willow, three-cornered grass (*Schoenoplectus americanus*), common reed (*Phragmites communis*)	stable
Scrub-shrub	East	myrtle oak (*Q. myrtifolia*) – scrub oak (*Q. inopina*) – sand pine (*Pinus clausa*) – saw palmetto (*Serenoa repens*) – sand live oak (*Q. geminata*) – Chapman oak (*Q. chapmanii*) – rosemary (*Ceratiola ericoides*) – waxmyrtle (*Myrica cerifera*)	?

Table 1 (continued).

Community type		Region	Common plant species	Status
Scrub-shrub (contd.)		Northeast	sand pine – sand live oak – Darlington oak (*Q. hemisphaerica*) – myrtle oak - yaupon – waxmyrtle – rosemary	?
		Northwest	waxmyrtle – yaupon – sweet acacia – toothache tree (*Zanthoxylum clava-herculis*) – groundselbush (*Baccharis halimifolia*) – *Iva* spp.	?
Thornscrub		West	mesquite - *Acacia* spp. – *Mimosa* spp. – granjeno (*Celtis pallida*) – guayacan (*Guaiacum angustifolium*) – cenizo (*Leucophyllum frutescens*) –whitebrush (*Aloysia gratissima*) – Texas prickly pear (*Opuntia engelmannii*) – tasajillo (*O. leptocaulis*) – *Condalia* spp. – amargosa (*Castela erecta*)	threatened
		South	yellow-flowering tree (*Acacia pennatula*) – *Opuntia* spp.– *Cephalocereus* spp.– Jamaica dogwood (*Piscidia piscipula*) – madre cacao (*Gliricidia sepium*)	?
Hammock	- maritime	East	live oak (Q. virginiana) - sand live oak – *Magnolia* spp.- sweetbay – american holly (*Ilex opaca*) – redbay (*Persea borbonia*)	threatened
	- hydric		cabbage palm – live oak – sweetgum - laurel oak – southern red cedar (*Juniperus silicicola*) – American hornbeam (*Carpinus caroliniana*) – water oak – loblolly pine - swampbay (*Persea palustris*) – sweetbay – red maple	threatened
	- tropical		gumbo limbo (*Bursera simaruba*) – strangler fig (*Ficus aurea*) – mastic (*Mastichodendron foetidissimum*) – pigeon plum (*Coccoloba diversifolia*) – lancewood (*Nectandra coriacea*) – poisonwood (*Metopium toxiferum*) – Spanish stopper (*Eugenia foetida*) – white stopper (*Eugenia axillaris*)	threatened
	- maritime	Northeast	live oak – sand pine – loblolly pine (*Pinus taeda*) – pignut hickory (*Carya glabra*) – sand hickory (*Carya pallida*) – saw palmetto	threatened
Upland Hardwood		East	southern magnolia (*Magnolia grandiflora*) – pignut hickory– sweetgum – Florida maple (*Acer barbatum*)	?
		Northeast	southern magnolia – pignut hickory – sweetgum – *Pinus* spp. – Florida maple – American beech (*Fagus grandifolia*)	?
		Northwest	American beech – southern magnolia – *Quercus* spp. – tulip poplar (*Liriodendron tulipifera*) – sweetgum – *Carya* spp. – loblolly pine	threatened
Beach Ridge & Dunes		Northeast	Barrier Islands: Slash pine (*Pinus elliottii*), dwarf live oak (*Quercus geminata*) – waxmyrtle – yaupon - grounselbush – saw palmetto	?
		Northwest	Cheniers: live oak – hackberry – water oak – red mulberry (*Morus rubra*) – honey locust (*G. triacanthos*) – toothache tree	threatened
		West	Barrier Islands: grassland-dominated communities with patches of live oak - black willow – waxmyrtle – groundselbush – hackberry - mesquite	?
		South	black olive – *Ficus* spp. – macayo (*Andira inermis*) – maculis – gumbo limbo (*Bursea simaruba*) – palma real (*Scheelea leibmanii*)	threatened
Salt Dome		Northwest	*Carya* spp. – southern magnolia – live oak – sweetgum – water oak – hackberry	stable

Table 1 (continued)

Community type	Region	Common plant species	Status
Levee and Spoilbank	Northwest	groundselbush – Chinese tallow (*Triadica sebifera*) – yaupon – wax myrtle – black willow	increasing
Live Oak Scrub	West	live oak – red bay – yaupon – wax myrtle – greenbrier (*Smilax* spp.) – mustang grape (*Vitis mustangensis*)	threatened
Live Oak Woodland	Northeast	live oak – loblolly pine – red cedar	threatened
	Northwest	live oak – water oak – american elm – hackberry – yaupon – red maple – green ash – dwarf palmetto	threatened
	West	live oak – Turk's cap (*Malvaviscus arboreus*) – granjeno – lime pricklyash (*Zanthoxylum fagara*)	stable
Palm Forest	East	cabbage palm – gumbo limbo – live oak – pigeon plum – saw palmetto	?
	West	sabal palm (*Sabal mexicana*) – tepeguaje (*Leucaena pulverulenta*) – anacua (*Ehretia anacua*) – Texas ebony	threatened
	South	Scheelea *spp.* – Sabal *spp.*	?
Tropical Evergreen	South	*Swietnia spp.* – macayo – *Nectandra spp.* – tinco (*Vatairea lundellii*) – *Ficus* spp. – magnolia (*Talauma sp.*) – rubber tree (*Castilla elastica*) – palma real – corozo (*Orbignya cohune*) – guatope – cucuá (*Poulsenia armata*)	threatened
Mesquite Grassland	West	honey mesquite – prickly pear – granjeno – lime prickly ash	stable
Tropical Savanna	South	nance (*Byrsonima crassifolia*) – sandpaper tree (*Curatella americana*) – spiny coyol palm (*Acrocomia mexicana*) – sombrero palm (*Brahea dulcis*)	increasing
Interdunal Pine	East	slash pine – cabbage palm – saw palmetto – gallberry - yaupon	threatened
	Northeast	slash pine – yaupon – wax myrtle – rosemary	threatened
Pine Savanna	East	longleaf pine (*Pinus palustris*) – slash pine – pond pine (*Pinus serotina*) – saw palmetto - gallberry	threatened
	Northeast	longleaf pine – slash pine – gallberry – turkey oak (*Q. laevis*)– shortleaf pine (*Pinus echinata*) – sand oak (*Q. incana*) – yaupon – saw palmetto – live oak	threatened
	Northwest	longleaf pine – slash pine – sweetbay – black gum – wax myrtle – live oak – blackjack oak (*Q. marilandica*) – laurel oak	threatened

Human Development

Human development (i.e., population increase, urbanization, oil and gas exploration, and pollution) is an issue that affects coastal forests in all regions of the gulf (*table 2*). The coastal population from Texas to Florida is projected to increase from 14 million in 1988 to 18 million in 2010, an increase of 22 percent. The most rapid growth has been, and will continue to be, along the Florida (27% growth rate) and Texas (22 percent) coasts (Culliton et al. 1990). In Florida, 3.9 million people lived within 25 km of the east gulf shoreline in 1990 (U.S. Census Bureau 1995) and this number is estimated to exceed 6.5 million by 2010 (Culliton et al. 1990). Harris County, Texas (Houston) is another hotspot of rapid population growth. It is projected that the county's population will increase by 900,000 between 1988 and 2010 (Culliton et al. 1990). Given these projections, it is clear that coastal forests around the gulf will be increasingly threatened by development.

In the eastern gulf region, drier sites containing maritime and tropical hammocks and scrub-shrub communities are usually the first forests displaced by development and the last to be conserved through acquisition. Commercial development removes almost all of the existing vegetation, while residential developments tend to maintain selected canopy species (e.g., live oak [*Quercus virginiana]*) but remove large areas of native shrubs and forbs that provide important fruits for many fall migrants (Parrish 1997).

Johnson et al. (1992) listed only a dozen sites along >300 km of coast in southwest Florida where upland hammock and scrub-shrub communities exist in patches >40 ha. In the Florida panhandle, Johnson et al. (1992) found maritime hammocks occupied the smallest proportion of public lands followed by scrub and mesic pine flatwood communities.

In the northeast gulf region, human impacts on coastal forests were limited during the 18th and 19th centuries, particularly on barrier islands because of their inaccessibility. Human intrusion increased significantly by the end of the 19th and the beginning of the 20th centuries (Stalter and Odum 1993). Improved transportation facilitated access to barrier islands and by 1975, over 15 percent of the barrier island area on the U.S. east and gulf coasts had become urbanized (Lins 1980).

Several authors (Boyce and Martin 1993, Grossman et al. 1994, Noss et al. 1995) have described the difficulty of finding intact coastal forest systems along coastal Alabama and Mississippi. Although no trend data are available for the loss of coastal forest in this region, barrier island development has increased by more than 300 percent in the Southeast United States in the past 50 years (Johnson and Barbour 1990). In Mississippi, the past few decades have witnessed extensive destruction of coastal habitats for residential construction, commercial sites, shipping channels, garbage disposal, and similar activities. Despite the threat of development in Alabama and Mississippi, much of the remaining maritime communities are protected through state or federal government ownership. For example, Gulf Islands National Seashore protects most of the barrier islands along the northern gulf coast in Florida and Mississippi. In Alabama, much of the remaining maritime communities are protected through Bon Secour National Wildlife Refuge. At the state level, the Mississippi Department of Marine Resources is protecting coastal lands through its active Coastal Preserves Program, an effort that includes building partnerships with other government and nongovernment agencies.

Table 2— *Factors contributing to the loss and degradation of coastal forests around the Gulf of Mexico.*

	Gulf Coast Regions				
Major factors	**East**	**Northeast**	**Northwest**	**West**	**South**
Development	X	X	X	X	X
Agriculture			X	X	X
Cattle grazing			X	X	X
Pulpwood production	X	X	X		
Pine plantations	X	X			
Logging			X		X
Exotic species	X	X	X	X	X

Development has reduced the coverage of important stopover habitats in the northwest region of the gulf. The Chenier Plain forests of Louisiana and Texas, for example, provide important stopover habitat because they are the first forests available to trans-gulf migrants in spring and the last forests available to trans-gulf migrants in autumn. Seventy-three Nearctic-Neotropical species are known to use chenier forests in the spring and 66 Nearctic-Neotropical species use them in autumn (Barrow et al. 2000). In the Chenier Plain, development has decreased the area of chenier, upland, and swamp forests while increasing urban areas and wooded spoil banks. From 1952 to 1974, native forests were reduced by 17 percent (2,890 ha) while urban areas and spoil bank habitats increased by 46 percent (10,811 ha). A 17 percent loss over a 25-year period may not seem drastic, but coastal forests were never extensive in the Chenier Plain, and they only occupied 6 percent of the total area in 1974 (Gosselink et al. 1979). In the Chenier Plain of Louisiana, the cover of forested wetlands in the Mermentau Basin was stable from 1990 to 1996 and evergreen upland forests increased at the expense of mixed upland forests. The conversion from mixed forests to evergreen forests was largely a result of activity by the timber industry (Ramsey et al. 2001).

In east Texas, bottomland hardwood forests, known as the Columbia Bottomlands, once stretched across 283,290 ha in the floodplains of the San Bernard, Brazos, and Colorado Rivers. Development, grazing, and more recently timber removal for wood chipping have reduced these forests to patches that collectively cover 71,632 ha (U.S. Fish and Wildlife Service 1997). Surveys have detected 237 species of birds in the Columbia Bottomlands, and radar data indicates that these forests host hundreds of thousands of birds during migration (U.S. Fish and Wildlife Service 1997). The effects of human population expansion and urbanization also have taken their toll in the western region of the gulf. In the Lower Rio Grande Valley of Texas, for example, Hidalgo and Cameron counties were part of the top 100 counties in the nation with the largest population increase from 2000 to 2001 (U.S. Census Bureau 2002). The main effect of urbanization in this area has been the extensive removal of native Tamaulipan thornscrub. Clearing of Tamaulipan thornscrub for agriculture and urban development began in the early 1900s and by 1988 95 percent of the existing thornscrub had been cleared (Jahrsdoerfer and Leslie 1988).

Lease hunting is also popular in this area, and thornscrub is removed in strips to increase edge habitat for game species. Vega and Rappole (1994) determined the effect of this style of thornscrub removal (i.e., cleared in strips) on avian communities by comparing avian use of partially cleared thornscrub habitat to the use of undisturbed thornscrub habitat. Overall, the authors found that the partially cleared thornscrub habitat supported fewer species.

The coastal forests of the Mexican states of Tabasco and Campeche (south gulf region) include mangroves and swamps that are a part of the Biosphere Reserve of Pantanos de Centla, a Ramsar wetland of international importance and an Area of Importance for Conservation of Aves (AICAS) (Arizmendi and Marquez 2000). These forests are also at the heart of Mexico's oil and gas industry. As a result of this industry, the forested wetlands of the region have been altered through drainage, pollution, and salinization. It has been estimated that 33 percent of the migrants that use the Mississippi flyway also use the mangroves that surround the Laguna de Terminos in Campeche for stopover and wintering habitat (Secretariat of Environment, Natural Resources, and Fisheries 1997).

Agriculture, Livestock Grazing, and Related Activities

Agriculture, livestock grazing, and their associated effects have transformed coastal forests in three of the five regions of the gulf (*table 2*). In the Chenier Plain, for example, many of the coastal forests have been cleared for agricultural uses (Gosselink et al. 1979). Often, agricultural lands are then converted to urban areas and are rarely returned to their natural state.

Grazing is also an issue in the Chenier Plain of Louisiana and the Columbia Bottomlands of Texas where virtually all of the remaining coastal forests have been grazed by livestock or over-browsed by white-tailed deer (*Odocoileus virginianus*) (Barrow et al. 2000). Grazing alters the structure of chenier forests by changing species composition and by reducing the understory. Barrow et al. (2000) investigated how these structural changes may affect Nearctic-Neotropical migrants by comparing migrant use of grazed forests to migrant use of undisturbed forests. Overall, the authors found that most *en route* forest-dwelling migrants can tolerate some degradation of chenier forests. Select groups, such as early migrants, dead-leaf foragers, frugivores, and nectarivores used grazed forests significantly less than undisturbed forests (Barrow et al. 2000).

As discussed above, the majority of Tamaulipan thornscrub in south Texas and northern Mexico has been cleared for agriculture and urban development (Jahrsdoerfer and Leslie 1988). Similarly, citrus, sugar cane, and vegetable agriculture in the Lower Rio Grande Valley have resulted in extensive fragmentation of native riparian habitats and over 90 percent have been cleared from the United States side of the

border (Collins 1984). Sabal Palm Forest, which once covered 16,188 ha in the Lower Rio Grande Valley is now restricted to less than 40 ha in Cameron County, Texas (Bezanson 2002, Tunnell and Judd 2002). The remaining coastal forests of the Lower Rio Grande Valley and of south Texas in general are important stopover habitat (Gauthreaux 1999). It is known that the region supports many circum- and trans-gulf migrants in spring and autumn, as well as, provides habitat for migrants needing to make landfall during storm events (Forsyth and James 1971, Langschied 1994, Tunnell and Judd 2002).

Maritime habitats are reduced to marginal extents in the southern Gulf of Mexico and little information is currently available on the trend of coastal forests. It is known that central Veracruz was once comprised of 19 vegetation types that extended over a wide elevation gradient. Today, over 75 percent of these habitats have been converted into sugar cane plantations and cattle pastures (Ruelas 2000). Conversion of forest for agriculture and livestock grazing is also a concern in southern Veracruz. Dirzo and Garcia (1992) mapped the coverage of tropical forest in the Sierra Los Tuxtlas for 1967, 1976, and 1986. By comparing these maps, the authors determined that deforestation for development, agriculture, and livestock grazing had reduced forest coverage to 13,600 ha or 16 percent of the original area (85,000 ha) by 1986.

Though fragmented, the remaining tracts of forest in Veracruz are crucial because of the resources they provide to millions of migrating birds. The area is unique in that a geographic bottleneck is created by the intersection of the eastern slope of the Sierra Madre Oriental and the Central Volcanic Belt. This geographic feature sets the stage for the largest raptor migration site in the world. Approximately 4.3 million raptors migrate through the area each fall. Millions of non-raptors funnel through the bottleneck as well. For example, at least 7 million swallows were counted during the 1999 fall migration, and on a peak day in the season Yellow Warblers (*Dendroica petechia*) passed through the area at a rate of just under 500 individuals per hour (Ruelas 2000). Four hundred sixty-five species (raptors and non-raptors) have been identified in the area, 220 of which are Neotropical migrants (Ruelas 2000). From fat deposition data we know that forests in this region provide important resources for some species during autumn migration (Winker 1995).

The coastal forests of Campeche and Yucatan provide yet another example of fragmented habitat. The distribution of these forests, which may be important staging or stopover habitat for many trans-gulf migrants, has been decreased in the last century by the conversion of forests to pastures (Olmsted and Garcia 1998).

Pine Plantations, Pulpwood Production and Logging

Coastal forests have been altered by timber-related activity in four of the five regions of the gulf (*table 2*).

In the eastern gulf region, many hydric hammocks and forested wetlands have been converted to pine plantations (Simons et al. 1989). Deciduous trees are removed, the ground is bedded, and pine seedlings (typically loblolly pine [*Pinus taeda*]) are planted at densities of 1,110/ha (Simons et al. 1989). Gulf Hammock, one of the largest hydric hammocks remaining in the Big Bend region of Florida (40,470 ha), has experienced large-scale losses (approximately 80 percent removed between 1970 and 1989) through such practices (Simons et al. 1989), and these trends likely will continue.

In 1992, Simons et al. (2000) studied migrant use of bottomland forest versus pine forest along the Mississippi coast. The authors determined that a greater number of migrant individuals and of migrant species were detected in bottomland forest. Surveys were conducted on a finer scale the following year by comparing migrant use of three habitat types: bottomland forest, pine forest with an understory, and pine forest without an understory. A greater number of migrant individuals and migrant species were found in bottomland forest and in pine forest with an understory (Simons et al. 2000). These findings suggest that the observed habitat preference was the result of differences in habitat quality (Simons et al. 2000).

The United States produces 28.5 percent of the world's industrial timber products with the majority of the exports coming from the southern states. As consumer demands have changed, production has shifted from solid wood (i.e., lumber) to composite (i.e., pulpwood) products (Prestemon and Abt 2002). In the past decade, chipping for pulpwood production has become more common as is evident in the construction of over 100 new chip mills across the South (Forest Ethics 2002). From 1989 to 1999 hardwood chip exports increased by 369 percent and softwood chip exports increased by 373 percent. Chipping encourages clearcutting because there is no need to discriminate between tree species and tree size, and native forests have declined as a result of this harvest method.

Lumber was once an important economic resource in the south region of the gulf. In Tabasco, lumber is no longer an important commodity because the resource was overly exploited and few mature mahogany trees remain (West et al. 1969). The coastal forests of Yucatan also experienced a period of intensive logging that extended from 1600-1900 (Olmsted and Garcia 1998). Today, the mangrove forests of this region are

gradually declining because the local human population exploits them for timber and fuel (World Wildlife Fund 2002).

Exotic Species

A threat posed to many coastal forests stems from invasion of exotic species (Johnson and Barbour 1990, Barrow et al. 2000). We will discuss just a few examples here. In the east gulf, the threat of exotic species is most common south of 28° latitude where freezing temperatures are rare. Three species, Australian pine (*Casuarina equisetifolia*), Brazilian pepper (*Schinus terebinthifolius*), and sisal (*Agave sisalana*), create the greatest problems (Johnson and Barbour 1990). Australian pines invade newly exposed sands where dredge spoils are dumped or storm over-wash occurs. Once established, Australian pines form a dense canopy and thick litter layer that inhibit germination of native species. Restoration of sites dominated by Australian pine has proven difficult.

Chinese tallow tree (*Sapium sebiferum*) is a widespread, invasive species that was introduced to the United States in 1784 and currently has naturalized populations from North Carolina to south Texas (Bruce et al. 1997). The species is very prolific and in Galveston County, Texas, for example, Chinese tallow woodlands have increased from 2 to 12,141 ha since 1970 (Barrow and Renne 2001). Chinese tallow tree affects native communities by altering species composition and structure and thus, affects the resources available to migrating birds. To determine the use of tallow woodlands by migrating landbirds, Barrow and Renne (2001) compared migrant use of riparian forests to their use of tallow woodlands during spring migration. The study confirmed that some migrants were more common in tallow woodlands, but species richness was not significantly different between the two habitat types. The authors also compared the insect load of Chinese tallow to that of native species and found that not only was the insect load lower in tallow, but that important food resources like Lepidopteran larvae were absent (Barrow and Renne 2001). Thus, it is possible that tallow woodlands provide the cover needed during stopover, but lack the food resources needed for continued migration.

Climate Change

Increasing storm severity resulting from the warmer conditions of global climate change (Emanuel 1987) may alter coastal landscapes or entire regions through shifts in structure and composition of plant communities (for example, Doyle and Girod 1997). The areal extent of altered habitat due to strong storms like hurricanes can be vast. Hurricane Hugo, for example, affected 23 counties and damaged 1.8 million ha of wooded lands in South Carolina (Sheffield and Thompson 1992); more than 90 percent of the forested landscape of 6 counties was damaged. No one has assessed the consequences that landscape-level vegetation changes would have on migrating landbirds.

From a geologic perspective, coastal communities are in a constant state of flux because of the accretion and loss of sandy substrates in response to the constant force of wind and wave (Johnson and Barbour 1990). Changes of this type may occur quickly when catastrophic storms strike the coast, or they may occur gradually over a period of several decades (Johnson and Barbour 1990). Two hurricanes striking Grayton Beach State Park in the Florida Panhandle in the 1970's sent foredune sand into scrub and hammock vegetation behind the dune. If not stabilized, migrating sand banks such as this can engulf forest vegetation over a very large area (Johnson and Barbour 1990). Upland areas of Anclote Key, on the other hand, appear to be moving gradually northward in response to changes in nearby seagrass beds (Hine et al. 1987). Accreting sands to the north are colonized quickly by Australian pines (Johnson et al. 1992), while the maritime hammock on the southern end of the island is eroding.

Sea-level rise is another result of global climate change. The effects of rising sea-levels become amplified in areas like the Mississippi River delta where natural subsidence occurs. In the Mississippi Deltaic Plain, subsidence combined with eustatic sea-level rise results in a relative sea-level rise that is as high as 1.2 cm/yr (Baumann et al. 1984). This increase in water level triggers a chain of events that can be devastating to coastal forests. Coastal forests in this region follow a seasonal cycle of flooding and drying, but increased flooding duration brought on by sea-level rise can lead to waterlogging stress. Bottomland hardwood species would eventually die from waterlogging stress, while the regeneration of swamp species would eventually cease due to permanent flooding (Conner and Day 1998).

Remaining Tracts of Extensive Coastal Forest

Not all coastal forests are in dire straits. Whereas the live oak scrub of central Texas (between Baffin Bay and Matagorda Bay) is threatened by development (Collins 1987), the live oak woodlands of south Texas are relatively stable. This forest type occurs in the Coastal Sand Plain of Kennedy County, an area that is vast and sparsely populated (*fig. 1*). Historically, this

habitat consisted of small groves of trees (or mottes), but in some areas they have expanded and coalesced to form large contiguous forests (Tharp 1939, Johnston 1963, Fall 1973). Live oak woodlands now occupy well over 29,000 ha within the South Texas Brushlands physiographic area (Proudfoot and Beasom 1997).

There are other coastal forest systems around the gulf that are still extensive (*fig. 1*), but are threatened by the pressures of human activities. The Columbia Bottomlands of east Texas (71,632 ha) represent the largest expanse of forest along the Texas coast even though development, logging and chipping, drainage, and clearing for agriculture have reduced forest coverage by 75 percent (U.S. Fish and Wildlife Service 1997).

Other extensive tracts of forests (*fig. 1*) can be found in Everglades National Park (park extends over 610,684 ha) and Big Cypress National Preserve (621,600 ha), both in southern Florida. In the northeast region of the gulf, large tracts of forest occur around Apalachicola Bay (Apalachicola National Forest and surrounding public lands totaling >273,000 ha), the Blackwater River State Forest (76,729 ha), Eglin Air Force Base and surrounding public lands (>302,000 ha), the Lower Pascagoula River basin (431,753 ha south of the confluence of the Leaf and Chickasawhay Rivers) (Woodrey et al. 2001), the DeSoto National Forest (202,755 ha), the lower Pearl River Basin (42,898 ha) (Watson 1988), and the Pontchartrain Basin (including Lakes Maurepas and Borgne, ca. 87,253 ha). In the northwest region, extensive bottomland hardwoods, swamps and adjacent forests are present in the Atchafalalaya (337,601 ha) (U.S. Fish and Wildlife Service 1978), Sabine and Mermentau (>209,937 ha) (Ramsey et al. 2001) River basins of Louisiana, and in the Big Thicket National Preserve (39,256 ha) in Texas.

In Mexico, important wooded areas (*fig. 1*) include the remnant thornscrub and mesquite woodlands of Tamaulipas (12,141 ha present at Rancho Rincon de Anacahuitas); mangroves and swamps around the Humedales del Sur de Tamaulipas, the Laguna de Tamiahua, and the Laguna La Mancha (48 ha); tropical evergreen forests (13,600 ha) near Los Tuxtlas, Veracruz; and mangroves, swamps, palm stands and thornscrub of the Humedales de Alvarado in Veracruz (279,890 ha of wetlands), and of the Pantanos de Centla in Tabasco (302,706 ha of wetlands).

Most of the large forested systems remaining along the coasts of the Gulf of Mexico are associated with river basins and deltas. We offer here a caveat on seasonally-flooded, floodplain forests as stopover habitat. These productive forests provide excellent habitat for migrating birds, but not for all species of migrant landbirds. Those species that specialize on searching for food in the leaf litter of the forest floor, like Swainson's Warbler (*Limnothlypis swainsonii*) and others, must find alternate sites. Other specialists may also have fewer opportunities to find suitable microhabitats within floodplain forests. The hydrology of these systems precludes a well-developed understory. Several species specialize in foraging amongst thickets beneath the canopy: Worm-eating Warbler (*Helmitheros vermivora*) and *Vermivora* spp., for example, search for clumps of dead leaves on branchlets that become suspended in vine tangles and thickets of the understory. Often floodplain forests are dominated by one or two tree species, like bald cypress (*Taxodium distichum*) and/or tupelo-gum (*Nyssa* spp.) (*table 1*), and do not provide an abundance or diversity of fruiting and flowering plants that provide food items useful in meeting the energetic demands of *en route* migrants.

Thoughts on Conservation Strategies for Coastal Forests

Planning for the effective conservation of gulf coastal habitats for forest-dwelling birds during their annual migrations will not be a simple task. We know that most eastern migrant landbirds migrate over or near the shore of the Gulf of Mexico, but this is a vast area and conservation funds for targeting stopover habitats is limited. We offer here a few thoughts to consider when developing a conservation strategy for the coastal forests of the Gulf of Mexico.

Gulf-Wide Considerations

Broad frontal passages and consequently pathways and densities of migrating birds shift from year to year and sometimes within a given migration season. Migration pathways over or around the Gulf of Mexico are affected, in large part, by the major wind patterns over the gulf when birds are aloft (Gauthreaux 1991). Wind patterns also affect the origination of long-range migratory movements of birds prepared to migrate. Interestingly, the ways that prevailing wind patterns influence migration passages around and over the gulf are interpreted differently by some researchers (see Rappole and Ramos 1994, Gauthreaux 1999). The precise interpretation is not necessary for our analysis because we base it on the actual position and density of migrating birds. Results from our meta-analysis of patterns of migration movements and landfalls are summarized in *Figure 1*. The map is based on a synthesis of both field and radar studies. We present this map in the hope that others will work to improve it and its usefulness to conservation efforts. The heavily shaded areas are those that are used consistently year to year (even with

the acknowledged shifting nature of wind patterns and the corresponding migratory bird density) and in both seasons (Gauthreaux 1999, Gauthreaux and Belser 1999).

In the eastern United States, there are several migratory pathways. To the east, these go through Florida and the Caribbean. Some species even migrate through the western Atlantic. To the west of Florida there are two main migratory strategies: 1) trans-gulf migrants cross the Gulf of Mexico in primarily a north-south direction; and 2) circum-gulf migrants fly around the western border of the gulf, but much of the movement may be over water. It is movements across and around the gulf that we are interested in here. Due to prevailing southerly winds, the majority of migration movement in autumn is around the western gulf coast (Able 1972). Many birds are known to migrate along the Texas coast but off shore over gulf waters in both spring and autumn (Forsyth and James 1971, Gauthreaux 1999). Thus the western gulf coast becomes important during days of inclement weather (head winds and rain). Some trans-gulf flights cut across the waters of the northwest gulf (Forsyth and James 1971) and depart and/or make landfall along the United States-Mexico borderlands and the upper Texas and southwest Louisiana coasts (Gauthreaux 1999, Gauthreaux and Belser 1999). The southwestern coast of the gulf is shaded dark because of the geographic bottleneck created by two mountain ranges on the west and the gulf to the east forcing birds to concentrate in a narrow coastal plain. Fewer individuals use the lighter-shaded areas, but the areas are important because of the dynamic nature of pathway zones. In some years, the greatest concentrations of migrants within a migration season will occur in some of these lightly-shaded zones. We know much less about patterns of use along the southern coast of the gulf, but there is evidence of migrant landfall along the Yucatan Peninsula in autumn (Paynter 1953, Buskirk 1980).

Regional Planning

Within a region, should planners target coastal forests that lie inland (25-100 km from the shoreline) or coastal fringe sites? We believe an approach that incorporates both areas is required. The importance of inland sites will vary depending on whether the coast is parallel to the predominant direction of movement or not. Wooded habitats along the gulf shoreline may be used by concentrations of migrants that encounter stormy weather near the coast or by individuals that must cease migratory flight at the first opportunity due to physiological demands (e.g., dehydration, lipid depletion, or exhaustion). Wooded vegetation near the coast may serve as habitat for staging migrants waiting for favorable weather conditions before embarking on gulf-wide flights; this is especially true where the coast is perpendicular to the predominant flight direction. Inland sites may function as resting and feeding areas for birds ready to depart on their nocturnal flights (again the extent of this depends on the orientation of the coast with respect to predominant flight direction). In autumn, all sites may provide cover and food for molting birds. Throughout each region, we recommend designing landscape mosaics that provide adequate habitat configurations. The amount of habitat required will depend on the expected density of use by birds (migrant and resident). Boundaries for landscape mosaics could be delineated by natural landforms or they could follow the boundaries of habitats identified in existing regional conservation/management plans (e.g., joint ventures, Partner's in Flight plans, The Nature Conservancy ecoregional plans, wildlife refuges or parks, etc.). In *Figure 1*, we have identified the locations of known wooded tracts that remain as extensive intact systems. Habitats within these systems may be important to migrating birds. Large distances between these wooded systems appear to occur in the western, southern, and eastern regions. We know much less about the location and status of smaller forest patches. The importance of distance is related to the likelihood of encounter by migrating birds; this depends on the predominant direction of flight. Mapping the dispersion and type of wooded patches within each region should be one goal of conservation planners. The predominant flight direction needs to be considered.

Landscape Mosaics

Delineation of migrant-landscape relations with predictive models (e.g., Simons et al. 2000, Gutzwiller and Barrow 2002) can be an effective approach to incorporate broad-scale habitat associations into conservation decision processes (Gutzwiller and Barrow 2001). Consideration should be made of how migrants find suitable or likely suitable habitats near the Gulf of Mexico. The altitude of trans-gulf migration ranges from about 600-2,500 m (Gauthreaux 1991). How far can migrants see habitat patches from these heights? Once this is determined, we should be able to estimate a useful range of interpatch distances required within a landscape mosaic. Again the probable direction of flight must be considered. At least, we can suggest what maximum distance may be allowed between any two habitat patches along the expected flight path and perpendicular to it. Conservationists may be able to manipulate the landscape structure as to maximize the interception of migrating birds by restoring or creating patches of habitat perpendicular to their north-south movements (Gutzwiller and Anderson 1992). We, of course, would like to know what constitutes a suitable

patch size. Patch sizes need to be larger where expected use is greatest; this can be determined from *Figure 1*. Migration routes are not completely deterministic for most species.

The approach we advocate here is a general one and will serve the needs for most species. If any particular species has more precise routes; they must be determined and habitat must be provided—especially for rare and endangered species. For instance, nearshore habitats in Florida may be particularly important for Cape May Warbler (*D. tigrina*), Black-throated Blue Warbler (*D. caerulescens*), Kirtland's Warbler (*D. kirklandii*), and Connecticut Warbler (*Oporornis agilis*) (Hunter et al. 1993). The Mexico and Texas coastlines appear to be important for Nashville Warbler (*Vermivora ruficapilla*). Enough habitat patches have to be present to allow the successful completion of migration for each species. The "programmed" routes may change to accommodate current landscapes, but habitats must be suitable in any reasonable alternative routes.

Concentrations at particular places do not necessarily mean that the habitats at these locations are particularly good. It may only mean that these were the only habitats available. We should be careful to look at landscape context of all stopover areas. In many cases, the landscape may concentrate the birds; suitability may be a separate issue.

Suitability of Wooded Habitats

In the vicinity of the Gulf of Mexico, individual migrants do not seem to return to the same stopover areas from year to year (Barrow et al. 2000). Apparently birds are programmed to take their chances at a variety of locations. This makes us doubt that a too-detailed accounting of what they do is relevant. Apparently they can do a variety of things. Emphasis should be made of habitat structure and complexity. We believe that in all cases (but especially during migration) that the availability of resource concentrations is constantly changing. Residents have daily exposure to the habitat and are able to track these changes; migrants do not. What they seem to do instead is move through the habitat and continuously sample it (Moore et al. 1990). They congregate where there are more resources because it is not necessary to move as often or as far as they need to move when resources are scarcer. Thus the concentration of resources themselves results in higher densities in the most suitable places. The location of hot spots will continuously change because the food resources will vary in time and space, and the competitive environment is in constant flux. In more complex habitats, resource patches should be scattered and diverse so as to accommodate a variety of species. In many cases, it may not be necessary to manage for a particular situation; managing for complexity should be enough. The loss of complexity and heterogeneity where exotics predominate may be one of the main problems with their introduction (Barrow and Renne 2001).

Coastal habitats are used throughout the year and are important for residents as well as migrants (especially in the neotropics). Fortunately, the same rules for habitat suitability apply to both. Landscape considerations would be different for the two groups, however.

On the Diets of *En Route* Migrants

Nearctic-Neotropical migrant landbirds tend to be insectivorous, frugivorous, nectarivorous, or omnivorous. Therefore, insects, fruits, and flowers are especially important habitat components at stopover sites. A more thorough study of requirements of stopover areas should be made. It is uncertain that energy content is the only important consideration for food. We do know that water is often required (Leberg et al. 1996). We do not know how much energy is needed to complete flight; this would vary by species. In the spring, energy may also be needed to accommodate changes in the reproductive systems of both males and females; energetic needs may be especially important in females. It is likely that specific metabolic requirements may also be needed to bring about these changes, and particular foods may be required in the diets of migrants, especially females where morphological and physiological changes are greatest. It needs to be determined if specific substances are needed. If they are required, the availability of them needs to be evaluated. In autumn, requirements for molt may need to be determined. Of course, molt can be rescheduled more easily than reproduction.

Acknowledgments

We thank B. Ford for inviting us to write a synthesis of the coastal forests of the Gulf of Mexico and the migratory birds they support. We also thank T. Rich, T. Doyle, B. Vairin and T. Charron for providing helpful reviews of the manuscript.

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California Black Rail (*Laterallus jamaicensis coturniculus*) Distribution and Abundance in Relation to Habitat and Landscape Features in the San Francisco Bay Estuary[1]

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Key words: California Black Rail, habitat associations, *Laterallus jamaicensis coturniculus*, tidal salt marsh.

Introduction

The majority of California Black Rails (*Laterallus jamaicensis coturniculus*; >90 percent) are found in the tidal salt marshes of the northern San Francisco Bay region, primarily in San Pablo and Suisun Bays (Manolis 1978, Evens et al. 1991). Smaller populations occur in San Francisco Bay, the Outer Coast of Marin County, freshwater marshes in the foothills of the Sierra Nevada, and in the Colorado River Area (Trulio and Evens 2000). Loss of more than 80 percent of historic tidal marsh habitat, as well as habitat fragmentation and degradation have directly and indirectly impacted this and other tidal marsh breeding species (Goals Project 1999). Although there are few historic records of Black Rail presence and abundance in the Bay, recent survey efforts indicate that the species is absent from some marshes in the northern Bay region and that population sizes may be low enough to cause concern (Evens et al. 1991, Nur et al. 1997, Evens and Nur 2002). Due to its small population sizes, the California Black Rail has been listed as a State of California Threatened Species and a Federal Species of Management Concern.

We conducted standardized tape-playback surveys for California Black Rails at 31 tidal salt marshes in San Pablo Bay, Suisun Bay, northern San Francisco Bay and western Marin County, California (*fig. 1*) in 2001 with the aims of: 1) providing the best current information on distribution and abundance of Black Rails; 2) estimating the current population size; 3) comparing our survey results with results of surveys conducted in 1996 and earlier; and 4) identifying vegetation, habitat, and landscape features associated with the presence of Black Rails.

Methods

Dawn surveys were conducted during the breeding season in April and May 2001. Methods followed a standardized tape call-back/response protocol (Evens et al. 1991, Nur et al. 1997). The protocol involved listening passively for 1 minute after arriving at the listening station, then broadcasting tape-recorded Black Rail vocalizations: 1 minute of "grr" calls followed by 0.5 minutes of "ki-ki-krr" calls. The surveyor then listened for another 3.5 minutes for a total of 6 minutes per listening station. We calculated an abundance index for rails at each marsh by dividing the number of rails detected within 50 m of the observer by the sum of the area of marsh within 50 m at each of the points surveyed. We calculated absolute abundance at each site using DISTANCE 3.5 software (Buckland et al. 1993, Thomas et al. 1998). For statistical analysis of predictors of rail presence, we determined presence or absence of rails within 50 m of each survey point.

To examine the effects of local scale habitat characteristics on Black Rails, we collected information on vegetation cover and habitat structure within 50 m of each survey point. Variables included distance to nearest tidal channel and the channel's width; percent cover of channel, open ground and vegetation, and the proportion contributed by each plant species; and at a sample of points within 10 m of the survey point, vegetation height and number of stems at 10 cm intervals from the ground (Nur et al. 1997).

To examine the effects on Black Rails of habitat fragmentation, patch size and patch isolation, we examined the following landscape level variables: marsh size, marsh core area (area > 50 m from marsh edge), perimeter to area ratio, fractal dimension (scale-independent measure of perimeter to area ratio), proportion of marsh area within 250 m, 500 m, 1000 m and 2000 m of survey point; proportion of urban area within these same radii; distance to nearest 25 ha, 50 ha and 100 ha marsh; and distance to nearest marsh edge, upland edge and urban area. We recorded UTM coordinates at each point in the field, using a global positioning unit. We used ArcView GIS 3.2a and extensions (ESRI 2000a),

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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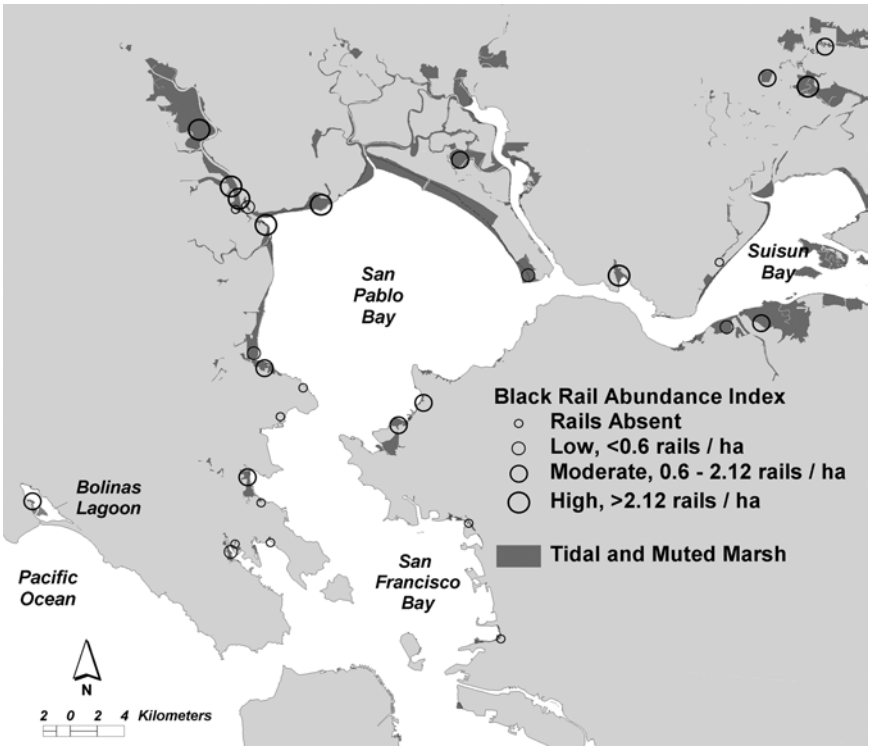

Figure 1— California Black Rail survey sites and abundance indices, 2001.

Spatial Analyst (ESRI 2000b) and Patch Analyst (Rempel 2000) to derive a set of landscape parameters characterizing that point. GIS data for San Francisco Bay habitats were obtained from the San Francisco Estuary Institute's (SFEI) EcoAtlas GIS (version 1.50b4). GIS data for Tomales Bay and Bolinas Lagoon habitats were obtained from the Point Reyes National Seashore. For surrounding uplands, we derived a composite landuse layer for the San Francisco Bay area consisting of the most recent 1:24000 landuse maps from the California Department of Water Resources (1994, 1995, 1999), where available, and 1: 24000 landuse maps from the USGS Mid-continent Ecological Science Center (1996) elsewhere.

We looked for habitat and landscape-level predictors of Black Rail presence using logistic regression (Hosmer and Lemeshow 1989) pooling all survey points across all marshes. We developed separate multi-variable models considering only local habitat variables (vegetation composition and structure) and only landscape level variables, as well as a combined model. In developing each model, we started with all variables showing a correlation of at least 0.80 with rail presence/ absence, and worked in a backwards step-wise fashion, removing variables with significance of $P > 0.05$. All variables retained in the final models had a significance of $P < 0.05$.

Results

Of the ten marshes previously surveyed, abundance indices were lower at nine marshes in 2001 than in 1996 and earlier surveys, and higher in one marsh. Of 21 marshes surveyed for the first time, Black Rails were detected at only nine sites. The absolute density averaged 2.63 (±1.05 se) birds/ha in San Pablo Bay and 3.44 birds/ha (±0.73 se) in Suisun Bay. We estimated that San Pablo Bay had 15,000 Black Rails (range 11,000–19,000 birds, based on the 90 percent confidence interval of mean abundance), the highest Black Rail population in the Bay region in 2001. We estimated there were 12,000 Black Rails in Suisun Bay region (range 6,700 to 17,200) and 280 Black Rails in the outer coast marshes (range 2–606 birds).

At the habitat level, with all variables considered simultaneously, Black Rail detections were positively associated with the density of vegetation below 10 cm in height and with the proportion of pickleweed (*Salicornia virginica*), rushes (*Juncus* spp.), gumplant (*Grindelia stricta*), peppergrass (*Lepidium latifolium*), alkali bulrush (*Scirpus maritimus*) and cattails (*Typha* spp.) within 50 m of each survey point; there was a negative relationship to average vegetation height (*table 1*). At the landscape level, again with all variables considered simultaneously, Black Rail presence was positively related to the amount of marsh in the surrounding 250 m and the size of the core area of the

Table 1-- *Local habitat and landscape level variables associated with California Black Rail presence: logistic regression models.*

Significant local habitat variables[1]	Sign[3]	Significant landscape level variables[2]	Sign[3]
% Cover gumplant (*Grindelia stricta*)	+	Distance to bay or large channel	-
% Cover rush (*Juncus* spp.)	+	Distance to nearest large (100 ha) marsh	-
% Cover peppergrass (*Lepidium latifolium*)	+	Marsh core area (area > 50 m from marsh edge)	+
% Cover pickleweed (*Salicornia virginica*)	+	Marsh peripheral area (total area – core)	-
% Cover alkali bulrush (*Scirpus maritimus*)	+	Area of marsh within 250 m	+
% Cover cattails (*Typha* spp.)	+		
Number of stems under 10 cm (vegetation density)	+		
Vegetation maximum height	-		

[1]All local habitat variables considered simultaneously. Model statistics: Pseudo $R^2 = 0.165$, Log-likelihood ratio statistic = 36.43, df = 8, $P < 0.0001$.
[2]All landscape level variables considered simultaneously. Model statistics: Pseudo $R^2 = 0.067$, Log-likelihood ratio statistic = 16.97, df = 5, $P = 0.0046$.
[3]Sign of logistic regression coefficient.

marsh (interior area of a marsh more than 50 m from a marsh edge); and negatively to the distance to the nearest large (100 ha) marsh and distance to water (*table 1*). When all habitat level and landscape level variables were considered simultaneously in a multi-scale combined model, only the local variables were significant. Thus, Black Rails responded both to local vegetation characteristics and to broader landscape features, but presence or absence at the local scale was better predicted by vegetation characteristics than by landscape characteristics. Our data indicate that Black Rails prefer marshes that are close to water (bay or river), large, away from urban areas, and saline to brackish with a high proportion of *Salicornia*, *Grindelia*, *Scirpus maritimus*, *Juncus*, and *Typha*.

Land managers seeking to acquire existing tidal marsh habitat, or to improve or restore habitat for Black Rails should consider that: (1) large marshes in areas with lower levels of urban development are more likely to benefit Black Rail populations than smaller marsh fragments in urban areas; and (2) management practices that promote dense vegetation, especially that of *Salicornia*, *Grindelia*, and *Scirpus maritimus*, or, in more brackish areas, *Juncus* and *Typha*, should be encouraged.

We recommend nest monitoring of Black Rails in order to better estimate nesting success and the factors that influence it. In particular, information is required to establish whether the marsh habitat preferred by Black Rails is one that promotes successful reproduction and survival.

Acknowledgments

Thanks to Y. Chan, J. Wood, R. Leong, W. NeVille and numerous field assistants. J. Evans provided valuable insights and comments. C. McCreedy assisted with landscape metric calculations. The following agencies gave access to marsh study sites: San Pablo Bay National Wildlife Refuge, California Department of Fish and Game, California State Parks, East Bay Regional Park District, Solano County Farmlands and Open Space, City of Vallejo and Sonoma Land Trust. Surveys were conducted under authority of a Memorandum of Understanding with J. Gustafson, Habitat Conservation and Planning Branch, California Department of Fish and Game. This work was made possible by funding from R. Morat of the U. S. Fish and Wildlife Service Coastal Program and from the Bernard Osher Foundation, the Richard and Marcia Grand Foundation, Gabilan Foundation, CalFed Bay/Delta Program, and the U.S. Environmental Protection Agency.

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Developing Spatially Explicit Habitat Models for Grassland Bird Conservation Planning in the Prairie Pothole Region of North Dakota[1]

Neal D. Niemuth[2], Michael E. Estey[2], and Charles R. Loesch[2]

Abstract

Conservation planning for birds is increasingly focused on landscapes. However, little spatially explicit information is available to guide landscape-level conservation planning for many species of birds. We used georeferenced 1995 Breeding Bird Survey (BBS) data in conjunction with land-cover information to develop a spatially explicit habitat model predicting the occurrence of Northern Harrier (*Circus cyaneus*) in the Prairie Pothole Region of North Dakota, USA. Presence of Northern Harriers was positively associated with the amount of grassland in the landscape and presence of Northern Harriers at adjacent stops, and negatively associated with forest cover and an eastern geographic gradient. The resulting spatially explicit map showing predicted presence of Northern Harrier corresponded well with results of a conceptual grassland bird habitat model applied to the same landscape. Detections of Northern Harrier in 1997 BBS data used for validation were strongly correlated with model predictions. Our findings indicate that empirical models using BBS data and conceptual models can be used in conjunction with landcover data to develop spatially explicit models predicting general suitability of landscapes for some species of birds.

Key Words: conservation planning, GIS, grassland bird, Northern Harrier, spatially explicit habitat model.

Introduction

Concern over decreasing bird populations has stimulated a variety of bird conservation plans, many of which (e.g., North American Waterfowl Management Plan, Partners in Flight, The Nature Conservancy's Migratory Bird Program) explicitly promote a landscape approach to bird conservation. Landscape characteristics are an important consideration in bird conservation planning for a variety of biological reasons. Bird habitat selection is hierarchical, with birds first selecting habitat at broad scales, then making fine-grained selections such as nest and foraging sites (Wiens 1973, Johnson 1980). Landscape-level conservation thus provides a broad habitat foundation within which birds can select habitat at a fine-grained scale. In addition, landscape characteristics can influence avian demographics through nest predation and brood parasitism (Porneluzi and Faaborg 1999, Young and Hutto 1999).

Landscape characteristics also are important from logistical and management standpoints. If habitat is purchased or otherwise selected for management based on landscape characteristics, local characteristics (e.g., vegetation composition and structure) within a patch can be modified relatively easily. But it is difficult to modify the landscape around a patch with suitable local characteristics if landscape characteristics are not suitable. Conceptual models have been developed to guide landscape-level conservation planning (e.g., Fitzgerald et al. 1999), but specific landscape-level habitat relationships are not known for most species of birds (Flather and Sauer 1996, Haig et al. 1998, Scott et al. 1993).

Much of the information regarding North American bird populations comes from the Breeding Bird Survey (BBS), an annual, continent-wide survey (Sauer et al. 2000). The BBS is used primarily to monitor bird populations but is rarely viewed in context of surrounding habitat (Flather and Sauer 1996). We used georeferenced BBS data in conjunction with land-cover information to determine landscape-level habitat relationships for the Northern Harrier in North Dakota. The Northern harrier is typically considered area sensitive, requiring large blocks of suitable habitat to be present (Herkert et al. 1996, Niemuth and Boyce 2000, Robinson 1991). However, size of habitat patch may not be as important as the total amount of grass in the landscape, as Northern Harriers will nest in relatively small (8 ha) patches of grass in proximity to extensive grassland areas (Herkert et al. 1999).

Our analysis had three primary objectives: (1) develop a model identifying landscape characteristics associated with the presence of Northern Harrier; (2) link the model to a geographic information system (GIS) to create a map showing predicted probability of Northern Harrier presence across the Prairie Pothole Region of

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California**.

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North Dakota; and (3) compare the resulting probability map with a map created by a GIS-based conceptual model identifying Grassland Bird Conservation Areas (GBCAs) in the study area. GBCAs identify large blocks of grassland potentially suitable for area-sensitive grassland bird species.

Methods

Study Area

The study area was that portion of North Dakota east and north of the Missouri River, approximating the Prairie Pothole Region of the state (*fig. 1*). The landscape surface was formed by glacial action and is characterized by numerous depressional wetlands and prairie flora (Bluemle 1991). The climate is cool and dry, and soils are typically heavy (Winter 1989). Agriculture is the primary land use with cropland dominating in the eastern portion of the study area, and the amount of grassland generally increasing farther west.

BBS Data

We obtained BBS data for 1995 and 1997 for 30 routes within our study area (*Fig. 1*) from the United States Geological Survey Patuxent Wildlife Research Center, Laurel, Maryland. Each 40-km route contained 50 stops, or survey points, 0.8 km apart; details of route placement and sampling were described by Bystrak (1981). Because changes in land use such as enrollment of cropland in the U.S. Department of Agriculture Conservation Reserve Program (CRP) can impact populations of grassland birds (Reynolds et al. 1994), BBS data and satellite imagery were acquired for approximately the same time period. We acquired digitized survey routes from the National Atlas of the United States (http://nationalatlas.gov) as an ArcView shapefile (Environmental Systems Research Institute, Redlands, California). Most analyses of BBS data use 40-km survey routes as the observational unit; samples at this scale are coarse, and land cover and avian communities can vary considerably within each route. We calculated locations for each of the 50 stops on each BBS route by creating a point at the start of each digitized route and every 0.807 km thereafter to the end of the route. Stop locations were verified using BBS route maps (Keith Pardieck, USGS, pers. comm.). Accuracy of stop points was visually verified by comparing points to intersections on public road layers, which in our study region typically follow public land survey lines at 1.61-km intervals.

Landcover Data

Landcover data were derived from a mosaic of Thematic Mapper satellite images (30-m resolution) acquired from May 1992 through September 1996. Individual images were classified, resampled to 2.02-ha minimum mapping unit, and mosaicked into a single grid. User accuracy for all images exceeded 80 percent[3]. Wetland information was obtained from the National Wetlands Inventory (NWI) digital database and integrated into the landcover grid as basins identified by the most permanent wetland type within each basin (Cowardin et al. 1995). Predictor variables (*table 1*) were estimated using a GIS.

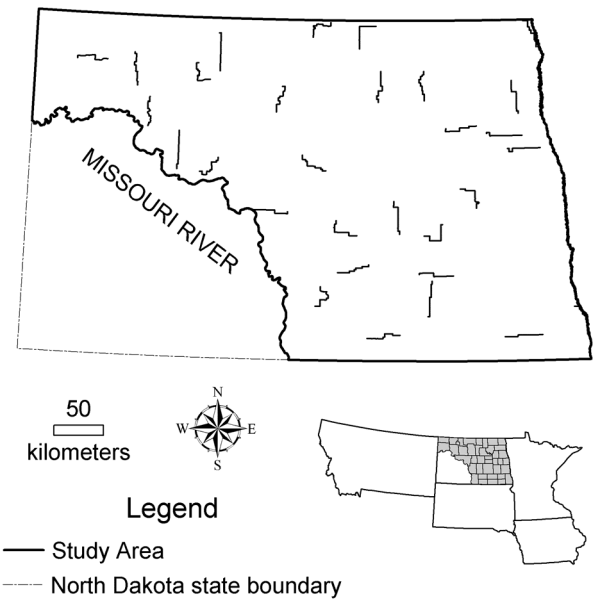

Figure 1— Location of 30 BBS routes North Dakota that were sampled in 1995 or 1997 and included in analysis. Bird-landscape relationships were only modeled east of the Missouri River.

Our study area covered a large geographic region, so we included easting and northing Universal Transverse Mercator (UTM) coordinates as linear and quadratic terms to model possible gradients in factors such as climate, regional landscape characteristics, resource availability, and species range. Because the spatial scale of sampling may influence results (Porter and Church 1987, Wiens 1989a), we sampled landscape data at three scales using circular moving window analysis, which summarizes data within a "window" of a selected size around each cell in a GIS data layer. Landscape data were in raster format and circle radii were irregular, so the area within each moving window was 48, 191, and 452 ha, respectively, for circles with radii of about 400, 800, and 1200 m. Spatial analyses were performed using the ARC/INFO Grid module (Environmental Systems Research Institute, Redlands, California, USA).

[3]unpublished data, U.S. Fish and Wildlife Service and Ducks Unlimited, Bismarck, North Dakota

Table 1— *Candidate predictor variables used to determine associations between presence of Northern Harriers and landscape characteristics at 1350 BBS stops in North Dakota.*

Landscape Variable	Description
Undisturbed Grass (%)	Predominant mix of cool-season grasses and forbs planted on previously cropped land. This land cover is generally undisturbed but may be hayed or grazed intermittently. Examples include CRP plantings and dense nesting cover on U.S. Fish and Wildlife Service waterfowl production areas.
Grassland (%)	Predominant mix of native grasses, forbs, or scattered low shrubs on unbroken prairie. This land cover is typically grazed or hayed annually.
Hayland (%)	Predominant mix of alfalfa and cool-season grasses hayed once or twice annually.
Cropland (%)	Tilled and planted with small grains or row crops that are harvested annually; includes fallow fields.
Forest (%)	Areas of mature trees.
Patches (*n*)	Number of disjunct patches identified by GIS for all land-use categories. Cells of the same habitat type were considered as belonging to the same patch only if they had at least one edge in common.
Wetlands (*n*)	Number of disjunct NWI[1] wetland basins within each buffer, regardless of basin type.
Temporary (%)	Area of temporary wetland basins derived from NWI data.
Seasonal (%)	Area of seasonal wetland basins derived from NWI data.
Semipermanent (%)	Area of semipermanent wetland basins derived from NWI data.
Northing	UTM[2]coordinate indicating north-south position.
Easting	UTM coordinate indicating east-west position.
Harrier Presence	Presence or absence of Northern Harrier at adjacent BBS stop.

[1]National Wetlands Inventory
[2]Universal Transverse Mercator

Model Development

We used the presence of Northern Harrier at BBS stops to develop a resource selection function (RSF; Manly et al. 1993), assuming that the relative probability of encountering a species could be predicted by landscape-level characteristics, x_i, according to the model

$$w(x) = \exp(\beta_0 + \beta_1 x_1 + \beta_2 x_2 + ... + \beta_k x_k)$$

where β_i were estimated using logistic regression.

We developed candidate models at each of three scales and then used Akaike's Information Criterion (AIC) to select models that best fit the data at each scale (Burnham and Anderson 1998). Development of models was exploratory, but based on other research we predicted that presence of Northern Harriers would be positively associated with grasslands, temporary wetlands, and seasonal wetlands and negatively associated with forests, agriculture, landscape fragmentation, and large bodies of open water (reviewed in MacWhirter and Bildstein 1996). We calculated AIC differences (Δ_i) to allow comparison of models within and among scales, and considered models with $\Delta_i < 2$ in selection of the final model (Burnham and Anderson 1998). We examined differences in Northern Harrier response to grass type (i.e., grassland and undisturbed grass) by comparing AIC values for models with grass types combined to AIC values for models with each grass type included separately. If the Northern Harrier responded differently to grass types, AIC scores for models with separate grass types should have improved more than the penalty for including an additional variable(s). Selection of the final model was based on parsimony, species biology, and interpretability. Statistical analyses were performed using Number Cruncher Statistical System (NCSS, Kayesville, Utah, USA).

Individual stops within each route were 0.807 km apart and likely exhibited positive spatial autocorrelation (i.e., stops close to each other were more likely to be similar than stops farther apart). Spatial autocorrelation can cause apparent statistical significance when none exists (Legendre 1993) and obscure ecological patterns (Carroll and Pearson 2000). We addressed spatial structure of the data set by explicitly incorporating spatial location into our analysis as a trend surface variable (Haining 1990, Legendre 1993) using linear and quadratic terms and by including an autologistic term that incorporated presence of Northern Harriers at adjacent stops (Augustin et al. 1996).

Model Evaluation

Evaluating models based on BBS data is complicated because a site where the bird was not detected might actually be used. Traditional model assessments (e.g., classification success, Cohen's Kappa, Receiver Operating Characteristics) assume that use or nonuse is known (Fielding and Bell 1997). Because nonuse was not known for certain, we evaluated RSF models using a variant of the correlation approach used by Boyce et al. (2002). RSF scores for landscapes surrounding BBS stops in a validation data set were ranked and sorted into 27 groups of 50 and Spearman's rank correlation was calculated for the rank of each group and the number of Northern Harrier detections in each group. Models that perform well show a strong correlation between RSF rank and number of detections (Boyce et al. 2002). Model performance was assessed using BBS data from 1997. This was primarily a same-place, different-time validation, as 27 routes in our study area were sampled in each of the two years. However, three of the routes sampled in 1997 were different from those surveyed in 1995, so 150 of the validation points were from a different time and place.

We created a spatially explicit map showing the relative probability of detecting Northern Harriers throughout the landscape by using the final RSF in conjunction with corresponding GIS layers. The resulting map was then compared to the GBCA map, which was refined from a conceptual model (Fitzgerald et al. 1999) in cooperation with Partners in Flight, the North American Bird Conservation Initiative, and the Prairie Pothole Joint Venture.[4] The GBCA model identified potential grassland bird habitat consisting of a core and matrix. Cores were comprised of a minimum of 95 percent compatible habitat (e.g., grassland, temporary and seasonal wetlands, up to 30 percent permanent and semipermanent wetlands) with minimum dimensions of 1.6 km x 1.6 km and < 5 percent hostile habitat (e.g., forest, urban areas). Matrices encompassed a 1.6-km buffer area around the outer boundary of cores. A GBCA has a minimum area of 23 km^2 (4.8 km x 4.8 km) with > 40 percent of the area consisting of compatible habitat[4].

Results

Twenty-seven routes and 1,350 stops were sampled with Northern Harriers detected at 39 and 40 stops in 1995 and 1997, respectively. Landscapes surrounding BBS stops varied considerably in type and distribution of landcover (*table 2*), and some landscape characteristics were strongly correlated. At the 800-m scale, area of grassland and agriculture were negatively correlated (r = -0.85), and number of habitat patches and number of wetlands were positively correlated (r = 0.78). Correlation among variables at 400-m and 1200-m scales was similar. Consequently, the relative fit of candidate models was similar among scales, with AIC scores generally lowest with landcover data from the 800-m sampling window.

Variables in competing models were similar (*table 3*). We selected a final model where relative probability of detecting a Northern Harrier, w(x), was predicted by

$$w(x) = \exp(-3.13 - (0.0000018 * \text{Easting}) + (0.013 * (\text{Grassland} + \text{Undisturbed Grass})) - (0.13 * \text{Forest}) + (0.8 * \text{Harrier Presence}))$$

In the model evaluation, the number of stops with Northern Harriers detected in ranked RSF groups was positively correlated (r = 0.56, 25 df, P = 0.002) with RSF values. The map showing relative probability of detecting Northern Harrier (*fig. 2a*) was similar to that created by the conceptual GBCA model (*figs. 2b* and *2c*).

[4] Unpublished data, M. E. Estey, U.S. Fish and Wildlife Service, Bismarck, North Dakota

Table 2— *Mean, range, and standard deviation of landcover variables used in development of landscape-level habitat models for the Northern Harrier.*[1]

Landscape Variable	Mean	Minimum	Maximum	sd
Undisturbed Grass (%)	4.9	0	91	9.9
Grassland (%)	20.0	0	99	23.6
Hayland (%)	0.9	0	24	2.6
Cropland (%)	61.8	0	100	31.2
Forest (%)	1.7	0	55	6.5
Patches (*n*)	39.3	1	163	24.3
Wetlands (*n*)	19.3	0	81	13.8
Temporary (%)	0.7	0	14	1.5
Seasonal (%)	2.5	0	25	3.4
Semipermanent (%)	2.0	0	44	4.5

[1] Values shown are for landcover within 800 m of BBS stops.

Table 3—*Variables, Akaike differences (Δ_i), and Akaike weights (w_i) for candidate models predicting presence of Northern Harriers in the Prairie Pothole Region of North Dakota, USA.*

Model	Δ_i	w_i
Easting, Undisturbed Grass + Grassland, Harrier Presence, (Forest) [1, 2]	0.0	0.26
Undisturbed Grass + Grassland, Harrier Presence, (Forest)	0.2	0.24
Easting, Undisturbed Grass + Grassland, (Forest)	0.6	0.19
Undisturbed Grass + Grassland, Harrier Presence, (Forest), (Hay)	1.8	0.11
Easting, Undisturbed Grass, Grassland, Harrier Presence, (Forest)	1.8	0.10
Easting, Undisturbed Grass + Grassland, Harrier Presence, (Forest), (Hay)	1.9	0.10

[1]Parentheses indicate negative relationship. Variable codes defined in Table 1.
Δi indicates the difference between the AIC score for each model and the lowest AIC score of the candidate models for each species.
+ indicates grassland and undisturbed grass cover classes were combined in the model.
[2]Selected as final model.

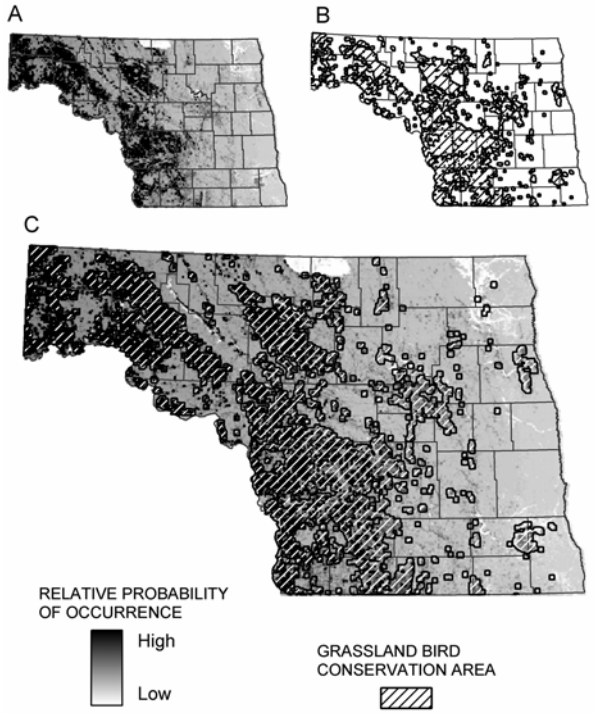

Figure 2— Conservation planning models for the Prairie Pothole Region of North Dakota including (A) relative probability of detecting Northern Harrier; (B) Grassland Bird Conservation Areas; and (C) Grassland Bird Conservation Areas overlain on Northern Harrier probability map.

Discussion

Northern Harrier Habitat Associations

The models predicting presence of Northern Harriers as a function of landscape characteristics in our analysis agree well with findings of previous studies. Harriers were positively associated with grassland and undisturbed grassland, and negatively associated with forest, as would be expected from a grassland specialist. Northern harriers often select dense cover for nesting (Evrard and Bacon 1998, Kantrud and Higgins 1992), but our analysis was based on harrier detection, which was most likely when birds were foraging or perched, rather than at nests. Our data indicated no strong selection for undisturbed grassland (typically Conservation Reserve Program plantings or dense nesting cover at Waterfowl Production Areas) over grassland (*table 3*), although in the model with both grass types considered separately, regression coefficients were nominally greater for undisturbed grassland (0.02) than grassland (0.01). Two competing habitat models showed a negative relationship with increasing area of annually harvested hay fields in the sample window, which is consistent with previous findings of low use of annually hayed or burned grasslands by Northern Harrier (Hecht 1951, Duebbert and Lokemoen 1977).

We found little evidence of selection for wetlands. This agrees with previous findings that Northern Harriers in western North America are more upland oriented than those in eastern North America (summarized in MacWhirter and Bildstein 1996), although Northern Harriers certainly use wetlands in North Dakota for foraging and nesting (Stewart 1975). Presence of Northern Harriers did not appear to be influenced by habitat patchiness, although the small number of harrier observations likely reduced the power of the analysis to detect additional, but less pronounced, relationships with other characteristics such as wetland area and patchiness. Presence of Northern Harriers also may be influenced by habitat characteristics at scales other than those sampled.

The negative relationship with the easting trend surface variable may reflect broad-scale patterns of land use, as eastern North Dakota typically has more cropland and less grass than western North Dakota (Cowardin et al. 1995). Lower numbers of Northern Harrier in eastern North Dakota are evident in BBS general distribution and relative abundance maps (e.g., Sauer et al. 2000), which are based on inverse distancing of route data and do not incorporate habitat relationships. In addition to reflecting possible broad-scale patterns in land use,

trend surface variables may incorporate gradients in precipitation, population distribution, vegetation characteristics, and other unmodeled landscape characteristics that influence occurrence of Northern Harrier. A similar geographic trend was found in duck nest success in the study area (Reynolds et al. 2001). Inclusion of trend surface variables in spatially explicit models improves model fit and reduces spatial autocorrelation in model residuals.[5] Significant correlation between ranked and grouped RSF values and bird detection in the validation data set indicate that the model performed well and was robust from 1995 to 1997.

Correspondence with GBCA Model

The spatially explicit probability map developed from the BBS data corresponded strongly with the map produced using the conceptual GBCA model (*Fig. 2*). This is not surprising, given that the GBCA model identified large blocks of grass without trees, which, with the exception of the easting trend surface variable and proximity of other Northern Harriers, is similar to the habitat relationships identified in the empirically derived Northern Harrier habitat model. The Northern Harrier is a widely distributed species that uses many types of grass; empirical probability maps developed for other species of grassland birds in the region do not match the GBCA map as well, with differences between GBCA maps and empirical models differing among species. For instance, Baird's Sparrow (*Ammodramus bairdii*) has a more restricted distribution than Northern Harrier and probability maps showed it more likely to be found in western North Dakota than in the eastern part of the state.[5] LeConte's Sparrow (*A. leconteii*) selected for dense cover and wetlands relative to upland grasses.[5]

Even with differences among species, both modeling approaches provided useful information that aids managers and conservation planners in identifying potential habitat at the landscape level, which is a primary step in effective conservation planning. Conceptual or expert-based habitat models can be an important step in identifying wildlife habitat (Marcot 1987), and results of conceptual models can agree well with empirical models as is the case with the Northern Harrier in North Dakota and other species elsewhere (Clevenger et al. 2002).

[5] unpublished data, U.S. Fish and Wildlife Service, Bismarck, North Dakota

Using BBS Data to Develop Bird/Habitat Models

Using BBS data in conjunction with RSFs and landcover information produced a biologically plausible model for the Northern Harrier, although number of detections was low. Using BBS data to develop useful habitat models will work best when birds and predictor variables are adequately sampled. The number of used sites as well as model generality may be increased by summing presence data for multiple years, although this approach must consider species biology and changes in landcover, precipitation, and food/prey availability among years.

The 400-m radius of the BBS stop sample area and the high visibility of the Northern Harrier likely reduced potential roadside bias of BBS data, although roadside bias is minimal for many grassland and shrubland bird species (Rotenberry and Knick 1995). Also, use of habitat likely was higher than indicated by BBS data, as not all individuals present are detected during the single, short sample period at each point. Regardless of detectability, the habitat model provides a relative probability of detecting a species, but relative probabilities will vary among species due to differences in detectability. As the BBS is an index of populations (Bystrak 1981), the maps produced by our analysis should be considered an index of the probability of encountering a species based on the landscape characteristics included in each model. Finally, data from BBS stops are not statistically independent, and spatial autocorrelation must be considered when developing and interpreting spatial models.

Role of Habitat Modeling in Conservation Planning

Habitat models such as those presented in this paper, whether based on empirical data or expert opinion, are tools for identifying areas where target species are likely to occur. The models we have presented do not include demographic parameters, which, although difficult to assess, are important considerations in conservation planning. Similarly, landscape-level models do not incorporate fine-grained habitat characteristics, such as vegetation composition and structure, which also influence habitat selection (Madden et al. 2000). Species occurrence and statistical modeling also may be influenced by other factors such as land use (e.g., cultivated vs. grazed wetlands), local correlation among variables, combinations of variables not encountered in the model-building data set, errors in classification of landcover data, soil quality, vegetation, vegetation succession, local conditions, and interactions between predictor variables.

Presence of target species in an area of habitat is influenced by a variety of other, non-habitat factors, including weather, annual variation in distribution, prey availability, competition, and predation (George et al. 1992, Igl and Johnson 1999, Niemuth and Solberg 2003, Wiens 1989b). Bird response to landscape characteristics likely will change in areas with different resource availabilities, and application of the models should be limited to interpolation within the range of geographic and habitat variables used to develop the models. Like all models, landscape-level habitat models are imperfect for a variety of reasons. However, such models provide an objective, quantitative method of evaluating landscapes for conservation. Ideally, habitat models for conservation planning should be based on many years of data and incorporate annual variation as well as demographic parameters. But in the absence of better information, these models provide some basis for making conservation decisions.

Our results suggest that broad landscape characteristics influence occurrence of Northern Harrier, and likely other species of grassland birds in the Prairie Pothole Region of North Dakota. We believe the coarse-grained approach to conservation planning is appropriate in our region given the hierarchical nature of habitat selection. We reiterate the advantages of managing habitat within an appropriate landscape as opposed to altering a landscape surrounding a point with desired features. Similar models have been developed and used effectively for planning waterfowl management activities in the region (Cowardin et al. 1988, Reynolds et al. 1996). Development of habitat models for non-waterfowl species will aid integration of conservation efforts for all bird species.

Unfortunately, the level of biological data available for waterfowl is lacking for most other species of migratory birds, especially that information needed for landscape-level modeling. In the absence of detailed autecological studies explaining resource selection and reproductive success, the combination of landscape information, geo-referenced BBS data, and RSF analysis provides a powerful tool for developing coarse-grained models that present an indication of avian distribution and landscape-level habitat selection. This information can be used to provide direction for future sampling and analysis, or the models can be incorporated into plans for integrated landscape-level conservation planning (e.g., Freemark et al. 1993, Scott et al. 1993, Askins 2000). Given the importance of landscape characteristics to avian habitat selection and demography, landscape-level habitat models are an important consideration in conservation planning for birds.

Acknowledgments

We thank the many volunteers who annually collect BBS data, especially R. E. Martin, G. B. Berkey, R. K. Murphy, E. Freeberg, and R. L. Rytter. We thank B. C. Dale, D. A. Granfors, B. McCready, R. E. Reynolds, and T. D. Rich for helpful comments on an earlier draft of this paper. B. C. Dale, S. K. Davis, D. H. Johnson, R. E. Reynolds, and C. A. Ribic provided valuable observations and discussion. We also thank K. L. Pardieck of USGS Patuxent Wildlife Research Center for providing BBS stop data and route information, K. Van Cleave of Northern Prairie Wildlife Research Center for providing literature, M. S. Rosenberg for providing software and assistance, and the Great Plains Regional Office of Ducks Unlimited, Inc., for helping develop landcover information.

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Prairie Conservation in Canada: The Prairie Conservation Action Plan Experience[1]

Dean Nernberg[2] and David Ingstrup[3]

Abstract

In Canada, grassland conservation has been mobilized and directed through the development of Prairie Conservation Action Plans and Action Plan Committees in the three prairie provinces of Alberta (45 partner agencies and organizations), Saskatchewan (26 partners), and Manitoba (26 partners). In Alberta, 43 percent of the native prairie remains; in Saskatchewan and Manitoba the amount of mixed-grass prairie remaining is less than 20 percent, while tall-grass prairie in Manitoba has been reduced to less than one percent. Although there are many similarities in the approaches taken to conserve remnant prairie in each province, there are many contrasts due to differences in jurisdictional, political, cultural, climatological, industrial, and agricultural backgrounds. Moreover, the differences in size and total area of remaining prairie, by province, has stimulated differences in programs, projects, and methods for conserving this natural resource. In Alberta, the vision is 'To Conserve the Biological Diversity of Native Prairie and Parkland Ecosystems for the Benefit of Current and Future Generations', focusing strongly on biodiversity and landscapes. In Saskatchewan, the vision is 'The Native Prairie is To Be Sustained in a Healthy State in Which Natural and Human Values are Respected', with a strong focus on supporting sustainable livestock production and working landscapes. While in Manitoba, the main focus is 'Identifying and Implementing Economic Activities That Go Hand in Hand with the Restoration and Maintenance of Healthy Prairie Ecosystems', with attention on deriving economic benefit from the land in a sustainable fashion. The success of the Prairie Conservation Action Plan Committee process in Canada is due largely to the ability of all prairie stakeholders to sit around the same table and discuss difficult prairie conservation issues in an amiable and respectful fashion.

Key words: Alberta Prairie Conservation Forum, grassland conservation, Canada, Manitoba Prairie Conservation Action Plan, birds, native grassland, native prairie, PCAP, prairie conservation, Prairie Conservation Action Plan, Saskatchewan Prairie Conservation Action Plan.

Introduction

The Prairie Conservation Action Plan (PCAP) was initially developed by World Wildlife Fund Canada in 1988 as part of the 'Wild West' program. After this five-year plan ended, the three Canadian Prairie Provinces developed five-year PCAPs with implementation strategies. In Saskatchewan and Alberta, committees and subcommittees were struck to undertake tasks and deliver on goals set out in their respective provincial PCAPs. The partners represent a wide array of sectors and stakeholders, including; environment, agriculture, conservation, resource extraction, industry, producer groups, government, non-government, general public, and academia. The benefits of the PCAP process are: prairie conservation and land-use stakeholders sit regularly around the same table; there is better communication and cooperation among partners on native prairie issues; and a better understanding of the full scope of issues at hand and the potential for implementing prairie conservation measures in Canada.

As each of the three prairie provinces is different and the issues relating to prairie conservation are correspondingly distinctive, they deliver their own PCAPs in a slightly different fashion. We will present some of the key partners working individually and collaboratively from each province and highlight some of their contributions to prairie conservation. See *Figure 1* for a representation of the three prairie provinces of Canada and the ecoregions of the prairie region of Canada and their extension into the United States of America.

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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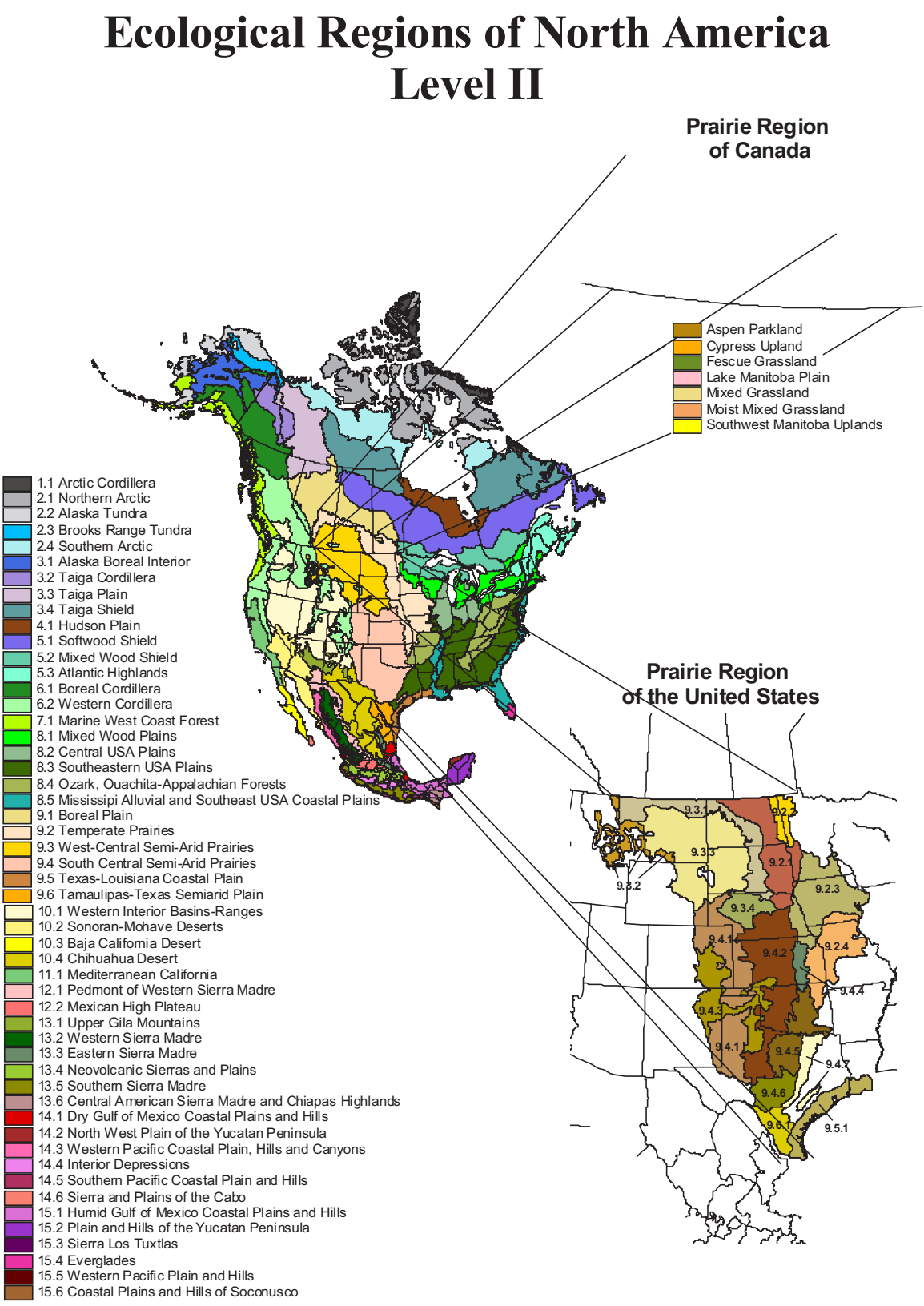

Figure 1— The prairie provinces of Canada and ecoregions of the prairie region of Canada and the United States. Map produced by Canadian Plains Research Centre, Regina, Saskatchewan. Map produced by Canadian Plains Research Centre, Regina, Saskatchewan, Canada.

Manitoba

The grassland region of Manitoba covers approximately 14,700 km^2. This area in the southwest part of the province consisted mainly of aspen parkland and mixed grass prairie. Native vegetation remains on less than 18 percent of that original landbase. The tallgrass prairie, which formed the smallest component of grassland habitat in Manitoba and is restricted mainly to the Red River Valley floodplain, is now reduced to less than 0.1 percent of its original extent. Most of the remnant prairie habitat suffers from fragmentation, long-term idling, poor condition and degradation, and the invasion of shrubs, trees, and exotic species. These parcels of remnant prairie contain many of the rare and endangered species for that region.

In Manitoba, the PCAP theme is 'Identifying and Implementing Economic Activities That Go Hand in Hand with the Restoration and Maintenance of Healthy Prairie Ecosystems'. There were 36 partners that originally drafted the Manitoba PCAP. The partners contribute in various ways through programs delivered to public and private landowners and/or through the conservation and management of native prairie on their own land. The Manitoba Habitat Heritage Corporation (MHHC) works actively to preserve remaining prairie habitat through landowner conservation easements and land purchase. These partners continue to inventory and assess habitats in the mixed grass and tall grass ecozones of Manitoba. The Manitoba PCAP partners are involved with implementing landowner stewardship programs (for riparian and upland) and activities such as rotational grazing demonstrations in the mixed and tall grass zones to show the potential to maximize cover and reduce invasive species. In the tall grass zone the partners are involved in fire management to conserve and improve the condition of the native prairie. Much of the work in Manitoba is concentrated on land acquisition and management of remnant tallgrass prairie in the lower Red River Valley and development of conservation easements and stewardship agreements on mixed grass prairie in the southwestern portion of the province.

Saskatchewan

The grassland region of Saskatchewan covers approximately 241,000 km^2. This is divided into four ecoregions. Other than the Cypress Upland, which is a unique landscape that was not glaciated during the last glacial period, these regions are distributed from the northeast to southwest in the grassland region of Saskatchewan. The amount of native dominated prairie remaining in these ecoregions, respectively, is: Aspen Parkland (1.05 million ha, 12.9 percent of ecoregion), Moist Mixed Grassland (1.05 million ha, 15.5 percent), Mixed Grassland (2.70 million ha, 31.3 percent), and Cypress Upland (0.36 million ha, 71 percent) (Gauthier et al. 2002). About 21 percent (5.17 million ha) of the Saskatchewan grassland region remains as native prairie.

Saskatchewan's PCAP theme is 'The Native Prairie is To Be Sustained in a Healthy State in Which Natural and Human Values are Respected.' There are 23 partners in the Saskatchewan PCAP Committee, which is chaired by the Saskatchewan Stock Growers Association. The PCAP is unique as it is the first producer-led, multi-stakeholder funded coordination of native prairie programming in North America. An action-oriented plan, consisting of 85 actions that are tied to five goals, guides partner activities. The Committee meets three to four times per year. Progress is evaluated annually and communicated through the production of "Partner Updates" which consist of an inventory of Partner activities relative to each action, as well as a list of progress and shortfalls in Plan implementation. The current PCAP expires in the spring of 2003 and work is in progress to have a new Plan in place to ensure continuity. The partners contribute in various ways through programming delivered to public and private landowners and/or through the conservation and management of native prairie on their land. The PCAP office and paid manager work also to facilitate the coordination of the PCAP partners and to produce extension and education programs and materials. The PCAP has been effective in reducing or eliminating duplication of programs and activities, contributing to the development of effective, unified communication strategies, and identifying and addressing gaps in existing or proposed programs.

Some of the key partners and their activities include:

Saskatchewan Wetland Conservation Corporation (SWCC)

SWCC delivers wetland, native prairie, and riparian habitat programs in Saskatchewan. Through this partnership, the Corporation links agricultural, industry, and wildlife interest to land-use programming in Saskatchewan. The Corporation leads coordination of the North American Waterfowl Management Plan (NAWMP) activities in the province.

SWCC has inventoried and assessed over 5.5 million ha of prairie land in Saskatchewan, particularly in areas with a high degree of cultivation, although this has included 2.5 million ha in the Missouri Coteau. The Missouri Coteau is an elevated land feature that runs through southern Saskatchewan into North and South Dakota and has an above-average proportion of remnant native prairie. The Corporation has a number of programs to deliver stewardship activities, namely the

Riparian Stewardship Program and the Native Prairie Stewardship Program. Under the latter program they have signed up 500 volunteer landowners to conserve over 80,000 ha of native prairie. Moreover they produce numerous extension publications such as 'Managing Your Native Prairie Parcels,' 'Managing Saskatchewan Wetlands,' and the new 'Classification and Management of Riparian and Wetland Sites,' and 'Land Manager's Guide to Grassland Birds of Saskatchewan'.

Agriculture and Agri-Food Canada

The Prairie Farm Rehabilitation Administration (PFRA), a branch of Agriculture and Agri-Food Canada, was set up in response to the depression during the 1930's. They manage a significant portion of the remaining prairie in Saskatchewan and some areas of Manitoba and Alberta as federal pastures for grazing and biodiversity. Their lands total 930,000 ha with 84 percent still native prairie. They undertake periodic inventories and range condition assessments to monitor the condition and use of these lands.

The Semi-Arid Prairie Agriculture Research Station is undertaking research on native forages, grazing systems, and planted native mixes for grazing trials. They are investigating the use of native plants for conventional agriculture as well.

Saskatchewan Provincial Pasture Program

The provincial pasture program is operated under Saskatchewan Agriculture, Food, and Rural Revitalization. They manage a total of 325,000 ha of land, some of which was converted to tame forages. They manage 1 million ha of rangeland through grazing leases. They have modified these crown lease agreements to incorporate sustainable management and have recently placed conservation easements on a significant portion of this land so that it can not be broken. They provide landowner technical assistance through on-site visits and workshops and extension publications.

Nature Saskatchewan

Founded in 1949, this provincial non-government organization delivers programs addressing the conservation of species at risk and conservation of habitat through stewardship and easements. Through Operation Burrowing Owl, they have agreements with 460 landowners protecting habitat at 603 sites. This includes 22,594 ha on private land and 38,920 ha on public land. The Piping Plover (*Charadrius melodus*) is another major species of concern for this organization.

Native Plant Society of Saskatchewan (NPSS)

The NPSS has been instrumental in developing key resource materials on the conservation and evaluation of native prairie. They have an active membership and Coordinator and work to develop guidelines and encourage new policy and directives. Some of their publications include 'Native Seed Harvesting,' 'Saskatchewan's Native Prairie: Taking Stock of a Vanishing Ecosystem and Dwindling Resource,' and 'Acreage Living: A Conservation Guide for Owners and Developers of Natural Habitat'.

Saskatchewan Burrowing Owl Interpretive Centre (SBOIC)

The SBOIC delivers in-house tours and outreach programming on Burrowing Owls (*Athene cunicularia*) and issues affecting their conservation. The SBOIC features wild, captive, and imprinted owls and a 0.5-ha prairie restoration project. The SBOIC is a key delivery partner of the Owls and Cows Tour and the Eco-Extravaganza. Highly skilled interpretive staff use imprinted Burrowing Owls as a flagship species to effectively communicate the need for native prairie conservation and management to diverse audience groups.

Saskatchewan Environment (SE)

The provincial environment department operates a Representative Areas Network (RAN). They have incorporated 5.1 million ha of ecologically important lands (including holdings of many partners already mentioned) into these RAN sites. Through their Fish and Wildlife Development Fund they have secured 45,000 ha of wildlife habitat.

Saskatchewan Wildlife Federation (SWF)

The Habitat Trust Program, delivered by SWF, has secured over 20,000 ha of prairie and aspen parkland habitat. Over 90 percent of this habitat is natural.

Missouri Coteau Initiative

This Initiative is an example of attempts to coordinate and deliver a large-scale ecosystem landscape-planning program. Most of the large non-government conservation organizations are working in this region in southern Saskatchewan because one-third still remains as natural prairie. The Missouri Coteau is an important area for wildlife including many species at risk, waterfowl, shorebirds, grassland birds, and colonial waterbirds. Saskatchewan's cow-calf industry stewardship programs delivered by the partners strive to provide win-win benefits for wildlife and agriculture.

Table 1— *Area (1,000s of ha) of native prairie remaining in the four grassland ecoregions of Alberta and the breakdown between private and crown lands*[1]

	Mixed grassland	Moist mixed grassland	Northern Fescue	Foothills Fescue	Total
Crown land	1,694 (66%)	326 (57%)	264 (42%)	76 (17%)	2,361 (56%)
Private land	882 (34%)	248 (43%)	366 (58%)	360 (83%)	1,856 (44%)
Total	2,577 (54%)	574 (31%)	630 (40%)	436 (29%)	4,217 (43%)

[1]Total percentage is the proportion remaining of historic extent; percent private or crown land is the proportion of remaining prairie under that ownership type. The Commission on Economic Cooperation terms the Northern Fescue portion listed here as part of Aspen Parkland and the Foothills Fescue as Fescue.

Eco-Extravaganza and the Owls and Cows Tour

These outreach programs are organized by the PCAP Manager and delivered by several PCAP partners. Interactive games, skits, and songs are used to communicate information to K-6 students on prairie and riparian areas, species at risk stewardship, and the positive role played by the ranching industry in the conservation and management of native prairie. Teacher evaluations indicate extremely high levels of satisfaction with these programs. Target areas for programming are determined annually by the PCAP Office in consultation with delivery partners.

Four town-hall evening meetings are held annually at communities within the Eco-Extravaganza target area to promote and communicate information to landowners and land managers on stewardship programs offered by PCAP partners. The meetings feature presentations by various PCAP partner groups on their programs, displays, and publications. In their evaluations, participants indicated that they liked that non-government and government groups were working together with producers to communicate information of stewardship programs.

Alberta

The grassland region of Alberta covers approximately 97,000 km^2. The amount of native prairie remaining varies among the four grassland ecoregions (*table 1*). On average, 43 percent of the native prairie is remaining over the Alberta grassland region (excluding Parkland) totaling 4.2 million ha[1]. The proportion of native prairie remaining varies between private and public land (*table 1*).

[1]Unpublished database on file at Alberta Environment, Lethbridge, Alberta, Canada.

Alberta's focal theme is 'To Conserve the Biological Diversity of Native Prairie and Parkland Ecosystems for the Benefit of Current and Future Generations.' As in Saskatchewan, the partners in Alberta contribute in various ways through programming delivered to public and private landowners and/or through the conservation and management of native prairie on their land as well as education extension to the public at large. There are 43 partners in the Alberta Prairie Conservation Forum (PCAP Committee) with various subcommittees to tackle issues and needs. They have recently re-drafted their Prairie Conservation Action Plan for another five-year term. The Forum meets three times per year and the executive an additional time between each meeting. The Forum and its subcommittees produce numerous publications and public awareness materials, including Occasional Papers, on substantive broad topics, and Prairie Notes, discussing issues of the day.

Some of the key partners and their activities include:

Irrigation District (EID)

The EID delivers water for irrigation and domestic use and provides use of grasslands in a sustainable fashion. They are the largest private landowner in Alberta managing over 250,000 ha of land. Almost 80 percent of this land is native mixed grass prairie. Much of their wetland and grazing management is done in association with Ducks Unlimited Canada.

Alberta Conservation Association (ACA)

The ACA works with ranchers to develop principles of sound grazing management practices for the benefit of wildlife and their client's ranch.

Target areas and key projects include:

1. Milk River Ridge/Writing-On-Stone -68,000 ha
2. Special Area #4 – 29,000 ha
3. Pakowki Lake – 31,500 ha

They administer the Native Prairie Land Stewardship Program, previously known as the Sharp-tailed Grouse Habitat Program. They are working with landowners to develop range management plans and improvements are implemented on a cost-share basis.

Alberta Fish and Game Association – Operation Grassland Community (OGC)

OGC was developed in 1989 to provide stewardship and education to conserve native prairie habitat and wildlife, particularly species at risk. The OGC program grew from what was initially the Operation Burrowing Owl program and now provides community stewardship initiatives, on-farm planning workshops, and a youth education campaign. OGC is working with 220 landowners and has enrolled 23,000 ha of native prairie.

Alberta Riparian Habitat Management Project – 'Cows and Fish'

This project provides information to producers, resource managers, and the general public through presentations, field days, and workshops to promote an understanding of practical solutions to the management of riparian areas. They have consulted with over 22,000 people and given almost 400 presentations. Assessments of 1000 km of stream at over 800 sites have been made and they have undertaken an inventory and riparian health assessment with over 400 landowners. The staff of Alberta Public Lands working on this project has produced numerous well-received and used publications, handbooks, and other resource materials.

Southern Alberta Land Trust Society (SALTS)

The SALTS is a locally-based, rancher-driven, nonprofit organization dedicated to preserving the ecological, productive, scenic, and cultural value of Alberta's prairie and foothill regions. The Society developed to resist the pressures of urban development and to assist ranchers who wish to maintain the landscape in active working ranches. It includes an education program to inform urban populations of the value of natural landscapes and the ecological and social costs of urban expansion.

Special Areas

The Special Areas Act was passed in Alberta in 1938. This allowed the provincial government to lease out tax-recovery land and crown lands, to provide municipal services, and to undertake programs to rehabilitate the land for the betterment of the residents of the Special Areas. These areas encompass 2.1 million ha of which 60 percent is native prairie. The entire native prairie on this land has been protected by law from breaking.

Oil and Gas Producers and Regulators

There has been, and continues to be, considerable activity in this industry and their activities do result in disturbance on the remaining native prairie. The energy sector has made significant strides to minimize the impact of their activities upon native prairie.

Region-Wide

Nature Conservancy of Canada (NCC)

The NCC protects ecologically sensitive lands in the Manitoba, Saskatchewan, and Alberta grassland natural regions. Important habitat for waterfowl, grassland birds, shorebirds, colonial waterbirds, species at risk, and other wildlife species through a number of securement techniques such as land purchase and conservation easements. The NCC initiated work in the grassland region of Alberta in spring 2001. They have completed two projects securing and managing 4,500 ha and are currently working with seven landowners managing 8,000 ha. They are focused on three landscape areas: Cypress Uplands, Sage Creek Uplands, and the Milk River Ridge.

Ducks Unlimited Canada (DUC)

DUC is a major deliverer of wetland conservation and waterfowl management programs on the prairies. They lead delivery of NAWMP but work on other bird and prairie conservation initiatives as well. DUC works with private and public landowners to develop long-term agreements for integrated wildlife and range management plans. Projects focus on water control structures and installing fencing and stock watering systems to improve rotational grazing systems.

In Saskatchewan project areas are concentrated in the Missouri Coteau, Allan Hills, and landscapes in northwest Saskatchewan. Examples of Alberta DUC projects include:

1. Contra Costa Project – located east of Brooks, AB on EID land:
   - 30,800 ha of native prairie
   - 3,000 ha of managed irrigation-fed wetlands
2. Cameron Project – located east of Vauxhall, AB on Crown land:
   - 23,500 ha of native prairie
   - 400 ha of managed irrigation-fed wetlands

DUC is re-drafting its strategic plan for southern Alberta to concentrate their conservation efforts on the Northern Pintail (*Anas acuta*). They wish to achieve no net loss of native prairie in the important pintail breeding areas. This area includes 1.1 million ha that DUC will attempt to secure over the next 25 years.

Environment Canada - Canadian Wildlife Service

As a regional federal PCAP partner, the Canadian Wildlife Service (CWS) is involved in many PCAP activities on federal land and in collaboration with other partners. CWS provides a representative to act as a liaison among the provincial PCAP Committees. As a Department, Environment Canada works on protection, securement, and restoration of wildlife habitat by supporting a number of initiatives such as Partners in Flight, NAWMP and its Prairie Habitat Joint Venture, the Species at Risk Habitat Stewardship Program, EcoAction, and other federal government conservation programs. They are the lead department in implementation of the Migratory Bird Convention Act, Canadian Environmental Assessment Act, and the Species at Risk Act. Also, they manage habitat including National Wildlife Areas (NWA) and Migratory Bird Sanctuaries (MBS). In Alberta there are three NWAs (376 ha) but a fourth NWA at Canadian Forces Base Suffield (45,800 ha) is proposed and there are four MBSs (14,150 ha); Saskatchewan has eight NWAs (21,348 ha) and 14 MBSs (61,461 ha); Manitoba has two NWAs (63 ha) and no MBSs. These are key sites for the demonstration of prescribed burning, ecological grazing, and the restoration of prairie habitat, including wild-harvesting and production of native seed stocks. CWS produces numerous resource publications and undertakes research and monitoring on a wide variety of migratory birds, species at risk, and key habitats.

There are many successes from the PCAP process and reasons for continuing the broad-based partnership of prairie stakeholders and collaborative communication provided by PCAP Committee and Forum round-table gatherings. These include:

1. PCAP partners manage a significant portion of the remaining native prairie and are working with private landowners on much of the rest,

2. Increased awareness and appreciation for the value of native prairie and the need for conservation,

3. Create and maintain a positive working relationship among the partners across all sectors, and

4. Work by consensus that has facilitated communication and increased collaboration and coordination among the native prairie stakeholders.

Consensus among stakeholders may be difficult at times, but the PCAP process builds a strong foundation of trust and is one that could be used successfully in many other landscapes and ecoregions.

Acknowledgments

We thank the PCAP partners in Alberta, Saskatchewan, and Manitoba for most of the material and information, including images used in the original oral presentation. D. Gauthier, Canadian Plains Research Centre, University of Regina, provided maps used in the presentation and the statistics on grassland habitat. Alberta Environment arranged for use of the Alberta Native Prairie Vegetation Baseline Inventory. A. Hammermeister assisted with the oral presentation and also provided graphics. Finally, we thank K. Scalise – PCAP Manager – for reviewing the paper and for providing information on PCAP Saskatchewan.

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Monitoring as a Means to Focus Research and Conservation - The Grassland Bird Monitoring Example[1]

Brenda Dale,[2] Michael Norton,[2] Constance Downes,[3] and Brian Collins[3]

Abstract

One recommendation of the Canadian Landbird Monitoring Strategy of Partners in Flight-Canada is to improve monitoring capability for rapidly declining grassland birds. In Canada, we lack statistical power for many grassland species because they are detected in small numbers, on a low number of routes, or show high year-to-year variability. In developing a Grassland Bird Monitoring program we focused our efforts on improving coverage of "at risk" and endemic grassland species by intensifying coverage of Breeding Bird Survey type routes within degree blocks where grassland is still relatively common. To evaluate the Grassland Bird Monitoring data, collected from 1996 through 2000, we compared values to those collected by the Breeding Bird Survey during the same time period. Adding random routes inside the core of grassland bird distribution had a number of positive results. New routes averaged 48 percent grassland coverage and 36 percent crop coverage while Breeding Bird Survey routes averaged 70 percent cropland. The number of routes available for analysis increased by more than 25 percent for eight of ten primary and two of ten secondary target grassland birds. The number of birds per route was higher for eight of ten primary species. We collected simple habitat information and determined that, for many of the species, only a small proportion of available grassland was used (Baird's Sparrow [*Ammodramus bairdii*], 36 percent; McCown's Longspur [*Calcarius mccownii*], 8.5 percent). A substantial proportion of detections for some bird species were in crop where successful reproduction is unlikely. For McCown's Longspur the proportion varied from 19.4 to 41.8 percent during the five-year study. Trends from Grassland Bird Monitoring routes were more positive than Breeding Bird Survey trends for the same time period for 12 of 18 species. For four of ten primary target species (Sprague's Pipit [*Anthus spragueii*], Baird's Sparrow, Lark Bunting [*Calamospiza melanocorys*], and McCown's Longspur) declines on Grassland Bird Monitoring routes were more dramatic than those from Breeding Bird Survey. This may indicate that habitat quality, as well as quantity, is an issue or that additional productivity or wintering ground issues are affecting populations of these species. The Grassland Bird Monitoring pilot study demonstrates the program's present and future utility for improving monitoring power while focusing conservation and research.

Key words: Baird's Sparrow, Breeding Bird Survey, conservation, grassland, grassland birds, McCown's Longspur, monitoring, Sprague's Pipit, trends.

Introduction

Effective conservation requires surveys able to identify declines and track recovery; carefully directed research; and conservation efforts that focus on prevention or reversal of conditions associated with declines. A well constructed monitoring program may be able to contribute to all three of these elements.

Begun as an internal plan to guide the Canadian Wildlife Service's (CWS) efforts to support worthwhile volunteer monitoring, the Canadian Landbird Monitoring Strategy (CLMS) was revised and adopted by Partners in Flight—Canada as its monitoring strategy (Downes 1994, Downes et al. 2000). Its goals are ambitious:

- Monitor the status of all Canadian landbirds;
- Make the information available, and encourage its use for research and conservation.

The basis for the CLMS is the "Integrated Monitoring" concept of the British Trust for Ornithology (Baillie 1990). A variety of monitoring activities are coordinated, and the results integrated (i.e. looked at together bearing in mind the ecology and life history of the species) to try and understand what element(s) of population dynamics are associated with population change. Research efforts are directed to precisely determine the cause of the decline and the means to reverse it. In some cases, integrated monitoring may even be

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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able to suggest initial means of conservation without further research. To be effective, an integrated monitoring system needs to collect information on distribution, relative abundance and trend, habitat association, and trends in habitat, productivity, and survival.

The CLMS first identified volunteer monitoring programs that had the potential to deliver one or more of the five components (distribution, trends, survival, productivity, and habitat) at a regional or national scale, and focused efforts on supporting and improving them. Another early step was to identify gaps and weaknesses. The CLMS identified grassland birds as a group that required improved monitoring coverage (Downes 1994). As of 1991 approximately 75 percent of grassland in prairie Canada had been converted to crop land (Statistics Canada 1992). Habitat loss continues with 570,000 ha (approximately 6 percent of what remained in 1991) lost in prairie Canada between 1991 and 1996 (Statistics Canada 1997). Grazing intensity on the remaining grassland often varies with market prices rather than the amount of forage available (Gayton 1991). Birds using this declining, and intensively used habitat, were a logical priority for improved monitoring efforts.

The primary North American landbird monitoring tool is the volunteer-based Breeding Bird Survey (BBS) which was established in 1966 and is managed by the U.S. Geological Survey (USGS) in the United States and by the CWS in Canada. It is a roadside survey with routes chosen using a stratified random design. The BBS shows that grassland birds are declining more rapidly than any other group of birds in North America (Sauer et al. 2000). However, BBS trends for individual grassland bird species, particularly "at risk" (listed by the Committee on Endangered Wildlife in Canada) or endemic (restricted to) species (*table 1*), are not always statistically significant ($P < 0.05$) even when the magnitude of the trend is substantial. Many grassland bird species occur on few BBS routes, occur in low numbers per route or show high year-to-year fluctuations in numbers. Any or all of these conditions can result in a low statistical power to detect a trend.

When the BBS was initiated two BBS routes were selected per degree block within the three prairie provinces. Remaining areas of extensive grassland in Canada are concentrated in a relatively small area and contain a minority of existing BBS routes in the prairies. Sparse survey coverage in the areas of highest grassland bird density means we have little information about species within the core of their population distribution.

In our Grassland Bird Monitoring (GBM) pilot study we tested means to make volunteer monitoring coverage in Canadian prairie grassland more effective for detecting trends and directing conservation of target grassland birds (*table 1*) by:

- Increasing monitoring coverage within that portion of the prairie provinces where remaining grassland habitat and grassland birds are concentrated;
- Collecting habitat information;
- Comparing bird occurrence and trend data from GBM to BBS data collected during the same period.

Table 1—*Target species of grassland bird monitoring.*

Primary[1]	Secondary[2]
Ferruginous Hawk (*Buteo regalis*)	Swainson's Hawk (*Buteo swainsoni*)
Long-billed Curlew (*Numenius americanus*)	Sharp-tailed Grouse (*Tympanuchus phasianellus*)
Marbled Godwit (*Limosa fedoa*)	Upland Sandpiper (*Bartramia longicauda*)
Burrowing Owl (*Speotyto cunicularia*)	Horned Lark (*Eremophila alpestris*)
Loggerhead Shrike(*Lanius ludovicianus*)	Clay-colored Sparrow (*Spizella pallida*)
Sprague's Pipit	Brewer's Sparrow (*Spizella breweri*)
Lark Bunting	Vesper Sparrow (*Pooecetes gramineus*)
Baird's Sparrow	Savannah Sparrow (*Passerculus sandwichensis*)
McCown's Longspur	Grasshopper Sparrow (*Ammodramus savannarum*)
Chestnut-collared Longspur (*Calcarius ornatus*)	Western Meadowlark (*Sturnella neglecta*)

[1]Primary species are either considered "at risk" grassland species by the Committee on the Status of Endangered Wildlife in Canada or primary grassland endemics (restricted to Great Plains [Mengel 1970]).
[2]Secondary species are all secondary endemics (grassland birds that also occur outside the Great Plains [Mengel 1970]).

Methods

Rather than develop a new survey method, we chose to simply intensify use of existing BBS methodology. BBS is a well designed survey using a stratified random design for routes and a standardized protocol that controls for many of the factors (observer, weather, time of day and year) that influence detectability of birds. The BBS recently underwent peer review that confirmed its scientific strength (O'Connor et al. 2000). We collected data for multiple seasons to allow the calculation of trends and a more thorough assessment of the GBM's usefulness.

Study Area

The pilot study took place in 19 degree blocks in southeast Alberta and southwest Saskatchewan where grassland is still reasonably common (*fig. 1*).

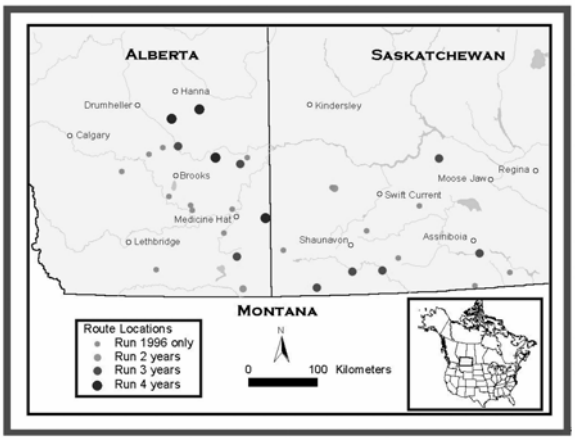

Figure 1—Locations of Grassland Bird Monitoring routes in southern Alberta and Saskatchewan.

Routes

In 1996 we followed BBS guidelines and randomly chose 35 GBM routes in southeast Alberta and southwest Saskatchewan. We modified the BBS route selection protocol slightly and accepted the nearest passable road, rather than the nearest secondary (or better) road. Routes were checked in the field before surveying and, if access was a problem, then routes were adjusted to the next nearest usable segment of road in keeping with BBS route selection procedures. Some individual stop locations were shifted by 0.1 km, in accordance with BBS guidelines, when noise levels from gas line compressor stations were deemed unacceptably high. In the initial year (1996) we attempted to collect data on all 35 routes but were unable to do so. In subsequent years we only surveyed routes which had been attempted in 1996. Thirty-one routes were surveyed in 1996, and 7-13 routes were completed in each of the other years. Seventeen routes were visited only once. Fourteen routes were surveyed two or more times (four surveyed 4 times, eight 3 times, and two 2 times - *fig. 1*).

Two observers conducted surveys in each year 1996-1998; no surveys were done in 1999 and only a single observer was available in 2000. Each observer was assigned routes from both Alberta and Saskatchewan. The observer changed for several routes between 1996 and 1997.

Data Collection

Bird data were collected in the identical manner as for the BBS, using a single observer, 3-minute point counts, and 400-m radius circles. We adhered to the weather standards and recorded weather parameters using the BBS system and codes. Start times were those applicable for BBS in the degree block in which the GBM route occurred.

We used a global positioning system (GPS) to record the exact location of each stop. We visually estimated the proportion of a number of crude habitat classes present within 400 m radius at each stop along the route in 1996 or 2000. Habitat classes included: Native Grass, Non-native Grass, Hay, Unclassified Grass (grass that could not be clearly assigned to one of the first three categories), Crop (includes both growing and fallow fields), Water, Settlement (farm yards, towns), Industry, and Other (trees, cliffs, badlands, and other rare habitats).

Trend Calculations

Fitted trends for the period 1996-2000 were calculated using an estimating equations approach (Link and Sauer 1994, Collins 2000) for GBM alone, BBS alone, and GBM and BBS combined.

GBM alone

Data for all 14 GBM routes surveyed at least twice between 1996 and 2000 were used. Any incomplete route (<50 stops) was reduced, in all years, to the number and identity of stops completed in the shortest incomplete survey.

BBS alone

Data from 91 BBS routes from the Canadian portion of Bird Conservation Region 11 for 1996-2000 were used. This included BBS routes from the same degree blocks as GBM routes. The weighting factors normally used to balance for inequality in sampling effort among degree blocks were not employed. To increase sample size, the selection and matching criteria used for the standard BBS analysis were ignored. Routes were included no matter what wind conditions they were run under. The

criterion that routes are run by the same observer each year was suspended. A route was included in the trend analysis for a species if it had at least two non-zero counts for that species.

Data Comparisons

The number of BBS and GBM routes in the above-mentioned data sets on which each species occurred at least twice was calculated. The percent increase in coverage (number of routes useable in trend analysis) brought about by GBM in the period 1996 to 2000 was calculated for each target grassland bird species.

The fourteen GBM routes surveyed at least twice between 1996 and 2000 were compared with 91 BBS routes from the same period in BCR 11 for three parameters:

1. The proportion of routes which were useful for trend analyses (i.e. at least two non-zero counts) of target species were compared using a two-sided Fisher's Exact Test;

2. The average count of individual species per survey stop (on routes where the species was encountered) was compared using a randomization test (Sokal and Rohlf 1981). Because several GBM routes were incomplete in some years we used average count per stop rather than birds / route in order to increase comparability;

3. The fitted trends were compared using a randomization test (Sokal and Rohlf 1981).

Habitat Calculations

All habitat variables were summarized for each route attempted at least once, and across all routes. Minimum, maximum, and mean coverage per route and standard error for each variable were calculated.

A simple frequency of occurrence was calculated for each species out of a maximum possible number of stop-visits for three habitat types. All routes (including incomplete and those attempted once), and all years of data were pooled, so stops surveyed in multiple years were included more than once in this summary. From this data pool we considered only stops with 100 percent Native Grass or 100 percent Total Grass, or 100 percent Crop. Stops with 95 percent Crop and 5 percent Settlement were treated as 100 percent Crop. Only species presence or absence was considered.

We calculated the proportion of birds occurring in two major habitat types (crop and grassland) for two bird species known to make use of crops. All detections for each of Baird's Sparrow and McCown's Longspur were extracted from the pool of complete and incomplete routes. Each individual detected was assigned to either grass or crop habitats according to the habitat data collected in 1996 or 2000. Birds detected at stops with a mix of grass and other habitats were assigned to grass unless notes on the data sheet indicated otherwise (one observer - BCD - consistently noted which habitat was used in mixed habitat situations). For each species, the proportion of birds in grass and crop habitat was totaled for each year and proportions were compared across the four years of data collection using Chi-square tests. The analysis was run twice: once including all routes surveyed and again excluding those routes which were only surveyed once.

The size of native grass habitat blocks on GBM routes was estimated based on the number of consecutive stops with 100 percent native grass. We then calculated frequency of occurrence of block sizes.

Results

Comparison to BBS

GBM increased the number of routes available for analysis over BBS for most target species (*table 2*). Burrowing Owl and Sharp-tailed Grouse (not shown in tables) were detected on several GBM routes but never on the same route twice. Not all target species were recorded in two or more years on every route but the increase in number of routes was still considerable.

The proportion of routes available for trend analysis was significantly larger for GBM routes than for BBS routes for 11 out of 18 species (*table 3*), including seven of nine tested primary grassland species. One additional primary species (Loggerhead Shrike) approached significance.

The average count per stop on GBM routes was non-significantly higher than BBS for six species and significantly larger for seven species, including four of nine tested primary target species (*table 4*). BBS had significantly higher counts for two species and was non-significantly higher for three other species.

Trends calculated from the BBS and GBM data sets yield different results (*table 5*). The trend was more positive (showed a larger positive trend or a smaller negative trend) for GBM than for BBS for 11 species but most trend differences were not significant. The GBM trend was significantly more positive for Long-billed Curlew ($P = 0.030$) and the BBS trend was significantly more positive for Savannah Sparrow ($P = 0.028$) and Lark Bunting ($P = 0.018$).

Table 2— *Number of Grassland Bird Monitoring and Breeding Bird Survey routes on which target grassland species were observed on two or more years.*

Species	GBM (N = 14)	BBS (N = 91)	Percent increase in coverage
Swainson's Hawk	14	59	23.7
Ferruginous Hawk	**4**	**11**	**36.4**
Upland Sandpiper	7	34	20.6
Long-billed Curlew	**8**	**17**	**47.1**
Marbled Godwit	**13**	**58**	**22.4**
Loggerhead Shrike	**7**	**25**	**28.0**
Horned Lark	14	69	20.3
Sprague's Pipit	**14**	**31**	**45.2**
Clay-colored Sparrow	13	91	14.3
Brewer's Sparrow	8	2	400.0
Vesper Sparrow	14	86	16.3
Lark Bunting	**6**	**10**	**60.0**
Savannah Sparrow	14	90	15.6
Grasshopper Sparrow	7	9	77.8
Baird's Sparrow	**13**	**28**	**46.4**
McCown's Longspur	**6**	**9**	**66.7**
Chestnut-collared Longspur	**12**	**20**	**60.0**
Western Meadowlark	14	81	17.3

Notes: Primary target species appear in bold.

Table 3—*Proportion of Grassland Bird Monitoring and Breeding Bird Survey routes on which target species were observed in two or more years.*

Species	GBM (N = 14)	BBS (N = 91)	P value
Swainson's Hawk	100	65	0.009
Ferruginous Hawk	**29**	**12**	**> 0.200**
Upland Sandpiper	50	37	> 0.200
Long-billed Curlew	**57**	**19**	**0.004**
Marbled Godwit	**93**	**64**	**0.033**
Loggerhead Shrike	**50**	**27**	**0.119**
Horned Lark	100	76	0.001
Sprague's Pipit	**100**	**34**	**< 0.001**
Clay-colored Sparrow	93	100	> 0.200
Brewer's Sparrow	57	02	< 0.001
Vesper Sparrow	100	95	> 0.200
Lark Bunting	**43**	**11**	**0.007**
Savannah Sparrow	100	99	> 0.200
Grasshopper Sparrow	50	10	< 0.001
Baird's Sparrow	**93**	**31**	**< 0.001**
McCown's Longspur	**43**	**10**	**= 0.005**
Chestnut-collared Longspur	**86**	**22**	**< 0.001**
Western Meadowlark	100	89	> 0.200

Notes: Primary target species appear in bold.

Table 4—*Number of target species counted per stop for Grassland Bird Monitoring and Breeding Bird Survey routes.*

Species	No. / GBM stop	No. / BBS stop	P value
Swainson's Hawk	0.051	0.053	> 0.200
Ferruginous Hawk	**0.019**	**0.040**	**> 0.200**
Upland Sandpiper	0.050	0.072	> 0.200
Long-billed Curlew	**0.191**	**0.173**	**> 0.200**
Marbled Godwit	**0.175**	**0.125**	**> 0.200**
Loggerhead Shrike	**0.055**	**0.037**	**> 0.200**
Horned Lark	1.446	0.750	0.011
Sprague's Pipit	**0.613**	**0.165**	**< 0.001**
Clay-colored Sparrow	0.373	0.656	0.011
Brewer's Sparrow	0.116	0.045	> 0.200
Vesper Sparrow	0.861	0.516	0.001
Lark Bunting	**0.372**	**0.183**	**0.048**
Savannah Sparrow	0.546	0.865	0.031
Grasshopper Sparrow	0.103	0.063	> 0.200
Baird's Sparrow	**0.365**	**0.105**	**< 0.001**
McCown's Longspur	**0.281**	**0.105**	**0.022**
Chestnut-collared Longspur	**0.732**	**0.523**	**> 0.200**
Western Meadowlark	1.799	0.904	0.003

Notes: Primary target species appear in bold. Only routes where target species were recorded are included.

Table 5—*Trends for target species in the period 1996-2000 for GBM alone, BBS alone, and the two surveys combined.*

Species	GBM trends (95% confidence)	BBS trends (95% confidence)	Combined trends (95% confidence)
Swainson's Hawk	0.5 (-14.0, 17.4)	-6.9** (-13.0, -0.3)	-6.4** (-12.1, -0.2)
Ferruginous Hawk	**11.0 (-39.4, 103.3)**	**4.8 (-21.0, 39.1)**	**6.9 (-14.2, 33.0)**
Upland Sandpiper	-1.5 (-20.3, 21.6)	3.8 (-7.1, 15.9)	2.5 (-7.5, 13.6)
Long-billed Curlew	**22.3 (-1.6, 51.9)**	**-0.1 (-16.9, 20.2)**	**7.3 (-5.8, 22.3)**
Marbled Godwit	**5.1 (-14.8, 29.6)**	**-8.0* (-16.3, 1.1)**	**-3.7 (-11.9, 5.1)**
Loggerhead Shrike	**1.1 (-21.4, 30.2)**	**-2.9 (-21.1, 19.5)**	**-1.5 (-14.6, 13.7)**
Horned Lark	-5.5* (-11.3, 0.7)	-12.3** (-15.7, -8.8)	-11.0** (-13.9, -7.9)
Sprague's Pipit	**-6.6 (-19.0, -7.6)**	**5.3 (-6.1, 18.1)**	**-0.7 (-10.5, 10.2)**
Clay-colored Sparrow	0.9 (-5.3, 7.5)	-0.5 (-3.2, 2.2)	-0.4 (-2.8, 2.2)
Brewer's Sparrow	-3.7 (-48.2, 79)	-28.1 (-42.7, -9.7)	-3.4 (-43.9, 66.4)
Vesper Sparrow	0.4 (-5.1, 6.1)	1.1 (-2.2, 4.5)	0.8 (-1.7, 3.4)
Lark Bunting	**5.2 (-43.2, 94.9)**	**90.5** (51.3, 139.8)**	**40.5** (2.4, 92.8)**
Savannah Sparrow	-6.1 (-13.2, 1.7)	-0.1 (-2.5, 2.5)	-0.4 (-2.6, 1.9)
Grasshopper Sparrow	-11.2 (-34.4, 20.4)	-16.4 (-59.8, 73.7)	-12.2 (-36.6, 21.7)
Baird's Sparrow	**-23.8** (-31.5, -15.2)**	**-9.8 (-23.1, 5.8)**	**-19.3** (-26.9, 11.1)**
McCown's Longspur	**-23.4 (-62.5, 56.4)**	**-17.6 (-35.7, 5.6)**	**-20.2 (-39.9, 5.8)**
Chestnut-collared Longspur	**-10.0* (-18.8, -0.2)**	**-19.0** (-31.9, -3.5)**	**-17.2** (-26.8, -6.3)**
Western Meadowlark	4.0 (-0.5, 8.6)	3.1* (-0.4, 6.8)	3.3** (0.4, 6.3)

Notes: Trends represent change/yr
Sample sizes for each species, by survey, are in *table 2*.
Primary target species are shown in bold.

* $0.05 < P < 0.20$

** $P < 0.05$

Table 6— *Summary of percent habitat coverage on 31 GBM routes.*

Habitat	Minimum cover	Maximum cover	Mean	SE
Native Grass	12.4	93.51	48.00	4.67
Non-native Grass	0	21.60	4.51	0.96
Hay	0	37.80	6.62	1.52
Unclassified Grass	0	17.49	2.66	0.89
Total Grass	22.90	100.00	61.79	4.74
Crop	0	77.10	35.56	4.80
All Other	0	13.40	2.65	0.53

Table 7— *Mean proportion of stops covered entirely by native grass, all grass, and crop where target species occurred.*

Species	Native grass	All grass	Crop
Swainson's Hawk	4.62	4.51	3.29
Ferruginous Hawk	**0.77**	**0.71**	**0.00**
Upland Sandpiper	3.08	3.72	0.33
Long-billed Curlew	**16.05**	**15.49**	**4.61**
Marbled Godwit	**20.41**	**19.56**	**6.91**
Loggerhead Shrike	**0.64**	**1.15**	**0.33**
Horned Lark	59.82	59.91	93.42
Sprague's Pipit	**67.91**	**62.92**	**2.63**
Clay-colored Sparrow	25.42	27.79	15.46
Brewer's Sparrow	7.96	7.43	0.99
Vesper Sparrow	58.54	60.62	53.62
Lark Bunting	**5.39**	**7.08**	**14.47**
Savannah Sparrow	46.34	46.64	54.93
Grasshopper Sparrow	6.68	9.29	0.33
Baird's Sparrow	**36.59**	**34.87**	**18.42**
McCown's Longspur	**8.47**	**7.26**	**24.34**
Ch.-collared Longspur	**45.44**	**43.36**	**9.54**
Western Meadowlark	92.04	93.36	63.16

Notes: Primary target species appear in bold

Table 8— *Proportion of observations of Baird's Sparrow and McCown's Longspur in grass and crop, by year.*

	Baird's Sparrow		McCown's Longspur	
Year	Grass	Crop	Grass	Crop
1996	90.4	9.6	58.2	41.8
1997	95.2	4.8	75.4	24.6
1998	92.0	8.0	80.6	19.4
2000	100.0	0.0	75.8	24.2

Habitat

Most of the 31 GBM routes, surveyed at least once, were dominated by grassland (*table 6*). Native grass made up almost half the coverage and varied from as little as 12 percent on some routes to almost 94 percent on others. Crop averaged less than 36 percent of cover. Only Horned Lark, Lark Bunting, Savannah Sparrow, and McCown's Longspur were seen more often at crop sites than grassland sites (*table 7*). Western Meadowlark commonly used crop as well as a high proportion of grassland sites. The proportion of available grassland utilized by other target species varied from less than 1 percent (Ferruginous Hawk) to almost 68 percent (Sprague's Pipit).

Up to about 10 percent of Baird's Sparrow and nearly 42 percent of McCown's Longspurs were found in crop

habitats (*table 8*). The first year of the study had the highest proportion of these two species seen in crop. The proportion of birds seen in crop on all routes varied significantly among years (χ^2 test, P = 0.0056 for Baird's Sparrow and P = 0.0007 for McCown's Longspur). The pattern was the same when we made similar calculations using only those routes sampled in two or more years.

The distribution of 100 percent native grass block sizes along GBM routes was extremely skewed (*fig. 2*) with many blocks representing a quarter-section of land (one stop) and only a few very large blocks. The largest blocks were of 25 consecutive stops; these blocks would represent areas of native grass of a minimum of 6.25 sections of land. Although the number of large blocks is low, more than half the survey stops were in blocks larger than two legal sections in extent.

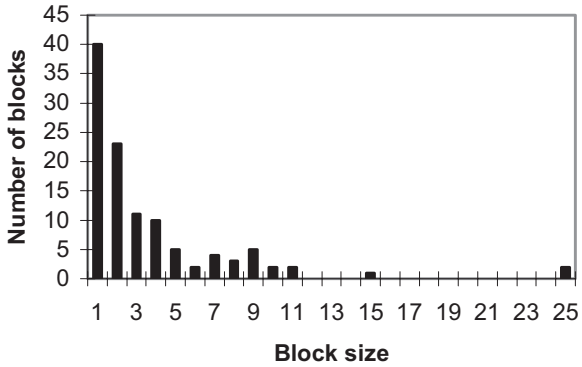

Figure 2— Frequency distribution of native grass block sizes represented on GBM routes. Block size is expressed as the number of consecutive survey stops located in 100 percent native grass habitats (one stop surveys an area roughly equivalent to one quarter section of land).

Discussion

Sources of Bias

We removed the route selection criteria for secondary roads but do not feel this is a source of bias. The original intent of BBS methodology in requiring secondary roads was to ensure roads would be passable in bad weather. In the prairies almost any road is passable in dry weather and even secondary roads may be impassable following rain. BBS exclusion of tertiary roads may have under-sampled remaining large blocks, which have fewer secondary roads (Droege 1990).

We dropped the requirement that the observer remain the same, and the restriction on wind conditions when accepting routes for analysis. Wind conditions were unacceptable, according to BBS standards, on only two GBM route/yr combinations but excluding those combinations would have reduced our already small sample size. Using counts from different observers and less than ideal conditions does increase between year variance and thus confidence intervals but should not bias population trends unless the occurrence of bad weather conditions was systematic, which it was not.

Comparisons here do not take into account degree block weighting factors which are used in standard analysis of BBS in Canada, but this should not bias the results because the number of GBM routes was evenly distributed across the sampled degree blocks. Dropping the weighting made our analysis more similar to that employed by the USGS, which does not normally weight routes to equalize the contribution of blocks to the trend.

Comparison to BBS

The pilot phase of GBM has shown the following improvements over BBS alone for target grassland species: an increase in the number of routes on which a species is detected, an increase in the proportion of routes suitable for use in trend calculation, and an increase in the number of individual birds per species detected.

The improvement in number of routes exceeds 25 percent for two secondary (Brewer's and Grasshopper Sparrows) and all but one (Marbled Godwit) primary target species; the increase was less for some of the more widespread secondary target species (*table 2*). These are conservative estimates of potential increase in survey coverage through GBM, since only 14 routes were run two or more times in the pilot phase. Some may argue that simply adding more BBS routes throughout BCR 11 would similarly increase power. An earlier phase of the GBM pilot study ran a series of "empty" (created but unassigned BCR 11 BBS routes) and gained very few additional records of target species.[1] The increase in routes useable for analysis is largely a result of adding additional random routes in degree blocks in the core of grassland and grassland bird distribution.

The higher proportion of GBM routes with target species (*table 3*) confirms that in areas with a higher percentage of grassland habitats there is a greater probability of detecting target species with each additional route surveyed. Proportion of routes, a second component of the statistical power of trend analyses, can thus be improved for most target species through implementation of GBM.

A third element of statistical power for trend detection (higher counts per stop) can be delivered by GBM

[1]unpublished data, B. Dale, Canadian Wildlife Service, Edmonton, Alberta.

(*table 4*). The higher number of individuals of target species also suggests that GBM may be providing coverage of the higher density portion of these species' distributions.

We emphasize that the trends themselves (*table 5*) are of less importance than the fact that the trends from the two surveys differ. The trends should be interpreted with caution. Trends for a short period from any survey may reflect short-term fluctuation rather than long-term trend. This is particularly true for many grassland species that respond to temporary weather related habitat conditions and other stochastic events.

The GBM trend was more negative than the BBS trend for five species including three species - Sprague's Pipit, Baird's Sparrow and Lark Bunting - whose populations tend to fluctuate greatly depending on precipitation levels. Precipitation levels declined during our pilot study period. Should a pattern of population decline, even where habitat is common, continue over a longer term then we must consider the possibility that the decline is being driven by productivity issues or problems during migration or winter.

It is not surprising that grassland species might be either increasing, or declining less steeply, in that portion of the landscape where grass is still relatively common, and which was the focus of the GBM pilot project. The BBS and GBM surveys may be tracking different portions of populations, or trends may differ between habitats, or some species may be undergoing range contractions. The difference in trends suggests that a standard analysis of BBS data *alone* may not provide sufficient information to determine grassland species trends. BBS appears to be sampling habitats in proportion to their occurrence in the landscape but the current number of active BBS routes is low in the small, less modified portion of the prairies with higher grassland bird abundance. GBM provides greater detail in this important portion of the range of many grassland bird species. Thus, the combined trend (*table 5*) may better describe what is happening to the entire population during this five year period.

The GBM pilot study resulted in significant improvement in the three elements (number of routes, proportion of routes, and birds/route) necessary to improve statistical power for monitoring eight of nine primary grassland species and seven of nine secondary species. Data for one primary and one secondary species (Burrowing Owl and Sharp-tailed Grouse) were insufficient to be tested. Our findings are consistent with those of Cochrane and Oakleaf (1982), who determined that BBS methodology was suitable to detect Long-billed Curlews but would require a great increase in the number of random routes to adequately monitor curlew population trends.

The different size of trends on GBM compared to BBS seems to indicate that trends in core areas (GBM) may differ from those calculated from the landscape as a whole (BBS). Separate and combined trends will add to our understanding of bird populations and their dynamics. It may allow us to target research and conservation more effectively. Certainly GBM route data should remain separate from the BBS data as a whole until this relationship is better understood.

Habitat

The frequency of grass and crop habitats on GBM (*table 6*) is very different from BBS routes. A recent study based on interpreted satellite imagery found about 70 percent of coverage on Canadian prairie BBS routes was cropland.[2] Because we have geo-referenced location, habitat, and bird information for each stop along the GBM routes the potential exists to calculate population trends by habitat type as determined by either ground or satellite surveys.

Knowledge about which habitats are used on a broad scale (*table 7*) supplements species or site-specific studies and provides information about habitat preferences which may assist us to understand bird population trends. Habitat specialists like Brewer's Sparrow, which need sage or other brush as well as grassland, used only 8 percent of available native grass sites. McCown's Longspur, which needs the shortest cover in the grassland habitat spectrum, used a very small proportion of available grassland and a higher proportion of crop sites than any natural habitat. This type of information contributes to our understanding of limiting factors and threats.

Habitat use information is valuable for understanding the reasons behind trends. Species like Horned Lark, Savannah Sparrow and Western Meadowlark use crop as well as much of the available grassland, have wider distributions, and show less year to year variability. Much of the remaining grassland and even much of the modified landscape is used by them. Their long term trends show less severe declines and have narrower confidence intervals than habitat specialists like Sprague's Pipit (Sauer et al. 2000), which must have native grassland of moderate height and thickness (Robbins and Dale 1999).

Knowledge of what proportion of the population is using crop habitat, and how this varies geographically and temporally may be able to help us understand reasons for decline and target our research more effectively. Species that will set up territories in crop or in

[2]unpublished data, P. Blancher, Canadian Wildlife Service, Ottawa, Ontario.

hay, where reproductive success may be less than in natural habitats, may suffer worse declines than those restricted to grassland alone. Hay covered a very small proportion (6.6 percent) of the cover at sites sampled by GBM and we did not attempt analyses related to that habitat. Crop was more common and we examined the proportion of all birds detected in each of grass and crop habitats for two species showing a high frequency of occurrence in crop: Baird's Sparrow and McCown's Longspur (*table 8*). The strong year effect may be related to moisture conditions, with higher usage of crop occurring in dry years with poor grass condition. A limited number of studies have explored productivity of birds in crops but the few that have been done consistently show low productivity values in agricultural habitats (Martin 1997). The reasons vary from outright destruction of nests (Cowan 1982) to a lack of pairing success in crop for Baird's Sparrow (Martin 1997). The high proportion of populations of these species using crop habitat is cause for concern.

The block size values (*fig. 2*) have several potential uses. For example, the number of individuals per stop by species in various block sizes could be compared to see if some species occur in greater numbers in larger blocks. There is reason to think large blocks are likely to support higher densities. Large holdings tended to be in better "range condition" (a measure of grassland community health) than small blocks of land (Smoliak et al. 1985). The state of grassland health is important to grassland birds. Sprague's Pipit, Vesper Sparrow, Baird's Sparrow, and Chestnut-collared Longspur are known to respond positively to range condition in North Dakota and Saskatchewan (George et al. 1992, Anstey et al. 1995).

Over a longer period, there is also the potential to calculate trends for small and large block sizes to determine if population dynamics in small blocks differ from those in large blocks. The GPS data for each stop will allow us to use satellite data to calculate a more accurate estimate of block size than that generated in this study. The GBM pilot study shows that collection of basic habitat information (on the ground and satellite data from geo referenced stops) may provide us with other insights helpful in understanding population dynamics of the target species. Examples explored here were proportion of population in particular habitats, proportion of habitat used, and comparison of trends in core and peripheral areas. Much more can still be learned from this data set: trends by density; trends by habitat; and, the influence of habitat type, block size, soil type, precipitation, and land use on both occupancy and trend. Increased understanding of population dynamics may allow us to more effectively target research and conservation efforts.

Next Steps for GBM

Our study confirms that intensified BBS (GBM) has the potential to improve our ability to monitor and understand population changes for many grassland species. The information generated may contribute to planning efforts of Partners in Flight, Prairie Canada Shorebird Conservation Plan, and the North American Bird Conservation Initiative and implementation of "all bird" conservation by the Prairie Habitat Joint Venture among others. To help realize the program's potential we suggest:

1. Upgrade the Grassland Bird Monitoring Program from pilot to operational status. Complete the random selection of two to four routes / degree block throughout those portions of the three prairie provinces with more than 20 percent remaining grassland cover in a degree block. We suggest the CWS act as the lead organization for this program in Canada and that data be stored in the BBS data base in a manner that random GBM routes are distinguishable from BBS so that both separate and combined analyses may continue to be generated. Avian trends for GBM alone and GBM and BBS combined should be calculated every 3-5 years.

2. Recruit additional agency and volunteer observers to run routes. This will make the monitoring program more robust to variation in availability of observers, as well as reduce the burden on any single agency of providing observers. Targeting agency personnel may reduce competition with BBS for volunteer observers.

3. Global positioning system data and habitat data should be collected, following a standard protocol, at each stop of all GBM and BBS routes. The habitat information would include estimates of cover by each of several major habitat classes, and road and ditch width information. Habitat data should be checked and updated every five years. Estimates of cover and landscape characteristics such as block sizes from should be generated from remote sensing coverage.

4. Using data collected in this pilot project, investigate the effect of habitat type, soil type, precipitation, and block size on occurrence and trend.

5. Integrate various kinds of information collected to produce status reports that identify potential causes of trends and suggest relevant research and conservation action.

6. Encourage the USGS to adopt a similar program so that the entire range of primary grassland bird species can receive intensive coverage.

Acknowledgments

We gratefully acknowledge the many non-government organizations and volunteers involved in the component surveys of the Canadian Landbird Monitoring Strategy. Most field costs for the Grassland Bird Monitoring pilot study were covered by the Canadian Wildlife Service, Prairie and Northern Region. Environment Canada Biodiversity funding covered field travel costs in 1996 and 1997. We thank all those who assisted us during the course of the pilot study. R. D. Dickson and J. Park selected new routes and prepared route maps. A. Bezener conducted many of the surveys in 1996. Data was entered by Bezener for 1996 and Dickson for 1997 and 1998. We received valuable comments from J. Sauer (USGS) on pilot study progress reports and from B. Gingras, K. De Smet, and N. Niemuth on the paper.

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Effects of Contour Furrowing on Soils, Vegetation, and Grassland Breeding Birds in North Dakota[1]

Terrell D. Rich[2]

Abstract

On certain soil types in the Northern Great Plains, mechanical treatment such as contour furrowing is used to break up "claypan" soils and increase grass production. The effect of this treatment on breeding bird communities has not been documented. I compared soil characteristics, vegetation, and the breeding bird community on two sites over three years in southwestern North Dakota. One site was contour furrowed in 1968 and the other, adjacent site, was not treated. The chemical makeup of the soil on the two sites was similar 20 years following treatment but vegetation cover differed. The treated site had greater cover of wheatgrass (*Agropyron* spp.) and non-persistent litter, and a lower cover of buffalo grass (*Buchloe dactyloides*), Wyoming big sagebrush (*Artemisia tridentata wyomingensis*), spikemoss (*Selagenella densa*), and an unidentified lichen than the untreated site. Breeding bird densities did not differ between the treated and untreated site in any of the three years, but the relative abundance of Chestnut-collared Longspurs (*Calcarius ornatus*) and Vesper Sparrows (*Pooecetes gramineus*) was greater on the treated site. Horned Larks (*Eremophila alpestris*) were the most common species on both sites, and there was little difference in the occurrence of Brewer's Sparrow (*Spizella breweri*), Lark Buntings (*Calamospiza melanocorys*), and Western Meadowlarks (*Sturnella neglecta*). Thus, mechanical treatment did not change the density of breeding birds but rather shifted the composition of the avian community. Sage grouse (*Centrocercus urophasianus*) apparently used the untreated site more than the treated site and may be adversely affected by this treatment.

Key words: Chestnut-collared Longspur, contour furrowing, grassland birds, grasslands, Horned Lark, land treatment, livestock forage, North Dakota, Vesper Sparrow.

Introduction

Land treatments such as chaining, plowing, disking, and seeding frequently are used to alter vegetation cover of western rangelands (Young and Evans 1978, Keller 1979, Urness 1979, Evans and Young 1987, Herbel 1987, McKenzie 1987, Wiedemann 1987). The objective, typically, is to decrease the cover of woody vegetation such as sagebrush (*Artemisia* spp.) (Parker 1979, Wiens and Rotenberry 1985) or juniper (*Juniperus* spp.) (Winegar and Elmore 1978, Martin 1978) and increase grass cover for livestock. While the impacts of such vegetation conversions on native wildlife may be positive or negative, depending on the species (Braun et al. 1976, Saab and Rich 1997, Wisdom et al. 2000), too often no monitoring is conducted to assess the effects and thereby provide scientific information for future land-management decisions.

In this study, I assessed the effect of contour furrowing, or deep plowing (Sandoval 1978), on soil characteristics, vegetative cover, and the breeding bird community for three years in southwestern North Dakota. Soils were in the Rhoades-Absher complex (USDA 1975) and have patches known as "pan spots" or "claypan" interspersed with patches of vegetation called "grassed highs" (*fig. 1*). Pan spots are devoid of vegetation because they are nearly impermeable to water and to the exchange of gasses, such as O_2 and CO_2, between the atmosphere and plant roots. These soils also may have salt content high enough to limit plant growth even if water is available (Roundy 1987, Seelig and Richardson 1991).

Contour furrowing consists of plowing the soil to a depth of about 0.3 m. Plowing breaks up the restrictive claypan and, depending on the depth of the water table and the amount of soluble salts beneath the surface, may improve the productivity of the soil (Sandoval and Reichman 1971, Sandoval 1978, Seelig and Richardson 1991). This practice also converts a level soil surface into a series of parallel ridges and furrows (*fig. 1*) along the contours of the landscape, hence the technique's name. The distance between adjacent ridges or furrows is about 2 m.

The vegetation was classified as wheatgrass-grama-needlegrass (Whitman and Barker 1994). Dominant grasses included wheatgrasses (*Agropyron smithii* and *A. dasystachyum*), needlegrass (*Stipa viridula*), blue grama (*Bouteloua gracilis*), and buffalo grass (*Buchloe dactyloides*). Other major components of the vegetation

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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Figure 1— Photographs of the untreated (above) and treated (contour furrowed) sites in Bowman County, North Dakota.

included plains pricklypear (*Opuntia polycantha*), Wyoming big sagebrush (*Artemisia tridentata wyomingensis*), spikemoss (*Selagenella densa*), and an unidentified lichen. Breeding birds in the area included the Horned Lark (*Eremophila alpestris*), Chestnut-collared Longspur (*Calcarius ornatus*), Lark Bunting (*Calamospiza melanocorys*), Western Meadowlark (*Sturnella neglecta*), Vesper Sparrow (*Pooecetes gramineus*), Brewer's Sparrow (*Spizella breweri*), and Sage Grouse (*Centrocercus urophasianus*). The first four species are among a suite of declining grassland birds in the region (Johnson and Schwartz 1993, Johnson and Igl 1995, USDOI 1996). Brewer's Sparrow and Sage Grouse also are declining across the west (Saab and Rich 1997, Connelly and Braun 1997). However, the latter two species are on the periphery of their ranges in south-western North Dakota whereas the others are widespread in the region (Kantrud 1981).

The null hypotheses tested were that there were no differences between the treated and untreated sites in 1) selected soil characteristics, 2) ground cover, 3) breeding bird density, or 4) relative abundance of breeding birds.

Study Area and Methods

The study took place in the Big Gumbo Planning Unit of the U. S. Bureau of Land Management in Bowman County, in extreme southwestern North Dakota (46°07'N, 103°59'W). This is within the Southwestern Slope, one of four physiographic regions commonly recognized in North Dakota (Kantrud 1981). The treated site was contour furrowed in 1968, is about 200 ha in size, and is adjacent to the untreated site. Both sites are part of the same soil mapping unit (USDA 1975) and were grazed at the same time of year under a rest rotation system as part of the same pasture. Grazing took place after bird and vegetation sampling.

In 1988, soil samples were collected at three depths from three sites in each of the following types of sites: untreated (9 samples in claypan and 9 in grassed highs) and treated (9 samples), for a total of 27 samples. Sample depth depended on the soil horizons at the sample point. Three depth categories were defined: The "top" sample extended from ground surface to 5 to 13 cm down; the "middle" sample extended from the previous depth to 23 to41 cm; and the "bottom" sample extended from the previous depth to 41 to 71 cm. Pan spots were smooth, flat areas devoid of vegetation where water stands following precipitation (*fig. 1*). Grassed highs were sites among the pan spots that were covered with vegetation, typically blue grama, buffalo grass, and pricklypear (*fig. 1*). Samples from the treated site were taken from the top of a ridge, the side of a ridge and the bottom of a furrow. Soils were analyzed for pH, electroconductivity (EC), Ca, Mg, Na, sodium absorption ratio (SAR) and exchangeable sodium. Canopy cover and frequency of occurrence for each plant species were assessed in a 20 x 50 cm frame placed at 1-m intervals (Daubenmire 1959) along a randomly selected transect in the treated and in the untreated sites. A total of 80 samples were taken in each of 1988, 1989 and 1990 from each site. In addition to vegetation, non-persistent litter (non-woody grass and forb material), persistent litter (woody material, prickly-pear), and bare ground also were estimated. Values for wheatgrass may have included small amounts of needlegrass (1-2 percent). Although the 80 samples were taken along the same transect, the precise locations of the sample frames likely varied slightly between years.

Bird surveys were conducted along each of three transects on the treated site and three on the untreated site. Each transect was censused once each year—1988, 1989 and 1990—under favorable weather conditions. Transects on the treated site were 700 m long, while those on the untreated site were 500 m long. All transects were 140 m wide. Distance from the centerline to each detected bird was measured perpendicularly to the nearest meter with a rangefinder. Bird densities were calculated according to Burhham et al. (1980). A measure of relative

abundance—birds/100 m of transect—also was calculated for each species.

To assess use of the area by Sage Grouse, seven parallel 100-m belt transects across the treated area and another 7 across the untreated area were conducted in 1988. The number of grouse pellet groups encountered in a 2-m wide belt was counted. Single pellets were not counted.

Differences in soil characteristics were tested with a two-factor ANOVA (Manugistics 1997), with depth category and treatment as the factors. I then ran a discriminant function analysis to see if the treated and untreated sites could be differentiated by any combination of soil characteristics. Differences in vegetation cover between the treated and untreated sites were tested with a nonparametric repeated measures ANOVA (Zar 1996). A nonparametric test was necessary because the data were not distributed normally and could not be brought adequately near normality through data transformations. A repeated measures test was chosen because the vegetation measurements on each site, although conducted in three different years, were not independent. Bird densities were calculated according to the program TRANSECT (Burnham et al. 1980) for each site for each year. Within-year comparisons between densities on the treated and untreated sites were made with t-tests, using the density and standard error estimates provided by TRANSECT.

Results

Soils

Values of all measured soil variables generally increased with depth (*Table 1*). A series of two-factor ANOVA's (*Table 2*) showed that there was an effect of depth category for pH, electroconductivity, Mg, Na, sodium absorption ratio (SAR) and exchangeable

Table 1— *Soil characteristics ($\bar{x} \pm sd$) at different soil depths. Units are in Milli-Equivalents/Liter unless otherwise noted.*

Characteristic	Depth Category[a]			F	P
	Top	Middle	Bottom		
pH	6.89 (0.80) a	7.34(0.33) b	7.79 (0.37) c	6.05	<0.05
EC[b]	2.70 (1.39) a	5.44 (2.41) b	8.04 (3.63) c	18.99	<0.001
Ca	11.71 (9.19) a	19.62 (7.22) b	19.02 (6.67) b	2.82	<0.10
Mg	4.91 (4.05) a	11.72 (6.69) a	25.48 (14.92) b	31.28	<0.001
Na	14.44 (11.79) a	35.93 (21.72) b	59.62 (32.42) c	15.68	<0.001
SAR[c]	6.22 (4.70) a	9.62 (4.57) b	12.96 (4.71) c	6.14	<0.05
Ex. Na (%)[d]	6.99 (5.92) a	11.15 (5.47) b	14.89 (5.11) c	6.51	<0.05

[a] Means with the same letter within a characteristic are not significantly different across depth categories (df = 2, 18).
[b] Electroconductivity in deciSiemens/meter.
[c] Sodium absorption ratio.
[d] Exchangeable sodium.

Table 2— *Soil characteristics ($\bar{x} \pm sd$) in the treated and in the untreated areas. Units are in Milli-Equivalents/Liter unless otherwise noted.*

Characteristic	Treatment[a]			F	P
	Treated	Untreated			
		Claypan	Grassed High		
pH	7.23 (0.57) a	7.60 (0.41) a	7.19 (0.86) a	1.52	<0.50
EC[b]	7.01 (3.95) a	6.11 (3.05) a	3.06 (1.55) b	11.42	<0.005
Ca	18.93 (5.93) a	15.36 (8.39) a	16.06 (10.53) a	0.52	<0.50
Mg	19.69 (14.19) a	6.15 (14.20) a	6.27 (4.37) b	13.77	<0.001
Na	49.78 (37.02) a	44.91 (22.87) a	15.31 (11.58) b	10.68	<0.005
SAR[c]	10.71 (6.39) a	11.83 (1.91) a	6.25 (5.16) b	4.68	<0.05
Ex. Na (%)[d]	12.16 (7.29) a	13.89 (2.07) a	6.98 (6.29) b	5.65	<0.05

[a] Means with the same letter within a characteristic are not significantly different across treatments (df = 2, 18).
[b] Electroconductivity in deciSiemens/meter.
[c] Sodium absorption ratio.
[d] Exchangeable sodium.

sodium (EC). There was no effect of depth for Ca. There also was an effect of treatment for EC, Mg, Na, SAR and exchangeable sodium. There was no effect of treatment for pH or Ca. Discriminant function analysis of these data by depth category resulted in a single significant function (P = 0.0023) that explained 79.85% of the variance and classified 23 of the 27 samples correctly. However, discriminant analysis of these data by treatment did not yield a significant function. Thus, soil characteristics are not useful in distinguishing the treated from the untreated site.

Ground Cover

Cover of western wheatgrass and non-persistent litter were significantly greater on the treated site while cover of buffalo grass, sagebrush, the lichen, and spikemoss were significantly greater on the untreated site (*Table 3*). The latter two species were nearly absent from the treated site, even after 20 years. Cover of blue grama, pricklypear, persistent litter and bare ground did not differ significantly between the treated and untreated site.

Bird Densities and Relative Abundances

Horned Larks, Chestnut-collared Longspurs and Western Meadlowlarks occurred on both sites in all three years. Vesper Sparrows, Lark Buntings and Brewer's Sparrows occurred on the treated site in all years but on the untreated site in only two of three, two of three, and one of three years, respectively. Sample sizes were sufficient for calculating densities only for Horned Larks and for all species combined. A few additional species were detected on the transects but they were all classified as flyovers.

There was no significant difference between the density of Horned Larks on the treated and untreated site in any year, with the possible exception of 1990 (*Table 4*). However, the sample size for Horned Larks on the treated site (N = 21) was substantially below the minimum number of detections (N = 40) recommended for accurate density estimation (Burnham et al. 1980). For all species combined, there also was no difference in density between sites in any year (*Table 4*).

Although it is not possible to calculate densities for the other species, their relative abundance showed that Vesper Sparrows and Chestnut-collared Longspurs occurred more frequently on the treated site (*Fig. 2*). Western Meadowlarks and Lark Buntings occurred at about the same rate on both sites while Brewer's Sparrows were rare on both sites.

Sage Grouse pellet groups occurred at a rate of 0.5 ± 0.5 (se) per 100 m on the treated sites and 3.0 ± 2.9 per 100 m on the untreated site. These means are significantly different (t = 2.76, P < 0.05).

Table 3— *Percent ground cover ($\bar{x}$ ± sd) on treated (T) and untreated (U) sites, chi-squared values and significance of the difference between treated and untreated sites.*

Variable	Site	Percent cover	χ^2_r	P
Blue grama	U	3.0 (5.9)	10.12	NS
	T	2.2 (5.9)		
Buffalo grass	U	7.0 (17.0)	24.62	<0.001
	T	2.3 (9.5)		
Western wheatgrass	U	4.5 (7.6)	182.60	<0.001
	T	27.4 (23.0)		
Big sagebrush	U	5.5 (13.3)	11.58	<0.05
	T	1.7(5.7)		
Pricklypear	U	4.6 (12.6)	0.28	NS
	T	2.8 (8.3)		
Lichen	U	2.8 (4.1)	100.96	<0.001
	T	0.1 (0.4)		
Spikemoss	U	8.4 (22.7)	15.02	<0.05
	T	0.0 (0.2)		
Persistent litter	U	2.9 (7.2)	8.29	NS
	T	1.7 (5.1)		
Non-persistent litter	U	3.9 (5.9)	134.63	<0.001
	T	15.2 (13.1)		
Bare ground	U	55.0 (39.0)	0.06	NS
	T	55.8 (32.1)		

Table 4— *Breeding bird density (birds/ha) on treated (T) and untreated (U) sites by year.*

		1988 [a]		1989		1990	
Variable	**Site**	**N**	**$\bar{x}$ ± SE**	**N**	**$\bar{x}$ ± SE**	**N**	**$\bar{x}$ ± SE**
Horned Lark	U	67	8.0 (1.2)	64	4.2 (1.6)	44	4.3 (0.6)
	T	74	7.0 (9.0)	44	4.2 (0.7)	21	1.6 (0.4)
All species combined	U	90	13.9 (2.4)	96	9.8 (1.8)	62	6.5 (1.3)
	T	134	13.8 (1.7)	111	9.5 (1.1)	73	6.2 (1.0)

[a] There were no significant differences between the treated and untreated sites for a given year

[b] Sample size (N = 21) is below the minimum recommended - no tests were run with this cell.

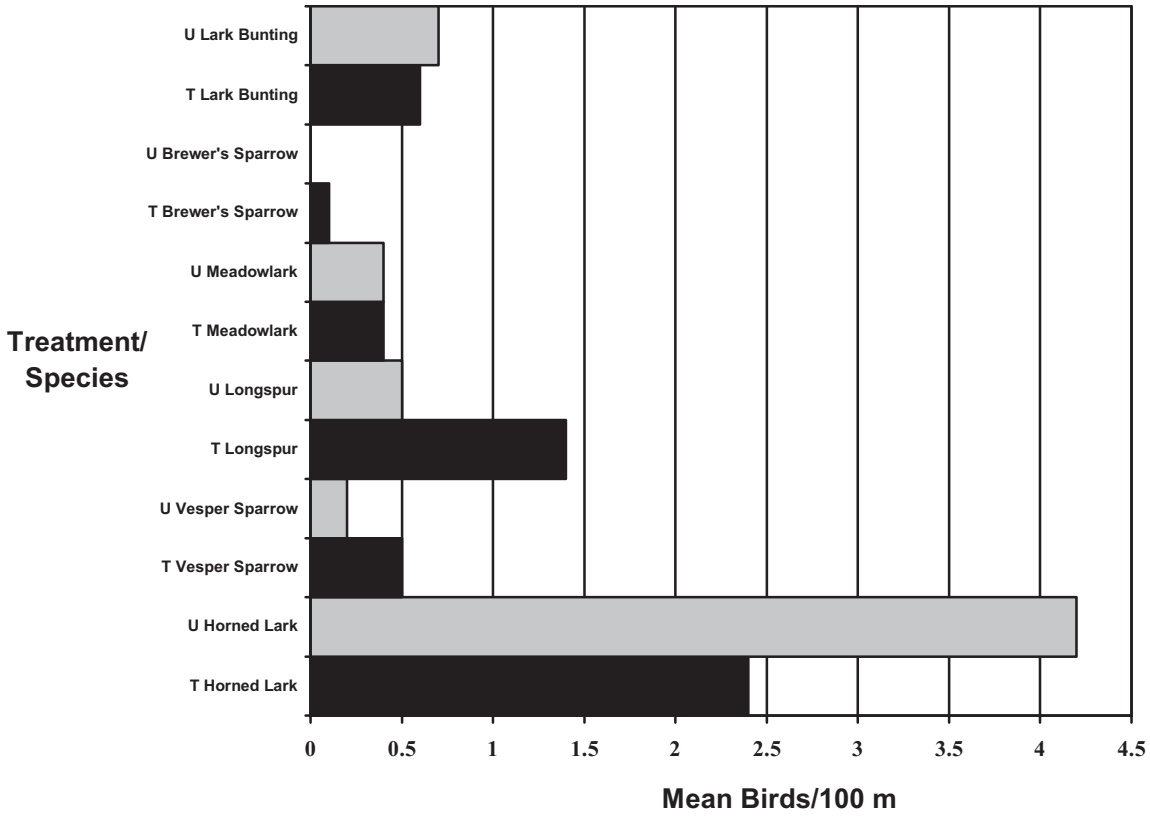

Figure 2—Mean birds/100 m for all breeding species encountered on treated (T) and untreated (U) sites for all years combined.

Discussion

Contour furrowing did not have any obvious effect on the characteristics of the soil measured in this study - pH, EC, Ca, Mg, Na, SAR and exchangeable Na. All generally increased with soil depth on both the treated and untreated sites, but this suite of variables was not useful in discriminating between the treated and untreated sites. This suggests that over the 20-year period between the soil treatment and the sampling, no substantial changes took place in the characteristics of the soil. Furrowing did have a pronounced effect on the vegetation. Western wheatgrass showed the most dramatic change of any type of cover. The 3-year mean for wheatgrass cover was over 27% on the treated site while less than 5% on the untreated site. This apparently was facilitated by mechanically breaking up the claypan to provide improved permeability to water, plant roots (Sandoval 1978) and gasses (Seelig and Richardson 1991), precisely the response that mechanical treatment seeks to produce. A byproduct of this growth of grass was the increase in non-persistent litter. Buffalo grass, big sagebrush, the lichen, and spikemoss all had greater cover on the untreated site. The lichen and spikemoss had not reestablished

appreciably on the treated site, even after 20 years. These species tended to occur together in patches on the grassed highs of the untreated site.

A final feature that provided a strong contrast between the treated and untreated sites was the vegetation configuration and physical structure of the sites. The untreated site was very patchy, with dense areas of vegetation interspersed with bare claypan sites. In contrast, the treated site was much more uniform in vegetative cover (*fig. 1*) and had an obvious ridge/furrow structure. I suspect that this mechanical treatment makes it extremely unlikely that the treated site would revert to its former plant composition and physical structure except perhaps over the longest time period.

In each of the three years of the study, densities of Horned Larks were remarkably similar between the treated and untreated site, as were the densities of all species combined. Horned Lark densities on both sites were relatively high and were similar to those reported for shortgrass prairie in Colorado (Beason 1995).

Both Vesper Sparrows and Chestnut-collared Longspurs comprised a greater proportion of the bird community on the treated site. It seems likely that the great increase of wheatgrass on the treated site caused this shift in the composition of the breeding bird community. Horned Larks occupy a great variety of vegetation types across their range (Beason 1995) but a common feature of all of them is substantial amounts of bare ground. Interestingly, the percent cover of bare ground was not different between the two sites. But the configuration of that bare ground was very different, being uniformly distributed on the treated site and patchily so on the untreated site. Chestnut-collared Longspurs (Kantrud 1981, Hill and Gould 1997, Johnson et al. 1998) and Vesper Sparrows (Bent 1968, Kantrud 1981, Rising 1996) also occupy a variety of habitats, preferring more grass cover than Horned Larks.

This distribution of vegetation also had unknown effects on the selection of nest sites, nest success, productivity and return rates of breeding birds. On the untreated site, nests would have to be placed in the grassed highs. The advantage would be that these patches were very dense, with close growing buffalo grass sod, spikemoss, blue grama and pricklypear. The disadvantage would be that predators could perhaps more efficiently search for nests as they could ignore areas of bare ground. On the treated site, predators would have no such obvious clues as to the location of nests. Sage Grouse apparently used the untreated site significantly more than the treated site. As the cover of sagebrush was nearly the same on both sites, one must look to other reasons for this preference. Pellet groups were almost always deposited on the bare soil, immediately adjacent to a grassed high. This suggests that grouse were roosting or loafing where the high grass provided both protection from the wind and visual protection from predators. Constant winds and cold temperatures in a landscape with little topographic relief and little sagebrush cover would place a premium on the microrelief offered by grassed highs. Also, as Sage Grouse are large birds, they are relatively conspicuous when standing in a uniform expanse of wheatgrass (pers. obs.). But when these birds are standing in the untreated habitat, they blend in with the patchy pattern there and can be very difficult to pick out, even when you know where birds have just landed.

Finally, it is worth noting that Brewer's Sparrow, which is showing steep population declines over much of its range (Saab and Rich 1997, Sauer et al. 1997), occurred at low densities despite very low cover of sagebrush. This is consistent with the observations of Igl and Murphy (1996) who found this species in Conservation Reserve Program fields in the area where sagebrush was <0.01 percent of the total vegetative cover. So although this species is considered to be a sagebrush obligate (Braun et al. 1976, Paige and Ritter 2000), it obviously will occupy sites where grass cover far exceeds that of sage (see also Rotenberry et al. 1999).

Acknowledgments

The manuscript was greatly improved by the comments of P. D. Vickery, D. H. Johnson, J. M. Ruth, M. F. Carter, and J. A. Fitzgerald. I thank D. Rufledt for help with soil sampling, analysis, and interpretation.

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Abundance of Grassland Sparrows on Reclaimed Surface Mines in Western Pennsylvania[1]

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Abstract

Grassland songbird populations have experienced some of the most severe declines of any migratory songbird guild in North America and are continuing to disappear from portions of their historic ranges. Habitat loss and degradation have been implicated as primary causes of these declines. However, intensive surface coal mining and subsequent reclamation in western Pennsylvania have created large tracts of grassland habitat during the past 30 to 40 years. We estimated the area of habitat suitable for breeding grassland songbirds on reclaimed strip mines in nine western counties of Pennsylvania using a stratified random sample design. We used distance sampling methods to estimate abundance of Henslow's (*Ammodramus henslowii*), Savannah (*Passerculus sandwichensis*), and Grasshopper (*Ammodramus savannarum*) Sparrows. We estimated that 35,373 ha (95 percent CI = 26,758 - 46,870) of reclaimed-mine grassland suitable for breeding grassland songbirds were present in our 1.85 x 10^6 ha study area in 2001. Henslow's, Savannah, and Grasshopper Sparrow abundances were 4,884 (95 percent CI = 2,128 – 8,460), 1,921 (95 percent CI = 848 – 2,790), and 9,650 (95 percent CI = 4,390 – 13,614) singing males, respectively. Reclaimed-mine grasslands in western Pennsylvania supported substantial grassland songbird populations during the 2002 breeding season. Therefore, management of reclaimed surface mine areas as grassland reserves may help prevent populations of some species, notably Henslow's Sparrow, from becoming endangered.

Key words: *Ammodramus henslowii, Ammodramus savannarum,* Grasshopper Sparrow, grassland birds, grassland habitat, Henslow's Sparrow, *Passerculus sandwichensis,* Pennsylvania, reclaimed surface mine, Savannah Sparrow.

Introduction

Many North American grassland bird species have experienced severe and consistent population declines during the past 30 years (Robbins et al. 1986, Herkert 1994, Sauer et al. 1996). In fact, since 1966 the guild of grassland bird species had the lowest percentage of increasing species in the U.S. Breeding Bird Survey (Pardieck and Sauer 2000). Population declines are rooted in the near collapse of the native tallgrass prairie ecosystem and severe losses in most other native prairie systems (Samson and Knopf 1994, Warner 1994). Most states have lost 99 percent of their native tallgrass prairie, and grasslands top the list of critically endangered native ecosystems (Noss et al. 1995).

Losses in native grassland ecosystems were largely the result of conversion to agriculture. Many grassland bird species, however, adapted to newly created agricultural habitats, and those that exploited these habitats expanded their ranges eastward with the felling of Eastern forests during the 19th Century (Askins 1999). However, changes in agricultural practices during the past 50 years, including conversion of pastures and hayfields to row crops, made much agricultural habitat unsuitable for native grassland species (Warner 1994). Population declines in grassland bird species observed today reflect those changing practices and the loss of agricultural areas to urban sprawl (Vickery et al. 1999).

Widespread habitat loss, fragmentation, and consequent population declines have drawn considerable conservation and research attention to grassland bird communities. Grassland symposia (Vickery and Herkert 1999) and special sessions on grassland birds during national meetings (this volume) have highlighted the plight of these species and the need to understand their population dynamics and habitat needs. This is especially apparent for the Henslow's Sparrow (*Ammodramus henslowii*), previously evaluated as a candidate for the U.S. Endangered Species List, which has a restricted geographic range and low relative abundance (Smith 1992, Pruitt 1996). Although not recommended for Federal listing (Federal Register 1998, 63(174) pp. 48162-64), it was identified as one of the highest priority bird species on the National Audubon Society's Watch List (Pashley 1996). Grasshopper Sparrows (*Ammodramus savannarum*) and Savannah Sparrows (*Passerculus sandwichensis*) currently have much wider geographic ranges but also have

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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experienced consistent population declines (Peterjohn and Sauer 1999).

With loss and degradation of native grassland habitats and recognition that most agricultural habitat essentially serves as a population sink (Bollinger et al. 1990, Kershner and Bollinger 1996, Rohrbaugh et al. 1999), managed habitat areas have become vital for many grassland bird communities. Agricultural set-asides (e.g., CRP lands) and prairie reserves provide reservoirs of grassland habitat that may help support remaining populations of some grassland bird species (Delisle and Savidge 1997, Koford 1999, Coppedge et al. 2001, Johnson and Igl 2001). In addition, reclaimed surface mines have inadvertently become a source of grassland bird habitat. Whitmore and Hall (1978) documented the presence of grassland birds on reclaimed surface mines 25 years ago, although the contribution of those populations was not recognized for many years. Recent studies have confirmed the existence of substantial grassland bird populations on reclaimed mines throughout the Midwest and Northeast, which indicates these habitats may be important for conserving many grassland species (Yahner and Rohrbaugh 1996, Bajema et al. 2001).

In the eastern United States, and particularly in Pennsylvania, reclaimed bituminous coal fields are beneficial to grassland birds (Yahner and Rohrbaugh 1996). Widespread surface mining and subsequent reclamation in western Pennsylvania have resulted in an extensive patchwork of reclaimed sites among forests, woodlots, and agricultural fields. The acidic, nutrient-poor soils of reclaimed sites provide little potential for agricultural or timber production, and grasses and legumes tend to be the most successful and persistent vegetation types (Vogel 1981, J. Mattice pers. obs.). These often undisturbed fields have a slow rate of ecological plant succession, and they are ideal for Henslow's Sparrows and compatible for many other grassland-associated species (Bajema et al. 2001).

During a survey of the distribution of breeding birds in Pennsylvania (Brauning 1992) conducted in the 1980s, a large number of locations of grassland birds, including Henslow's, Grasshopper, and Savannah Sparrows, were on reclaimed surface mines. However, this survey did not provide abundance estimates, and population sizes could not be quantified. In an attempt to document population trends for the Henslow's Sparrow over its historic and current range, a federal status assessment was compiled in 1996 (Pruitt 1996). This assessment revealed that many states had inadequate data on population size because of a lack of consistent statewide monitoring efforts. Pruitt (1996) noted that "there is a need to coordinate and standardize monitoring" to improve the accuracy of global population estimates. We present large-scale, statistically defensible population estimates for several grassland bird species and an estimate of the area of suitable reclaimed surface mine habitat in western Pennsylvania. Specifically, we attempted to quantify the contribution of reclaimed surface mines in western Pennsylvania to populations of three obligate grassland bird species: Henslow's Sparrows, Grasshopper Sparrows, and Savannah Sparrows.

Study Area

We conducted our study in nine western Pennsylvania counties (Armstrong, Butler, Cambria, Clarion, Clearfield, Indiana, Jefferson, Somerset, and Venango), totaling 18,648 km^2, an area roughly equivalent to the state of New Jersey (*fig. 1*). These counties overlay the main bituminous coal field in Pennsylvania (Cuff et al. 1989), and coal is removed primarily by surface mining. Less than 30 percent of available coal has been mined in the majority of these counties. Post-mining reclamation, conducted primarily since the 1960s, has restored topographical contours and established vegetative cover on disturbed soils using a grass mixture dominated by fescue (*Fescue* spp.), clover (*Trifolium* spp.), and bird's-foot trefoil (*Lotus corniculatus*) (Buckwalter 1983, Piehler 1987, D. W. Brauning, pers. obs.). Trees and shrubs, primarily pine (*Pinus* spp.), locust (*Robinia* spp.), and autumn olive (*Elaeagnus umbellata*) were usually planted in reclaimed sites but often failed to become established.

Methods

Quantification of Reclaimed Areas

We used a geographic information system (GIS) to overlay a square grid of 9-km^2 blocks over the entire 9-county study area. For the purpose of creating a stratified sampling scheme, we then used a GIS map of permitted and abandoned mine sites, combined with a vegetation cover classification map from the Pennsylvania Gap Analysis Project (PA GAP, Final Report, Pennsylvania State University and U.S. Geological Survey, June 2000), to estimate the percent area of reclaimed surface mine in each block. However, an informal evaluation of this GIS map found that although it provided an indication of the amount and location of mining activities, it did not include all reclaimed areas, and it included mining activities other than surface mining for coal (e.g., deep mining or other types of mineral extraction). Therefore, we calculated an index of the amount of reclaimed surface mine in each block in the entire study area by using a spatial smoothing function, calculating the average area permitted and abandoned for a 9-block "neighborhood" (a

given block and the 8 blocks immediately surrounding that block). This smoothing function allowed us to take into account the values of surrounding cells when assigning index values to each cell. These index values then were used to stratify the blocks into areas of high, medium, or low amounts of mined area (*fig. 1*). This stratification of our index to mining activity, as long as it was correlated with the actual amount of mined area, improved the precision of our estimates of reclaimed surface mine area and bird abundance (Cochran 1977:99-101).

We used a stratified random sampling design to select blocks from each of the high, medium, and low strata (Cochran 1977). There were 495 blocks (4,455 km^2) in the high stratum, 698 blocks (6,282 km^2) in the medium stratum, and 870 blocks (7,830 km^2) in the low stratum. Based on our estimates of the relative effort it would require to survey a block in each stratum type and estimates of the relative variability in amounts of habitat among blocks in each stratum, we used an optimal allocation equation (Cochran 1977:96-99) to calculate the number of blocks to sample in each stratum. We sampled 74 blocks: 18 high-density, 25 medium-density, and 31 low-density. For each sampled 9-km^2 block, we identified, on the ground, all reclaimed surface mine area in grasses and legumes, not actively managed (e.g., mowed), with <25 percent coverage (determined from visual estimation at the site) of shrubs or trees. We classified these patches as suitable grassland sparrow habitat and limited bird survey efforts to this subset of reclaimed surface mine conditions. These areas were mapped directly into a GIS database using methods and equipment described by Diefenbach et al. (2002).

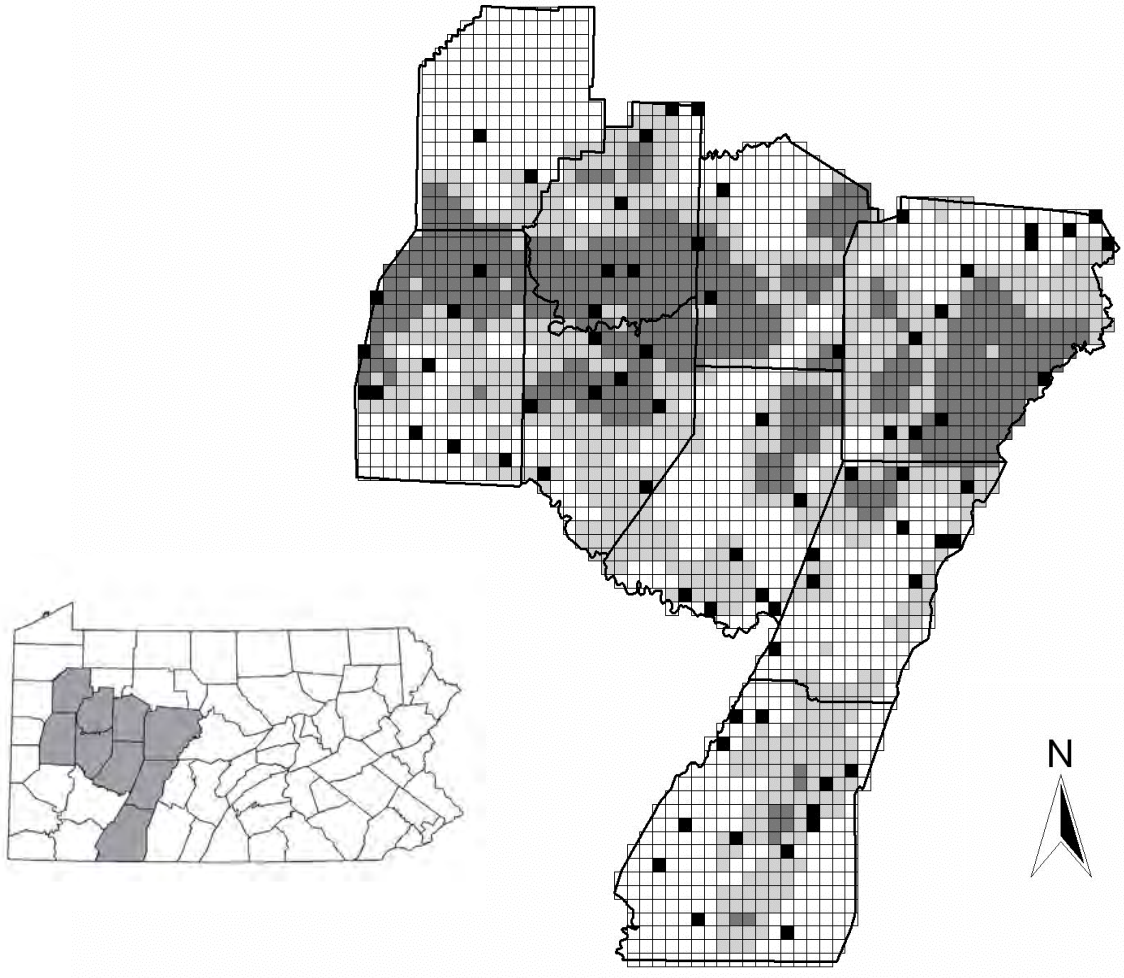

Figure 1— Map of the state of Pennsylvania with the study area shaded, and a larger diagram of the nine-county study area detailing the stratification and sampling scheme. White, light gray, and dark gray blocks represent low, medium, and high amounts of mining activity, respectively. Black indicates the locations of the 74 randomly selected blocks in our sample.

Bird Surveys

Two field technicians surveyed birds by walking parallel line transects within grassland patches on reclaimed mine areas. Each patch was surveyed once during the summer. Technicians surveyed each individual reclaimed habitat patch independently but often surveyed patches in the same block. Transects were separated by 250 m and located perpendicular to the long axis of a grassland patch. We placed the first transect 100 m from the grassland edge and walked parallel transects in the habitat patch until the entire patch was surveyed.

Observers walked at a slow pace (approximately 1 km/hr with occasional pauses) along transects across the extent of contiguous habitat and measured transect length with a handheld Global Positioning System (GPS). Surveys were conducted from 0530 to approximately 0930 EST, between 15 May and 1 July 2001. We did not conduct surveys during heavy rain, intense heat, or excessive wind. After mid-June, fieldwork often ended by 0900 because hot and humid conditions caused grassland birds to cease singing.

Observers recorded only visually detected, singing male Henslow's, Grasshopper, and Savannah Sparrows. Observers measured line-of-sight distance (m) to birds from line transects with Yardage Pro 500 laser binoculars (Bushnell Corporation, Overland, Kansas, U.S.A.), as recommended by Buckland et al. (2001). We measured the horizontal angle from the transect using a compass equipped with a sighting mirror (Silva Ranger CL515, Johnson Outdoors, Binghamton, NY, U.S.A.).

Data Analysis

We estimated the hectares of suitable reclaimed surface mine area in the 9-county area using estimators for a stratified random sampling design (Cochran 1977). We estimated log-normal 95 percent confidence intervals for the area estimate (Chao 1989).

We estimated parameters of the detection function for each observer and species using program DISTANCE, version 3.5, release 5 (Thomas et al. 1998). DISTANCE uses the perpendicular distance of observed objects from the transect line to estimate a model of the probability of detection by distance. The monotonic, decreasing key function (half-normal, hazard, or uniform), with possible cosine adjustment terms, that best fit the data was selected using Akaike's Information Criterion (AIC, Burnham and Anderson 1998). We used this key function to estimate $f(0)$, which then was used in the abundance estimator described below (Buckland et al. 2001). Methods for fitting detection functions, truncating observations at extreme distances, and other particulars of distance sampling are described in detail in Buckland et al. (2001).

Two observers conducted independent surveys and, therefore, we stratified data by observer. We used exact distances in the analysis but inspected the histogram of observations, binned by distance, to decide whether truncating observations at the farthest distances (<5 percent of observations) was warranted (Buckland et al. 2001).

The sampling unit in our study was a 9-km^2 block, which complicated the procedure for estimating abundance and precluded our use of program DISTANCE to estimate abundance. Therefore, we estimated abundance as:

$$\hat{N} \quad \sum_{s\ 1}^{3}\left[\frac{n_s}{b\ 1}\left(\sum_{obs\ 1}^{2}\left[\frac{n_b \hat{f}(0)_{obs}}{2}\times 10{,}000\right]\right)\times\frac{A_s}{h_s}\times B_s\right]\Big/\left[L_{s1}+L_{s2}\right]$$

where $\hat{N}$ is the estimated number of birds for a given species, s is the number of strata, h_s is the number of blocks in stratum s, obs references the observer, n_b is the number of birds observed in block b, $\hat{f}(0)_{obs}$ is the estimated probability density function of detected distances from the line evaluated at zero distance for observer obs, $L_{s,obs}$ is the total transect length (m) for observer obs in stratum s, A_s is the m^2 of habitat found in stratum s, and B_s is the total number of blocks in stratum s. This estimate of abundance was the density estimator described by Buckland et al. (2001), weighted by transect length for each observer and multiplied by the estimated area of habitat in the study area.

We estimated 95 percent confidence intervals (CI) with Monte Carlo simulation using a FORTRAN program written by D. R. Diefenbach. First, we generated random-normal variates for the estimated parameters of each observer's detection function (using the point estimate and estimated standard error for each parameter). For each stratum, we then randomly selected, with replacement, an equivalent sample size of blocks from our dataset and used the corresponding amount of habitat and number of singing males observed. This bootstrap resampling allowed us to incorporate sources of sampling variability due to estimating the amount of habitat as well as the number of birds among transects. We repeated this bootstrap procedure 1,000 times to obtain estimates of N as described above. We ordered these estimates of N and selected the 2.5 and 97.5 percentiles as the limits for 95 percent CI.

Results

Within the 74 surveyed blocks, we mapped 108 reclaimed areas totaling 1,634 ha of suitable grassland

songbird habitat. These patches of habitat ranged in size from 1 to 120 ha and averaged 15 ha. We estimated a total of 35,373 ha (95 percent CI = 26,758 – 46,870) of suitable reclaimed surface mine grassland habitat in the 9-county study area.

Observers walked a total of 70.45 km of transects and recorded 325 Grasshopper Sparrow, 144 Henslow's Sparrow, and 83 Savannah Sparrow singing males within the 108 surveyed areas. We estimated the total population of singing males occupying the estimated 35,000 ha of suitable reclaimed surface mine habitat to be 1,921 Savannah Sparrows (95 percent CI = 848 – 2,790), 9,650 Grasshopper Sparrows (95 percent CI = 4,390 – 13,614), and 4,884 Henslow's Sparrows (95 percent CI = 2,128 – 8,460). From the estimates of total suitable reclaimed-mine grassland area and total populations, we calculated an average density of singing males of each species on suitable reclaimed surface mine habitat over the entire study area: 7 Savannah Sparrow, 28 Grasshopper Sparrow, and 14 Henslow's Sparrow singing males per 100 ha.

Discussion

Concern about declines of grassland bird species continues to grow, but our knowledge of even basic population ecology remains incomplete. Research attention needs to be focused on better understanding population dynamics of these birds. To date, few researchers have attempted to document the size of the populations of grassland birds at regional scales, and published estimates have been based on diverse methods. We used a statistical sampling design and distance sampling to obtain the first regional estimates for Henslow's, Grasshopper, and Savannah Sparrow populations on reclaimed surface mines in Pennsylvania. Obtaining regional population estimates will allow us to track temporal population trends of these grassland bird species.

We have not quantified reproductive success on these reclaimed sites in western Pennsylvania. However, we have anecdotal evidence of successful reproduction, including observations of active nests and feeding behavior of adults of all three species on our study sites (J. Mattice, pers. obs.). We realize the importance of estimating productivity on these sites because these reclaimed areas could potentially function as population sinks, as has been seen in other fragmented habitats (Winter and Faaborg 1999).

Our estimates of bird abundance incorporated the sampling variance associated with the sampling design to estimate the amount of habitat within the study area as well as the sampling variance associated with the estimates of abundance of birds among blocks. However, the accuracy of our estimates depends on how well we met the three assumptions of distance sampling techniques. One assumption is that measurements of distance and angle of birds from the transect line are accurate. We attempted to meet this assumption by using laser rangefinders to measure distance and compasses with sighting mirrors to measure angles. Our evaluation of these methods indicated they provided precise measurements with no systematic bias.

Another assumption is that birds did not move in response to the observer prior to being detected, and we attempted to meet this assumption by searching for birds on or near the transect line well ahead of the observer. Our detection functions exhibited no evidence of birds moving away from the transect line prior to being detected (Buckland et al. 2001:33), but if it did occur our estimates are negatively biased ($\hat{N} < N$; Buckland et al. 2001:32).

The last assumption is that all birds on or near the transect line were detected with certainty. We know this assumption was violated because of the behavior of these species of grassland songbirds and our criteria for recording an observation. These birds often spend a substantial portion of time on the ground where they cannot be seen, and we recorded only visually detected singing males because that was the only way to identify birds to species and to measure distances. Consequently, we likely underestimated abundance, and preliminary research on the proportion of birds that are detectable suggest that our underestimates may be as great as 50 percent (M. R. Marshall, pers. comm.). We are conducting research to estimate the proportion of time singing males are detectable, and we plan to use this information to reduce the underestimation of abundance estimates (Buckland et al. 2001:57-58). Although we believe our estimates represent a minimum number of birds on the study area, we have adjusted for detectability differences related to observer skill, and we provide an associated measure of precision that can be used to test for statistically significant differences in abundance over time or space.

Pennsylvania's contribution to the global population of Henslow's Sparrows is substantial, with approximately 5,000 singing males on reclaimed sites in our 9-county study area. Moreover, we believe we have underestimated their abundance. To place our estimate in context for conservation and management planning, we chose to compare it to estimates for states reported in the 1996 Henslow's Sparrow Federal status assessment (Pruitt 1996). Although these estimates were based on different methods, we found comparisons informative. Few states estimated populations in excess of several hundred birds, and only Oklahoma, Missouri, and Kansas reported populations in excess of 1,000 birds in known colonies or projected to occur in the matrix of

natural and agricultural grasslands. In comparison to our estimates for Pennsylvania, Missouri is the only state with a larger population of Henslow's Sparrows (Pruitt 1996).

Since publication of the Henslow's Sparrow status assessment (Pruitt 1996), many studies, including this one, have been initiated to evaluate the status of Henslow's Sparrow populations. In some instances, significant new populations were identified. Notably, many of these have been on reclaimed surface mines, including locations in Indiana (Bajema et al. 2001), Illinois, and Ohio (Ingold 2002). These surveys indicate larger populations than expected from the 1996 assessment, suggesting that much of the extant population occurs on reclaimed surface mines. Therefore, management of reclaimed strip mine areas as grasslands may help mitigate overall declines in global grassland songbird populations due to habitat loss and degradation.

Acknowledgments

We thank S. McConnell and K. Behrens for conducting bird surveys; J. Bishop, J. McQuaide, and J. Sinclair for help with data analysis; and J. Vreeland, E. Long, and M. Marshall for helpful comments that greatly improved earlier versions of the manuscript. We would also like to thank C. Norment and D. Dearborn for valuable contributions during the review process. This research was funded by the U.S. Geological Survey and the Pennsylvania Game Commission.

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The Distribution and Abundance of Obligate Grassland Birds Breeding in New England and New York

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Abstract

It is clear that grassland bird populations have declined significantly during the last 30 years. Declines are widespread in North America, making grassland birds a continental conservation priority. In New England and New York steep population declines for many species warranted listing in many states. Habitat loss through farm abandonment and the subsequent succession of grassland habitat to forest is the principle cause of the observed population declines. Because of the concern for grassland bird conservation and the lack of an understanding of the regional distribution and relative abundance of grassland birds in New England and New York, we coordinated a survey of breeding grassland birds throughout this region from 1997-2000. We estimated the occurrence and relative abundance of seven obligate grassland bird species at 1,140 sites. Sites included hayfields, fallow fields, pastures, airports, and military bases. Of the seven species surveyed, Savannah Sparrows (*Passerculus sandwichensis*) and Bobolinks (*Dolichonyx oryzivorus*) were most common, occurring on 72 percent and 69 percent of all sites, respectively. Eastern Meadowlarks (*Sturnella magna*) were detected on 37 percent of all sites. Upland Sandpipers (*Bartramia longicauda*), Vesper Sparrows (*Pooecetes gramineus*), Grasshopper Sparrows (*Ammodramus savannarum*), and Henslow's Sparrows (*Ammodramus henslowii*) were generally uncommon and occurred on <20 percent of the surveyed sites. We used bird distributions and geopolitical affinities to define eight sub-regions throughout the Northeast to better direct conservation actions. Each sub-region was important for different species: Grasshopper Sparrows were most widely distributed in the Finger Lakes sub-region. Upland Sandpipers and Vesper Sparrows were most abundant in the South-Central Maine sub-region, Bobolinks were most common in the Connecticut River/New Hampshire sub-region, Eastern Meadowlarks were most widespread in the Mohawk Valley of New York, but we estimated the highest relative abundance in the St. Lawrence Plains. With these data, we gained a clear understanding of which areas in each state were most important for each species. This information can assist in setting conservation priorities in New England and New York and provide baseline information for the development of a comprehensive regional grassland bird management plan.

Key words: Bobolink, Eastern Meadowlark, Grasshopper Sparrow, grassland birds, Henslow's Sparrow, New England, New York, Northeast, power analysis, Savannah Sparrow, Upland Sandpiper, Vesper Sparrow.

Introduction

The decline in grassland bird populations throughout North America, and in New England and New York (hereafter Northeast; Askins 1993, Peterjohn and Sauer 1999) has stimulated research and conservation action directed towards grassland bird conservation (Andrle and Carroll 1988, Bollinger et al. 1990, Vickery et al. 1994, Norment 2002). In New England and New York, nine species of grassland birds are listed as endangered, threatened, or of special concern, due primarily to habitat loss (Vickery 1992). For example, native grassland habitats in the Northeast, such as coastal heathlands and sandplain grasslands, have been reduced by >90 percent of their pre-colonial extent (Noss et al. 1995). Farm abandonment, and the subsequent succession of open habitat to forest, has reduced agricultural grassland area by 60 percent (Vickery et al. 1994), leaving the remaining habitat fragmented and patchily distributed. Because many grassland bird species in this region are area-sensitive, some species are limited to the few remaining large tracts of habitat making

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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management of specific sites critical to regional population persistence (Vickery et al. 1994).

Management of grassland habitats in the Northeast is an integral component of a regional grassland bird conservation plan (Norment 2002). Due to the succession of grassland habitats to shrublands and young forests, land managers must interrupt this process with mowing, prescribed burning, or herbicide spraying to maintain grassland bird breeding habitat. The intensive management necessary to maintain grassland habitats and the difficulty in estimating the historical extent of grasslands in the Northeast have prompted debate over the prioritization of these species in regional conservation plans (Norment 2002). Regardless of the historical reference concerning the extent of grasslands in this region, the development of a regional grassland bird conservation plan will depend on the acquisition, interpretation, and dissemination of information regarding the distribution and abundance of these species throughout the region.

To this end, we coordinated and conducted a regional survey of obligate grassland birds (sensu Vickery et al. 1999) throughout the seven states of the Northeast from 1997-2000. The primary objectives of this study were: 1) to determine the distribution and relative abundance of grassland birds breeding in the Northeast; 2) to increase our understanding of regionally important concentrations of grassland birds to focus conservation efforts; and 3) to develop a framework for a monitoring program. Because the Breeding Bird Survey (BBS), a roadside counting survey, does not adequately detect many grassland bird species in the Northeast with adequate frequency to estimate population trends (Sauer et al. 1997), habitat specific regional surveys are necessary to provide accurate population estimates. Developing and maintaining robust monitoring programs is a challenge that must be overcome as timely and accurate detection of declining populations is of paramount importance to species and habitat conservation. We think the results of this survey provide a framework for developing a regional grassland bird monitoring program.

Methods

We defined eight sub-regions to implement the survey and facilitate conservation planning throughout the region (*fig. 1*). Within each sub-region we selected grassland sites using Natural Resource Conservation Service aerial photographs to identify grassland and agricultural areas. We used DeLorme™ atlases to cross reference grassland areas identified on aerial photographs with road maps. We considered sites suitable if they were open (clear of trees and shrubs), greater than ≈ five ha, and dominated by grasses and forbs. We established 100-m radius points at each site, the number of which was determined by the size of the site. We determined site ownership (private or public) to demonstrate the importance of incorporating private landowners in bird conservation initiatives. All point centers were >300 m apart to ensure independence of samples and were at least 100 m from non-suitable habitat (forested edge or other).

Figure 1— Locations of 1,140 sites surveyed for grassland birds in the northeastern United States, 1997-2000 and identification of eight sub-regions.

We counted birds that were seen or heard for five minutes at each point from 0600-1100 between 1 May and 30 July and indicated whether an individual was within or outside the 100-m radius point. Each survey point was visited at least twice during a breeding season and the maximum number of individuals detected was used as an estimate of species abundance for that point. We included the following species defined as obligate grassland birds (Vickery et al. 1999) in the analysis: Upland Sandpiper (*Bartramia longicauda*), Vesper Sparrow (*Pooecetes gramineus*), Savannah Sparrow (*Passerculus sandwichensis*), Grasshopper Sparrow (*Ammodramus savannarum*), Henslow's Sparrow (*Ammodramus henslowii*), Bobolink (*Dolichonyx oryzivorus*), and Eastern Meadowlark (*Sturnella magna*). We present results as the average number of birds per point where point is considered to be within the 100-m radius for all species except Upland Sandpiper (Ralph et al. 1995). Upland Sandpipers have large territories, are very mobile, and more frequently detected >100 m.

Therefore, we used an unlimited radius to determine the average number of Upland Sandpipers per point.

To design a robust sampling procedure for a future, trend-based monitoring program for the Northeast, we used program MONITOR (Gibbs et al. 1998) to conduct a power analysis based on existing temporal variation observed in our counts. The analysis was based on an average coefficient of temporal variation (CV = 0.90). Our monitoring objectives were to detect a 10 percent decline in grassland bird population sizes (at α = 0.10, two-tailed) with surveys involving two repeat visits within a year to sampling points over a 10-year period. We used a general estimate of the sample variability for the more common grassland bird species (Savannah Sparrow, Bobolink, Eastern Meadowlark) to conduct this power analysis which may not be an accurate estimate of the power to detect population trends for the more rare grassland birds (Henslow's, Grasshopper and Vesper sparrows). For these rare Northeast grassland birds, species specific monitoring programs may be necessary to adequately track population changes over time. Our primary goal of this power analysis was to estimate the effort necessary to monitor grassland birds and to provide a framework for how a monitoring program may be implemented.

Results

We surveyed 1,140 sites for grassland birds in the Northeast (*fig. 1*). Savannah Sparrows and Bobolinks were the most common and widespread species and occurred at 71 percent and 69 percent of all sites, respectively (*fig. 2A,B*). Eastern Meadowlarks occurred at 37 percent of the sites while Grasshopper Sparrows, Vesper Sparrows, Upland Sandpipers, and Henslow's Sparrows occurred on <20 percent of sites (*fig. 2C-G*). Upland Sandpiper and Henslow's Sparrows were only detected on 7 percent and 3 percent of all sites respectively.

The relative abundance and distribution of each species differed among the sub-regions of the Northeast (*fig. 2A-G*). Bobolinks had the greatest relative abundance and were most widespread in the Connecticut River Valley/New Hampshire sub-region (*table 1*). Eastern Meadowlarks had the greatest relative abundance in the Southern New England subregion and were most common in the St. Lawrence Plains (*table 1*). Grasshopper Sparrows had the greatest relative abundance in the Southern New England sub-region and were most common in the Finger Lakes sub-region (*table 1*). Henslow's Sparrows had the greatest relative abundance and were most common in the St. Lawrence Plains (*table 1*). Savannah Sparrows had the greatest relative abundance in the St. Lawrence Plains and were most common in Aroostook County Maine (*table 1*). Upland Sandpipers had the greatest relative abundance in the Southern New England sub-region and were most common in the South/Central Maine sub-region (*table 1*). Vesper Sparrows had the greatest relative abundance in the Mohawk Valley subregion and were most common in the South/Central Maine sub-region (*table 1*).

To aid in prioritizing specific sites for conservation, we identified where multiple species of high conservation importance co-occurred. Upland Sandpipers and Vesper sparrows had similar ranges (*fig. 2E* and *F*) and co-occurred on 52 percent of the sites where at least one of the species was detected. Eighty-five percent of the sites where Upland Sandpipers and Vesper Sparrows co-occurred were in the commercial blueberry barrens of eastern Maine (*fig. 3A*). We detected Upland Sandpiper, Vesper and Grasshopper sparrows together on nine sites in the Northeast (*fig. 3B*).

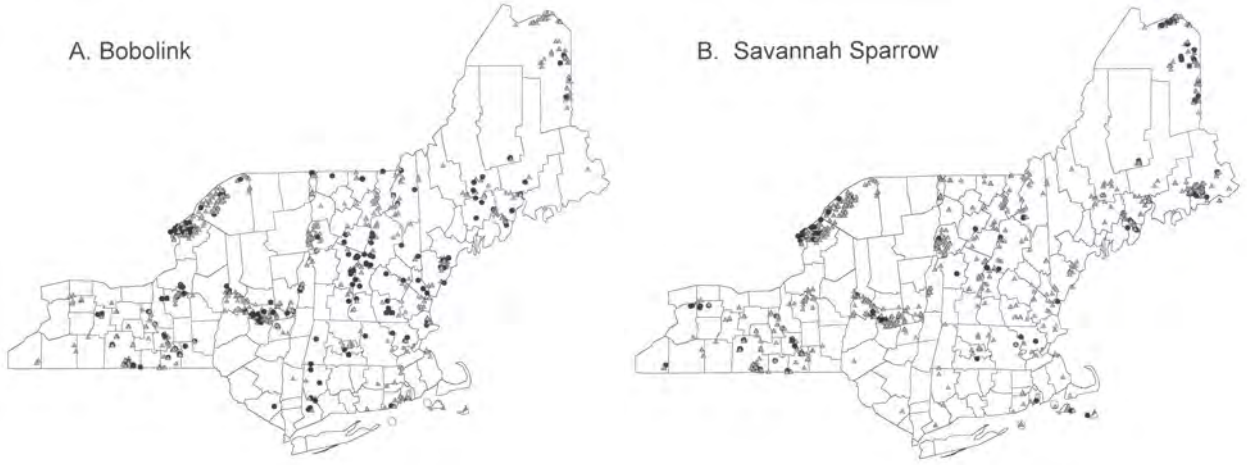

Figure 2— Species maps indicating occurrence and relative abundance among 1,140 sites sampled in the northeastern U.S. (gray triangles = 1-10 individuals detected, black circles = >10 individuals detected) of A) Bobolink, B) Savannah Sparrow.

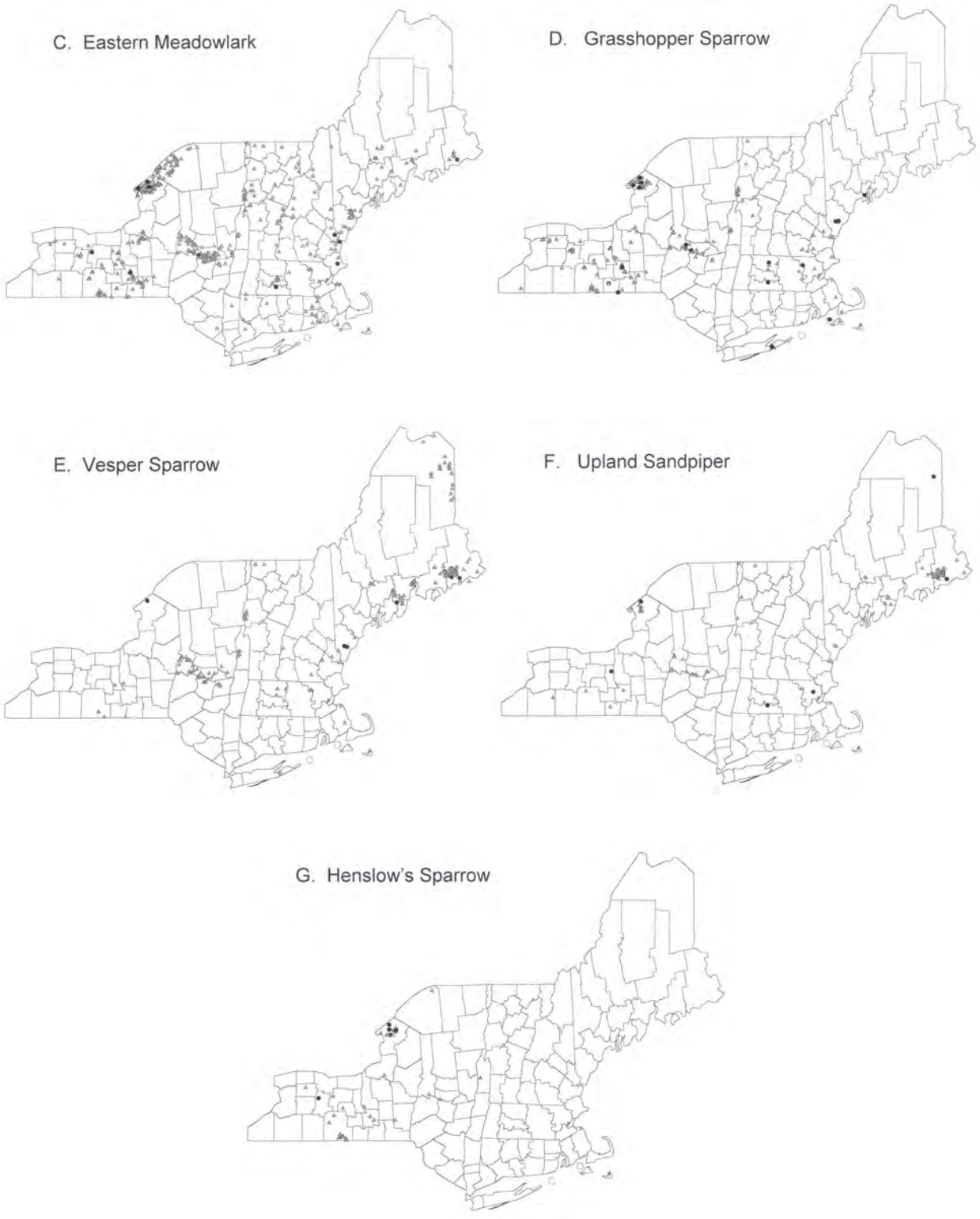

Figure 2— (continued) Species maps indicating occurrence and relative abundance. C) Eastern Meadowlark, D) Grasshopper Sparrow, E) Vesper Sparrow, F) Upland Sandpiper, and G) Henslow's Sparrow.

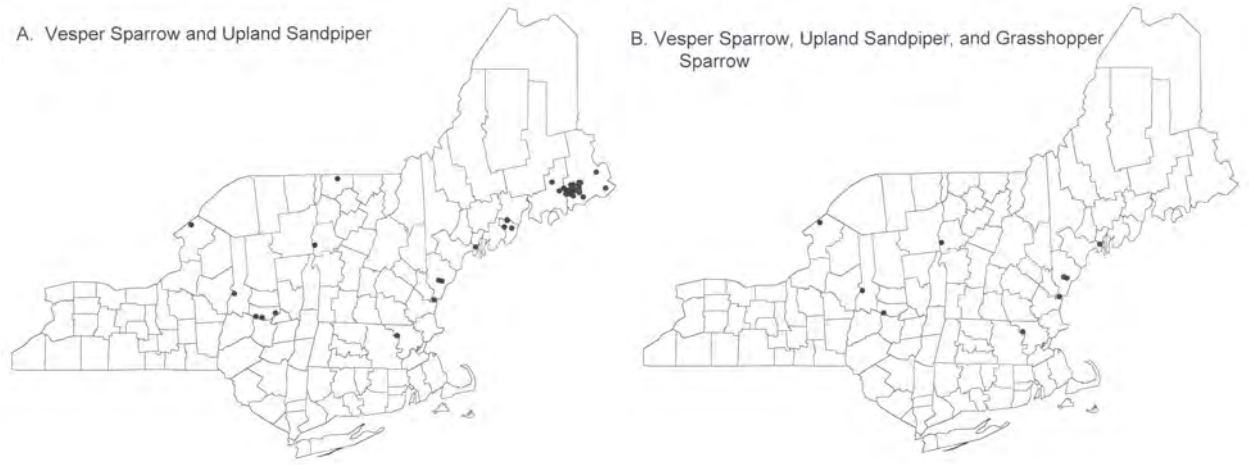

Figure 3— Sites among 1,140 sites sampled in the northeastern U.S. where A) Vesper Sparrow and Upland Sandpiper and B) Vesper Sparrow, Upland Sandpiper, and Grasshopper Sparrow co-occurred.

Based on our power analysis, we determined that we could detect a 10 percent annual decline in grassland bird populations with power >0.90 over a 10-year period if 25 sites were surveyed in each sub-region (200 sites total). Each site would need to be surveyed four times during this 10-year period with two visits/point/survey year. We recommend that the first two surveys be conducted in the first 5-year period and third and fourth surveys be conducted in the second 5-year period.

Discussion

This survey estimated the distribution and relative abundance of grassland birds in New England and New York and indicated which sub-regions were important for each species. These data can be used to prioritize future regional and state grassland bird conservation efforts, provide context for states within a larger geographic framework, and are an important step in the development of a regional grassland bird conservation plan (Wells and Rosenberg 1999). For example, Upland Sandpipers and Vesper Sparrows had similar distributions and were most common in the South-Central Maine sub-region. These data demonstrate the importance of this area to the regional conservation of these two declining species. We think future research should be focused on this area to determine the effects of blueberry management on the reproductive success and habitat selection of these two species.

Upland Sandpiper has been identified as an area sensitive species with a 50 percent probability of occurrence on sites >200 ha (Vickery et al. 1994). Due to the life history requirement of large, contiguous open habitat, this species distribution has become highly fragmented throughout the Northeast. The largest populations in New England occur at Westover Air Force Base in Massachusetts, and on the blueberry barrens in eastern Maine. Although Upland Sandpiper population trends in the Northeast have not changed significantly between 1966-1995 (Sauer et al. 1997), this may be because the BBS was not sensitive to changes for this rare, locally distributed species; Carter (1992) found that in the Northern Piedmont and Ridge and Valley strata of the Eastern Piedmont Plateau Region, Upland Sandpiper populations have declined by 3 percent and 18 percent respectively.

Vesper Sparrows in the Northeast are found in pastures, barrens, and cultivated land, and have been estimated to be declining by 6 percent annually (Rising 1996, Sauer et al. 1997). In Massachusetts, statewide grassland bird surveys in 1993 and 1998 revealed a decline of approximately 50 percent (A. L. Jones, unpubl. data[1]). Henslow's Sparrow has undergone a range contraction in the past 50 yrs and is declining at an estimated rate of 13 percent annually (Sauer et al. 1997). This species is characteristically found in wet meadows, grassy swamps, often interspersed with shrubs (Rising 1996). Because of evident population declines at the range limit of the Eastern subspecies of Henslow's Sparrow (*A. h. susurrans*), this species was considered highest grassland bird conservation priority in the region (Wells and Rosenberg 1999). This survey indicates that the Finger Lakes and St. Lawrence Plains sub-regions were most important to the conservation of Henslow's Sparrows in the Northeast and sites where this species was detected should be given high conservation priority.

[1]Unpublished data on file at Massachusetts Audubon Society, 208 South Great Road, Lincoln, MA 01773

Table 1— *The average number of individual grassland birds detected per point (+sd) and the frequency of occurrence (proportion of sites where species was detected) within each of eight sub-regions in the Northeast, 1997-2000.*

Sub-region	Number of sites sampled	Species						
		Bobolink	Eastern Meadowlark	Grasshopper Sparrow	Henslow's Sparrow	Savannah Sparrow	Upland Sandpiper	Vesper Sparrow
1. Finger Lakes	224	5.7 (7.4) 0.77	1.5 (2.5) 0.51	1.6 (4.0) 0.38	0.4 (2.4) 0.10	4.9 (7.4) 0.79	0.3 (1.3) 0.07	0.1 (0.7) 0.05
2. St. Lawrence Plains	121	7.9 (26.9) 0.83	2.6 (3.3) 0.64	1.4 (3.4) 0.21	0.9 (3.2) 0.12	7.3 (20.7) 0.87	0.2 (1.1) 0.06	0.1 (1.5) 0.01
3. Mohawk Valley	124	4.6 (5.4) 0.08	1.4 (1.7) 0.62	0.6 (1.8) 0.19	0.1 (0.4) 0.02	2.8 (3.3) 0.71	0.1 (0.3) 0.03	0.5 (1.0) 0.26
4. Champlain Valley	56	4.8 (5.5) 0.77	0.8 (1.4) 0.34	0.7 (2.0) 0.20	0.0	5.4 (5.9) 0.86	0.2 (0.7) 0.07	0.4 (1.0) 0.14
5. Aroostook County	107	2.2 (3.2) 0.63	0.1 (0.1) 0.01	0.0	0.0	6.2 (7.4) 0.90	0.2 (1.9) 0.03	0.4 (1.2) 0.17
6. South/Central Maine	222	3.3 (5.2) 0.48	0.5 (1.1) 0.23	0.3 (2.6) 0.02	0.0	3.9 (5.4) 0.67	0.1 (0.8) 0.22	0.2 (1.3) 0.41
7. Connecticut River/ New Hampshire	130	10.5 (12.9) 0.92	0.9 (2.3) 0.28	0.1 (0.6) 0.05	0.0	3.9 (5.4) 0.75	0.1 (0.8) 0.01	0.2 (1.3) 0.04
8. Southern New England	156	8.4 (22.1) 0.51	2.9 (21.5) 0.30	4.3 (34.3) 0.18	0.0	3.2 (8.7) 0.36	3.0 (34.3) 0.05	0.4 (1.1) 0.14

The importance of the Northeast to grassland bird conservation has been questioned because this open habitat is thought to be an artifact of European land use. Thus, observed declines in grassland bird populations can be explained by the region's natural succession to a forest dominated landscape (Wells and Rosenberg 1999, Norment 2002). However, Winne (1997) analyzed pollen taken from pond sediments in Washington County, Maine and found that some blueberry barrens in this region had been open grassland pine/shrub barrens for at least the past 1,700 yrs. Other available evidence (Askins 1993, 2000) and the presence of a unique taxonomic subspecies of the Greater Prairie Chicken (Heath Hen *Tympanuchus cupido cupido*) in coastal New England provide strong evidence that native grasslands occurred sporadically in New England and likely throughout the Northeast (Jones and Vickery 1997a, Vickery and Dunwiddie 1997).

Because there are a number of unique subspecies of grassland birds in the Northeast, this region is important for the conservation of their genetic diversity across North America (Wells and Rosenberg 1999). Their analysis found that the Northeast supports 100 percent of the eastern subspecies of Henslow's Sparrow (*A. s. susurrans*), 55 percent of eastern subspecies of Savannah Sparrow (*P. s. savanna*), 13 percent of the nominate form of Eastern Meadowlarks (*S. m. magna*), and 12 percent of eastern subspecies of Grasshopper Sparrow (*A. s. pratensis*).

Conservation of grassland birds in the Northeast is a challenge ecologically, financially, and politically (Norment 2002). Land ownership and land use practices clearly have profound impacts on the quality of habitats within landscapes and the conservation of biotic diversity will not be achieved solely on public or protected lands. Results from this project indicated that approximately 82 percent of the sites we surveyed were in private ownership making it imperative that grassland bird conservation planners integrate their knowledge of the needs of breeding grassland birds into initiatives to conserve and/or manage private farmland for grassland birds (see Jones and Vickery 1997b).

Several federal programs exist to aid private landowners with management of wildlife, such as the Natural Resource Conservation Service's Wildlife Habitat Incentives Program, the Department of Agriculture's Conservation Reserve Program (CRP), and the U.S. Fish and Wildlife Service's Partners for Fish and Wildlife Program. These programs provide cost sharing to landowners for develop, manage, or enhance habitat for upland wildlife, wetland wildlife, and endangered species. For example, grassland bird species richness was used effectively in Maine to help prioritize applicants to the CRP program.

Accurately detecting population changes is paramount to the conservation of wildlife populations, the success of which is hinged on developing meaningful monitoring programs (Gibbs et al. 1998). These data provide a sampling frame from which a regional monitoring program can be developed and implemented. Sites within sub-regions could be randomly selected for resampling to provide statistically reliable estimates of population trend. A robust regional monitoring program could be developed using these data as the initial count and a framework for site selection within each sub-region. Minimal field effort would be required to conduct two visits per 100-m radius point at 25 sites within each sub-region. Documenting a population trend can only be meaningful, however, if opportunities for changes in management or land-use exist (Elzinga et al. 2001). Because grassland habitats require relatively high levels of management to maintain grass-dominated systems they are especially amendable to monitoring programs that are integrated into adaptive management plans. Any Northeast grassland bird monitoring program should also include information about how specific management actions effect species abundance, and optimally, reproductive success.

Acknowledgments

We thank all the state agencies in New England and New York for providing logistic support, information, and coordination in state surveys, especially J. Dickson in Connecticut. Without their cooperation this project would not have been possible. R. Askins, P. Paton, B. Dale, and T. Rich provided valuable comments that greatly improved this manuscript. This survey was funded in part by the National Fish and Wildlife Foundation, U.S. Fish and Wildlife Service, and the Maine Outdoor Heritage Fund. The following organizations also provided invaluable assistance: Cornell Laboratory of Ornithology, Audubon Society of New Hampshire, Vermont Institute of Natural Science, New York State Federation of Bird Clubs, The Nature Conservancy, and The National Audubon Society. B. Zuckerburg coordinated volunteers. We would also like to thank the 27 interns and over 75 volunteers who made these surveys possible.

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Status and Conservation of the Bobolink (*Dolichonyx oryzivorus*) in Argentina[1]

Adrián S. Di Giacomo,[2] Alejandro G. Di Giacomo,[2] and Julio R. Contreras[3]

Abstract

The nearctic breeding Bobolink (*Dolichonyx oryzivorus*) is experiencing a decline in North America. Some authors suspect winter survivorship in South America could be responsible for the decline. We analyzed historical and current records of this species in Argentina, and found: 1) the Bobolink's winter range has decreased by at least 25 percent; 2) they are more regularly found in the provinces of Formosa and Corrientes; 3) at present Bobolinks primarily use natural wet grassland habitats associated with main rivers and huge marshes (Paraguay, Paraná, Pilcomayo and Esteros de Iberá); and 4) of 45 records compiled in the past 96 years, 60 percent have occurred during events of El Niño Southern Oscillation (ENSO) and 85 percent during events of flooding of Paraguay-Paraná basin. Natural grasslands are the main threatened habitat in Argentina (only 0.3 percent of area is protected). The decrease of natural grasslands appears to be affecting Bobolinks as well as local residents. The status of the Bobolink in Argentina should be assessed to determine if areas of major concentration exist in agricultural crops and grasslands in the north of the country, and to identify measures for its conservation. We recommend cooperation between North American and Argentine ornithologists to increase the research on migrant grassland birds such as Bobolink, Upland Sandpiper (*Bartramia longicauda*), Swainson's Hawk (*Buteo swainsoni*), and other species. This is an excellent opportunity to link the conservation needs of nearctic migrants and globally threatened resident species that have declined precipitously, such as Strange-tailed Tyrant (*Alectrurus risora*), Black-and-White Monjita (*Heteroxolmis dominicana*), Saffron-cowled Blackbird (*Xanthopsar flavus*) and seedeaters (*Sporophila* spp.).

Key words: Argentina, Bobolink, conservation, *Dolichonyx oryzivorus*, grasslands, winter ecology.

Introduction

The Bobolink (*Dolichonyx oryzivorus*) is a migratory icterid that breeds in the grasslands of North America and then migrates to South America in the non-breeding season (Jaramillo and Burke 1999).

It is evident that there have been recent declines of Bobolink populations in many states, as has occurred with other North American grassland birds (Askins 1993, Knopf 1994, Peterjohn and Sauer 1999). According to BBS data, Bobolinks have been declining significantly since 1966 throughout their breeding range; the annual rate of decline has been 3.8 percent between 1980 and 1996 (Peterjohn and Sauer 1999). Various land use changes such as the amount of cropland, and the timing and frequency of cutting hay fields, have been identified as the main causes of decline for Bobolinks in North America, both at regional and continental scales (Herkert 1997). Currently, Bobolinks are protected in the United States and Canada under the "Migratory Bird Treaty Act," are listed in some states as a "Species of Special Concern" (Martin and Gavin 1995), and are listed as a species of concern in three Bird Conservation Regions (BCRs 12, 13 and 23) by the U. S. Fish and Wildlife Service (USFWS 2002).

The breeding biology of Bobolinks has been carefully studied, but very little is known about this species' basic biology and current threats on the non-breeding grounds (Martin and Gavin 1995). For example, the non-breeding range is not known in detail (Ridgely and Tudor 1989, Martín and Gavin 1995, Paynter 1995). Essentially nothing is known about their abundance on the winter range, or if it occurs in densities similar to other neartic passerines that winter in South American grasslands, such as the Dickcissel (*Spiza americana*; Basili and Temple 1999). Minimal habitat requirements, feeding ecology, and social behavior are not known for the non-breeding grounds. The scarce information about wintering Bobolinks is dispersed, often a repetition of old data, and sometimes inaccurate.

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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For example, Martin and Gavin (1995) indicated that during the non-breeding season Bobolinks are found in "pampas" (southern temperate grasslands) of South America. But they also have been found in wetlands and field crops. Pettingill (1983) considered Bobolinks to be a pest because they damaged rice crops, but recent Argentinean observations have not confirmed this assertion. In addition, shooting and trapping on wintering grounds could be another possible factor affecting current declines (Pettingill 1983, Martin and Gavin 1995), but others threats such as changes in wintering habitat need careful study (Vickery et al. 1999, Vickery and Herkert 2001).

In this review we have gathered all published data, and much unpublished information, concerning Bobolinks in Argentina, the most austral area of its non-breeding grounds. The objectives are: 1) to compare the historical and recent records of Bobolinks in Argentina in order to detect any change in their distribution or range; 2) to compile basic ecological information available for Argentina regarding habitat requirements, feeding ecology, and social behavior.

Methods

We determined the historical range of the Bobolink by compiling records before 1990. These records were obtained from labels on specimens in Argentine museums, from a thorough literature search, and from personal communications. Records between 1990 and early 2002 were obtained during field trips in the provinces where previous historical records existed. We have worked extensively in northeastern Argentina since 1980, and have carried out systematic grassland censuses in El Bagual Ecological Reserve (Formosa province) since 1995. These records in El Bagual include habitat, behavior and size of flock. In addition, we have contacted resident ornithologists in all the provinces where we think that Bobolinks might occur.

We constructed two maps, one with historical records (before 1990) and another with recent records (after 1990). We then looked for distribution changes between these two time periods. Data concerning the non-breeding ecology of Bobolinks were compiled and analyzed considering the geographical location, the habitat, the number of individuals, and feeding or social behavior.

In addition, we looked for possible correlations between the Bobolink records in northeastern Argentina and both the "El Niño Southern Oscillation" (ENSO) as well as the flooding dynamics of the Paraguay-Paraná river system. Both phenomena are known to produce severe changes in the climatic and environmental conditions in the breeding area (England 2000), during migration (Lack 1960), and in northeastern Argentina (Contreras and Contreras in press). Climatic data for our comparisons were obtained from databases and tables (Quarleri 1975, Quinn and Neal 1987, Andersen et al. 1993, National Climatic Data Center 2001, Contreras in press).

Results

Distribution and Phenology

We compiled a total of 52 Bobolink records in Argentina between 1903 and 2002. Eleven records came from museum specimens and there were 41 records provided by experienced ornithologists.

Bobolinks in Argentina were distributed in two separate regions (*figs. 1, 2*). They were reported in northwestern Argentina, in the provinces of Salta, Jujuy and Tucumán. This area is a transition between Yungas Forest and Chaco Woodland on the Andean foothills. It is a region with few records (N = 5) from areas where the forest has been largely replaced by agricultural fields. The greatest number of records in Argentina came from the northeastern lowlands in the provinces of Misiones, Corrientes, Formosa, Chaco, Santa Fé, Entre Ríos and Buenos Aires (N = 47). All these records were located in, or near, the Río de la Plata Basin.

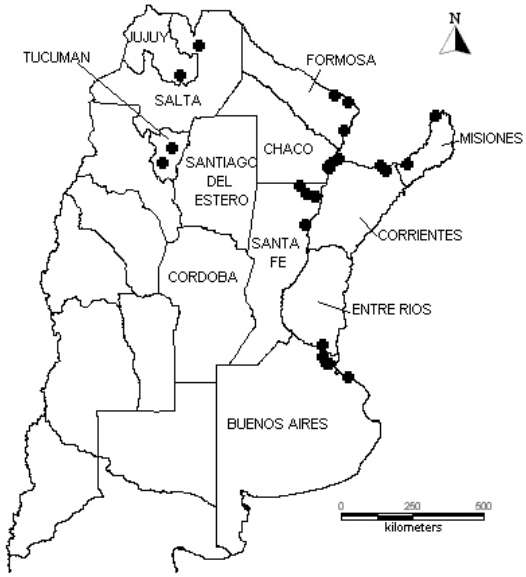

Figure 1– Sites where Bobolinks were recorded between 1903 and 1989 (historical records, N= 28) in Argentina.

Bobolinks were found in Argentina from early November to March, with extreme dates from November 6 to March 25, though there are two additional records of possible vagrant birds in Tucumán (1 individual in

April 1994, Blendinger 1998) and Punta Rasa, Buenos Aires (1 individual in May 1980, Jaramillo 2000). The majority of records (56 percent) were in December and January (*fig. 3*).

In recent years Bobolinks were found in only six of ten provinces, which represented a 25-30 percent decrease from the historical distribution.

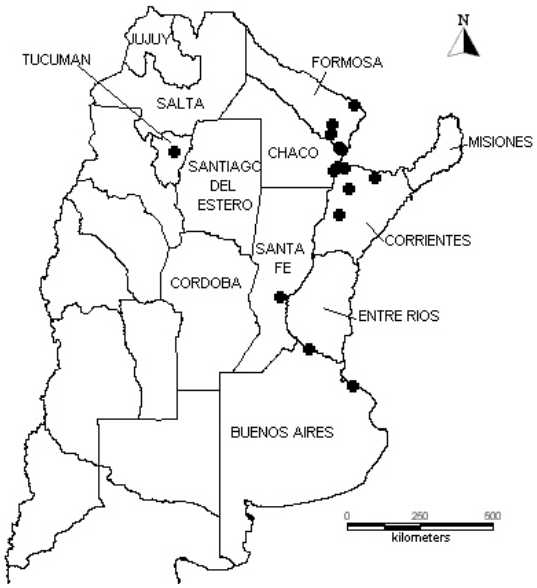

Figure 2– Sites where Bobolinks were recorded between 1990 and 2002 (recent records, N= 23) in Argentina.

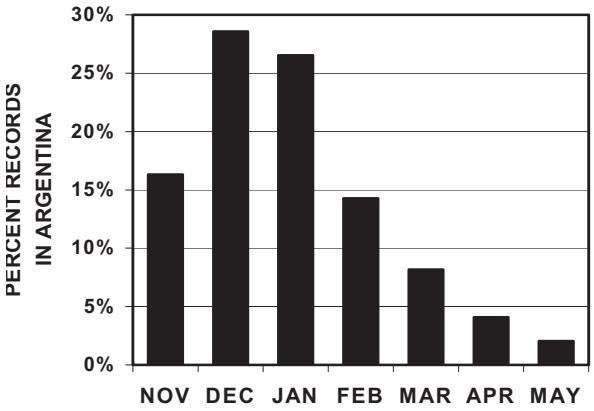

Figure 3– Seasonal occurrence of Bobolinks recorded in Argentina between 1903 and 2002 (N= 49).

Bobolinks did not appear regularly at every site. They were found only in some years. An analysis of 45 records between 1906 and 2002 showed that 60 percent occurred during events of the El Niño Southern Oscillation (ENSO) and 85 percent during events of flooding of the Paraguay-Paraná basin.

Habitats

In Argentina, Bobolinks were primarily found in natural grassland habitats (55 percent) associated with the main rivers (Paraguay, Paraná, Pilcomayo, Río de la Plata) or streams (Pilagá, Mbiguá). The remaining records were recorded in marshes (41 percent; Esteros de Iberá) and crop fields (4 percent).

Observations in El Bagual Ecological Reserve were carried out in tall (0.80 – 1.20 m height) grasslands of two main types associated with the Mbiguá stream. *Imperata brasiliensis*, a community typical located in terraces of streams, dominated the more xeric grassland. The other grassland is wetter and is dominated by *Paspalum intermedium* grasses located in lowland depressions or near the marshes (Götz and Di Giacomo 2001).

Food

Pereyra (1938) indicated that Bobolinks fed on seeds of reeds (*Schoenoplectus californicus*) in northeastern Buenos Aires province during December 1930. Pettingill (1983) cited rice and corn seeds as food near the Parana River in the agricultural fields in NE Santa Fé province during January 1978.

In El Bagual Ecological Reserve several flocks of Bobolinks were recorded (November 1995, January and November 1998) feeding on seeds of natural grasses (*Paspalum intermedium* and *P. rufum*). During December 1999 and January 2000 Bobolinks fed on seeds of *P. urvillei*. In December 1998, a small flock (≤50) was recorded in a road near the Reserve feeding on seeds of an invasive grass *Sorghum halepense*.

Social Behavior

In Argentina, Bobolinks were often found in monospecific flocks. Combining all records (historical and present), excluding museum specimens, 59 percent were of flocks of ≤50 individuals and 8 percent were records of single individuals. The records of single birds were mainly in the marginal areas of the species' range in the south (Buenos Aires province) or northwest (Tucumán province).

Historically, the maximum size of the flocks reached 5,000 birds in Santa Fé province (Hartert and Venturi 1909) and a maximum of 1,500 birds has been observed recently in Formosa province. In El Bagual Ecological Reserve during 1995-2001, mean flock size was 160 individuals (N = 39) and the biggest flocks of each season had a mean of 365 (N = 7 seasons).

In Argentina, Bobolinks often were found with other blackbirds that use marsh habitat. In Formosa province, 8 of 39 flocks were associated with marsh icterids.

Seven flocks were associated with Unicolored Blackbird (*Agelaius cyanopus*) and one flock was found with Chestnut-capped Blackbird (*Agelaius ruficapillus*; A. G. Di Giacomo, pers. obs.). In Buenos Aires province Bobolinks were recorded with 25 Brown-and-Yellow Marshbirds (*Pseudoleistes virescens*; Barrios et al. 1992). Only one record at El Bagual Reserve found Bobolinks with Baywing Cowbird (*Molothrus badius*) and White-browed Blackbird (*Leistes superciliaris*)– icterids not typical of marshes.

Bobolinks were observed at a roosting site in dense and tall vegetation on the border of the Mbigua stream in El Bagual Ecological Reserve. This flock, which totaled 200 Bobolinks and 15 Unicolored Blackbirds, was flushed 9 November 2001 at 6:00 AM from a patch of *Cyperus giganteus*.

Discussion

Historically, Bobolinks bred in native grasslands of North America, but recently most of the populations have shifted to agricultural grassland habitats, such as hay fields and pastures (Bent 1958, Herkert 1997). In Argentina any pattern of change of their primary winter habitats has not yet been identified.

The information we have gathered does not fit the classic view that the Bobolink is "abundant pest bird in rice crops of the Pampas" (Pettingill 1983, Martin and Gavin 1995). We think the Bobolink is a scarce visitor in lowland grasslands and marshes. Though our surveys in Chaco, Formosa, Corrientes and Entre Ríos were more oriented towards natural grasslands and marshes, we often surveyed agricultural lands because natural grasslands were currently fragmented by crops and pastures. Some of our surveys were performed only in agricultural fields in Santa Fé and Buenos Aires provinces, where natural grasslands are rare.

The association of Bobolinks with flocks of marsh birds such as *Agelaius* and *Pseudoleistes*, emphasizes the Bobolink's preference for wet grassland areas in Argentina. This wet habitat is located in the same areas as rice crops in northeastern Argentina. Although rice production has increased 200 percent between 1970 and 2000 (SAGPyA 2002) within the Bobolink's range, the records of Bobolinks in crop fields are still scarce in NE Argentina. However the shift of habitat type in the wintering grounds could occur with a more drastic conversion of remnant lowland grasslands in rice fields as occurred with Dickcissel, another neartic migrant, that winter in Venezuela (Basili and Temple 1999). As Vickery and Casañas (2001), we think it is necessary and a high priority to conduct systematic censuses in rice plantations, other agricultural fields, and natural grasslands to better understand this species' habitat preferences.

Bobolinks in Argentina feed primarily on grass seeds (Martin and Gavin 1995). The preferred habitat requirements should be studied, with special attention to the phenology of natural grasses and the summer stages of main crops, as rice, in northeastern Argentina. The milk stage of rice reported by Pettingill (1983) would not occur earlier than mid-January-February (J. Tillous, pers. comm.), and this could explain the presence of Bobolinks feeding in natural grasses in November and December.

Shooting and trapping could be additional possible causes for the Bobolink's current decline (Martin and Gavin 1995). We have frequently found several individuals for sale as cage birds in major cities of Argentina (Córdoba, Buenos Aires, Rosario). The current price of Bobolink in the market is between $5-10. Wetmore (1926) reported this species in the markets of main cities as Mendoza and Tucumán in 1921. In 1978, Pettingill (1983) also found Bobolinks for sale in a shop of Venado Tuerto city, Santa Fé province, for $4 for a male. These observations suggest that Bobolinks have been part of the illegal market of birds for many years.

The effect of agrochemical accidents on Bobolinks also needs to be studied in the main area of rice production because this crop is highly dependent on agrochemical products (Iolster and Krapovickas 1999).

The coincidence of Bobolinks in Argentina with ENSO and flooding in the Rio de la Plata Basin suggests that this climatic event provides more optimal conditions in the lowland grasslands for Bobolinks. These events are known to produce great disturbances in the rivers and streams of this basin, altering the main physical and biotic conditions (Contreras and Contreras in press), producing outbreaks of insects and seeds in several habitats that appear to favor migrant birds (England 2000). Another important direct effect of ENSO years that would affect migrant Bobolinks would be the increase of southerly winds (England 2000). Using BBS data, J. Price[1] showed a significant increase in the latitudinal range of breeding Bobolinks during ENSO years. More accurate data are necessary to correlate climatic and biological information for Bobolinks.

In Argentina there are 24 species of globally threatened birds associated with the temperate and subtropical grasslands (Di Giacomo and Krapovickas 2002). Their original ranges have declined substantially and remaining populations are now small and fragmented. Habitat

[1]J. Price, unpublished data on file at American Bird Conservancy, 6525 Gunpark Drive, Boulder, CO 80301

loss, a consequence of the change in land use in the vast region of Argentina's grasslands, is likely to be the main cause of these population declines. It seems likely that the Bobolink could be also experiencing a similar decline in its winter distribution in Argentina. Species such as Strange-tailed Tyrant (*Alectrurus risora*), Black-and-White Monjita (*Heteroxolmis dominicana*), and Saffron-cowled Blackbird (*Xanthopsar flavus*) and several species of seedeaters (*Sporophila* spp.) live in the same habitats as Bobolinks (Vickery et al. 2002). According to our findings, maintaining the current status of Bobolinks and another nearctic migratory grassland birds is highly dependent on the conservation of natural grasslands in South America.

Natural grasslands are critically threatened in Argentina; only 0.3 percent of the original area has been protected (Krapovickas and Di Giacomo 1998). At least 90 percent of the original Argentine grasslands have been converted to agriculture and urbanization.

More recent data on habitat selection and movements is needed for successful species-based conservation projects in South America which would complement the efforts carried out in the breeding grounds in United States and Canada. We recommend urgent cooperation between North American and Argentine ornithologists and institutions to increase research and conservation projects in wintering grounds of the migrant grassland birds such as Bobolink, Upland Sandpiper (*Bartramia longicauda*), Swainson's Hawk (*Buteo swainsoni*), and others. This is an excellent opportunity to link the conservation needs of nearctic breeding migrants and the globally threatened neotropical resident species.

Acknowledgments

This research was supported by Vogelbescherming BirdLife/Nederland, Aves Argentinas/AOP and Alparamis S. A. We are grateful to P. D. Vickery, J. C. Reboreda and T. Rich for reviewing the manuscript. We appreciate the financial support of Partners in Flight (PIF) Third Conference Committee, National Audubon Society and BirdLife International to attend the PIF Conference in Asilomar, California, March 2002. We thank H. Casañas, A. Giraudo, F. Moschione, T. Narosky, M. Pearman, M. R. de la Peña and G. Pugnali, for providing us with their unpublished records of Bobolinks. G. Scrocchi helped us review specimens in IML (Tucumán). J. Tillous provided us helpful information about rice crops in NE Argentina.

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The Importance and Future Condition of Western Riparian Ecosystems as Migratory Bird Habitat[1]

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Abstract

Riparian forests have long been considered important habitats for breeding western landbirds, and growing evidence reinforces their importance during the migratory period as well. Extensive modification of natural flow regimes, grazing, and forest clearing along many rivers in the western U.S. have led to loss and simplification of native riparian forests and to declines and endangerment of riparian-dependent birds species. Efforts to conserve, restore, and manage the distinctive biological diversity of riparian ecosystems must rest upon a clear understanding of the primary physical and biological process that structure and maintain that diversity on a landscape scale.

Key words: ecosystem processes, flow regimes, riparian forests, western landbirds.

Introduction

Conservation of terrestrial birds depends on a clear understanding of their habitat requirements and the physical and biotic processes that create and maintain those habitats (Askins 2000). Riparian forests are typically more productive and biologically diverse than surrounding uplands and are structured by the distinctive fluvial geomorphic processes and hydrologic conditions found on bottomlands (Brinson 1990, Knutson et al. 1996). Riparian habitats cover less than 1.0 percent of the landscape in western North America (Knopf et al. 1988), yet they support a disproportionately large number of bird species and greater densities of birds than other forested habitats (Johnson et al. 1977, Mosconi and Hutto 1982, Woinarski et al. 2000).

Effective conservation must address critical habitats for birds during all phases of the annual migratory cycle. Riparian forests have long been considered important habitats for breeding western landbirds. Nearly 50 percent of breeding bird species in the western U.S. nest only in riparian vegetation types, including 45 percent of 235 known breeding species in Montana (R. L. Hutto, pers. comm.). In three southwestern states, 48 percent of bird species nest only in riparian and other wetland habitats and an additional 21 percent nest in greater densities in riparian than in other habitats (Johnson et al. 1985). During winter, avian densities and species richness are greater in lowland riparian forests than in other habitats in western Mexico (Hutto 1980). Growing evidence also reinforces the importance of riparian habitats during the en route migratory period (Hutto 1998, 2000; Skagen et al. 1998, Finch and Yong 2000). Densities of Yellow Warblers (*Dendroica petechia*) and Wilson's Warblers (*Wilsonia pusilla*) as great as 48.0 and 33.7 birds/ha, respectively, were recorded in southeastern Arizona riparian forests during spring migration (Skagen et al. 1998). Here, both isolated oases and extensive riparian corridors appeared to have high value for en route migrants.

Riparian forests in the semiarid western U.S. are dominated by early successional woody species, primarily Plains cottonwood (*Populus deltoides*), Fremont cottonwood (*Populus fremontii*), and willows (*Salix* spp.) (Friedman et al., in review). These forests are dependent upon flow-related geomorphic processes for the establishment of new cottonwood and willow patches. The regeneration of these woody species requires the presence of bare moist alluvial surfaces that are laid down during infrequent high intensity floods (Friedman et al. 1997). Cottonwoods are intolerant of shade and rarely become established from seed under existing trees. The bare, moist alluvial surfaces must be available for seed germination during a species-specific window of time after which seeds lose germinability. The seedlings require continuously moist substrates during the first week of growth. Further, survival and recruitment of cottonwood trees necessitates access to groundwater for developing saplings and safety from future disturbances.

Structural diversity of semiarid riparian forests reaches a maximum after approximately 90 years with the development of a mature cottonwood canopy and shrub

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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understory. In the absence of stream flows and geomorphic processes to create suitable sites for new germination and establishment, forest structure declines with the attrition of mature cottonwoods and as stands give way to shrubs and ultimately upland grasses (Boggs and Weaver 1994). Friedman et al. (1997) present a clear description of the roles of fluvial processes and channel morphology in cottonwood regeneration and forest dynamics in the Great Plains.

Scott et al. (2003) illustrate how fluvial geomorphic processes and long-term grazing can influence the structural complexity of riparian vegetation and the abundance and diversity of breeding birds along rivers in arid regions of western North America. Along the upper Missouri River in central Montana, recent geomorphic changes in the form of lateral and vertical sediment accretion in conjunction with establishment and succession of woody vegetation (primarily cottonwood and willow) on these new alluvial surfaces was correlated with higher vegetation structural complexity. Grazing activity simplified the structure of riparian vegetation. Correspondingly, the diversity and abundance of breeding bird communities increased significantly with increases in the structural complexity of habitat patches.

In contrast to structurally simple vegetation, structurally complex riparian vegetation hosts greater abundances of many species such as Yellow Warbler, Common Yellowthroat (*Geothlypis trichas*), Yellow-breasted Chat (*Icteria virens*), American Redstart (*Setophaga ruticilla*), American Goldfinch (*Carduelis tristis*), Lesser Goldfinch (*C. psaltria*), Song Sparrow (*Melospiza melodia*) (Krueper et al. 2003, Scott et al. 2003). Safeguarding the growth of structurally complex vegetation requires both the maintenance of the geomorphic processes responsible for tree establishment and management of grazing and other land-use activities in riparian forests. Protection from grazing can result in quick vegetative recovery (Krueper et al. 2003). Long-term conservation strategies, however, should go one step further. To ensure structurally complex habitats in the distant future, geomorphically active reaches that have potential for cottonwood and willow generation should be specifically identified and protected from grazing.

Anthropogenic disturbances to western riparian ecosystems are pervasive and increasing as a result of human population growth in the region. Extensive modification of natural flow regimes, development in flood plains, grazing, conversion of lands to agriculture, and forest clearing along many rivers in the western U.S. have led to loss and simplification of native riparian forests and to population declines of riparian-dependent bird species. Even the Yellowstone River, the longest free-flowing river remaining in the contiguous United States, is seriously threatened by land management decisions. Designated as one of only ten "American Heritage Rivers" by President Clinton and called "The Last Best River" by National Geographic (Chapple 1997), the Yellowstone River is clearly one of the premier aquatic resources in the nation. It is not as pristine, however, as it was when Lewis and Clark explored its banks in 1806. Bank stabilization, dikes, rock barbs, jetties, and other manmade channel and flood plain modifications have been and continue to be permitted at a pace that may cumulatively threaten the ecology of the entire river system.

Ultimately, avian conservation across broad regions and over long time scales will benefit from the insights of riparian ecologists who are well-versed in the biology of the plant species that comprise important habitat for avian species and who can predict how plant communities will change through time. Without this understanding, the future condition of specific tracts of riparian forests may be misjudged, with serious implications for migratory bird species associated with these systems.

For example, consider valuations of riparian stands based on current conditions alone. *Figure 1* portrays two hypothetical forests. The first is along a free-flowing river where vegetation structure has been simplified by intense grazing. The second is a diverse, multi-layered forest along a river where the flow has been recently altered by dam construction. Based on current conditions alone, the second stand may be valued highly and designated for “protection.” Yet, the first stand has great potential to persist and become more structurally diverse with the removal of grazing (Krueper et al. 2003) because the ecological processes are intact. In contrast, the second forest faces the attrition of the mature stand and a possible return to grasses and shrubs only. The prospects for future forest regeneration are limited because the river flow has been altered. Under these conditions, geomorphic activity may occur only in wide river reaches or along tributary confluences.

Efforts to conserve, restore, and manage the distinctive biological diversity of riparian ecosystems must rest upon a clear understanding of the primary physical and biological processes that structure and maintain that diversity on a landscape scale. Across the semiarid western U.S., the interplay of fluvial processes, channel morphology, and water management, modified by myriad physical, biological, and climatic factors, set in motion the series of events that ultimately determine the future condition of riparian forests. Because many forest sites will change dramatically through the decades, conservation efforts focused at a large spatial scale with consideration of fluvial geomorphic proc-

esses can help ensure that high quality migratory bird habitat persists through time.

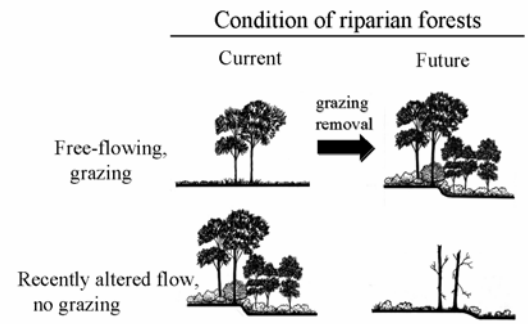

Figure 1— A hypothetical example of the present and predicted future conditions of riparian forests relative to flow regime (free-flowing rivers and rivers with recently altered flow) and grazing.

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A Preliminary Study of Riparian Songbirds in Costa Rica, with Emphasis on Wintering Louisiana Waterthrushes[1]

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Abstract

We made preliminary observations on the winter distribution, ecology and behavior of Louisiana Waterthrushes (*Seiurus motacilla*) in Costa Rica during January 1999 and 2000. We visited 24 headwater streams in three of the four principal mountain ranges in the country (Cordilleras Tilarán, Central, and the Talamanca) and confirmed the presence of waterthrushes on ten of these. In all three regions waterthrushes occurred on medium to high gradient streams, averaging 3.5 meters across (range, 1-8m) and at estimated densities of 2-10 birds per kilometer of reach length. Individuals of one to three species of resident obligate riparian songbirds, e.g., Torrent Tyrannulet (*Serpophaga cinerea*), American Dipper (*Cinclus mexicanus*), and Buff-rumped Warbler (*Basileuterus fulvicauda*), were observed along with waterthrushes at three sites (all four species were observed at a single site). Resident riparian passerines were observed at three sites where we did not detect any Louisiana Waterthrushes. We observed agonistic interactions (e.g., agitated chipping, aerial chases, and countersinging) among waterthrushes on three streams, indicating that the species is territorial in winter. We observed no behavioral interactions, however, among riparian songbird species, including at a site where multiple individuals of four species were present. Similar to relationships established for the waterthrush on its breeding grounds in Pennsylvania, headwater habitat characteristics such as extensive forest canopy cover, lack of sedimentation, and abundant aquatic invertebrates, especially within the orders Ephemeroptera and Trichoptera, appear to support the greatest numbers of over-wintering waterthrushes and/or the most diverse riparian songbird communities in Costa Rica.

*Key Word*s: Costa Rica, habitat selection, Louisiana Waterthrush, riparian birds, wintering ecology.

Introduction

It is estimated that worldwide there are as many as 80 species of obligate stream songbirds (i.e., species occurring more or less exclusively in association with fast-flowing stream habitats throughout the year), but only a few of these have been studied in detail (Master et al. 2000). These include White-throated Dipper (*Cinclus cinclus*), American Dipper (*Cinclus mexicanus*), Grey Wagtail (*Motacilla cinerea*) (Bakus 1959a, 1959b; Tyler 1972; Sullivan 1973; Price and Bock 1983; Ormerod 1985; Ormerod and Tyler 1986, 1987; Tyler and Ormerod 1994a) and Louisiana Waterthrush (*Seiurus motacilla*) (Eaton 1958; Craig 1984, 1985, 1987; Robinson 1995; Prosser and Brooks 1998; Mulvihill 1999; Master et al. 2000; Mulvihill et al. 2002; O'Connell et al. 2003). Guilds or assemblages of riparian songbirds have received even less attention (but see Orenstein 1975, Budris 1981, Round and Moss 1984, Tyler and Ormerod 1994b).

On its breeding grounds in the eastern United States, the Louisiana Waterthrush is the only obligate riparian passerine. Recent studies of its reproductive and foraging ecology have demonstrated that the waterthrush is a useful bioindicator of stressors on forested headwater streams across Pennsylvania (Mulvihill 1999, O'Connell et al. 2003). On its wintering grounds, where it retains a close association with headwater stream habitats, it can potentially share this habitat with one or more resident obligate riparian passerines, e.g., Buff-rumped Warbler (*Basileuterus fulvicauda*), Torrent Tyrannulet (*Serpophaga cinerea*) and American Dipper (Mulvihill et al. 1999). There are very few published studies giving details of the waterthrush's winter ecology and no studies have explored the species' possible usefulness as a bioindicator on its wintering grounds or examined its distributional co-occurrence and ecological interactions with resident riparian songbirds. Therefore, we performed a preliminary reconnaissance of possible study sites, and subsequently more detailed habitat analyses and behavioral

[1]A version of this paper was presented at the **Third International Partners in Flight Conference**, March 20-24, 2002, Asilomar Conference Grounds, California.

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observations, in Costa Rica during week-long expeditions in January 1999 and 2000.

Study Sites and Methods

We visited potential study streams in three of the four major mountain ranges in Costa Rica including the Cordilleras Tilarán (mostly near Monteverde Cloud Forest Biological Reserve on the Pacific Slope), Central (mostly near Volcán Poas on the Caribbean Slope), and Talamanca (near Tapanti National Park and La Amistad National Park on the Caribbean and Pacific Slopes, respectively) (*fig.1*). Our objective in 1999 was to visit and rapidly assess as many streams as possible over as wide an area of the country as was feasible. We visited a total of eighteen streams, spending from 30 min to several hours at each, and traversing reach lengths of 100-1000m, in order to ascertain if waterthrushes or other riparian songbirds were present. Estimates of riparian bird density were calculated as the number of individuals of each species observed for a given length of stream explored, expressed as number of birds/km of stream reach. We assumed similar habitat and dispersion of birds of each species for unexplored reach lengths ranging from 0-900 m. Presence of waterthrushes was confirmed by visual and aural detection, including both call notes and full song, the latter heard on two occasions. Behavioral observations of all riparian birds were conducted opportunistically during systematic searches for waterthrushes on each stream reach. On one stream, the Rio Quirí, which received the most extensive coverage in both years, waterthrushes and other riparian birds were color banded to facilitate recognition of individuals.

Nine streams, including six new sites and return visits to the three most promising 1999 sites, were investigated during January 2000. Field testing of several protocols for quantitatively assessing riparian habitat characteristics, including macroinvertebrate abundance and composition, was a major emphasis during the 2000 expedition. Protocols were tested on four streams, based on high known levels of riparian bird activity and site accessibility, including the Rio Quirí, Rio Mastate, Rio Negro and Rio Bellavista (*fig. 1*). Two sites within a 500 m stream reach were randomly chosen for assessing habitat variables on each stream. We used the U. S. Environmental Protection Agency's Rapid Bioassessment protocol which subjectively scores stream channel characteristics including embeddedness of substrate, water velocity, sediment deposition, channel flow, channel impacts, riffle frequency,

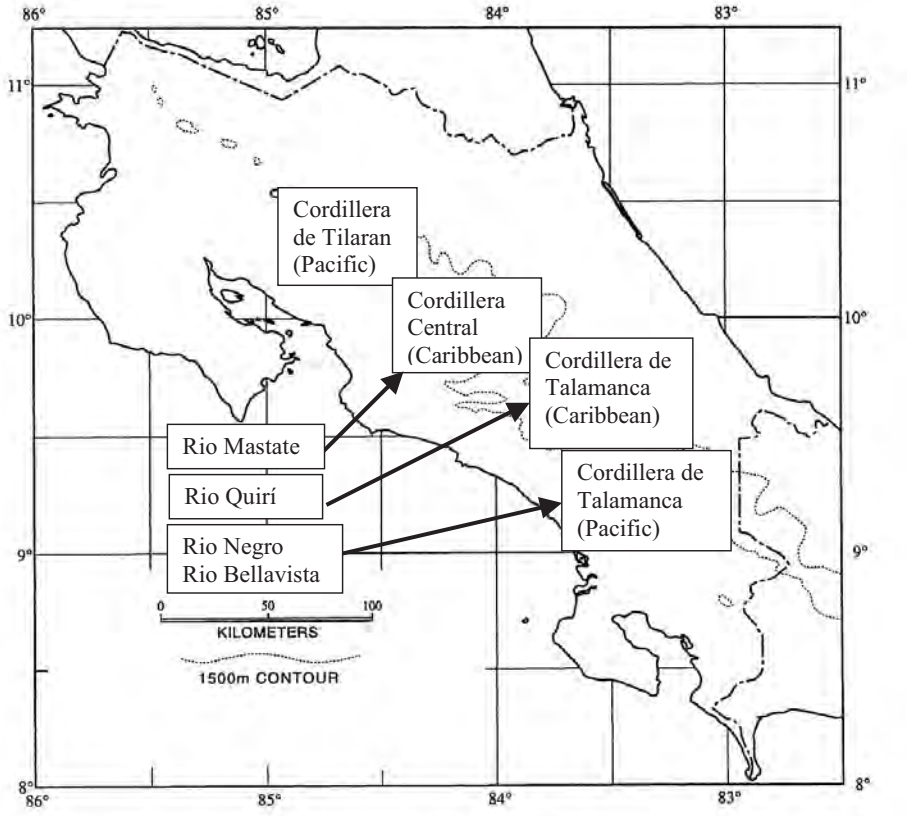

Figure 1—Map of Costa Rica depicting general regions (rectangles) where streams were surveyed during January of 1999 and 2000 and the location of the four streams on which habitat data was collected during 2000.

bank stability, bank vegetation cover, and width of riparian vegetation zone (Plafkin et al. 1989). High total scores indicated relatively pristine conditions. We also measured the wetted perimeter at these sites. Values for this index, employed in our breeding ground studies of the Louisiana Waterthrush, were derived from a ratio of the wetted surface of a stream cross section to the average stream depth across the same transect. Large values indicated stream channels with relatively extensive foraging microhabitat for waterthrushes, i.e., proportionately large areas of accessible water surface due to shallow water depth and/or abundant exposed submerged rocks and large woody debris. Canopy height for associated riparian forest was determined using a range finder and percent canopy cover was calculated using a spherical densiometer. Availability of stream macroinvertebrates was assessed based on five random rock flips at each of our two sampling stations. Invertebrates were carefully dislodged from each rock into a shallow pan and enumerated by taxonomic order.

Results and Discussion

We detected at least one riparian passerine on 13 of 24 streams sampled during both years. Most frequent was the Louisiana Waterthrush which was observed on 10 streams (*table 1*). Buff-rumped Warblers were seen on four streams while Torrent Tyrannulets and American Dippers were observed on three streams each. We observed multiple riparian species (but always including waterthrushes) on just three streams. The Rio Gonzales and Rio Negro each had three species, while the Rio Quirí was the only stream on which all four species were observed together.

We detected Louisiana Waterthrush at maximum densities ranging from 2.0-10.0 individuals/km of stream reach (*table 1*). The upper value is identical to what Eaton (1953) observed for one stream in Cuba. Robinson (1995) observed individual waterthrushes in Panama using 200 and 300 meter reaches (3.3-5.0 birds /km). Several of our observations of waterthrushes support previous observations that the species is highly territorial on its wintering grounds (Eaton 1953, Rappole et al. 1992, L. Reitsma pers. comm.). At Rio Mastate, we observed aggressive interactions among three birds that involved agitated chipping, aerial chasing, and full volume countersinging. Similar aggressive interaction (but no singing) between two waterthrushes was observed at Quebrada Cuecha. At Rio Quirí, waterthrushes responded weakly (i.e., approached but did not countersing or behave aggressively) to tape playback of territorial song recorded on the breeding grounds.

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Table 1—*Species density (number per km of stream reach) on all inhabited streams.*

Stream	Reach (m)	Louisiana Waterthrush	Torrent Tyrannulet	Buff-rumped Warbler	American Dipper
Rio Quirí	300	6.6	6.6	6.6	9.9
Rio Negro	300	3.3	0	3.3	3.3
Rio Gonzales	250	2.0	2.0	2.0	0
Quebrada[1] Cuecha	150	10.0	0	0	0
Rio Java	100	10.0	0	0	0
Rio Sarapiqui tributary	250	8.0	0	0	0
Rio Poasito	400	5.0	0	0	0
Quebrada Arboles Caidos	200	5.0	0	0	0
Rio Mastate	300	4.3	0	0	0
Rio Bellavista	300	3.3	0	0	0
Quebrada Segundo	200	0	5.0	0	0
Quebrada Neblina	500	0	0	2.0	0
Rio Poasito tributary	300	0	0	0	2.5

[1]Quebrada = stream

During extensive observations of the four species at Rio Quirí, we observed no interspecific aggression, even on one occasion when all four species were in view simultaneously at a small waterfall plunge pool. Dippers and waterthrushes both fed primarily picking on submerged insects in the water, with dippers picking more in rock crevices and deeper water (often while submerged) and waterthrushes more in shallow water and on rock and debris surfaces. Torrent Tyrannulets perched on large in-stream boulders and fed primarily by hawking for flying insects. Buff-rumped Warblers were usually observed gleaning insects along the exposed stream bank and at the water's edge, sometimes sally-gleaning insects from the undersides of vegetation overhanging the stream (George 2003). Streams with higher estimated maximum waterthrush densities and/ or multiple riparian songbird species present averaged 3.5 m wide (range1-8 m), had relatively high EPA Rapid Bioassessment and wetted perimeter values, moderate to heavy canopy cover, benthic habitat dominated by cobbles (2.5-15 cm) and rocks (15-50 cm), and moderate to high macroinvertebrate abundance, especially for the orders Ephemeroptera and Trichoptera. The Rio Quirí, with the greatest overall abundance of macroinvertebrates, had the highest estimated maximum riparian bird densities (*table 1*) and, again, was the only stream we visited that supported all four species.

Conclusions

Habitat selection has important ramifications for the persistence of a species because it influences reproductive and mortality rates (Petit et al. 1995). Therefore, understanding habitat use forms the basis for conservation of these species (Cody 1985, Probst and Crow 1991). This study, although preliminary in nature, offers some insight into habitat selection, distribution, ecology and behavior of Louisiana Waterthrushes on their wintering grounds in Costa Rica. Characteristics of the headwater streams where we estimated the highest maximum densities of wintering waterthrushes, and other riparian songbirds, were similar to those associated with the most productive Waterthrush breeding habitats in Pennsylvania (Mulvihill 1999, Master et al. 2000, O'Connell et al. 2003). Waterthrushes, therefore, belong to a minority of neotropical migrants which are habitat specialists on their wintering grounds, in this case, preferring conditions nearly identical to those in breeding habitats (Stiles 1980, Hutto 1992, Petit et al. 1995). The degree of apparent niche partitioning observed, with regard to the several resident riparian species, and their defense of territories against conspecifics, indicates that waterthrushes are not migrant opportunists relegated to peripheral, disturbed habitats but rather are competitive habitat specialists well adapted to their tropical wintering grounds (Sliwa and Sherry 1992, Sherry and Holmes 1995). Notwithstanding significant advances in recent decades, more information on habitat requirements and on the influences and consequences of habitat selection is needed for many neotropical migrant landbirds in order to implement conservation strategies (Blake and Loiselle 1989, Strong and Sherry 2001).

Acknowledgments

Travel funding was provided by the Carnegie Museum of Natural History's Edward O'Neil Field Research Fund. Logistical support was provided by the Museo Nacional de Costa Rica, Department of Biological Sciences, East Stroudsburg University and Powdermill Nature Reserve. We thank A. Chrisney, C. Rimmer and T. Rich for reviewing the manuscript.

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Using Songbird Monitoring to Guide and Evaluate Riparian Restoration in Salmonid-Focused Stream Rehabilitation Projects[1]

Ryan D. Burnett,[2] Thomas Gardali,[2] and Geoffrey R. Geupel[2]

Abstract

A restoration effort, primarily focused on reducing stranding and improving passage of anadromous fish, has been undertaken along sections of lower Clear Creek, Shasta County, California. Similar projects are occurring throughout California and, indeed, all of North America. To monitor the effects of these efforts at Clear Creek we implemented a multi-faceted songbird monitoring study. We have collected three years of data on abundance, diversity, reproductive success, and habitat associations of songbird populations at Clear Creek study plots where extensive watershed/salmonid restoration activities are in progress or slated to occur and at several reference sites where no restoration is planned. We used preliminary site-specific results and the California Partners in Flight Riparian Bird Conservation Plan to provide multi-level management recommendations. Monitoring songbirds on this and other restoration sites has proven a pragmatic approach on several levels. Songbird monitoring can (1) measure the effectiveness of restoration; (2) provide the necessary feedback for adaptive management; (3) guide restoration design by providing information on the health and habitat associations of the local bird populations; (4) be cost effective; and (5) provide education and outreach opportunities.

Key words: adaptive management, Clear Creek, monitoring, restoration, riparian, songbird.

Introduction

The extensive human-caused loss and degradation of functioning ecosystems has made clear the need to accelerate their recovery. Species associated with the most impacted ecosystems have suffered local extirpations and/or population declines. In California, for example, riparian habitat is the single most important habitat type for landbirds (Gaines 1977, Manley and Davidson 1993); unfortunately, it is estimated that less than 5 percent of the state's riparian habitat remains (Smith 1980). Species such as the Least Bell's Vireo (*Vireo bellii pusillus*) and Willow Flycatcher (*Empidonax traillii*), once common breeders in riparian habitat throughout the Sacramento River Valley, have been extirpated from the region, and several others are rare or declining (Grinnell and Miller 1944, Gaines 1977, RHJV 2000).

Hence, numerous riparian restoration efforts have recently been undertaken in the Central Valley of California and throughout the state.[3] Integral to restoration projects is the inclusion of monitoring to evaluate the objectives of the project (SER 2002). Unfortunately, many restoration projects focus on only a single threatened or endangered species, and the project goals and objectives reflect this bias. In such situations, restoration efforts probably are not addressing the needs of the majority of species within an ecosystem. Conversely, the entire host of ecological variables in a system influenced by restoration is too great to measure in a reasonable timeframe and at a reasonable cost.

With the current threats to riparian songbirds in California it is paramount that restoration efforts take into account these and other riparian taxa when planning, implementing, and monitoring such projects. Because birds occupy an extremely diverse range of niches within an ecosystem and a relatively high position in the food chain, they are ideal indicators of environmental conditions (DeSante and Geupel 1987, Temple and Wiens 1989, Rich 2002). Along with the relative ease of study (e.g., nationally standardized protocols and relative abundance of songbirds) and the cost effectiveness of a monitoring program, songbird monitoring provides researchers with feedback from a whole community of organisms, not just a single species. Thus, birds are a model organism for measuring the success of restoration and changes in land management.

Songbird monitoring of riparian restoration projects can provide data on several different levels. Here we

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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describe how songbird monitoring can limit negative impacts and increase the benefits of a restoration project to songbirds and potentially other riparian dwelling taxa as well. We then describe the Clear Creek Project as an example of the effectiveness of songbird monitoring in riparian restoration, including site-specific examples of how this data has been used to enhance restoration so that its benefits extend beyond just salmonids.

Uses of Songbird Monitoring Data

Songbird monitoring can provide the following components key to a successful ecosystem-based restoration project:

1) Data on the current distribution and habitat uses of birds specific to a site before restoration begins, in order to avoid disturbing hot spots of bird diversity or abundance or sites used by species of special conservation interest

2) Feedback on the short-term negative effects restoration activities may have on songbirds, in order to find ways to minimize these effects for future phases of a project

3) Species- and site-specific habitat associations that can be used to develop restoration design and revegetation planting mixes

4) An excellent outlet to the public for educating the local community about a restoration project

5) Feedback on the overall success of restoration in improving habitat for songbirds and, perhaps, a broad range of taxa although the latter needs formal testing. This last is most important.

The Clear Creek Restoration Project

In 1998 a team of Federal, State, and local officials came together in order to restore riparian habitat along the Lower Clear Creek Watershed in Shasta County, California. The watershed had been subjected to a long history of human-induced disturbance, starting with the discovery of gold in 1848. Since that time the creek has been extensively altered, first from gold mining, followed by the building of Whiskeytown Dam 17 miles upstream from its confluence with the Sacramento River, and most recently from aggregate mining. The primary focus of the restoration team was to create higher quality anadromous fish habitat in the floodway.

Despite extensive human alteration of the Clear Creek watershed, initial surveys of the riparian habitat indicated that it supported a rather intact riparian bird community, with several species that have disappeared from much of the Sacramento Valley, such as Song Sparrow (*Melospiza melodia*), Yellow-breasted Chat (*Icteria virens*), and Yellow Warbler (*Dendroica petechia*), breeding in fairly high numbers.

To preserve what appeared to be a fairly healthy bird population and provide recommendations to create higher quality riparian habitat, in 1999 the Point Reyes Bird Observatory (PRBO), as part of the Clear Creek Restoration Team, initiated a project to monitor the effects of restoration on the songbird community at Clear Creek.

We implemented a multiple-method monitoring plan in order to gain information on abundance, distribution, reproductive success, survival, and habitat associations of songbirds and on how restoration efforts influenced each of these parameters. The five methods employed to meet these objective were nest monitoring, constant-effort mist-netting, territory mapping, point counts, and area searches (Ralph et al. 1993).

To assist in their restoration project, the Clear Creek restoration team has employed many of the recommendations we have made based on the results of our data collected at Clear Creek as well as data from other riparian restoration sites in the Central Valley and the riparian bird conservation plan (RHJV 2000). Here we provide examples of how our data have led to recommendations and on-the-ground implementation. (For a complete description of methods, results, and recommendations, see Burnett and DeStaebler 2002).

Songbird Habitat Associations

Using point count data, we related bird species richness and the abundance of each riparian focal species (RHJV 2000) to habitat characteristics. We then used the focal species correlations to build predictive models. When developed at the scale of a restoration project, habitat correlations and models can provide meaningful site-specific information about the influence of habitat features on the abundance, richness, and distribution of species, which can be used to help guide restoration design. The following two examples from Clear Creek illustrate how bird monitoring can influence restoration design.

First, positive correlations between mugwort (*Artemesia douglasiana*) and both species richness and the abundance of several focal species (*table 1*) led to the recommendation and inclusion of mugwort in planting mixes at Clear Creek. Second, a model predicting Yellow-breasted Chat abundance determined the habitat variables (e.g., California Blackberry, *Rubus ursinus*) that locally influence its distribution (*table 2*). Although the chat is a California Species of Special Concern (CDFG and PRBO 2001) and

Table 1— *Bird variables positively influenced by the relative cover of mugwort at Clear Creek.*

Variable	Correlation coefficient	P
Spotted Towhee (*Pipilo maculatus*) abundance	0.32	0.041
Song Sparrow (*Melospiza melodia*) abundance	0.47	0.003
Species richness	0.27	0.10

Table 2— *Stepwise linear regression model predicting Yellow-breasted Chat abundance at Clear Creek.*

Variable	Regression coefficient	se	P
Sedge species (*Carex* spp.)	0.01	0.005	0.01
California Blackberry (*Rubus ursinus*)	0.07	0.02	0.001
Sandbar Willow (*Salix exigua*)	0.01	0.005	0.01
Black Mustard (*Brasica nigra*)	0.03	0.01	0.03

Dependent variable = Log Yellow-breasted Chat abundance
N = 39, F (4, 34) = 8.70, P < 0.001, Adj. R^2 = 0.51

an uncommon breeder in the Central Valley, it is fairly abundant at Clear Creek (Burnett and DeStaebler 2002), and, therefore, an important species to manage for at this site.

With these species-specific models, as well as correlations with broader population indices, we were better able to identify habitat components at Clear Creek associated with important focal species and the songbird community as a whole. With this information, restorationists at Clear Creek are able to address the needs of the local songbird community and thereby generate a more ecologically valuable restoration project.

Completing the Adaptive Feedback Loop

In future years, with continued monitoring, we will be able to use reproductive success, annual survival, abundance, species richness, and territory sizes at restoration plots and reference sites to gain a better understanding of habitat associations and determine the effectiveness of the restoration in creating high quality songbird habitat. Furthermore, by comparing songbird-monitoring data with fish monitoring data we will be able to evaluate whether this restoration effort—and potentially other projects—can be mutually beneficial to salmonids and songbirds.

Conclusion

Incorporating songbird monitoring into salmonid-focused riparian restoration projects such as Clear Creek can transform a single-species focused restoration project into a multi-species community-based effort that will undoubtedly benefit more species. With the loss of over 95 percent of the riparian habitat in California, it is essential that restoration projects based in these habitats broaden their scope beyond the needs of individual species and take an ecosystem-based approach. Without the use of multi-species monitoring programs it is impossible to determine whether the needs of an entire system are being met. Songbird monitoring is a practical means by which the necessary feedback can be obtained to assess the broadscale effectiveness of a restoration project.

Acknowledgments

The CalFed Bay Delta Program and the U.S. Bureau of Reclamation provide funding for the Clear Creek project. We thank the Western Shasta Resource Conservation District, who administered the grant, as well as the Bureau of Land Management for supporting this project. We also are grateful to field supervisors Jim DeStaebler and Julian Wood as well as the many interns who spent numerous hours in the field collecting data. Ann Chrisney and Diana Humple provided helpful comments on earlier drafts of this manuscript. This is PRBO contribution #1118.

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A Watershed-Scale Survey for Stream-Foraging Birds in Northern California

Sherri L. Miller[2] and C. John Ralph[2]

Abstract

Our objective was to develop a survey technique and watershed-scale design to monitor trends of population size and habitat associations in stream-foraging birds. The resulting methods and design will be used to examine the efficacy of quantifying the association of stream and watershed quality with bird abundance. We surveyed 60 randomly selected 2-km stream reaches of all stream orders in the Smith River watershed in northern California. In addition to counts and foraging activity of American Dippers (*Cinclus mexicanus*) and other bird species that forage in the stream, we collected a large variety of physical and biological measurements of the stream and bank habitats to identify the factors most related to abundance. We found highest dipper densities on larger streams and main stems of the river, and they were present in cascades significantly more often than expected. We also conducted an intensive color-banding and census effort along one creek where we banded most of the resident breeding population over four years. By surveying about once per month between April and November, we have located nests, documented triple-clutching, nest fidelity, and feeding of nestlings by three or more birds at one nest.

Introduction

There has been great interest in the vegetation of riparian habitats and their importance to the many birds that nest and forage in them, but stream-foraging birds are also affected by riparian habitat, through the habitat's relationship to stream quality. For example, American Dipper (*Cinclus mexicanus*) abundance and reproductive success have been found to be low with acidic stream conditions (Tyler and Ormerod 1994) and extensive cattle grazing (Osborn 1999). Loegering and Anthony (1999) found the extent and condition of riparian habitat and streamside trees to be a predictor of abundance for three stream-associated species: American Dippers, Belted Kingfishers (*Ceryle alcyon*), and Great Blue Herons (*Ardea herodias*). Land use practices, such as timber harvesting and recreation, may also affect the condition of streams and rivers within a watershed, and result in changes in bird abundance or reproductive success. It is important to assess the effects of landscape scale forest management programs, such as the federal-lands Northwest Forest Plan, on birds that depend on streams to forage.

Our objectives were to develop a protocol and sampling design for watershed scale surveys of stream-foraging birds that could be used to: (1) model associations of bird abundance and riparian and stream habitat types, (2) model relationships between stream bird abundance and covariates that quantify physical and biotic parameters of the stream and riparian habitats, and (3) monitor stream-bird densities to identify trends from year to year.

Methods

Our research was conducted in northwestern California in the Smith River watershed (*fig. 1*), a relatively small (about 206,200 ha) natural system without dams. Topography is usually steep and many of the small streams are difficult to access. The dominant vegetation is mixed-conifer forest, but some unique botanical areas and about 21,900 ha of old-growth coastal redwood are included in the watershed. The lower portion of the main stem, where the river is bordered by agricultural land managed for grazing and cut flowers, was not included in the study area. Several major streams in the southwest and northwest portions of the watershed are located on approximately 14,600 ha of private timberlands. Most of the remaining lands in the watershed are on national forests. Past and current land uses include logging, mining, recreation, and some grazing.

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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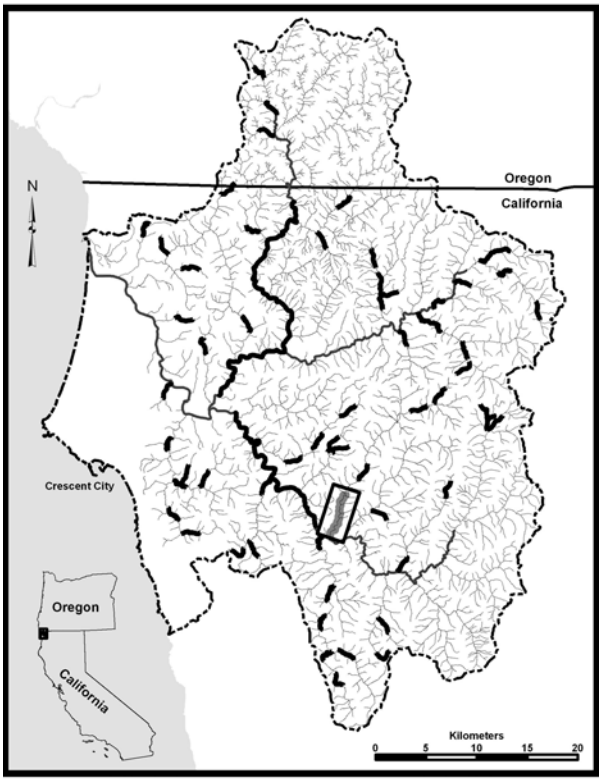

Figure 1— The Smith River watershed in Del Norte County, California. Thick, black lines are surveyed 2-km stream segments and surveyed sections of the main stems. Hurdy Gurdy Creek, the 7-km demographic study area, is contained in the rectangle near the south fork of the river.

We randomly selected sixty 2-km stream segments throughout the watershed for sampling. All stream segments were within 1 km of a road or trail and were classified as stream Orders 1 (small) through 5 (large) (Strahler 1957), a measure of stream size and flow volume. On the main stems of the river—the middle (above the south fork confluence), south, and north forks—we surveyed birds along the entire length of river between access points and collected habitat measures in the pre-selected 2-km segments.

We walked in the streams or at the edge while recording location and behavior for all stream-foraging birds seen or heard, including American Dippers, Belted Kingfishers, Spotted Sandpipers (*Actitis macularia*), Common Mergansers (*Mergus merganser*), Wood Ducks (*Aix sponsa*), Great Blue Herons, Green Herons (*Butorides striatus*), Osprey (*Pandion haliaetus*), and other occasionally-observed species. In addition to counts, we recorded foraging activity, nest locations, and observed activity at nests.

We mapped each stream habitat unit (a length of similar habitat type) as pool, run, riffle, rapid, or cascade (Bisson et al. 1981). Habitat types were classified by gradient and depth, from pools, low gradient and deep water, through cascades, steep gradient or waterfalls. We recorded many habitat measures of the stream and bank vegetation including bank substrate and vegetation; nest substrate availability and characteristics; water depth, width, and flow speed; stream substrate size and depth of silt; and availability of perching and foraging substrate. Macroinvertebrate samples were collected using a Surber net sampler (Hauer and Resh 1996) at foraging locations and at 3 systematic locations in the segments.

In the lower 7 km of Hurdy Gurdy Creek, a tributary to the south fork (*fig. 1*), we captured dippers using mist-nets placed across the stream. Captured birds were color-marked and data were collected on age, breeding status, molt extent, condition, and wing, bill, and leg measurements. The study reach was surveyed 3 to 4 times each year when water levels permitted access, generally from April through November, completing over 110 km of survey. Bird locations were mapped to identify territories and site and pair fidelity. Nest locations were recorded and nests checked for activity throughout the breeding season.

Results

We surveyed 61 stream segments in 2000, 2002, and 2003. Order 1 streams generally flow intermittently, largely during winter and spring, yet, we observed dippers in these streams during the breeding season. We found higher densities of dippers in stream Orders 3 and 4 (*fig. 2*), with the highest density, 4.6 dippers per km, in Order 4 streams. We found significant differences in the number of dippers per kilometer by stream order ($p=0.005_{\text{alpha } 0.05,\ 4\ df}$) using analysis of variance with a general linear model for unbalanced sampling design (Zar 1984, SAS 1996). Higher densities in Order 3 and 4 streams, and lower density in Order 1 streams, were indicated by Duncan's Multiple Range Test (Zar 1984, SAS 1996).

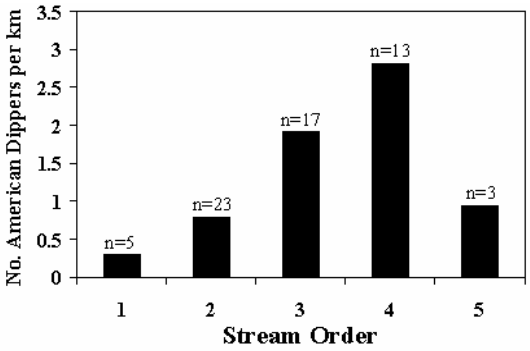

Figure 2— The number of American Dippers per kilometer of stream survey, Smith River, California. We surveyed randomly selected 2-km segments in stream orders 1 through 5; n = the number of segments surveyed in each order.

Table 1— *The percentage of each stream habitat type for total meters sampled and the number of sampled segments by stream order (Strahler 1957). Habitat types (Bisson et al. 1981) are classified by gradient and depth, from pools, low gradient and deep, through cascades, steep gradient or waterfalls.*

Stream order	Stream habitat type					Number of segments
	Pool	Run	Riffle	Rapid	Cascade	
1	6	25	13	52	2	5
2	15	14	27	41	3	23
3	16	27	28	25	5	17
4	23	24	45	8	1	13
5	19	27	51	1	0	3

Table 2— *The proportion of stream habitat types on the surveyed 2-km stream segments in the Smith River watershed in Del Norte County, California. The expected number of American Dippers according to the proportion of each habitat available and the number of dippers observed during surveys.*

Habitat type	Pool	Run	Riffle	Rapid	Cascade
Proportion of the 120 km of streams surveyed	0.16	0.21	0.31	0.29	0.03
Expected number of dippers by habitat type	29	38	56	53	5
Number of observed dippers, Total = 181	23	33	63	48	14

The percentage of each habitat type by segment was similar for stream Orders 1, 2, and 3 (*table 1*). Stream Orders 4 and 5 had a higher percentage of riffles and a lower percentage of rapids. Few cascades were observed in all stream orders. We observed dippers more often in cascades (short, steep waterfalls) and less often in pools (calm, deep water) than expected given the amount of each habitat available (*table 2*). Using a Chi-square analysis (Zar 1984) we found the birds did not use the habitats in proportion to the amount of each habitat available (χ^2=16.643$_{\text{alpha 0.05 = 9.488 df = 4}}$, K=5).

We captured and color-marked 17 adult and 20 juvenile dippers during four breeding seasons, from 2000 to 2003. Five nests were located and observed during surveys. One female, an adult when captured, nested successfully in the same territory for the four years of the study. In the second year, this female successfully raised three broods in two months. During the third year of observations at this nest we observed three birds feeding nestlings in succession: the banded female, the banded male, and an unbanded bird. We observed three banded female dippers using the old and new nests within the same territories over multiple years. We continued to observe the banded adults and juveniles on Hurdy Gurdy Creek throughout our survey season. Only three banded juveniles were observed after their first year, apparently having dispersed. In fall 2002, a color-banded dipper was observed on the Rogue River, 153 air miles and two watersheds to the northeast. This bird had been banded as a juvenile in 2001.

Discussion

Because the distribution of habitat types was similar for all orders (*table 1*), lower numbers of dippers in pools and higher numbers in cascades appeared to represent a real difference in habitat use by the dippers. Prey abundance, quality, or accessibility also may play a roll in differences in habitat use. We are continuing to analyze habitat data from foraging activity to address these questions.

In the future we will assess the effectiveness of our sampling design to measure dipper abundance at the watershed scale. We will compare density estimates derived from the 2-km segments to 1-km subsamples of the data. If we can obtain similar statistical power from 1-km segments, we could complete more samples in a season. Because the birds were relatively shy for assessing foraging success rates and habitat characteristics, a separate sampling effort to collect foraging activity and foraging plot data would be necessary. We will be using our repeated observations of color-banded birds to quantify detectability. We plan to conduct additional surveys on three or four consecutive days for four sessions throughout a breeding season to complete the dataset for this analysis.

We are continuing to study molt patterns in this near-coastal population. The timing of molt is important for a monitoring design. Changes in behavior during molt, such as less vocalizing or secretiveness, might affect detectability. We may need to adjust for differences in detectibility by changing the sampling period or accounting for biases when analyzing data. Knowing

when fledglings complete the first pre-basic molt, losing their easily distinguished immature plumage, will help us interpret density estimates, especially since second and third broods are a possibility. A better understanding of molt limits may help us identify second-year birds and better understand the demographics of this species. Documenting plumage changes on juveniles throughout the season will help us better identify age by sightings alone.

Because we observed dippers on even the small and intermittent Order 1 streams, it is important to sample all orders when assessing abundance at a watershed scale. Osborn (1999) surveyed two Order 1 streams and observed dippers on both, but others surveyed only larger streams (Price and Bock 1983, Loegering and Anthony 1999). The large number of small streams in most watersheds can represent a sizeable portion of a watershed and could provide habitat for an important component of the dipper population.

We are continuing analyses to examine relationships in abundance and stream and riparian habitat conditions. We will incorporate our findings into a protocol that assesses dipper abundance at a watershed scale.

Acknowledgments

We thank A. Kudrez for her energy, enthusiasm, and abilities the first year of this study. We appreciate all of the dedication and hard work of our stream surveyors, A. Kudrez and B. Love (both members of the Americorps Watershed Stewardship Program), J. Kellermann, D. Zane, and M. Morrissette. B. Noyes taught us how to be safe on the rivers. We thank all the volunteers who assisted on Hurdy Gurdy Creek with banding and surveys, including: E. Elias, M. McKenzie, P. Ralph, C. P. Ralph, S. Campbell, and many others. The Partners in Flight program of Region 5 of the USDA Forest Service assisted with funding for the study.

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Riparian and Woodlot Landscape Patterns and Migration of neotropical Migrants in Riparian Forests of Eastern South Dakota[1]

David L. Swanson,[2] Kurt L. Dean,[3] Heather A. Carlisle,[4] and Eric T. Liknes[2]

Abstract

Woodland habitat types in the northern Great Plains compose only a very small fraction of the total land surface. These woodlands occur primarily as natural riparian forests or as scattered anthropogenic woodlots and shelterbelts. Natural riparian woodlands have been markedly reduced over the past century, but anthropogenic woodlands have increased during this same period. In this paper, we review and synthesize mist net and point count data from riparian corridor woodlands (Missouri and Big Sioux rivers) and farmstead woodlots in southeastern South Dakota to compare neotropical migrant abundance, species richness, diversity, and community similarity in these two habitats during spring and fall migrations. We hypothesized that the larger and more contiguous woodland area and greater vegetative diversity of riparian corridor woodlands relative to woodlots would attract higher numbers and more species of neotropical migrants. Point count abundances were higher in woodlots than in riparian corridors in both spring and fall, whereas capture rates were similar in spring, but higher in Missouri River woodlands than at other sites in fall. Species richness and diversity were similar in riparian corridors and woodlots at both seasons. Community overlap between riparian corridors and woodlots was high in spring, but was lower in fall. In general, these data suggest that overall abundance and diversity of neotropical migrant communities are similar between riparian corridors and farmstead woodlots, despite some differences for individual species. In addition, recaptured migrants were capable of gaining mass during stopover in woodlots. Farmstead woodlots appear to effectively supplement natural riparian corridor woodlands as stopover sites for neotropical migrants. Thus, conservation of even small woodland parcels may benefit neotropical woodland migrants during migration.

Introduction

Woodland habitats in the northern Great Plains are scarce, making up less than 4 percent of the total land surface area in southeastern South Dakota (Castonguay 1982). Two principal types of woodland habitats currently exist in this area, natural riparian corridor woodlands and human-planted farmstead woodlots and shelterbelts. Historically, woodlands in eastern South Dakota existed almost exclusively along riparian corridors (Van Bruggen 1996). The extent of these natural woodlands has been markedly reduced by clearing for agriculture and inundation behind dams. For example, Hesse et al. (1988) documented reductions of at least 41 percent in riparian woodland area along the Missouri River from the mouth to Ponca, Nebraska, since the late 1800s. The section of river studied by Hesse et al. (1988) is downstream from the dams, so does not include woodland area lost by inundation under reservoirs. Natural woodland area in eastern South Dakota, however, has been supplemented since the time of European settlement by human-planted woodlands around agricultural fields and farmsteads. Such artificial woodlands occur in narrow linear strips (shelterbelts) or as larger, less linear, woodlots. The size and vegetative diversity of shelterbelts and woodlots are lower than those for natural riparian woodlands (Martin 1980, Dean 1999).

neotropical migrants occur in both natural and artificial woodlands during migration through eastern South Dakota (Martin 1980, Tallman et al. 2002). Populations of many of these species are declining (e.g., Robbins et al. 1989). Reductions in available stopover habitat along the migratory route potentially contribute to these population declines because migration is a period of the annual cycle where energy demands peak (Moore et al. 1995). Since marked reductions in available riparian corridor woodlands in the northern Great Plains have occurred concomitantly with increases in artificial woodland habitats, artificial woodlands might serve, at least partially, to substitute as stopover habitat for lost riparian corridor woodlands. No previous studies have compared neotropical migrant use of these two habitats during migration. We studied migrant use of these woodland habitats using both mist nets and point counts to determine if abundance, species richness, and diversity of neotropical migrants during migration differ between natural riparian corridor woodlands and farmstead woodlots in southeastern South Dakota. We reasoned that the greater woodland area, more contig-

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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uous nature of woodland habitats, and higher vegetative diversity of riparian corridor woodlands should make them more favorable as stopover habitat for neotropical migrants than farmstead woodlots. Thus, we hypothesized that neotropical migrant abundance, species richness, and diversity should be higher in natural riparian corridor woodlands than in anthropogenic farmstead woodlots.

Methods

Mist Net and Point Count Sampling

We review here point count and mist net data for neotropical migrants from Dean (1999) for riparian corridors in southeastern South Dakota and from Carlisle (1998) and Swanson et al. (2003) for farmstead woodlots in the same area. Dean (1999) studied four riparian corridor woodland sites in Clay and Union counties, South Dakota, two in the Missouri River riparian corridor, one in the Big Sioux River riparian corridor, and one on a tributary (Brule Creek) of the Big Sioux River (*fig. 1*). Prominent neotropical migrants in southeastern South Dakota are flycatchers, vireos, thrushes, warblers, and tanagers (Tallman et al. 2002). Other neotropical migrant species, such as cuckoos, Gray Catbird (*Dumetella carolinensis*), grosbeaks, Indigo Buntings (*Passerina cyanea*), and orioles, migrate through and also nest in the area; and resident and migrant birds of these species are difficult to distinguish. For this study, we limited analyses to flycatchers, vireos, thrushes, warblers, and tanagers to reduce the confounding effects of residents in the analyses.

Dean (1999) conducted point counts and mist net sampling (5-7 9-m nets, 30-mm mesh) daily, weather permitting, during both spring (15 April-2 June) and fall (15 August-5 October) migration periods in 1993-1995. Sampling was rotated among the four study sites on a 4-d cycle. Spring and fall sampling periods covered the bulk of the neotropical migrant movement through eastern South Dakota (Tallman et al. 2002). Point counts and mist net sampling (7-10 9-m nets, 30-mm mesh) were conducted during the same dates in spring and fall in 1996 and 1997 in woodlots in Clay and Union counties, South Dakota (Carlisle 1998, Swanson et al. 2003). Farmstead woodlot mist netting was conducted in a single woodlot of about 3.5 hectares in area for at least six days per week, weather permitting, during the migration periods. In riparian corridor woodlands, nets were opened from sunrise until approximately 1100 CST. Mist nests were opened during the same time period in the farmstead woodlot, but nets were also often opened for 2-3 h prior to sunset. Capture rates did not differ substantially for morning and evening capture periods in woodlots, so data were pooled. In neither riparian corridors nor the woodlot was sampling conducted on days with rain or with winds in excess of 35 km/h. For captured birds we measured mass to the nearest 0.1 g (Ohaus LS200 Model portable scale), wing chord, tarsus, and visible fat (on a scale of 0-5, Helms and Drury 1960). Birds were then banded with a standard U.S. Geological Survey aluminum leg band and released.

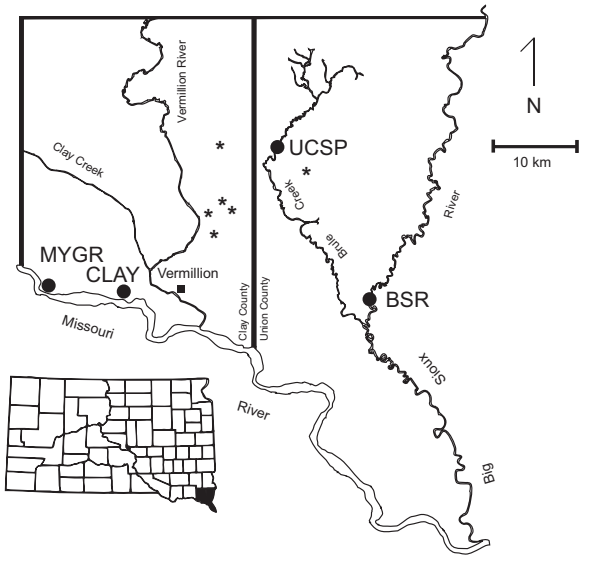

Figure 1— Map of the study area in southeastern South Dakota showing the locations of the four riparian corridor and the six woodlot (asterisks) study sites. MYGR and CLAY are study sites in the riparian corridor woodlands of the Missouri River. The BSR study site is in the riparian corridor of the Big Sioux River and the UCSP study site includes riparian woodland along Brule Creek (a tributary of the Big Sioux River) and adjacent (and contiguous) upland deciduous forest. Modified from Dean (1999).

Swanson et al. (2003) surveyed seven points in six different farmstead woodlots (*fig. 1*), which ranged from about 0.7 to 3.5 hectares in area. The largest woodlot had two points separated by over 200 m. All other woodlots had a single survey point. Woodlot points were surveyed three times per week during the migration periods. Each riparian corridor study site had 5-10 survey points established at 200-m intervals along roughly linear transects (Dean 1999). Fixed radius (25-m) point counts were used in both studies (Hutto et al. 1986). Surveys at each point lasted 10 min and all birds detected by sight or by sound, and their distances from the point center (inside or outside of 25 m), were recorded. Birds observed while walking between points were also identified and counted as beyond 25 m from the point center. Point counts in both studies were conducted between 0600 and 1000 CST and survey routes were traversed in opposite directions on successive counts to reduce possible temporal variation. Point count surveys were not undertaken on days with rain or

winds in excess of 35 km/h. From point count data, we calculated densities (birds • km^{-2}) from detections ≤25 m from the point center and relative abundance (birds/point) from all detections, irrespective of their distance from the point center (Swanson 1999).

Statistical Analyses

Spring and fall capture and point count data were pooled over the entire study periods for both riparian corridors (three years pooled) and farmstead woodlots (two years pooled) to reduce effects of year-to-year variation in migration traffic. Overall abundance (numbers of observations) and captures in riparian corridors and woodlots were compared by Chi-square goodness-of-fit tests, after correcting for differences in sampling effort (numbers of points surveyed or number of net hours) (Rappole et al. 1979). The correction for differences in sampling effort was accomplished by adding the total numbers of points surveyed or the total number of net hours for the two riparian corridors and the woodlots and dividing by three to produce an average effort for the three habitats. A correction factor was then generated by dividing the actual effort for each of the two riparian corridors and the woodlots by the average effort for the three habitats. The numbers of captures or observations in each habitat were then divided by the correction factor to provide values for point count observations or captures corrected to equal effort. Because sampling effort and sample sizes (numbers of birds observed and captured) differed among riparian corridors and woodlots (*table 1*), we calculated rarefaction curves (James and Rathbun 1981) for combined observation and capture data for each study area. Rarefaction curves were compared by ANCOVA after double-logarithmic transformation to produce straight lines. Diversity was calculated as the Shannon Diversity Index ($H' = -\Sigma\ p_j \ln p_j$, where p_j is the proportion of total individuals belonging to species j) and diversities for the different study areas were compared by *t*-test (Zar 1996). In cases where multiple comparisons were made, we employed a sequential Bonferroni procedure for adjusting α-levels to reduce the probability of type 1 errors (Rice 1989). Community overlap among the two riparian corridors and farmstead woodlots was determined as Morisita's Index, which ranges from 0.0 (no similar species) to 1.0 (identical communities).

Mass change for recaptured birds in woodlots was calculated as mass at recapture minus mass at initial capture. Mass was standardized to the same time of day (1200, Cherry 1982) for these calculations to avoid confounding effects of mass gains during the day (Carlisle 1998). This was accomplished by first regressing condition index (mass/wing chord, Winker 1995) on time of day for each species (10 captures per season minimum) and calculating an average change in condition index per h. Condition index for an individual bird was standardized to 1200 by multiplying the average change in condition index per h for that species by the time difference between capture and 1200, then adding or subtracting this value from the condition index at the time of capture. Mass at 1200 was then computed from the value for condition index at 1200. Carlisle (1998) grouped recaptured birds into 1-d (recaptured one day after initial capture) and 2+-d (recaptured two or more days after initial capture) categories for analyses of mass changes to determine whether low initial rates of mass gain occurred during stopover in farmstead woodlots. ANOVA was then used to test for differences in percent mass change (all neotropical migrants pooled) among stopover duration categories, years and seasons. Few recaptures were obtained in riparian corridors. To examine mass changes during stopover for migrants in riparian corridors, variation in condition index ([mass • wing chord^{-3}]•10,000) at first capture with time after sunrise was analyzed by least squares regression for individual species with greater than 30 captures per season (Winker et al. 1992).

Table 1– *Sampling effort for point counts (total points surveyed) and mist netting (net hours) in riparian corridors (1993-1995) and farmstead woodlots (1996-1997) in southeastern South Dakota during spring and fall migration periods. Data are from Carlisle (1998), Dean (1999) and Swanson et al. (2003).*

	Points surveyed		Net hours	
Site	**Spring**	**Fall**	**Spring**	**Fall**
Missouri River	336	377	1,013	1,073
Big Sioux River	495	513	1,173	1,037
Woodlots	232	284	4,342	5,107

Results

Point Counts

Densities (birds • km^{-2}) and relative abundances (birds/point) over the entire migration period were higher in woodlots than in either riparian corridor in both spring and fall (*table 2*). We compared the overall numbers of observations among study areas by Chi-square, after correcting for unequal sampling effort (Rappole et al. 1979). The overall numbers of neotropical migrants observed in woodlots was significantly higher than that in both Missouri and Big Sioux River riparian corridors in both spring and fall. Test statistics for these comparisons ($P < 0.001$ and $df = 1$ in all cases) were: Woodlots vs. Missouri River (spring), $\chi^2 = 241$; Woodlots vs. Big Sioux River (spring), $\chi^2 = 307$; Woodlots vs. Missouri River (fall), $\chi^2 = 441$; Woodlots vs. Big Sioux River (fall), $\chi^2 = 570$. Overall numbers of observations

did not differ significantly between the two riparian corridors at either season.

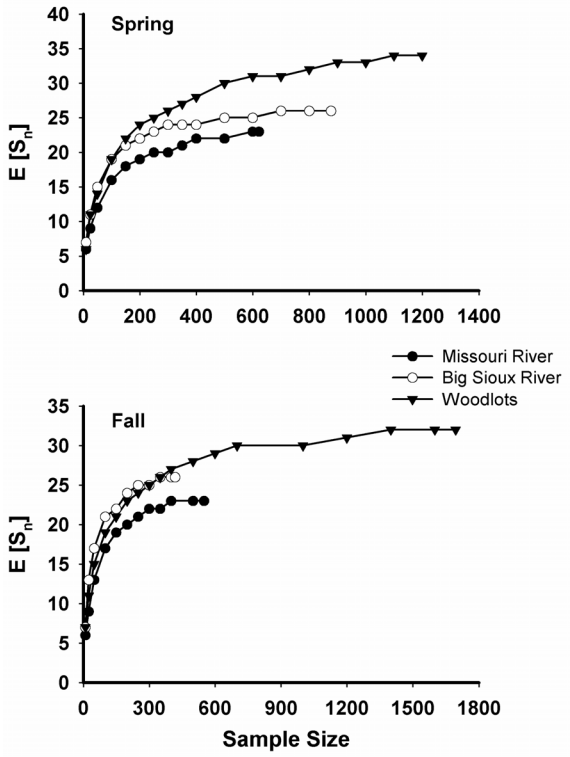

Figure 2— Rarefaction curves generated from pooled observation and capture data for riparian corridor and woodlot study sites in southeastern South Dakota. These curves provide a cumulative measure of the expected number of species for any given sample size. These curves indicate that species richness in woodlots and Big Sioux River sites was higher than at Missouri River sites at both seasons. In general, woodlot species richness during migration is similar to that at riparian corridor woodland sites.

Mist Net Sampling

Capture rates were higher at the Missouri River study sites than at other study sites during both spring and fall (*table 2*). Overall captures among sites were also compared with Chi-square tests corrected for different net hours (df = 1 in all cases). The overall number of captures in spring (*table 2*) was significantly ($P < 0.001$) greater at Missouri River sites than at other sites ($\chi^2 = 46.2$ for Big Sioux River; $\chi^2 = 204$ for the woodlot). Overall capture numbers were also significantly greater at Big Sioux sites than at the woodlot site in spring ($\chi^2 = 13.9$, $P < 0.001$). Missouri River sites also had significantly ($P < 0.001$) higher overall capture numbers than other sites during fall migration ($\chi^2 = 319$ for Big Sioux River; $\chi^2 = 267$ for the woodlot). Capture numbers in the woodlot were significantly higher than those at Big Sioux River sites in fall ($\chi^2 = 73.3$, $P < 0.001$).

Species Richness and Diversity

The overall numbers of neotropical migrant species (flycatchers, vireos, thrushes, warblers, and tanagers) observed or captured in spring were 26 at Big Sioux River sites, 25 at Missouri River sites (29 for the two riparian corridors combined), and 35 for woodlots. In fall, comparable numbers were 27 at Big Sioux River sites, 25 at Missouri River sites (28 for the two riparian corridors combined), and 33 for woodlots. Because sampling effort varied among study sites, we calculated rarefaction curves (*fig. 2*) for expected species richness for a given sample size (James and Rathbun 1981). ANCOVA on double log10-transformed rarefaction curve data indicated that the expected number of species ($E[S_n]$) for a given sample size differed significantly among sites in both spring ($F_{3, 42} = 240$, $P < 0.001$) and fall ($F_{3, 37} = 177$, $P < 0.001$). In spring, $E[S_n]$ was greatest in woodlots and lowest at Missouri River sites, and all sites differed significantly from each other. In fall, $E[S_n]$ was greatest at Big Sioux River sites and lowest at Missouri River sites, but the woodlot site $E[S_n]$ did not differ significantly from either riparian corridor site after sequential Bonferroni adjustment of α-levels. Significant P-values for individual-site comparisons were <0.001 (woodlot vs. Missouri sites), 0.005 (Big Sioux vs. Missouri sites), and 0.048 (woodlot vs. Big Sioux sites) in spring, and <0.001 (Big Sioux vs. Missouri sites) in fall. Shannon diversity indices (± SE) in spring were 0.97 ± 0.02, 1.14 ± 0.01, and 1.11 ± 0.01 for Missouri River, Big Sioux River,

Table 2– *Overall densities, relative abundances (RA), total captures and capture rates (Rate) for neotropical migrants in riparian corridor woodlands and farmstead woodlots in southeastern South Dakota during spring and fall migration periods. The riparian corridor values are from Dean (1999) and represent three-year (1993-1995) mean values, except for total captures. The woodlot data are from Carlisle (1998) and Swanson et al. (2003) and represent overall captures and capture rates over a two-year period (1996-1997).*

	Density (birds·km^{-2})		RA (birds·point^{-1})		Total captures		Rate (birds·[100 net h]$^{-1}$)	
Site	**Spring**	**Fall**	**Spring**	**Fall**	**Spring**	**Fall**	**Spring**	**Fall**
Missouri River	593	208	1.76	0.74	328	719	32.4	67.0
Big Sioux River	677	135	1.77	0.68	223	144	19.0	13.9
Woodlots	1,302	898	4.02	3.05	668	1,211	15.4	23.7

and woodlot sites, respectively. Fall diversities were 0.94 ± 0.02 for Missouri River sites, 1.22 ± 0.01 for Big Sioux River sites, and 1.15 ± 0.01 for woodlot sites. Spring diversity was significantly higher at both woodlot (t_{1929} = 6.83, P < 0.001) and Big Sioux River sites (t_{1835} = 8.29, P < 0.001) than at Missouri River sites, but did not differ between woodlots and Big Sioux River sites. In the fall, diversity was highest at Big Sioux River sites (t_{1404} = 11.50, P < 0.001 for Missouri River sites; t_{898} = 4.03, P < 0.001 for woodlots), and woodlots also had significantly greater diversity than Missouri River sites (t_{1448} = 9.82, P < 0.001).

Community overlap, measured by Morisita's index, was relatively high among all sites in spring. Morisita's Index values were 0.88 between Missouri and Big Sioux river sites, 0.87 between Missouri River and woodlot sites, and 0.89 between Big Sioux River and woodlot sites. Community overlap was lower and more variable in fall, as Morisita's Index values were 0.57 between Missouri and Big Sioux river sites, 0.43 between Missouri River and woodlot sites, and 0.73 between Big Sioux River and woodlot sites.

Body Mass and Stopover

Because of the 4-d sampling cycle among study sites in riparian corridors and the relatively large woodland area at these sites, there were very few recaptures of banded birds. Thus, we could not assess the efficacy of these woodlands for mass gains by recapture data. Winker et al. (1992) presented a method for assessing mass gains during stopover by regression of energetic condition ([mass • wing chord^{-3}]•10,000) on time since sunrise. A positive slope in these regressions suggests that migrants are gaining mass during the day. In this study, all regressions of condition index with time of day for neotropical migrants captured in riparian corridors were not significantly different from zero slope (*fig. 3, table 3*), which suggests that migrants did not gain mass during the morning sampling period. For woodlots, where sampling was conducted at the same site on a daily basis, we recaptured 8-14 percent of all birds banded at least one day after their initial capture (Carlisle 1998), thus allowing calculation of mass gain for migrants from recapture data. For woodlots, migrants generally lost mass or maintained mass during the first day of stopover, but gained mass during subsequent days (*fig. 4*). Birds recaptured two or more days after initial capture gained significantly more mass than birds captured only one day after initial capture ($F_{1, 207}$ = 9.34, P < 0.001, Carlisle 1998). In addition, fall birds gained significantly more mass than spring birds ($F_{1, 207}$ = 4.89, P = 0.028, Carlisle 1998).

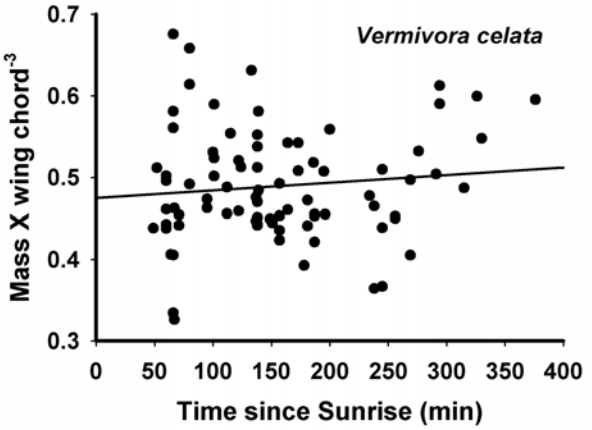

Figure 3— Condition Index ([mass • wing chord^{-3}]•10,000) as a function of time since sunrise for Orange-crowned Warblers (*Vermivora celata*) in spring in riparian corridors. The regression line was not significantly different from zero slope (P = 0.33). Similar regressions for all other neotropical migrant species having > 30 captures per season were also not significant (*table 3*), suggesting that migrants did not gain appreciable mass at riparian corridor stopover sites in either spring or fall over the morning hours sampled in this study.

Table 3– *Regression statistics for condition index ([mass • wing chord^{-3}]•10,000) vs. time since sunrise (h) for neotropical migrants with > 30 captures in riparian corridors in spring and fall.*

Species	Season	n	Y-intercept	Slope	F	R^2	P
Least Flycatcher (*Empidonax minimus*)	Spring	90	0.45	0.005	2.066	0.02	0.15
Warbling Vireo (*Vireo gilvus*)	Spring	51	0.46	-0.006	1.422	0.03	0.24
-----	Fall	261	0.45	0.002	0.550	0.002	0.46
Red-eyed Vireo (*Vireo olivaceus*)	Fall	41	0.40	0.006	0.924	0.02	0.34
Swainson's Thrush (*Catharus ustulatus*)	Spring	44	0.40	-0.0002	0.002	<0.001	0.97
Orange-crowned Warbler (*Vermivora celata*)	Spring	83	0.47	0.006	0.965	0.01	0.33
-----	Fall	143	0.44	0.004	1.076	0.01	0.30
Nashville Warbler (*Vermivora ruficapilla*)	Fall	72	0.45	0.001	0.199	0.003	0.66
Yellow Warbler (*Dendroica petechia*)	Spring	54	0.47	-0.0005	0.009	0.001	0.93
Yellow-rumped Warbler (*D. coronata*)	Spring	56	0.40	-0.003	0.985	0.02	0.33
Common Yellowthroat (*Geothlypis trichas*)	Spring	31	0.68	-0.006	0.728	0.02	0.40

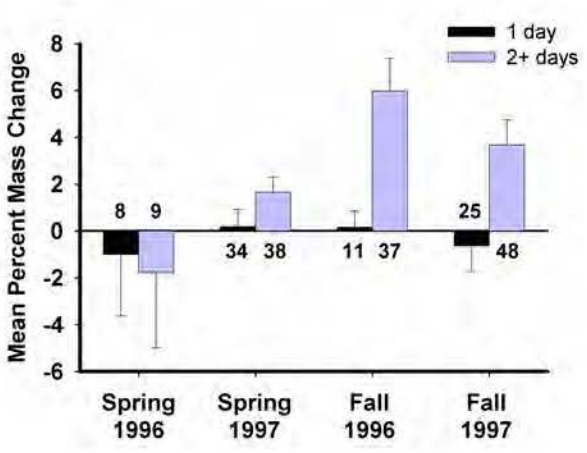

Figure 4— Mean (± SE) percent mass change for neotropical migrants (all species pooled) captured one day and ≥2 days after initial capture at the farmstead woodlot stopover site. Values under the bars are sample sizes. Mass values have been standardized to the same time of day (1200), as described in the text, to account for daily mass gains for migrants captured and recaptured at different times. Migrants were generally able to gain mass during multiple-day stopovers at this site, except during the wet spring of 1996. From Carlisle (1998).

Discussion

During the nesting season, abundance and species richness of woodland birds, particularly neotropical migrants, often are positively related to woodland area (see Askins 2000 for review). Much of the work documenting this positive relationship of abundance and richness of neotropical birds with woodland area in North America was conducted in eastern deciduous forest. Several studies, however, have documented a similar relationship (increasing species richness with increasing area) in the midwestern United States (Blake and Karr 1984, 1987; Cable et al. 1992), including eastern South Dakota (Martin 1981, Bakker 2000). Riparian woodlands in eastern South Dakota, with their greater woodland area, also support higher avian species richness than shelterbelts and farmstead woodlots, and some birds occur as nesting species only in the larger woodland areas of riparian corridors (Emmerich and Vohs 1982, D. Gentry and D. Swanson, unpubl. data). However, avian abundance may be equal or greater in shelterbelts and woodlots than in riparian corridor woodlands (Emmerich and Vohs 1982, D. Gentry and D. Swanson, unpubl. data). Connor and McCoy (1979) and Johnson (2001) caution that passive sampling effects (sampling larger areas in larger habitat patches) could also account for a positive species-area relationship. Most of the studies cited above have not accounted for passive sampling effects, so the contribution of passive sampling effects to the general species-area relationship detected in these studies is unknown.

A few studies have also examined species-area relationships during migration in the midwestern United States, with somewhat variable results (Martin 1980, Yahner 1983, Blake 1986). Martin (1980), in a study of shelterbelts in eastern South Dakota, found that abundance and species richness of spring migrants were as strongly and positively related to area as in breeding birds (Martin 1981). The shelterbelts studied by Martin (1980) were generally small, and were grouped into three size categories, with mean areas of 0.25 ha, 0.53 ha, and 1.46 ha, so those results apply only to smaller-sized shelterbelts. The number of transient birds during migration periods was positively correlated with woodlot area for woodlots in east-central Illinois that ranged in size from 1.8 to 600 ha (Blake 1986). Yahner (1983), however, found no relationship between avian species richness and woodland area during summer or during spring and fall migration periods for small shelterbelts (0.2-0.8 ha) in southern Minnesota. Again, these studies have not accounted for passive sampling effects, so the precise nature of the relationship between species numbers and woodland area during migration is not certain.

Our results documented similar abundance, diversity, and species richness in riparian corridors and woodlots during both spring and fall, despite the total woodland area being much greater in riparian corridors than in woodlots. Several factors may contribute to this result. The areas of the woodlots in this study fall mostly within the largest of the three size classes of Martin (1980), so species-area relationships of migrant birds may approach an asymptote at woodland areas approximating those for woodlots in this study. Martin (1980), however, suggested that the species-area data for shelterbelts in eastern South Dakota fit a curvilinear relationship better than an asymptotic relationship. Another possible explanation for the similar abundance, diversity, and species richness between woodlots and riparian corridors in this study is that riparian corridor woodlands in this region are more linear and narrow than the more extensive eastern deciduous forest habitats (Van Bruggen 1996). As a result, the full benefits of large areas of unfragmented forest to species richness and abundance are probably not realized, even in riparian corridor woodlands, in southeastern South Dakota. Finally, if passive sampling effects prominently influence the nature of the species-area relationship in woodland habitats, then the degree of association between species numbers and woodland area detected in studies not accounting for passive sampling may be overestimated. However, passive sampling effects are unlikely to account for the similarity in species richness among riparian corridors and woodlots in this study because we sampled more points in the larger

woodland areas of riparian corridors, although net hours were greater in the woodlot than in either riparian corridor (*table 1*). If passive sampling effects were pervasive in this study, then higher numbers of species would likely be expected at riparian corridor sites because of the higher numbers of points surveyed, but this is not what we found.

Some differences in abundance of individual species between riparian corridor woodlands and woodlots did occur in this study. For example, Warbling Vireos (*Vireo gilvus*) composed 41.5 percent of all captures and observations during fall migration in the Missouri River riparian corridor (Dean 1999). Comparable values for the Big Sioux River riparian corridor and for woodlots were only 8.5 percent and 3.3 percent, respectively. Such individual species differences were more prominent in fall than in spring, resulting in lower species overlap between riparian corridors and woodlots in fall than in spring. Nevertheless, most neotropical migrant species could be found in both riparian corridors and woodlots during spring and fall migration. Of species with at least nine total captures or observations, only Yellow-throated Vireo (*Vireo flavifrons*; riparian corridors in spring and fall) and Gray-cheeked Thrush (*Catharus minimus*; woodlots in spring) were restricted to either riparian corridors or woodlots. These species do occur in small numbers in both habitats during migration through southeastern South Dakota (pers. obs.), but they were not detected in both habitats during this study. Thus, both woodland types provided stopover habitat for most neotropical migrant species passing through this region.

These data suggest that neotropical migrants show generally similar patterns of occurrence in both riparian corridor woodlands and farmstead woodlots during migration periods, but they do not allow discrimination of the relative suitability of the two woodland types for stopover. This latter question requires assessment of whether or not migrants are able to gain mass at these sites during stopover periods. For woodlots, Carlisle (1998) reported recapture rates (individuals recaptured at least one day after their initial capture) of 8-14 percent for woodlots. Recaptured individuals tended to exhibit low initial refueling rates during the first day after initial capture, but, in three of four seasons, migrants gained substantial mass if recaptured two or more days after their initial capture (*fig. 4*). The lone exception was the spring of 1996, which was an unusually rainy season. Carlisle (1998) speculated that arthropod numbers might have been reduced relative to other years by this wet weather, thereby decreasing relative mass gain during that season. A similar pattern of low initial refueling rates at stopover sites, followed by mass gains during longer stopover periods, has been documented at a number of additional stopover sites (see Schwilch and Jenni 2001 for review). Such a pattern may relate to competition, to a lack of familiarity with the stopover site, or to a rebuilding of the gut following a period of migratory flight (Hume and Biebach 1996; Yong and Moore 1997; Karasov and Pinshow 1998, 2000). Alternatively, Schwilch and Jenni (2001) suggest that a low initial rate of mass gain may be an artifact of handling effects and that detection of such a pattern may be confounded by not knowing when a captured migrant actually arrived at a stopover site. These authors argue that low initial refueling rates are not a common phenomenon in migrating birds. In any event, the data of Carlisle (1998) indicate that migrants are capable of gaining mass during stopover in farmstead woodlots, so woodlots generally appear to serve as suitable stopover habitat for these birds.

Because of the 4-day sampling interval among sites in the riparian corridor study of Dean (1999), recapture rates of migrants were too low (<1 percent) to perform a similar analysis of mass changes during stopover. Regressions of energetic condition ([mass • wing chord^{-3}]•10,000) on time since sunrise were not significantly different from zero slope for any species during either spring or fall migration at riparian corridor stopover sites. This result may occur because sampling in riparian corridor woodlands occurred only during the morning and not over the entire day, so regressions generally covered only about a 5-hour period.

These data suggest, therefore, that riparian corridor woodlands and farmstead woodlots provide similar potential for stopover habitat for neotropical migrants, at least in this region, and possibly over a broad geographic range. This finding has some potentially major implications for the conservation of neotropical migrants, suggesting that conservation of even small woodland areas (1-4 ha) can provide benefits for migrants as stopover sites. Because much of the available woodland in eastern and central North America consists of relatively small parcels, and because restoration of small woodland parcels is more feasible than restoration of large, contiguous woodlands, increasing the number of small woodlots could enhance available stopover habitat for neotropical migrants. This could prove beneficial to neotropical migrant populations, as loss of stopover habitat is one potential factor contributing to population declines for some species (Moore et al. 1995). However, conservation of small woodland parcels in this area is of less benefit to breeding neotropical migrants because smaller parcels have lower species richness and lower percentages of neotropical migrants (D. Gentry and D. Swanson, unpubl. data). This reduced species richness of breeding birds in smaller woodlands is also apparently true elsewhere in eastern and central North America (Blake and Karr 1984, 1987; Cable et al. 1992; Bakker 2000). In addition, Bakker (2000) showed that small woodlands adjacent to grassland areas depressed occurrence of

grassland bird species in those grasslands. This is important because many species of grassland nesting species are also experiencing marked population declines (see Askins 2000 for review). Thus, overall conservation programs for birds must prioritize which species and which seasons are most important to conservation efforts in particular areas. Nevertheless, these results suggest that for migratory periods, conservation of small woodland parcels can offer important benefits to neotropical migrants.

Acknowledgments

These studies were funded by grants from the South Dakota Department of Game, Fish and Parks Wildlife Diversity Program and the U.S. Fish and Wildlife Service Region 6 neotropical Migratory Bird Program, and their support is gratefully acknowledged. We also thank T. Hills, D. Weinacht, and K. Rollinger for their able field assistance and R. Jensen, C. Beard, and J. Davidson for access to woodlots during our study. We also thank D. Johnson and S. Morris for providing valuable comments on an earlier version of this manuscript.

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Riparian Songbird Abundance a Decade After Cattle Removal on Hart Mountain and Sheldon National Wildlife Refuges[1]

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Abstract

Cattle were removed from the high desert riparian habitats of Hart Mountain and Sheldon National Wildlife Refuges in 1990. This study compares songbird abundance in 2000-2001 to that in 1991-1993 on 69 permanent plots. Of the 51 species for which detections were sufficient to calculate changes in abundance, 71 percent (36/51) exhibited a positive trend and 76 percent (16/21) of species exhibiting a significant change (either positive or negative) increased. The average increase among the 51 species was equivalent to 3.0 detections/km^2. Increasing species included species of concern in the Columbia Plateau: Yellow Warbler (*Dendroica petechia*), White-crowned Sparrow (*Zonotrichia leucophrys*), Song Sparrow (*Melospiza melodia*), Dusky Flycatcher (*Empidonax oberholseri*), Warbling Vireo (*Vireo gilvus*), Mourning Dove (*Zenaida macroura*), MacGillivray's Warbler (*Oporornis tolmiei*), and Orange-crowned Warbler (*Vermivora celata*). Aspen and willow associates, but not meadow associates, exhibited a significant increase in detections/km^2. Detections of ground/low cup and high cup nesting species, but not cavity nesting species, increased significantly. Ground/understory foraging species, aerial, and overstory foraging species increased significantly in detections/km^2, but bark gleaning species did not. For the 16 significantly increasing species in this study, patterns of change on Breeding Bird Survey routes during 1980-1999 suggest that the changes documented here are not merely a reflection of regional patterns.

Key words: aspen, cattle, grazing, Great Basin, riparian songbirds.

Introduction

During the last 15 years, much scientific and conservation attention has focused on the health of breeding songbird populations throughout the U.S. (e.g., Robbins et al. 1989, Martin and Finch 1995). In the semi-arid west, riparian habitats are of particular concern because they comprise only 1 percent of the landscape but support a higher diversity of breeding songbirds than any other habitat (Knopf et al. 1988a), and they have been severely affected by agriculture, recreation, timber harvest, water diversion, and, particularly, livestock grazing (Thomas et al. 1979, Chaney et al. 1990). Cattle deplete and sometimes eliminate riparian vegetation by grazing on the herbaceous layer and browsing on shrubs and young trees (Sedgwick and Knopf 1991), and they also cause soil compaction, channel widening, and lowering of the water table (Platts 1991).

Effects of cattle grazing on avian abundance have been demonstrated in several studies (see reviews in Saab et al. 1995, Tewksbury et al. 2002). In Saab et al.'s (1995) review of nine studies comparing species abundance in grazed and ungrazed systems, species most affected by grazing were primarily ground or near-ground nesting species and shrub nesting species, as expected from the greater effect that cattle have on the lower vegetation strata. Habitat generalists, canopy nesters, and cavity nesters tended to be less affected by grazing. However, effects throughout the avian community have been documented in cases where grazing has had a severe impact on vegetation (Krueper et al. 2003, Tewksbury et al. 2002).

The high desert riparian habitats of Hart Mountain and Sheldon National Wildlife Refuges (hereafter Hart and Sheldon), in southcentral Oregon and northwestern Nevada, respectively, are among those western landscapes affected by livestock grazing. On Hart, cattle were removed in the autumn of 1990, and a 15-year policy of no grazing was officially adopted in 1994 (USFWS 1994). Soon after cattle were removed, most riparian areas were classified as being in poor (50 percent) or moderate condition (25 percent) (USFWS 1994). Similarly, on Sheldon, season-long cattle grazing was recognized as one of the forces responsible for the poor health of riparian areas (USFWS 1981). Most cattle were removed in the autumn of 1990, although a few remained in one area until 1994, and an increasing feral horse population continued to impact some riparian areas throughout this study.

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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In 1991, the year following cattle removal on the refuges, a 3-year study of riparian songbird abundance and riparian vegetation condition was initiated. Dobkin (1994) found that cover of herbaceous vegetation had increased by the third year after cattle removal, consistent with both livestock removal and increased rainfall in the third year. The change in herbaceous vegetation was accompanied by a small increase in avian abundance, especially of ground and understory specialists (Dobkin 1994). There was little change in aspen or willow recruitment during the 3 years, consistent with the slow recovery of woody riparian vegetation. Dobkin et al. (1998) also compared riparian meadow plots inside a long-term livestock exclosure on Hart to adjacent plots recently grazed by cattle (1 to 3 years previously). They found that exclosure plots had higher avian species richness and abundance and were dominated by wetland and riparian birds rather than the upland species of recently grazed plots.

In this paper, we compare the abundance of riparian birds on a set of 69 plots surveyed 1 to 3 years and 11 to 12 years after livestock removal on Hart Mountain and Sheldon National Wildlife Refuges. Future analyses will include the final year of data collection (2002), and detailed vegetation measurements from each plot.

Study Area and Plots

Hart encompasses approximately 112,550 ha and includes Hart Mountain, a fault block that rises to 2,438-m elevation. Upland vegetation is primarily low sagebrush (*Artemisia arbuscula*), big sagebrush (*A. tridentata*) and silver sagebrush (*A. cana*) with some rabbitbrush (*Chrysothamnus* sp.). Riparian habitat provides the only trees except for scattered stands of mountain mahogany (*Cercocarpus ledifolius*), western juniper (*Juniper occidentalis*), a single stand of Ponderosa Pine (*Pinus ponderosa*), and white fir (*Abies concolor*) at higher elevations (USFWS 1994). Riparian habitats extend from 1,433 to 2,317 m in elevation, most are along narrow streams (<8 m width) varying from high to low gradient, and most zones of riparian vegetation are less than 50 m in width. Riparian habitat is classified into six cover types for the purpose of this study. Of the 134 linear km of riparian habitat on Hart, 29 percent is quaking aspen (*Populus tremuloides*) along perennial streams, 10 percent is quaking aspen in snow pockets (small, relatively high elevation depressions where snow collects), 11 percent willow (*Salix* sp.), 29 percent meadow (various species of grasses, sedges, and rushes), and 12 percent mixed deciduous shrub (including aspen, willow, black cottonwood, *Populus balsamifera,* mountain alder, *Alnus incana*, red-osier dogwood, *Cornus sericea*, waterbirch, *Betula occidentalis*, and chokecherry, *Prunus virginiana*). An additional 9 percent of streamside zones are dominated by non-riparian shrubs either because the valley and riparian zone were naturally narrow or because upland shrubs, primarily big sagebrush, have encroached to the streamside.

Sheldon encompasses 232,800 ha of high desert, and although only 32 km south of Hart, the climate is hotter and drier. Average precipitation is 15 cm at lower elevations (1,280 m) and 33 cm at higher elevations (2,225 m) at Sheldon (USFWS 1981), compared to 25.0 to 37.5 cm at Hart. The expansive uplands are broken by narrow canyons, rolling valleys, and broad rimrock tables. Upland vegetation is dominated by big sagebrush, low sagebrush, rabbitbrush, bitterbrush (*Purshia tridentata*), and greasewood (*Sarcobatus vermiculatus*). A few mountain mahogany, western juniper, and quaking aspen stands occur at higher elevations. Of the 83 linear km of riparian habitat on Sheldon, which occur primarily along Hell, Virgin, Thousand, Fish, and Badger Creeks, 52 percent is dominated by meadow, 12 percent by willow, and 7 percent by mixed deciduous shrubs. As much as 29 percent of riparian areas, however, are classified as nonriparian shrub (*table 1*). The amount of aspen and snow pocket aspen is negligible.

Table 1— *Distribution of avian plots relative to cover type availability (in km) on Hart Mountain and Sheldon National Wildlife Refuges. Riparian aspen includes some aspen in valleys but not along perennial stream segments. Proportion of length (km) is the proportion of the total perennial stream lengths on a refuge made up by each cover type.*

	Hart Mountain			Sheldon			
Cover type	Length (km)	Prop. length	No. plots	Length (km)	Prop. length	No. plots	Total plots
Meadow	39.0	0.29	7	42.7	0.52	9	16
Riparian Aspen	39.0	0.29	18	--	--	0	18
Snow Pocket Aspen	13.8	0.10	9	--	--	0	9
Willow	14.3	0.11	5	10.3	0.12	10	15
Nonriparian Shrub	12.2	0.09	8	24.3	0.29	1	9
Mixed Deciduous	16.1	0.12	0	5.7	0.07	2	2
Total	**133.9**		**47**	**82.9**		**22**	**69**

Plots were established in five cover types on five drainages on Hart (n = 47) and four cover types in six drainages on Sheldon (n = 22) (*table 1*). Of the 18 riparian aspen plots, all of which were on Hart, 14 were within multi-aged, mature stands; two were within decadent stands that had little or no regeneration and a large proportion of dead trees; and two were within a dense, even-aged stand that had burned in a 1972 wildfire. Stands of snow pocket aspen consist of trees that are shorter and more scrub-like than those in mature riparian aspen stands, but most also have some mature trees interspersed (Dobkin et al. 1995). Willow stands on riparian plots were typically narrow (<50 m) and varied substantially in sparseness and structural diversity. The two mixed deciduous plots, both along Idaho Creek on Sheldon, were in narrow, dense stands of mountain alder, red-osier dogwood, willow, and snowberry (*Symphoricarpos oreophilus*). Meadow plots varied from dry to moist to marshy and from narrow strips surrounded by non-riparian shrub to meadows extending the width of the plot. Seven meadow plots (4 in 1985 and 3 since 1993) and two willow plots (1990 and 1999) have undergone prescribed burning, and an additional 1 to 3 meadow plots were affected by a 1972 wildfire.

Methods

Each plot was 150 m long by 100 m wide, and most plots were at least 250 m apart. The width of the riparian vegetation on a plot ranged from <5 m to 100 m, but was typically less than the width of the plot. The centerline of the plot, which was marked at 50-m increments with permanent steel fence posts, ran near and parallel to the stream. Each plot was surveyed 3 times between 8 May and 24 June in 2000 and 17 May and 25 June in 2001. In 2001, four observers conducted surveys in a balanced design such that, except for a few exceptions, no person surveyed the same plot twice. Two observers conducted all surveys in 2000. In 1991-1993, each plot was surveyed six times, once on each of two consecutive days during each of 3 survey rounds between 7 May and 11 July (Dobkin and Rich 1998). In both 1991-1993 and 2000-2001, the order in which plots were surveyed within a day (and within a drainage) alternated between consecutive visits. During a survey, an observer walked slowly along the centerline recording the first occurrence of each individual seen or heard within the plot. Surveys were conducted between 0.25 and 3.5 hours after sunrise, and time allowed for a survey depended on cover type: 25 min in aspen, 20 in willow, and 15 in meadow or non-riparian shrub. Results provided an index to avian species abundance.

For each of the 69 plots, mean detections per visit were averaged among visits within a year, then among years within a phase (i.e., 1991-1993 and 2000-2001 are phases). The difference between phases was then calculated. The mean difference across all plots was calculated for each species and a paired t-test was used to determine whether the difference for each species was significantly different from 0. As a means of restricting the analysis to those species having a large enough sample to provide a reasonable power to detect a difference, only the 51 species with an average of ≥0.02 detections per plot-visit (equivalent to ≥1.3 detections/km^2) in either phase were used.

The comparison is restricted to passerines, doves, woodpeckers, and shorebirds that either nest or forage primarily in riparian habitat within the Hart-Sheldon landscape; shrubsteppe specialists are excluded because it is not clear how they would be expected to change as the riparian vegetation replaces shrubsteppe vegetation within plots but the shrubsteppe vegetation also improves. In three cases, "species" are combinations of species that were created to keep data recording and species identification consistent between phases. *Empidonax* includes Hammond's, Cordilleran, Pacific-slope, and Willow flycatchers, unidentified flycatchers, and the Olive-sided Flycatcher (genus *Contopus*); Dusky and Gray Flycatchers were analyzed separately. Hummingbird species include Broad-tailed, Calliope, and Rufous Hummingbirds, and unidentified hummingbirds. Sapsuckers include Red-naped and Red-breasted Sapsuckers, hybrids, and those recorded as unidentified. Scientific names for species mentioned in the text are given in *table 2*.

Species were assigned to primary habitats (aspen, willow, or meadow) based on the cover type in which its mean detections per plot-visit was highest in this study. Species were assigned to nesting guilds (ground/low cup, high cup, and cavity) and foraging guilds (ground/understory, overstory, aerial, and bark) based on Dobkin (1994) and Ehrlich et al. (1988). Within each guild, the proportion of species exhibiting a change was compared to 0.50, the proportion expected by chance, using a binomial test. Change in detections/km^2 (i.e., phase II – phase I) was calculated for each guild by pooling detections for all species within each guild and treating the plot as the primary sampling unit. Paired t-tests were used to determine whether the change in detections/km^2 was significantly different from 0 for each guild, and one-way ANOVAs were used to test for differences among guilds in change in detections/km^2. Standard errors are reported with means throughout the text and tables.

Table 2— *Species exhibiting significant increases and decreases in detections between 1991-1993 and 2000-2001. Changes in detections/km^2 are paired differences using the 69 original plots as sampling units; statistical significance based on paired t-tests with (*) p < 0.10, * p < 0.05, ** p < 0.01, *** p < 0.001. Species categorized by foraging and nesting guilds based on Dobkin (1994) and Ehrlich et al. (1988). Habitat association is the habitat in which the species was most often recorded in this study. Species in bold are riparian species of concern based on BBS trends (1966-1999) and Partners in Flight prioritization (see Methods).*

Species	Scientific name	Change in detections per km^2	Foraging guild	Nesting guild	Habitat association
Increasing species					
Yellow Warbler	***Dendroica petechia***	**28.2 *****	**Understory**	**Grnd/Low C**	**Willow**
White-crowned Sparrow	***Zonotrichia leucophrys***	**24.3 *****	**Ground**	**Grnd/Low C**	**Aspen**
Song Sparrow	***Melospiza melodia***	**23.0 *****	**Ground**	**Grnd/Low C**	**Willow**
Savannah Sparrow	*Passerculus sandwichensis*	17.9 **	Ground	Grnd/Low C	Meadow
Tree Swallow	*Tachycineta bicolor*	16.9 **	Aerial	Cavity	Aspen
Red-winged Blackbird	*Agelaius phoeniceus*	16.4	Ground	Grnd/Low C	Meadow
Dusky Flycatcher	***Empidonax oberholseri***	**12.2 *****	**Aerial**	**Grnd/Low C**	**Aspen**
Warbling Vireo	***Vireo gilvus***	**9.4 *****	**Overstory**	**High Cup**	**Aspen**
House Finch	*Carpodacus mexicanus*	8.5 **	Ground	High Cup	Aspen
Cliff Swallow	*Petrochelidon pyrrhonota*	7.7	Aerial	Other	Meadow
Common Snipe	*Gallinago gallinago*	5.9 *	Ground	Grnd/Low C	Meadow
Killdeer	***Charadrius vociferus***	**5.6 (*)**	**Ground**	**Grnd/Low C**	**Meadow**
Mourning Dove	***Zenaida macroura***	**5.5 ***	**Ground**	**Grnd/Low C**	**Willow**
MacGillivray's Warbler	***Oporornis tolmiei***	**3.9 ****	**Understory**	**Grnd/Low C**	**Aspen**
Empidonax[a]	***Empidonax* spp.**	**3.7 (*)**	**Aerial**	**Grnd/Low C**	**Aspen**
Dark-eyed Junco	*Junco hyemalis*	3.7 **	Ground	Grnd/Low C	Aspen
Western Tanager	*Piranga ludoviciana*	3.4 *	Overstory	High Cup	Aspen
Brown-headed Cowbird	*Molothrus ater*	3.3	Ground	Other	Willow
Orange-crowned Warbler	***Vermivora celata***	**3.1 ***	**Overstory**	**Grnd/Low C**	**Aspen**
Spotted Towhee	*Pipilo maculatus*	3.1 **	Ground	Grnd/Low C	Aspen
Fox Sparrow	*Passerella iliaca*	2.2 (*)	Ground	Grnd/Low C	Aspen
Yellow-rumped Warbler	*Dendroica coronata*	2.1	Overstory	High Cup	Aspen
Mountain Bluebird	*Sialia currucoides*	1.8	Aerial	Cavity	Aspen
Yellow-breasted Chat	***Icteria virens***	**1.6**	**Ground**	**Grnd/Low C**	**Willow**
Black-headed Grosbeak	*Pheucticus melanocephalus*	1.3	Overstory	High Cup	Aspen
Say's Phoebe	*Sayornis saya*	1.2 *	Aerial	Other	Willow
American Robin	*Turdus migratorius*	1.0	Ground	High Cup	Aspen
Western Wood-Pewee	***Contopus sordidulus***	**0.6**	**Aerial**	**High Cup**	**Aspen**
Common Yellowthroat	*Geothlypis trichas*	0.5	Understory	Grnd/Low C	Willow
Hairy Woodpecker	*Picoides villosus*	0.5	Bark	Cavity	Aspen
Violet-green Swallow	*Tachycineta thalassina*	0.4	Aerial	Cavity	Meadow
Cassin's Finch	***Carpodacus cassinii***	**0.3**	**Ground**	**High Cup**	**Aspen**
Northern Flicker	***Colaptes auratus***	**0.3**	**Bark**	**Cavity**	**Aspen**
White-throated Swift	***Aeronautes saxatalis***	**0.2**	**Aerial**	**Other**	**Willow**
Sora	*Porzana carolina*	0.2	Ground	Grnd/Low C	Meadow
Barn Swallow	***Hirundo rustica***	**0.0**	**Aerial**	**Other**	**Meadow**
Decreasing species					
House Wren	*Troglodytes aedon*	-17.6 **	Understory	Cavity	Aspen
European Starling	*Sturnus vulgaris*	-13.3 **	Ground	Cavity	Aspen
Wilson's Phalarope	***Phalaropus tricolor***	**-11.0 (*)**	**Ground**	**Grnd/Low C**	**Meadow**
Bullock's Oriole	***Icterus bullockii***	**-4.0 *****	**Overstory**	**High Cup**	**Aspen**
Willet	*Catoptrophorus semipalmatus*	-3.3 (*)	Ground	Grnd/Low C	Meadow

Table 2– *continued*

Species	Scientific name	Change in detections per km^2	Foraging guild	Nesting guild	Habitat association
Decreasing species (contd.)					
Brewer's Blackbird	***Euphagus cyanocephalus***	**-3.2**	**Ground**	**Grnd/Low C**	**Meadow**
Yellow-headed Blackbird	*Xanthocephalus xanthocephalus*	-3.0	Ground	Grnd/Low C	Meadow
Ruby-crowned Kinglet	***Regulus calendula***	**-2.4 ****	**Overstory**	**High Cup**	**Willow**
Lazuli Bunting	***Passerina amoena***	**-2.2**	**Ground**	**Grnd/Low C**	**Willow**
Western Meadowlark	***Sturnella neglecta***	**-2.0**	**Ground**	**Grnd/Low C**	**Meadow**
Wilson's Warbler	***Wilsonia pusilla***	**-1.7 ***	**Understory**	**Grnd/Low C**	**Willow**
Hummingbird species[b]	***Selasphorus/Stellula* spp.**	**-0.8**	**Understory**	**Grnd/Low C**	**Aspen**
Swainson's Thrush	***Catharus ustulatus***	**-0.8**	**Understory**	**Grnd/Low C**	**Aspen**
Sapsuckers[c]	***Sphyrapicus nuchalis, S. ruber***	**-0.4**	**Bark**	**Cavity**	**Aspen**
Downy Woodpecker	*Picoides pubescens*	-0.2	Bark	Cavity	Aspen

[a]Includes: Hammond's Flycatcher (*Empidonax hammondii*), Cordilleran Flycatcher (*E. occidentalis*), Pacific-slope Flycatcher (*E. difficilis*), Willow Flycatcher (*E. traillii*), and one *Contopus*, the Olive-sided Flycatcher (*Contopus cooperi*).
[b]Includes: Broad-tailed Hummingbird (*Selasphorus platycercus*), Calliope Hummingbird (*Stellula calliope*), and Rufous Hummingbird (*Selasphorus rufus*).
[c]Includes: Red-naped Sapsucker (*Sphyrapicus nuchalis*) and Red-breasted Sapsucker (*Sphyrapicus ruber*) and those recorded as hybrid or unidentified sapsuckers.

Riparian species of concern, for the purpose of this study, are those riparian associates that had either (1) a significant declining trend on North American Breeding Bird Survey (BBS) routes within U.S. Fish and Wildlife Service Region 1, which includes California, Oregon, Washington, Nevada, and Idaho; (2) a significant declining trend on BBS routes in the Columbia Plateau physiographic area; (3) a Partners in Flight score for the Columbia Basin >20; or (4) an Oregon Management Index score >10. The latter two scores, obtained from Partners in Flight's Columbia Plateau Bird Conservation Plan (Altman and Holmes 2000), are based on relative abundance, population trend, threats on the breeding and wintering grounds, and the extent of the species' breeding and nonbreeding distributions.

Results

Preliminary results one decade after cattle removal, 1991 to 1993 compared to 2000 to 2001, indicate that 71 percent (36/51) of riparian species exhibited positive trends ($P < 0.01$, binomial test) and 76 percent (16/21) of species exhibiting a significant change (either positive or negative) increased ($P < 0.05$) (*table 2*). The average increase among the 51 species was 0.045 detections per plot or 3.0 detections/km^2 (a rate significantly greater than zero, paired t-test, $P < 0.01$). The 16 significantly increasing species were Yellow Warbler, White-crowned Sparrow, Song Sparrow, Savannah Sparrow, Tree Swallow, Dusky Flycatcher, Warbling Vireo, House Finch, Common Snipe, Mourning Dove, MacGillivray's Warbler, Dark-eyed Junco, Western Tanager, Orange-crowned Warbler, Spotted Towhee, and Say's Phoebe (*table 2*). The five significantly declining species were House Wren, European Starling, Bullock's Oriole, Ruby-crowned Kinglet, and Wilson's Warbler (*table 2*). Here we interpret the pattern of increasing species by primary habitat, nesting guild, and foraging guild.

Aspen and willow associates ($t = 2.86$, $P = 0.006$; and $t = 3.83$, $P < 0.001$), but not meadow associates ($t = 1.44$, $P = 0.16$), exhibited a significant increase in detections/km^2 (*table 3*). The change in detections/km^2 did not vary significantly among the three habitat association groups ($F = 0.76$, $P = 0.47$, *fig. 1*). Increasing species comprised a significant proportion (0.77) of significant changes among aspen species ($P < 0.05$) but not among willow or meadow associates (*table 3*).

Detections of ground/low-cup nesting species and high-cup nesting species increased significantly ($t = 6.12$, $P < 0.001$; $t = 2.23$, $P = 0.03$), but cavity nesting species exhibited little change ($t = 0.78$, $P = 0.44$, *table 3*). The change in detections/km^2 varied significantly among nesting guilds ($F = 22.0$, $P < 0.001$, *fig. 1*). Ground/low-cup nesting species increased significantly more than either high-cup nesters or cavity nesters, and cavity-nesting species increased the least. A similar pattern is evident in the proportion of increasing species. Increasing species comprised a significant proportion (0.92) of significant changes among ground/low-cup nesting species ($P < 0.01$) but not among other nesting guilds (*table 3*).

Table 3— *Mean change and percent change in detections/km^2, and proportion of species increasing by habitat, nesting, and foraging guilds for riparian species on the 69 original plots on Hart and Sheldon National Wildlife Refuges in 2000-2001 compared to 1991-1993. Paired t-tests with 68 df used to determine significance of change in detections/km^2; binomial test used to determine whether proportion of species increasing differed from 0.50 (* P < 0.05, ** P < 0.01, *** P < 0.001). Guilds were pooled for binomial tests if denominators were < 6 because statistical significance of P < 0.05 can't be achieved in such cases.*

Guild	Change in detections per km^2 (SE)	Percent change[a] in detections per km^2	Prop. species exhibiting positive trend[b]	Prop. significant changes that are increases[c]
Habitat				
Aspen	64.9 (22.7)**	19	0.74 (20/27)*	0.77 (10/13)*
Willow	57.3 (14.9)***	75	0.73 (8/11)	0.67 (4/6)[d]
Meadow	31.4 (21.9)	13	0.62 (8/13)	1.00 (2/2)[d]
Nesting				
Ground/low cup	132.9 (21.7)***	40	0.67 (18/27)	0.92 (11/12)**
High cup	20.1 (9.0)*	20	0.80 (8/10)	0.60 (3/5)[e]
Cavity	-12.1 (15.4)	-7	0.56 (5/9)	0.33 (1/3)[e]
Foraging				
Ground/Understory	96.1 (25.3)***	20	0.63 (26/41)	0.72 (13/18)
Aerial	44.7 (14.8)**	39	1.00 (10/10)**	1.00 (3/3)[f]
Overstory	12.8 (4.3)**	32	0.71 (5/7)[g]	0.60 (3/5)[f]
Bark	0.1 (3.4)	0	0.50 (2/4)[g]	0.00 (0/1)[f]

[a] Percent change = (change in detections/mean detections in 1991-1993) x 100%
[b] Number species increasing divided by total number species in the guild.
[c] Number of significantly increasing species divided by number of species exhibiting significant changes (either increases or decreases).
[d] Categories pooled for binomial test; 6/8 = 0.75, P = 0.29.
[e] Categories pooled for binomial test; 4/8 = 0.50, P = 1.0.
[f] Categories pooled for binomial test; 6/9 = 0.67, P = 0.51.
[g] Categories pooled for binomial test; 7/11 = 0.64, P = 0.55.

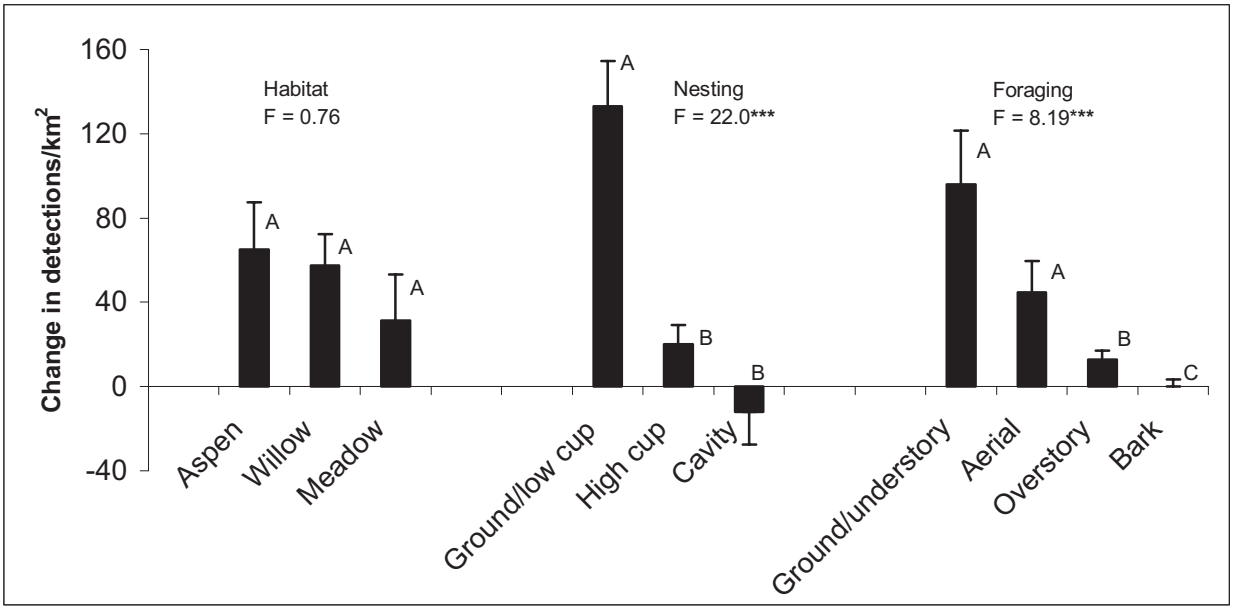

Figure 1— Change in detections/km^2 for riparian species within habitats of primary occurrence, nesting guilds, and foraging guilds. Change in detections is the difference between 2000-2001 and 1991-1993 detections pooled across species on the 69 original plots on Hart and Sheldon National Wildlife Refuges. Statistical tests are one-way ANOVAs (* P < 0.05, ** P < 0.01, *** P < 0.001). Within guild types, guilds with different letters above bars are those that differ significantly in detections/km^2 based on t-tests.

Ground/understory foraging species ($t = 3.79$, $P < 0.001$), aerial ($t = 3.02$, $P = 0.004$), and overstory foraging species ($t = 2.94$, $P = 0.004$) showed significant increases in detections, but bark-gleaning species did not ($t = 0.04$, $P = 0.97$, *table 3*). The change in detections/km^2 differed significantly among foraging guilds ($F = 8.19$, $P < 0.001$, *fig. 1*). Ground/understory foraging species increased significantly more than overstory foragers ($P = 0.002$) and bark gleaners ($P < 0.001$) and marginally more than aerial foragers ($P = 0.08$). Aerial foragers increased significantly more than overstory foragers ($P = 0.04$), and the change in detections of bark gleaners was significantly less than that of each of the other foraging guilds (all $P < 0.02$). Among ground/ understory foragers, increasing species comprised a marginally significant proportion (0.72) of significant changes ($P = 0.10$). Among aerial foragers, each of the ten species exhibited a positive trend, and the three significant changes were all increases (*table 3*).

Of the 26 riparian species of concern for which we had sufficient detections (*table 2*), 7 exhibited significant increases on original plots since the removal of cattle (Yellow Warbler, White-crowned Sparrow, Dusky Flycatcher, Warbling Vireo, MacGillivray's Warbler, Orange-crowned Warbler, and Mourning Dove). Three species of concern declined significantly since 1991-1993 (Bullock's Oriole, Ruby-crowned Kinglet, and Wilson's Warbler).

Discussion

Several patterns in the effects of grazing on avian communities have emerged. Saab et al. (1995) reviewed nine studies providing quantitative comparisons of species abundance in grazed and ungrazed systems (Page et al. 1978; Crouch 1982; Mosconi and Hutto 1982; Taylor 1986; Sedgwick and Knopf 1987; Medin and Clary 1990, 1991; Schulz and Leininger 1991; Knopf et al. 1988b). Species significantly affected by grazing, either across all studies or in at least one study, were primarily shrub nesting species (Red-winged Blackbirds, Common Yellowthroats, Willow Flycatchers, Yellow Warbler, American Redstart [*Setophaga ruticilla*], Gray Catbird [*Dumetella carolinensis*], and Yellow-breasted Chat) and ground or near-ground nesting species (Veery [*Catharus fuscescens*], Nashville Warbler [*Vermivora ruficapilla*], Fox Sparrow, Dark-eyed Juncos, White-crowned Sparrows, Savannah Sparrows, and Lincoln's Sparrows [*Melospiza lincolnii*]). As expected, habitat generalists, canopy nesters, and cavity nesters tended to be less directly affected by grazing. In a recent study, Krueper et al. (2003) documented dramatic changes in vegetation during the 5 years after cattle removal from the San Pedro River in Arizona and found that open cup nesters increased faster than cavity nesters, insectivores faster than omnivores, and neotropical migrants faster than residents. In a comparison across seven riparian systems in the western U.S., Tewksbury et al. (2002) found that open cup nesters, species nesting below 2.5 m, and long distance migrants were less abundant in grazed than ungrazed areas, but the difference was greatest for species nesting below 2.5 m.

In this study of riparian bird abundance one decade after cattle removal on Hart Mountain and Sheldon National Wildlife Refuges, we also found patterns of increases consistent with recovery from cattle grazing. Ground/low cup nesting species increased more than either high cup or cavity nesting species, and cavity nesting species increased less than either of the other two guilds. Ground/understory foraging species increased significantly more than overstory or bark foraging species, and bark foraging species increased significantly less than other foraging guilds.

Increases in this study were generally more widespread among species groups than might be expected. Significant increases were seen among aspen and willow associates, ground/low cup nesters, high cup nesters, and among ground/understory, overstory, and aerial foragers. Only meadow associates, cavity nesters, and bark gleaners did not increase significantly. Other studies also have found community-wide effects of cattle removal. Krueper et al. (2003) found significant increases in both open cup and cavity nesting species, both resident and Neotropical migrants, all foraging guilds (insectivores, omnivores, granivores), and all species groups categorized by vertical strata of occurrence (understory, midstory, and upperstory). Similarly, in a comparison of sites grazed for >50 years and sites free of grazing for >25 years along the Missouri River, effects were seen in both open-cup and primary cavity nesters, and low and high nesting species groups were equally affected (Tewksbury et al., 2002).

Widespread effects among foraging and nesting guilds illustrate the importance of understanding the mechanism by which cattle grazing affects avian communities. It is generally accepted that the species composition and structure of herbaceous and understory vegetation are affected by grazing. Presumably, this change in vegetation also affects the invertebrate population, and, as suggested by Krueper et al. (2003), it is likely that changes in the invertebrate population are not restricted to the lower layers of the vegetation. Studies of how invertebrate populations change with cattle removal, and how this affects avian communities, are largely lacking. However, our detailed vegetation measurements, collected in 1991-1993 and to be collected again in 2001-2002, will likely clarify the relationship between changes in particular aspects of plant species composition or structure and changes in avian abundance.

Regional rainfall may also have changed during the last decade. Cattle were removed from Hart Mountain and Sheldon National Wildlife Refuges at the end of a multi-year drought in the early 1990s. Since then, an increase in regional rainfall could have produced a positive response in riparian vegetation and a corresponding increase in riparian birds. One would expect any improvement due to regional rainfall patterns to be exhibited in other areas in addition to the refuges. To investigate this possibility, we compared our pattern of increasing species to that on Breeding Bird Survey (BBS) routes within the Columbia Plateau physiographic area and within U.S. Fish and Wildlife Service Region 1 during 1980-2001 (Sauer et al. 2002). Of the 16 significantly increasing species documented on the refuges in this study, 10 were sufficiently covered by BBS (i.e., observed on >14 routes) within the Columbia Plateau and all 16 were sufficiently covered within Region 1. Of the 10 sufficiently covered species within the Columbia Plateau, none was significantly increasing on BBS routes and 1 was significantly declining (Mourning Dove). Of the 16 sufficiently covered species within Region 1, only 1 was significantly increasing (Tree Swallow), but 3 were significantly decreasing (Common Snipe, Yellow Warbler, and Mourning Dove). Thus, the species increasing in abundance on Hart Mountain and Sheldon National Wildlife Refuges are not a reflection of regional patterns of species' increases. We will investigate this issue in more detail, by evaluating rainfall in relation to detections on the refuges and on BBS routes, after the final year of data collection.

Acknowledgments

This project was funded by the U.S. Fish and Wildlife Service, Region 1, Nongame Bird Program, and we thank M. Green and T. Zimmerman for their interest and guidance. We thank the observers in 2000 and 2001: D. Anderson, D. Moen, M. Schlenker, and A. Woodrow. Thanks to W. Pyle, A. Rich, M. Bray, J. Heltzel, J. Barnett, and J. Bart for useful suggestions throughout the study. The Sheldon-Hart Mountain National Wildlife Refuge Complex provided logistical support throughout; in particular, thanks to B. Reiswig, M. Nunn, J. Barnett, and C. Dippel for their support.

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Riparian Bird Population Monitoring in Utah, 1992-2001[1]

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Abstract

We report statewide linear and non-linear trends in density from 1992 to 2001 for six common bird species in the riparian areas of Utah. The six species examined here represent over 24 percent of all observations in the period. Four of the six species showed linear declines (Black-headed Grosbeak [*Pheucticus melanocephalus*], American Goldfinch [*Carduelis tristis*], American Robin [*Turdus migratorius*], and Broad-tailed Hummingbird [*Selasphorus platycercus*]) over this period, but the decline in only one species—the Broad-tailed Hummingbird—was considered significant here ($F = 19.45$, $P = 0.002$). Yellow Warbler (*Dendroica petechia*) numbers showed the only other significant linear trend, increasing significantly since 1992 ($F = 15.30$, $P = 0.004$); Song Sparrow (*Melospiza melodia*) numbers showed a non-significant increase. A parallel analysis, using Generalized Linear Models to identify non-linear patterns in population trends, showed two apparently consistent patterns of population change with synchronous timing of significant trend inflection points. The evaluation of these non-linear patterns, if they persist as additional analyses are competed, will be important to future assessments of Utah's avian conservation needs.

Keywords American Goldfinch, American Robin, Black-headed Grosbeak, Broad-tailed Hummingbird, distance sampling, Generalized Additive Model, monitoring, population, riparian, Song Sparrow, trend, Utah, Yellow Warbler.

Introduction

At the beginning of this study in 1992, little was known about Utah's riparian bird populations beyond a general sense of their importance. Their breeding status, distribution, densities, population trends, or use of habitat components in Utah were either not well documented or largely unknown. Further, Breeding Bird Survey (BBS) data suggested that long-term large-scale declines in bird populations had occurred, and were occurring, over large portions of North America (Robbins et al. 1989). Some declines were regional in scope; others were most notable in suites of species such as neotropical migratory birds (NTMB). But BBS data from our region were largely equivocal.

There are two major reasons why the BBS was not well suited to monitoring riparian bird populations in Utah. First, the state's relatively sparse human population and large area has hamstrung the volunteer-staffed BBS. This has hindered the completion of many rural routes in Utah, resulting in spatially and temporally spotty coverage. Second, the BBS is a road-based survey without an explicit habitat component. Breeding Bird Survey routes do, however, have an implicit habitat component due to the non-random positioning of roads and hence the BBS survey routes themselves. In Utah's largely roadless landscape, the potential bias introduced by this implicit habitat component is magnified. We have found that over 75 percent of all Utah's bird species breed or forage in riparian habitat and are considered 'riparian dependent' in Utah (Howe 1992, Parrish et al. 2002, but see Rich 2002). Riparian areas comprise less than 0.4 percent of the state's area (Edwards et al. 1995, Parrish et al. 2002), and BBS routes seldom are seldom adjacent to riparian habitat. As a result, Utah's most important habitat type for birds is largely unsampled by BBS routes. In 1992 we began the monitoring program to fill the gaps in basic knowledge of riparian bird densities and give habitat-specific population trends. This paper presents initial statewide trend results for six species discussed at the 2002 Partners in Flight meeting at Asilomar, California.

Methods

Field Methods

Thirty-two sites were randomly established in riparian habitat statewide in 1992 (*fig. 1*). Potential study sites (i.e., riparian habitat along non-ephemeral rivers and streams on publicly accessible land) within each of four randomly selected 1:24,000 scale map grid cells within each 1:100,000 scale map grid cells covering the state were enumerated, ordered using a random numbers table, and field checked for suitability (e.g., suffi-

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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cient vegetative coverage). The first suitable site was then accepted. Study design and sampling method, i.e., point count methods, followed Ralph et al. (1995). Point to observation distances were also measured (Howe 1993) to allow the data to be analyzed as point transects, a form of distance sampling (Buckland et al. 2001). Ten sampling points per site were systematically established from a random start, points were placed a minimum of 150 m apart. Sites were surveyed twice each breeding season. Count duration at each point was 8 min, and surveys were conducted between 15 min before sunrise and 10:00. Distance (estimated to the nearest meter) to each bird seen or heard was recorded along with the species, flock size, age/gender, and means of detection (i.e., seen, heard, or both).

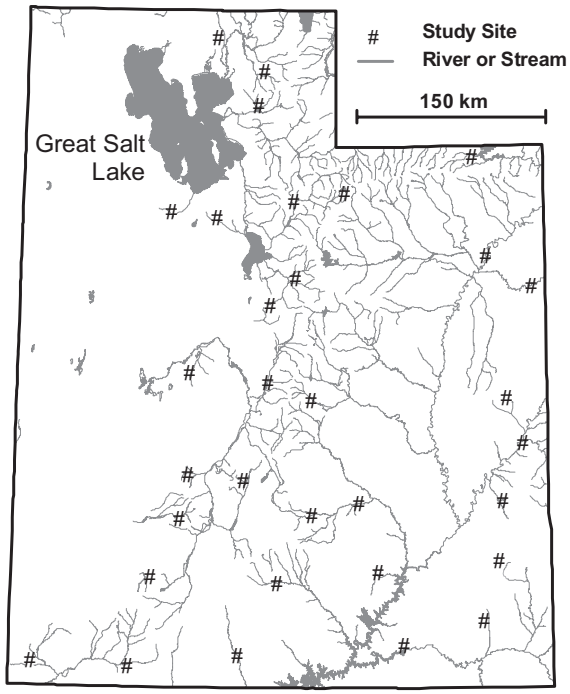

Figure 1— Locations of the 32 baseline riparian study sites in Utah, 1992-2001.

Analysis Methods

We present data for six species here: Black-headed Grosbeak (*Pheucticus melanocephalus*) and Song Sparrow (*Melospiza melodia*) illustrate the riparian dependent species, American Goldfinch (*Carduelis tristis*) and American Robin (*Turdus migratorius*) illustrate the riparian independent species, and Yellow Warbler (*Dendroica petechia*) and Broad-tailed Hummingbird (*Selasphorus platycercus*) are discussed as special cases, though both are considered riparian dependent species in Utah. Classification as to riparian dependence in Utah followed Howe (1992, but see Rich 2002).

Both visual and audible observations of non-juvenile, non-flyover birds were used for this analysis; all analyses were by species. Survey data were analyzed for estimated annual statewide densities (detections/ha) using DISTANCE v3.5 (Thomas et al. 1998), with distance sampling analyses following Buckland et al. (2001). Selection of annual detection functions were guided by Akaike's Information Criterion (Akaike 1973, Burnham and Anderson 1998), χ^2 model fit statistics, and visual inspection of detection probability and probability density plots (Buckland et al. 2001).

For simplicity's sake, we defined linear population trend as the mean annual change in density, for the 1992-2001 period, measured using simple linear regression (Allen 1983, Allen et al. 1983, Neter et al. 1996, Zar 1999). Trends in estimated density for each species were expressed as a percentage of the mean of density for all years, in order to express the trend as a relative percentage for each species. This approach was taken, as opposed to a route-regression analysis (Geissler and Noon 1981, Geissler and Sauer 1990, Sauer and Geissler 1990) as sample sizes were generally inadequate to reliably estimate density at each site in each year. To investigate patterns of population change, we used a Generalized Linear Modeling (GAM), non-linear non-parametric trend estimation method (detailed in Fewster et al. 2000) for the open-source statistical package 'R' (Wood 2001, Wood and Augustin 2002, R Development CoreTeam 2003, Wood 2003). Generalized Linear Models are a non-parametric form of the log-linear Poisson regression model and generalized linear models that incorporate a smooting function (Hastie and Tibshirani 1990, Fewster et al. 2000). This approach avoids parametric assumptions, offers an inferential context in which to compare non-linear patterns of variation, and identifies significant inflection points in the smoothed non-linear estimated trend. Smoothing is used to reduce the influence of short-term variation (e.g., caused by weather or measurement error), revealing underlying longer-term patterns of population change. The non-parametric smooth curve fitted in our models is based on a smoothing spline (Wahba 1990, Wood 2000) where the degree of smoothing is specified by the number of degrees of freedom (df). Here we have used a df of 3, or approximately 0.3 times the number of years in our time series (Fewster et al. 2000). This allows examination of intermediate patterns of non-linear population change without the noise of temporally local change or the strict assumption of linear (or even curvilinear) change over the whole period. Once a smooth curve has been fit (a process described in detail by Fewster et al. 2000), an annual abundance index curve can be calculated as:

$$(1) \quad I(t) \quad \frac{\text{total predicted density for year } t}{\text{total predicted density for year } 1} \quad \frac{\exp(\hat{s}(t))}{\exp(\hat{s}(1))}.$$

The index *I(t)* measures the relative change in estimated smoothed density, $\exp(\hat{s}(t))$, relative to an arbitrary reference year, $\exp(\hat{s}(1))$ as a smooth function of time. Here we used 1992, the first year of our study, as our reference year as a smooth function of time. It also allows the identification of significant inflection points in population trajectories by testing the second derivative of the trend curve *I(t)* at time *t*. Where the second derivative is positive, the trajectory is turning upward; where negative, the trajectory is turning downward. The magnitude of the second derivative can also be tested for a significant difference from zero (i.e., from a steady rate of change, or a roughly linear trend). Significant inflection points indicate years in which the estimated population trend changes substantially. Thus the method provides a level playing field on which to identify patterns of non-linear change between species. Confidence limits on the indices are estimated here by 399 bootstrapped resamples (Manley 1997, Fewster et al. 2000).

Results

Over 100,000 observations of over 200 species of birds have been collected in the 1992-2001 period. Over 75 percent of recorded observations have been of riparian dependent species. The number of sites with data for a given species in any given year ranged from 9 to 31, with a mean of 21 sites per species per year used for the analysis. Statewide mean densities (birds/ha ± se) for the 1992-2001 period were: Black-headed Grosbeak 0.288 ± 0.361, Song Sparrow 0.499 ± 0.007, American Goldfinch 0.411 ± 0.006, American Robin 2.161 ± 0.448), Broad-tailed Hummingbird 4.509 ± 0.718, and Yellow Warbler 3.107 ± 2.266. The two riparian dependent species presented here, Black-headed Grosbeak (*fig. 2A*) and Song Sparrow (*fig. 2B*), had higher annual density estimates in 1992, 1994-1995, and again in 1998. The two riparian independent species presented here, American Goldfinch (*fig. 2C*) and American Robin (*fig. 2D*), had higher annual density estimates in 1994 and 2000. Broad-tailed Hummingbird and Yellow Warbler are discussed separately.

Linear Trends

Linear trends for these six species (mean annual change expressed as a percentage of the mean of all years, here termed the grand mean), F, and p-values are given in *table 1*; comparable values for the Utah and Western Region BBS routes are also provided. The only species of these six to show significant statewide linear trends in density were Yellow Warbler and Broad-tailed Hummingbird (*figs. 2E* and *F, table 1*). For our data, all species showed large interannual variation in density estimates (*fig. 2*), and the linear models typically were not well fit (mean r^2 = 31.3, range = 6.4 – 70.9).

Non-Linear Trends

Generalized additive models were fit and abundance index values calculated for each of these six species (*fig. 3*). Index values consistently below 1 showed Black-headed Grosbeaks in an overall downward population trend. Yellow Warblers showed an overall increase in population trend, with index values consistently above 1. Three species (American Goldfinch, American Robin, and Broad-tailed Hummingbird) showed a pattern of general increase in 1992-1994, decrease in 1995-1998, followed by an upturn in the last 2-3 years. The trend pattern for Black-headed Grosbeak and Song Sparrow was almost the opposite, with modest decreases in the 1993-1996 period and increases in the 1997-1999 period.

Table 1— *Linear population trend estimates in Utah riparian habitat for the 1992-2001 period, expressed as a proportion of each species' mean statewide density (i.e., the grand mean). Comparable BBS data for Utah and the Western BBS region are also given (Sauer et al. 2003).*

Species	Riparian trend[a]	*P* (F)	UT BBS trend[b]	*P*	N	Western BBS trend[c]	*P*	N
American Goldfinch	- 2.2%	0.313 (1.16)	7.80%	0.137	20	- 4.15%	0.002	411
American Robin	- 11.9%	0.480 (0.55)	- 0.42%	0.627	58	- 0.04%	0.881	913
Black-headed Grosbeak	- 2.5%	0.153 (2.49)	3.82%	0.204	31	0.29%	0.598	499
Broad-tailed Hummingbird	- 63.1%	0.002 (19.45)	- 1.87%	0.369	40	- 0.48%	0.536	165
Song Sparrow	2.0%	0.419 (0.73)	7.43%	0.094	38	1.16%	0.014	691
Yellow Warbler	43.5%	0.004 (15.30)	3.40%	0.122	42	0.63%	0.183	651

[a]Linear trend derived from UDWR riparian study data, expressed as the per year percentage change in the grand mean.
[b]Linear trend derived from Utah BBS data, 1992-2001, expressed as annual percent change (Estimating equations method).
[c]Linear trend derived from Western US BBS region data, 1992-2001, expressed as annual percentage change (Estimating equations method).

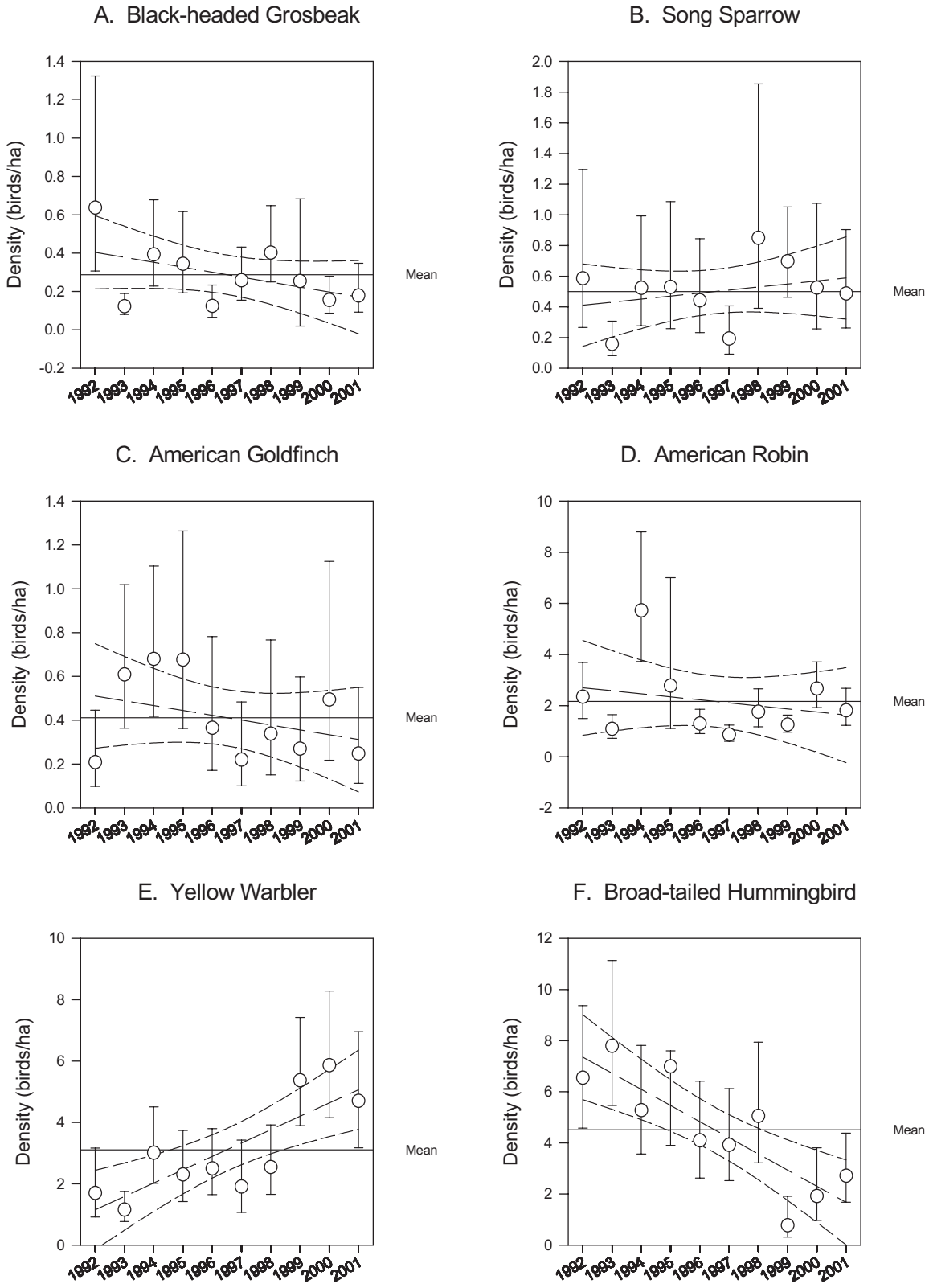

Figure 2— Annual density estimates (with 95 percent confidence intervals, shown as open circles) for the 1992-2001 period, overlain with the 10-year linear regression (long-dash line, with 95 percent confidence bands shown as short-dash lines) and 10-year grand mean (solid line). Species A, B, E, and F are considered riparian obligates in Utah, species C and D are not. Species E and F show significant increasing and decreasing linear trends respectively.

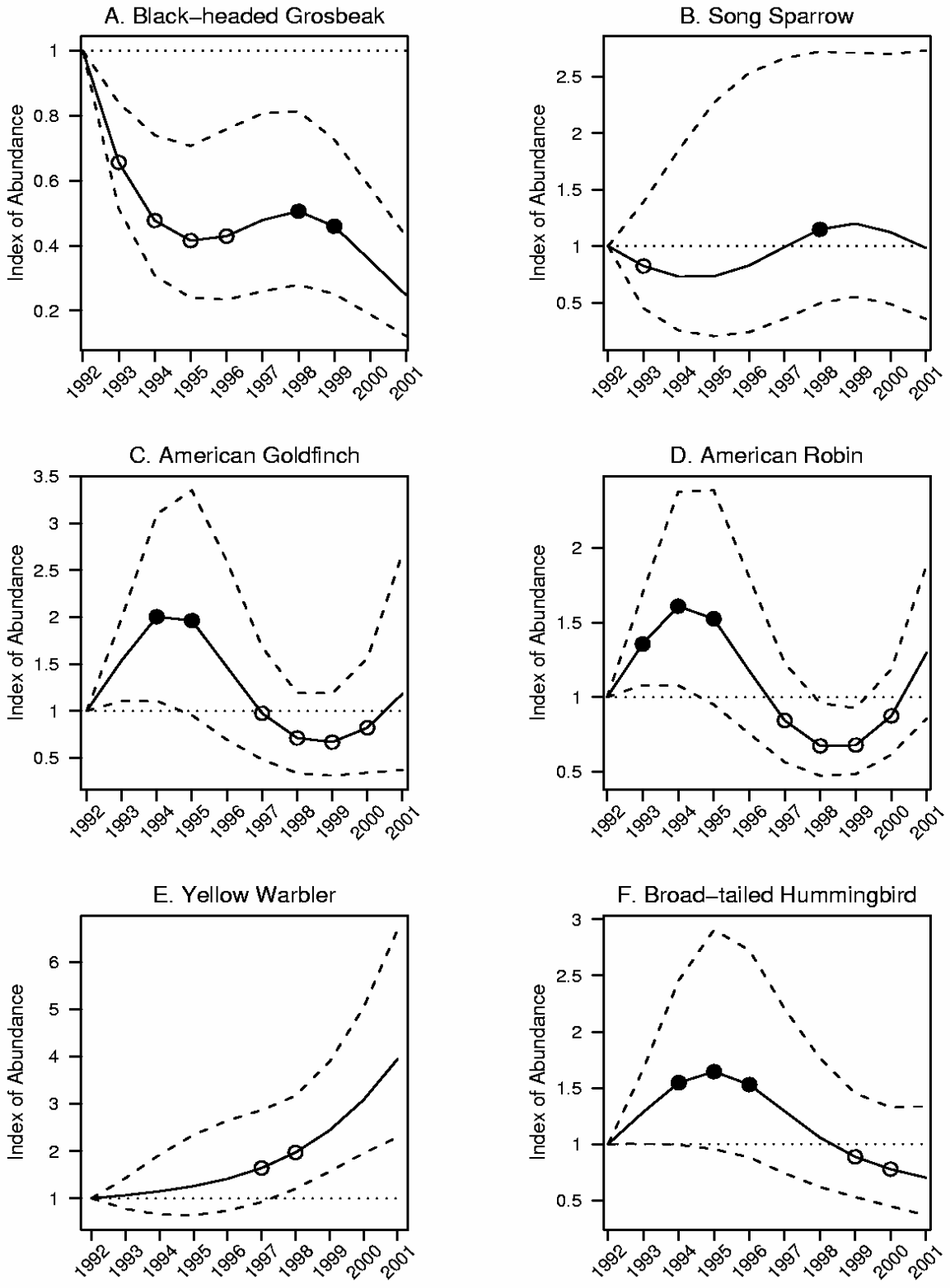

Figure 3— Density index curves for six species (solid line, with bootstrapped 95 percent confidence intervals shown as short-dash lines) from Generalized Additive Models with 3 degrees of freedom for the 1992-2001 period. Significant inflection points (years in which the second derivative of the annual abundance index curve differed significantly from zero, two-sided test, α = 0.05) are indicated by circles: closed for downturns, open for upturns. Both riparian species groupings (dependent: A and B, and independent: C and D) show fairly consistent patterns of years with significant up- and downturns.

The years in which significant upward (open circle) and downward (closed circle) inflection points in the rate of population change were also reasonably consistent within the riparian dependent and riparian independent species groupings (*fig. 3*). Black-headed Grosbeak and Song Sparrow results both showed significant upward inflections in the 1993-1996, and downward in the 1998-2000 period. Riparian independent species showed a roughly opposite pattern from these riparian dependent species with significant downturns in 1993-1995, and significant upturns in the 1997 -2000 period. The pattern of change in the abundance index curve for Broad-tailed Hummingbird followed that of the riparian independent species, while Yellow Warbler trends were consistently upward throughout, with significant upward inflections in the rate of population increase in 1997 and 1998 (*fig. 3*).

Discussion

Linear and non-linear trends in six species do not represent the totality of Utah's riparian bird population. Nor do they necessarily represent coherent patterns in the riparian dependent/independent groups to which they have been ascribed for a variety of reasons, not the least of which is the small number of species and their systematic selection. However, these six selected species are among the most abundant of Utah's riparian species and together comprise almost a quarter of all observations to date. Four of six linear trends are decreasing over a modest period in Utah's most important habitat and may be considered cause for concern, even though only two linear trends were even considered statistically significant, and one of these was increasing.

The 1992-2001 period was dominated by generally synchronous patterns of large interannual variation for each species grouping. While this study was not designed to investigate causal or even proximate factors influencing population trends, these patterns may provide a productive context for future research into population dynamics, responses, and conservation efforts (e.g., DeSante et al. 2001). For example, if the apparent distinction between the two groups' patterns holds up, it may imply a degree of separation of ecological processes driving annual densities in riparian and upland habitat contexts. Also, the relative consistency of these patterns suggests the potential for a productive, albeit retrospective (Nichols 2000), covariate analysis of the effects of weather and habitat change (e.g., Nott et al. 2002).

But the apparent synchrony of species' abundance fluctuations might also be a red herring. Within each of our riparian dependent/independent groups were a wide variety of body sizes, life spans, foraging habits, susceptibility to disease or predation, migration strategies, and wintering grounds. These suggest *a priori* that the range of observed trends within each riparian dependent/independent grouping would not be constrained to a discrete set of responses to affective environmental changes.

Also interesting is the haphazard extent of concordance between our data and the BBS in terms of either annual patterns of variation or long-term trends derived from Utah and Western BBS Regional data (Sauer et al. 2003). While local abundance is widely considered to be a dependent function of regional abundance (Ricklefs 1987, Cornell and Lawton 1992), spatial variation among areas of the state and between roaded and riparian habitats is the likely culprit confounding this relationship. It is, however, difficult to make much of this comparison given the obvious differences in our methodologies.

While tempered somewhat by the lack of agreement with BBS results, the recent conservation emphasis placed on Broad-tailed Hummingbirds in Utah does appear warranted (Parrish et al. 2002), and Black-headed Grosbeak populations bear watching. We are also getting reliable annual abundance estimates for riparian dependent species and populations largely underserved by the BBS, which remains our only viable alternate source of large-scale, long-term data. In terms of population trend analyses, this dataset remains a relatively young entity. Plots of long-term bird abundance (e.g., Holmes and Sherry 2001, Sauer et al. 2003) can often show 10-year periods of linearly increasing, decreasing and non-linear trends within a given species. In this context, we feel these trends should be considered preliminary, as even ten years is a brief period upon which to build trend analyses for notably variable populations. We are, however, approaching the point in Utah's riparian habitats where statistical power to detect more subtle trends becomes feasible for many species. The addition of non-linear trend estimation analysis tools show promise in distinguishing points where significant changes in population trajectories have occurred. Further investigation into the spatial and temporal qualities of these observed patterns may prove critical to the assessment of future avian conservation needs in Utah.

Acknowledgments

The authors would like to thank the Utah Division of Wildlife Resources, the many Utah Partners in Flight cooperators (the Department of Defense, the U.S. Bureau of Reclamation, U.S. Bureau of Land Management, U.S. Forest Service, U.S. Fish and Wildlife Service, National Park Service, the Central Utah Project, and

the Natural Resources Conservation Service), and the over 20 field crewmembers for their hard work and continued support that made this study possible.

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Suggestions for a Silvicultural Prescription for Cerulean Warblers in the Lower Mississippi Alluvial Valley[1]

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Abstract

Conservation of species with high Partners in Flight concern scores may require active habitat management. Cerulean Warbler (*Dendroica cerulea*) occurs at low numbers in the Lower Mississippi Alluvial Valley in the western part of its breeding range. A study of the breeding ecology of the species was initiated in 1992 on three sites there. Characteristics of individual trees used by the birds have been measured in detail. Elements of the vegetation utilized by male Cerulean Warblers, by female Cerulean Warblers, and as nests have been identified. A silvicultural prescription designed to produce these elements is being prepared as an experimental manipulation of habitats for the birds. The development of this suggested silvicultural prescription offers an example for development of similar prescriptions for other forest canopy dwelling bird species. One difficulty may be in assessing the response of the birds to the treatments when the available habitat exceeds the amount needed to support the spatial needs of the local small population, whether the measured response is one of abundance or of productivity. This is because the response may be smaller than can be detected by the experimental design used to conduct the experiment; available birds may not be numerous enough to produce a detectable response.

Key words: adaptive management, bottomland hardwoods, forest canopy, habitat management, habitat selection, mature forest, Parulidae.

Management Background

Land managers use objectives as central to the process of forest, wild land, and recreation management (e.g. Morrison et al. 1992). Put in a more colloquial way, "It isn't management unless you do it on purpose (Tony Melchiors, pers. comm.). Conservation work on priority bird species, such as those with high Partners in Flight concern scores (Carter et al. 2000), often seems to have an implied objective of "protection by purchase" thereby maintaining the habitat in perpetuity safe from habitat degradation. Especially true is this mindset when it comes to species of later successional stands, to species of older forests. An implicit "protection is necessary" focus frequently develops

Priority species may occur in places that have been managed for other purposes; presence of the species may be facilitated by past management or merely may be serendipitous. Thus, the occurrence of species of interest was not necessarily an objective of the management that produced the habitats in which they occurred. This is an important point, because the occurrence of the species of interest is thus a by-product of management directed toward some other objective. When we measure "habitat" of a species under such circumstances (e.g. Cerulean Warbler [*Dendroica cerulean*]; Kahl et al. 1985, Hamel 1992, Robbins et al. 1992, Gabbe et al. 2002) we measure the outcomes of management for objectives other than ideal habitat for the birds. Hence, the presence of suitable habitat has an unknown relationship to the initial management objectives for the property. In other cases, occupied habitat has resulted from secondary succession following cessation of agricultural or pasture land use (Oliarnyk and Robertson 1996); in these cases also, the succession was a result of a process other than purposeful forest management designed to produce habitat for a species.

Many species have habitat requirements that are not fully understood because of interactions with disturbance patterns and regional and physiographic differences in plant communities. Our conservation action is based on the hope that the unknown past is a good predictor of the unknown future. For yet another group of species, we perceive their continued existence to be in jeopardy, and we wish to ameliorate the jeopardy. For some of these species, continued existence has been jeopardized by past activities. Continued existence of other species is threatened by current activities as we understand their effects. For other species uncertainty about future population status is a result of ignorance of habitat requirements rather than past harm or current threat. We are saddled with the responsibility of assigning each species to a category of one to whom harm has occurred, one for whom threats are real, or one for whom the threats are simply unknown.

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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Cerulean Warbler (CERW), a Nearctic breeding, neotropic wintering, wood warbler (Robbins et al. 1992) is a species with such an uncertain future. The species breeds in forests of broadleaved trees in the eastern deciduous forest biome of the United States and southeastern Canada, where its center of abundance lies in the Ohio River valley (Hamel 1998, Rosenberg et al. 2000). The diet is primarily insects (Bent 1953). Populations of the species are believed to be declining or to have declined substantially during the past 35 years or so (Hamel 2000). Typical breeding habitat for the species is mature hardwood forest, and the birds are believed to be associated with large trees (Hamel 1992, 2000). Heterogeneous three-dimensional structure of the canopy within the forest is believed to be of particular importance to the birds (Lynch 1981, Hamel 2000, Jones et al. 2001). The birds occur in an environment that has been subject to a wide variety of land use changes and management strategies, on a host of scales, against a backdrop of potential climate change, in a context of rapidly increasing human population and technological capability, on both its North American breeding and South American nonbreeding grounds.

The species is one that appears regularly on lists of species that need protection (Hamel 1998). One set of suggested habitat characteristics is that of Kahl et al. (1985 in Hamel 1992), who noted habitat around song perches of CERWs to include 50-150 stems/ha >30 cm dbh, under a closed canopy (mean 85 percent cover, never <65 percent) at least 18 m tall, with a moderate number (1,030 - 2,800) of wood stems <2.5 cm dbh, and low density (<175/ha) of dead stems 2.5 - 9.9 cm dbh. Extensive study of CERWs in the northeastern part of the species range in southern Ontario (Oliarnyk and Robertson 1996, Jones and Robertson 2001) indicated that the birds use areas for nesting with complex forest canopies heterogeneous horizontally as well as vertically, and that the birds use a variety of tree species for nesting at the local scale.

Long ago, Widmann (1907) noted that the CERW was among the most abundant breeding warblers in the bottomland forests of the Sunken Lands of southeastern Missouri in the Lower Mississippi Alluvial Valley (LMAV). At present, the species is unrecorded in these same environments by the Breeding Bird Survey (Sauer et al. 2001). Priority land use in these environments is row crops. Forest land use is a distant competitor with agriculture (Allen et al. 2001). Forests are present in the LMAV chiefly as a result of agricultural subsidy programs such as the Wetland Reserve or Conservation Reserve, or flooding regimes that make agriculture unprofitable. The modest understanding of the tract size associations of CERWs in this landscape has catapulted the species into a role of flagship species for afforestation efforts (Mueller et al. 1999).

My purpose here is to outline the breeding biology in relation to habitat of the species, to indicate possible implications of this biology for forest management, and to suggest an approach to purposeful management of habitats for this species in the LMAV. Nowhere has specific action been taken consciously to produce habitat for the species although some experimental tests are currently underway (D. A. Buehler, pers. comm.). Because of the apparent dependence of the species upon locations with a particular constellation of forest features, purposeful management may be a requirement for the species' long-term persistence. No study of the production of habitat for CERWs has been conducted anywhere.

Methods

Study Areas

Three areas were selected for study of the breeding biology and habitat use of CERW in the LMAV. Sites were selected as representative of the habitats of CERWs in the LMAV. The work reported here began in 1992 and continues to the present. Each site was located in the unimpeded floodplain of the Mississippi River, subject to annual flooding. Each was a tract of forest well in excess of the 1600 ha reported to be the minimal size of tract in which the species occurred in these environments (Robbins et al. 1992). The sites had varied management history, lay in slightly different areas of the floodplain, and were dominated by slightly different forest communities. Two were in public and one in private ownership. Each area was marked at the intersections (grid points) of a 50 x 50-m grid.

Chickasaw National Wildlife Refuge is an 8,000-ha tract in Lauderdale County, Tennessee (35º 48' 56" N 89º 38' 52" W). Presently in public ownership since the late 1980's, the tract is managed by the U.S. Fish and Wildlife Service. The tract was owned and managed for sawtimber trees (diameters exceeding 27 cm) using single-tree and group selection practices (management techniques that produce small contiguous groups of trees of similar size and age and favored species) by the Anderson Tully County prior to public acquisition. Within this tract a 50-ha study site (N = 231 grid points) was located in the middle of the floodplain on a low flat and adjacent natural levee bordering a tributary to the Mississippi River. Forest here was dominated by sugarberry (*Celtis laevigata*), Nuttall oak (*Quercus nuttallii*), overcup oak (*Q. lyrata*), and sweet pecan (*Carya illinoensis*).

Desha Delta Hunt Club, in Desha County, Arkansas (33º 44' 39" N 91º 09' 31" W) is part of a 15,000-ha continuous tract of forest in the batture land of the Mississippi River. It is owned and managed by the

Anderson Tully County for sawtimber using single-tree and group selection practices. Within this area a 54-ha study site (N = 260 grid points) was located on ridge and swale topography close to the Mississippi River. Forest here was dominated by sugarberry, boxelder (*Acer negundo*), green ash (*Fraxinus pennsylvanica*), with a smaller amount of sycamore (*Platanus occidentalis*), and baldcypress (*Taxodium distichum*).

Meeman Shelby Forest State Park and Wildlife Management Area (35º 19' 46" N 90º 03' 40" W), is a unit of the Tennessee State Park system, in Shelby County, Tennessee. This 3800-ha area is part of a contiguous tract of forest that extends from the top of the bluff at the eastern edge of the Mississippi River floodplain to the bank of the river three km west. A 56-ha study area (N = 261 grid points) was located here at the toe of the bluff on a small alluvial fan produced by a creek that drains adjacent uplands. Portions of this area were harvested early in the past century, and parts of if were agricultural fields at that time as well. Forest here was dominated by cottonwood (*Populus deltoides*), boxelder, and sugarberry, as well as other species.

Behavioral Ecological Activities

CERWs were studied on the three study areas using spot-mapping, focal animal behavior sampling, and timed nest watches. The data resulting from focal animal sampling formed the primary basis for this report. Individual, usually unmarked, male or female CERWs were located by observers at predetermined portions of the study areas visited in a systematic fashion. These individual birds were followed through the forest for varying periods. Where possible, birds were selected *a priori* for observation. Often, however, and especially in the case of female birds, selection of focal animals was opportunistic. Individual trees in which the birds were observed were identified to species, their diameter at breast height (dbh, 1.5 m), height, and crown class were measured, and attachment of lianas noted; and trees were marked with numbered aluminum tags. Date, time, gender and individual identity of focal bird were noted, as well as height in the tree and activity in which the bird was engaged. Subsequent measures were made at timed, one-minute intervals. Because of the density of the foliage and the frequent perch changes by the birds, most observation sequences consisted of a single entry.

Tree species use was estimated for the birds by selecting the first entry for each gender for a given date-time observation sequence. Tree use was summarized by tree species, crown class, and diameter class, for female and for male CERWs. Tree species represented by at least 10 entries for females or for males were submitted to analysis. This criterion permitted evaluation of use vs. availability for 17 species of trees, representing 94 percent of the sample of use by females (N = 821 trees) and 97 percent of the sample of trees used by males (N = 2468 trees). These species represented 82 percent of the total number of trees available, and 78 percent of the total basal area of trees on the study areas. Use vs. availability was calculated from chi-square statistics, significance accepted at P = 0.05, corrected by a Bonferroni procedure for the 34 tests conducted (Rice 1989).

Nest trees (N = 68) were measured, as were those of the behavioral use, with addition of specific measures of height of the nest, distance and direction of the nest from the bole of the tree, and distance of the nest from the distal end of the branch in which it was placed. Distance of the nest from the bole, and distance from the distal end of the branch were summed into a measure of the crown radius of the tree at the nest, the nest radius. Nest radii for 16 of the nests were compared with projected crown radii using the equations of Goelz (1996), who developed equations for the average crown radii of open-grown trees. Crown radii of open-grown trees can be considered to be approaching the maximum for the species (Goelz 1996). Goelz (1996) presented no estimation equation for crown radius of *Acer negundo*; this tree species accounted for 14 CERW nests. Null expectation that observed nest radius would be less than predicted crown radius of open-grown trees of the same species and diameter was tested with a paired t-test. Null expectation arose in part because the nest trees were forest grown trees, and because no *a priori* reason existed to expect nests to be placed at the height at which the maximum crown radius of the nest tree was achieved.

Distance from nest to the edge of the nearest canopy gap was measured for a subset of the nests and for an equal number of randomly selected grid points. A canopy gap was defined as an opening in the canopy at least 10 m^2 in area. Gap distances were analyzed with analysis of variance statistics on square-root transformed data, with study area and nature of the measure (nest or random point) as main effects.

Tree species availability was estimated for each of the sites from a series of variable-radius-plot samples taken at grid point intersections. Measures identical to those of trees in the focal animals sample were made for each tree selected using a 6.889 m^2/ha basal-area-factor angle gauge. Number of trees was estimated for each sampled tree by use of a weighting factor. The weighting factor was the number of trees/ha calculated from the sampling area associated with the tree diameter/selection device combination. Shade tolerance of the trees was taken from Meadows and Stanturf (1997). Comparison of use and availability were conducted with chi-square statistics, testing the null hypothesis that use did not differ from that expected on the basis

of availability. Significance was accepted at P = 0.05, after Bonferroni correction for the number of tree species in the test.

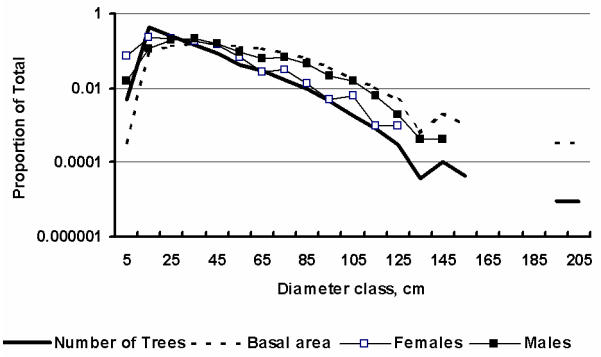

Figure 1— Use of trees by Cerulean Warblers in the Lower Mississippi Alluvial Valley. For number of trees and basal area, quantity graphed is the proportion of the total weighted value measured on sample plots that fell into the particular diameter class. For Cerulean Warbler use, quantity graphed is the proportion of the total number of trees used by that gender that fell into the particular diameter class. Sample sizes for the birds are N = 3690, for the study areas N > 200,000.

Habitat Modeling

Habitat measurements at grid intersection points included measurements made for the tree species availability measures above, plus estimates of canopy cover, and ground cover. Using the data on tree species locations from the focal animal sampling, grid points were assigned to groups as CERW habitat or non-habitat. Models of vegetation structure characterizing habitat utilization were constructed for these two groups using logistic regression. Separate models of habitat utilization were estimated for each of the study areas. Model results were then applied as predictors of habitat and non-habitat to other study areas than the one from which they were developed. Because these logistic regression models failed to predict habitat occupancy outside the study area from which they were developed, they will not be discussed further here.

Results

Trees Selected by the Birds

Use of Trees by Diameter Class

CERWs, particularly the males, used large trees more frequently than their availability in the stands (*fig. 1*). For males, use frequency exceeded available frequency for all diameter classes 35 cm and larger (P < 0.05). For females, use frequency exceeded available frequency in 7 of 10 diameter classes 35 cm and larger, a result that did not differ from expected. When use frequency by diameter class was compared separately for number of trees by species and species basal area, female CERWs appeared to use trees in proportion to the number of trees in the stands, while male CERWs appeared to use trees in proportion to their basal area in the stands (*fig. 1*).

Use of Trees by Crown Class

Female CERWs at Chickasaw NWR disproportionately used trees in the suppressed crown class (*table 1*). Male CERWs disproportionately used trees in the dominant and codominant crown classes. Nest trees were placed disproportionately in dominant and codominant trees as well.

Use of Trees by Shade Tolerance Class

Male CERWs on Chickasaw NWR disproportionately used shade intolerant trees and underused shade tolerant trees (*table 2*). Female CERWs used trees without regard for shade tolerance. Distribution of nests was similar to that of use by males.

Table 1— *Cerulean Warbler use of trees by crown class, Chickasaw National Wildlife Refuge, Lauderdale County, Tennessee. Expected values for these comparisons in the table (not shown) were based upon distribution of weighted number of trees sampled on 231 plots on the Chickasaw NWR Cerulean Warbler study area. Notation as "Low" or "High" indicates that the number of trees in that cell is Higher or Lower than expected at P = 0.05, by chi-square test.*

Tree use/crown class	Females	Males	Nests	Total
Dominant/codominant	47	189	14	240
	Low	High	High	
Intermediate	58	116	4	178
	Low	Low		
Suppressed	107	115	1	223
	High	Low	Low	
Total[a]	212***	420***	19***	651

[a] *P < 0.05, ** P < 0.01, *** P < 0.001

Table 2— *Cerulean Warbler use of trees by shade tolerance class, Chickasaw National Wildlife Refuge, Lauderdale County, Tennessee. Expected values for these comparisons in the table (not shown) based upon distribution of weighted number of trees sampled on 231 plots on the Chickasaw NWR Cerulean Warbler study area. Notation as "Low" or "High" indicates that the number of trees in that cell is Higher or Lower than expected at P = 0.05, by chi-square test.*

Tree use/shade tolerance class	Female	Male	Nest	Total
Intolerant	57	189	4	250
		High	High	
Moderately Tolerant	78	146	5	229
Tolerant	96	115	8	219
		Low	Low	
Total[a]	231 NS	928***	17***	698

[a] * P < 0.05, ** P < 0.01, *** P < 0.001, NS = not significant.

Use of Trees by Species

Male use exceeded availability by number of trees in eight of 17 cases, and was significantly lower than expected for four species (*table 3*). Female use exceeded availability by number of trees in four cases, and was significantly lower than expected once (*table 3*). Male use exceeded availability by basal area in seven of 17 cases, and was significantly lower than expected for three species (*table 4*). Female use exceeded availability by basal area in five cases, and was significantly lower than expected twice (*table 4*). Both sexes overused *Celtis laevigata*, *Acer negundo*, *Platanus occidentalis*, *Liquidambar styraciflua*, *Carya illinoensis*, and *Ulmus americana*. Both underused *Fraxinus pennsylvanica* and *Taxodium distichum*. Male use exceeded availability for *Populus deltoides* and *Diospyros virginiana*, while females used *Ulmus rubra* less often than expected. For *Quercus nuttallii*, male use exceeded availability by number of trees, and female use was significantly lower than expected on the basis of basal area.

Nest-Site Characteristics

CERWs in the LMAV chose nest trees of at least moderately shade intolerant species for 43 of 68 nests. Nests at Chickasaw NWR were often far from the bole of the tree (mean = 6.8 ± 1.0 m from the bole, N = 15). A comparison of measured nest radius with predicted crown radius was possible for 16 nest trees of five species (*table 5*). Mean value of nest radius did not differ from that predicted by Goelz (1996) for open-grown trees of that species and diameter, indicating that CERWs chose long limbs as nest substrates. Analysis of variance of distance to nearest gap for 54 nest sites on the three LMAV study sites and 54 randomly selected points from these areas ($F_{5,102,df} = 21.73$, $R^2 = 0.52$, $P < 0.01$) indicated significant differences among sites but not, however, between nest sites and random points for any study area (*table 6*).

Discussion

The predominant tree used by a male CERW is canopy dominant or codominant of a wide variety of species and often a shade intolerant species. My interpretation of the preponderance of higher frequency use vs. availability was that the birds used a wide variety of tree species, rather than they required these species, similar to the interpretations of Jones and Robertson (2001) and Oliarnyk and Robertson (1996) for a CERW population in southern Ontario. Results of such tests should probably be viewed with caution, as they may not be portable from one area to another. For example, Gabbe et al. (2002) report that CERWs prefer to use the relatively rare kingnut hickory (*Carya laciniata*) on their Illinois study area. Because *C. laciniata* accounted for 5 percent of the importance value of trees on the Meeman Shelby Forest study area, CERW use of that tree was expected to be 5 percent; but CERWs there did not use the tree. Consistent overuse by both male and female CERWs of boxelder was an indicator of the prevalence of the species in bottomland hardwoods, especially on the Meeman Shelby Forest study area, where the trees achieved large size. In bottomland hardwoods, boxelder is an indicator of past disturbance to the forest canopy (J. Goelz, pers. comm.). The significant underuse of certain tree species was perhaps more easy to explain than overuse. Underuse of *Taxodium distichum* by males (and failure to observe any use by females) was a clear indication that CERWs in bottomland hardwoods were using areas that were less prone to flooding than were those in which baldcypress grew. A similar interpretation was suggested by the underuse of *Fraxinus pennsylvanica* in proportion to its basal area.

Table 3— *Tree species availability and use by Cerulean Warblers in the Mississippi Alluvial Valley. Availability determined on the basis of weighted number of trees of the species in the stands. Expected values for the chi-square comparison calculated as the proportion of total number of trees available in that tree species* total number of trees used by that gender of Cerulean Warbler.*

Tree species	Proportion of trees available	Female use (N)	Female use (χ^2)	Female difference[a]	Male use (N)	Male use (χ^2)	Male difference[a]
Acer negundo	0.14	192	59.0	High	433	29.5	High
Acer rubrum	0.022	12	1.93		29	11.4	Low
Acer saccharinum	0.021	28	6.1		29	10.8	High
Carya illinoensis	0.037	57	23.1	High	174	74.3	High
Celtis laevigata	0.28	199	3.77		438	89.93	Low
Diospyros virginiana	0.0051	10	exp < 5		32	30.13	High
Fraxinus pennsylvanica	0.062	48	0.16		145	0.41	
Juglans nigra	0.0017	0	exp < 5		16	exp < 5	
Liquidambar styraciflua	0.039	62	28.6	High	184	81.6	High
Platanus occidentalis	0.020	36	23.1	High	279	1062	High
Populus deltoides	0.012	0	exp < 5		130	338.4	High
Quercus lyrata	0.028	22	0.034		67	0.047	
Quercus nuttallii	0.031	34	3.19		211	244.	High
Quercus pagodaefolia	0.00020	0	exp < 5		12	exp < 5	
Taxodium distichum	0.026	0	exp < 5		22	28.4	Low
Ulmus americana	0.041	37	0.37		84	2.7	
Ulmus rubra	0.056	20	14.6	Low	55	50	Low
Total	0.81	757			2340		
Critical value, χ^2, 1 df, at P = 0.05 after Bonferroni correction			10.12	4 High 1 Low		10.12	8 High 4 Low

[a]High or Low indicates that the observed use was significantly higher or lower than expectation.

The data here show that the predominant tree used by a female CERW was a tree in a suppressed crown position, apparently without regard for species or shade tolerance. This pattern of use appeared to differ from the pattern of use by male CERWs. This result, however, must be viewed with considerable caution. Female CERWs were very difficult to observe, and these results may be biased. The opportunity to observe the primarily silent females may have occurred only when the birds were close to the ground, and hence more likely to be seen in suppressed crowns. Differences in use by males and females of *Quercus nuttallii* with respect to number of trees (males used more often than expected) and basal area (females used less often than expected) may have indicated that males selected larger trees and females selected trees without regard to their size.

Taken together, the results for the gap distance measures and nest radius vs. crown radius comparison may be instructive for development of a silvicultural prescription. CERW nests were not located closer to gaps. Nest to gap distance measures (*table 6*) were much less than those reported by Oliarnyk and Robertson (33 ± 5 m; 1996). They were, however, similar to those recorded by Jones et al. (14.9 ± 3 m; 2001) prior to ice-storm disturbance of their Ontario study site. Subsequent to ice-storm disturbance, nest to gap distance in the Ontario site decreased to 3 ± 0.4 m, a value close to that recorded from the Desha Delta Hunt Club site in this study (*table 6*). Nest radii of CERW nest trees reported by Jones et al. (5.8 - 7.4 m; 2001) is likewise similar to the value observed in this study. Nest radii of CERW nest trees in the LMAV did not differ from expected crown radii of open-grown trees. Open-grown trees, however, express what might be considered the maximum possible crown radius, for which purpose Goelz (1996) chose them. Thus, CERW nests may have been placed in locations where the nest trees, at least on the side where the nest was located, were in an equivalent position with respect to available sunlight, as would be open-grown trees. Failure to detect differences in distance to gap between nest sites and random points indicated that, in the LMAV, the birds were found in areas where more habitat was available than was being used by the birds. This is the first demonstration of an association between CERW nesting and nearness to canopy gaps at some earlier time in the life of a nest tree in the LMAV.

Table 4— *Tree species availability and use by Cerulean Warblers in the Mississippi Alluvial Valley. Availability determined on the basis of basal area of the tree species in the stands. Expected values for the chi-square comparison calculated as the proportion of basal area available in that tree species* total number of trees used by that gender of Cerulean Warbler.*

Tree species	Proportion of basal area available	Female use (N)	Female use (χ^2,)	Female difference[a]	Male use (N)	Male use (χ^2)	Male difference[a]
Acer negundo	0.06	192	396	High	433	521	High
Acer rubrum	0.01	12	0.92		29	0.096	
Acer saccharinum	0.02	28	4.9		29	12.7	Low
Carya illinoensis	0.04	57	15.2	High	174	49.2	High
Celtis laevigata	0.14	199	52.9	High	438	17.3	High
Diospyros virginiana	0.0057	10	exp < 5		32	22.7	High
Fraxinus pennsylvanica	0.098	48	13.2	Low	145	39	Low
Juglans nigra	0.0020	0	exp < 5		16	exp < 5	
Liquidambar styraciflua	0.045	62	16.4	High	184	46.3	High
Platanus occidentalis	0.050	36	0.57		279	199	High
Populus deltoides	0.057	0	exp < 5		130	0.86	
Quercus lyrata	0.038	22	2.70		67	7.63	
Quercus nuttallii	0.094	34	24.2	Low	211	1.95	
Quercus pagodaefolia	0.00067	0	exp < 5		12	exp < 5	
Taxodium distichum	0.051	0	exp < 5		22	86.7	Low
Ulmus americana	0.024	37	15.5	High	84	10.7	High
Ulmus rubra	0.029	20	0.59		55	3.74	
Total	0.78	757			2340		
Critical value, χ^2, 1 df, at P = 0.05 after Bonferroni correction			10.12	5 High 2 Low		10.12	7 High 3 Low

[a] High or Low indicates that the observed use was significantly higher or lower than expectation.

Table 5— *Comparison of measured crown radius at the nest (nest radius) of Cerulean Warbler nest trees from three study areas in the Lower Mississippi Alluvial Valley with crown radius calculated for open-grown trees using procedures in Goelz (1996).*

Tree Species	N	Mean nest radius (m)	SE	Mean calculated crown radius (m)	SE	Mean difference (m)	SE
Carya illinoensis	4	9.2	1.63	7.3	0.41	-1.91	1.73
Fraxinus pennsylvanica	5	5.2	1.02	6.6	0.44	0.98	1.01
Liquidambar styraciflua	3	6.3	0.88	7.3	0.82	2.00	0.29
Populus deltoides	2	4.5	1.50	7.4	0.65	2.45	2.38
Quercus nuttallii	2	7.2	0.75	10.4	0.81	1.71	0.96
Mean value	16	6.2	0.53	7.7	0.28	0.72	0.68

Table 6— *Distance to nearest canopy gap for Cerulean Warbler nests in the Lower Mississippi Alluvial Valley. Values in columns marked with different letters indicate significantly different values in ANOVA.*

	Nest to Gap			Random point to Gap		
Site	**N**	**Mean Distance (m)**	**SE**	**N**	**Mean Distance (m)**	**SE**
Chickasaw NWR	14	20.16 A	1.97	14	20.58 A	3.22
Desha Delta Hunt Club	19	4.15 B	0.80	19	4.13 B	1.21
Meeman Shelby Forest State Park	21	26.09 A	2.01	21	30.94 A	3.65
Gap distance category mean		14.95	3.43		16.44	5.00

Rudiments of a Silvicultural Prescription

These suggestions are offered to land managers and others interested in CERWs to stimulate a dialogue about the production of breeding habitat for this species. They are made for stands of bottomland hardwood trees in the LMAV. Because similarities of habitat use and some characteristics of habitat between LMAV and Ontario sites (see above) exist, it is tempting to extend the suggested application of the prescription to the habitats of the species elsewhere as well.

To produce habitat for CERWs, silvicultural activities must accomplish at least the following, within the context of a tract of land extensive enough (Hamel 2000) to accommodate breeding by the species:

1. Produce large sawtimber trees, which have large, expansive crowns, approaching those of open grown trees of similar diameter.

2. Emphasize production of such large individuals of both shade intolerant and shade tolerant species.

3. Locate these trees in situations in which large shade intolerant dominant trees overtop large individuals of shade tolerant species in close proximity to each other, creating opportunity for trees in both dominant and suppressed canopy positions to develop long limbs.

4. Grow these trees in such a way that over the course of the rotation numerous gaps are present throughout the stand to stimulate growth of long limbs with abundant foliage.

No specific suggestions are available from this analysis for the question of how much canopy cover is necessary. The presence of unused habitat in all three study areas in the LMAV precludes making such a determination. Options to produce these structural elements both through even-aged and uneven-aged silvicultural systems exist. The apparent association between nesting habitat for these birds and canopy gaps (Hamel 2000) further suggests that repeated stand entry to conduct intermediate treatments during the course of a rotation will be necessary. It is unlikely that gap-phase succession based solely upon individual tree-fall can develop sufficient heterogeneity in space to maintain habitat without some more extensive disturbance (Hunter et al. 2001; J. Goelz, pers. comm.). Satisfactory metrics for specifying the three-dimensional structure of the canopy appropriate to this species are not available. Articulation of a silvicultural prescription to produce that structure must await that specification.

Acknowledgments

All the errors of interpretation belong to me. So does the gratitude for the very great assistance provided in the course of this project by discussions with colleagues, W. Smith, B. Cooper, S. Robinson, G. Vanderah, C. Nicholson, D. Buehler, R. Robertson, J. Jones, J. Barg, C. Woodson, C. Smith, Steve Meadows, and the very able field crews who have given so much blood to mosquitoes during this study. The manuscript has benefited from the clear thinking of J. Goelz, K. Islam, J. Jones, T. Dell, and C. Hunter.

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Distribution and Habitat Use of Swainson's Warblers in Eastern and Northern Arkansas[1]

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Abstract

Systematic surveys of hardwood forests along the Buffalo National River, the St. Francis Sunken Lands Wildlife Management Area, St. Francis National Forest, Bayou Meto Wildlife Management Area, and the White River National Wildlife Refuge in eastern and northern Arkansas were undertaken between 5 April and 30 June 2000 and 2001 to document current status, distribution, and habitat requirements of Swainson's Warblers (*Limnothlypis swainsonii*) in Arkansas. Swainson's Warblers (SWWAs) were detected at 16 sites in deciduous forests at the Buffalo National River, 11 locations at the St. Francis National Forest, 19 sites at the White River National Wildlife Refuge, and 10 sites in bottomland habitat at the St. Francis Sunken Lands. We measured vegetation characteristics at 48 SWWA detection sites and at 48 randomly located sites. At the Buffalo National River, sites occupied by SWWAs showed a significantly ($P < 0.001$) greater leaf litter cover ($\bar{x}$ = 59.5 percent) than random sites ($\bar{x}$ = 41.1 percent). When comparing warbler detection sites with random sites at the St. Francis Sunken Lands, there was no significant difference for any variable, which probably reflected the limited sample size. In the St. Francis National Forest, shrub cover (8.9 percent) and shrub stem density (14.1/m^2) were greater at SWWA detection sites than in random plots (1.1 percent and 3.1/m^2, respectively). Several differences were found at the White River National Wildlife Refuge, including greater canopy cover, leaf litter cover and shrub stem density, but lower total green cover and forb cover at sites with SWWAs than at random sites. Based on the pooled data set, SWWA detection sites differed significantly ($P < 0.05$) from random sites by having greater shrub cover ($\bar{x}$ = 13.3 percent vs. 10 percent), leaf litter cover ($\bar{x}$ = 69.5 percent vs. 51.0 percent), canopy cover ($\bar{x}$ = 89.3 percent vs. 80.9 percent), and stem density ($\bar{x}$ = 10.9/m^2 vs. 5.1/m^2). Using logistic regression, we found stem density and leaf litter cover to be significantly ($P < 0.05$) associated with the occupancy probability of SWWAs at a specific site. The model correctly assigned detection and random sites for 73 of 96 samples (76 percent). Management suggestions to improve habitat for SWWAs include implementing individual tree and small-group selection cutting in appropriate deciduous habitat and controlled burning in decadent cane stands. To develop effective conservation strategies, further investigation into the demographic patterns (e.g., reproductive success and survival), especially related to different habitat and landscape situations occupied by this species, is critically needed.

Key words: Arkansas, distribution, habitat modeling, *Limnothlypis swainsonii*, management, Swainson's Warbler.

Introduction

Historically a common species in its appropriate habitat (Morse 1989), the Swainson's Warbler (*Limnothlypis swainsonii*) is classified as one of 64 bird taxa having high regional conservation priority in the southeastern U.S. (Hunter et al. 2001). Both the Southeast and Midwest Working Group for Partners in Flight ranked the Swainson's Warbler (SWWA) as of high management concern in these respective regions of the U.S. (Hunter et al. 1993, Thompson et al. 1993). Based on these and other reports, the Swainson's Warbler has been placed on the National Audubon Society Watch-List (Audubon WatchList 2002) and is identified as a species of extremely high priority by the American Bird Conservancy (2001).

Within their breeding range, SWWAs typically inhabit bottomland hardwood forests with cane (*Arundinaria* spp.) in the Southeast, lowland forests in Maryland (Meanly 1971), rhododendron (*Rhododendron* spp.) - laurel (*Kalmia latifolia*) thickets in the Appalachian Mountains in West Virginia (Brown and Dixon 1994), and bay swamps and pocosins in the coastal plain of South Carolina (P. Hamel, pers. comm.). In Louisiana, SWWAs also have been found in dense unthinned mid-age pine plantations (A. Bassett, pers. comm.).

An estimated 70 to 84 percent of bottomland hardwood and riparian forests have been lost since European settle-

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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ment in the southeastern U.S. (Turner et al. 1981, Mitch and Gosslink 1993, Noss et al. 1995, White et al. 1998). These areas have been converted to farmland, reservoirs, industrial parks, and urban centers. The surviving remnant forests are significantly influenced by levee construction, river channelization, agricultural runoff, cattle grazing, timber extraction, nonindigenous species invasion, and fragmentation (Pashley and Barrow 1992, White et al. 1998, Graves 2001). The loss of southeastern bottomland hardwoods is estimated to be five times greater than the loss of other major hardwood forest types in the U.S. (Abernethy and Turner 1987). This probably has resulted in an even greater reduction in bird populations associated with this habitat due to the effects of fragmentation (Pashley and Barrow 1992) and has contributed to the extinction and extirpation of several species (e.g., Ivory-billed Woodpecker [*Campephilus principalis*], Carolina Parakeet [*Conuropsis carolinensis*], and Bachman's Warbler [*Vermivora bachmanii*]; Remson 1986, White et al. 1998).

Within bottomland forests, cane, the most typical vegetation type associated with SWWA habitat (Thomas 1994) is critically endangered (White et al. 1998). Deforestation of river floodplains for agriculture and livestock production, construction of flood control reservoirs, and fire suppression (Steyermark 1963, Marsh 1977, Thomas 1994, White et al. 1998) have spared only remnant patches of this native "bamboo" in the Southeast (Noss et al. 1995).

Current and historical information on status and distribution of SWWAs in Arkansas is limited. Widmann (1895) found the SWWA as a breeding bird in canebrakes in the St. Francis Sunken Lands of southeastern Missouri and northeastern Arkansas in the late 1800s and early 1900s. Meanly (1971) reported the species in the lower White River bottoms, at the East Moon Lake and Scrubgrass Bayou areas, and along the Arkansas River between the mouth of Bayou Meto and Pendelton Ferry. Observations at White River National Wildlife Refuge in 1980 showed SWWAs to be fairly common in areas dominated with an understory of cane, which was found throughout the refuge (James and Neal 1986). Singing males were found in hardwood timber stands in the Saline River bottoms in Franklin County, in the northwest along the White River, and at Buffalo Point, Buffalo National River (James and Neal 1986).

Recent reports from northeast Arkansas are extremely scarce. Between 1966 and 1998 Breeding Bird Survey (BBS) results for SWWAs showed a nonsignificant annual decline of 17 percent in Arkansas (Sauer et al. 2000). Due to the low abundance of birds and the relatively low number of BBS stops adjacent to streams and rivers, however, this result may not reflect SWWA population trends accurately in Arkansas (see Smith et al. 1993).

Developing management strategies that will successfully reverse declines of this species requires identification of the habitat factors that are associated with viable populations. However, information on SWWA population size, its distribution, habitat requirements, breeding biology, and reproductive success in Arkansas is limited (James and Neal 1986; Graves 1992, 2002; Brown and Dixon 1994; Thomas 1994; Stotz et al. 1996). To begin to identify some of these habitat and population information needs, the aims of this research were (1) to obtain information on the occurrence and extent of SWWA distribution within the Buffalo National River, the St. Francis Sunken Lands Wildlife Management Area, St. Francis National Forest, Bayou Meto Wildlife Management Area, and the White River National Wildlife Refuge in eastern and northern Arkansas; and (2) to collect quantitative information on vegetation structure and characteristics to distinguish SWWA detection sites from randomly-located sites.

Study Areas

Swainson's Warbler surveys were conducted at the Buffalo National River (BNR), St. Francis Sunken Lands (SFSL) Wildlife Management Area (WMA), St. Francis National Forest (SFNF), Bayou Meto Wildlife Management Area (BMWMA), and White River National Wildlife Refuge (WRNWR) in eastern and northern Arkansas from 5 April to 30 June during both 2000 and 2001 (*fig. 1*).

BNR lies primarily in Newton and Searcy counties in northwestern Arkansas, south of Harrison. The area encompasses 38,475 ha of open farmland, oak-hickory forests, bluffs, and box canyons bisected by 217 km of the free-flowing Buffalo River.

SFSL is located in Greene, Craighhead, and Poinsett counties in northeastern Arkansas, east of Jonesboro. The area comprises approximately 10,400 ha of Arkansas Game and Fish Commission land, of which the majority lies within the main levees of the St. Francis River. It represents one of the largest contiguous tracts of bottomland hardwood forest remaining in northeastern Arkansas.

SFNF is situated in Lee and Phillips counties in east central Arkansas near the cities of Helena and Marianna. The 8,500 ha of upland and bottomland forest are bordered by the Mississippi and St. Francis Rivers to the east and include Crowley's Ridge to the west.

BMWMA is located in Arkansas and Jefferson counties in east central Arkansas south of Stuttgart and west of DeWitt. The management area encompasses 13,648 ha of bottomland hardwood forest and marshes and is managed by the Arkansas Game and Fish Commission.

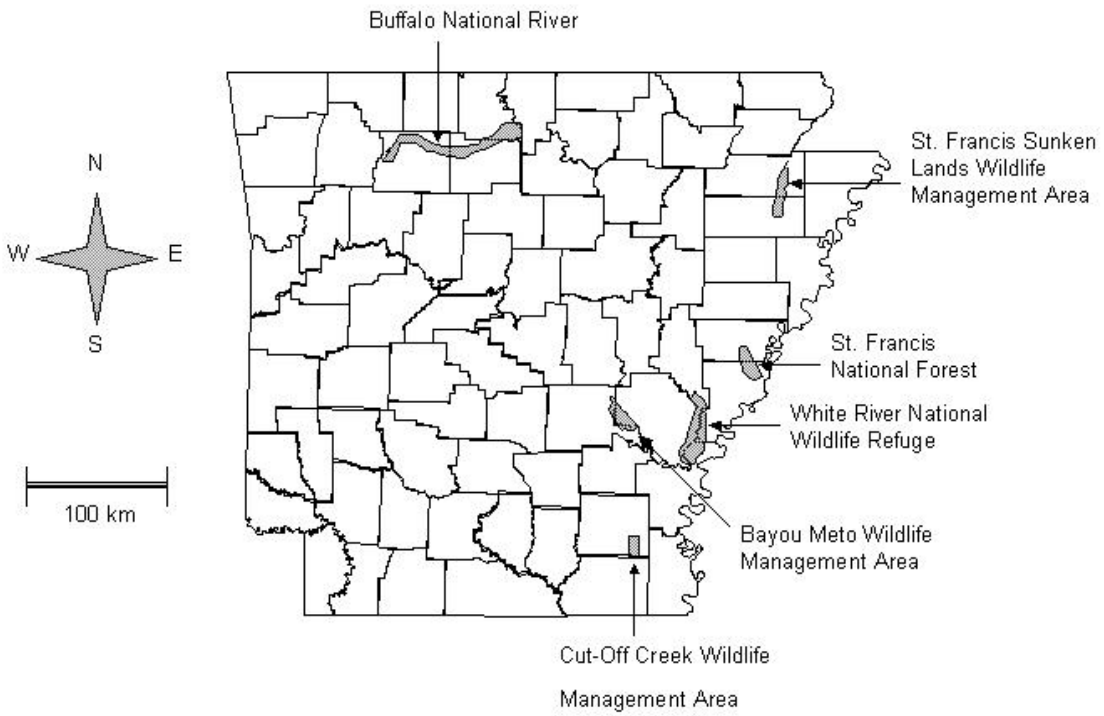

Figure 1— Locations of five survey areas—Buffalo National River (BNR), St. Francis Sunken Lands (SFSL) Wildlife Management Area (WMA), St. Francis National Forest (SFNF), Bayou Meto Wildlife Management Area (BMWMA), and White River National Wildlife Refuge (WRNWR)—and Cut-off Creek Wildlife Management Area, where habitat data at occupied Swainson's Warbler sites were collected in Arkansas in 2000 and 2001.

WRNWR is located in Arkansas, Phillips, and Monroe Counties in eastern Arkansas near the town of St. Charles. The refuge is the largest contiguous bottomland hardwood forest in the Mississippi Alluvial Valley under one ownership, encompassing 62,775 ha within the floodplain of the lower White River. The Grande Prairie borders the refuge to the west.

During a bird identification workshop with Arkansas Game and Fish Commission personnel, J. Bednarz and workshop participants located one SWWA incidentally in an upland area at Cut-off Creek Wildlife Management Area on 16 May 2000. Cut-off Creek Wildlife Management Area is located in southeastern Arkansas in Drew County just southwest of Dumas, AR (*fig. 1*). This 3,645 ha management area consists mainly of bottomland hardwood forest with some upland forest. No SWWAs were detected in the bottomland habitats at this site.

Methods

Broadcast surveys for SWWAs were conducted along primitive roads, All Terrain Vehicle (ATV) paths, hiking trails, and along waterways. All broadcast sampling along roads and trails was accomplished between sunrise and 12:00 noon. Audio output was set on high so that human observers could hear the broadcast from 50-70 m away on a day with clear atmospheric conditions. Along terrestrial survey routes, sampling sites were spaced approximately 200 m apart. SWWA primary song (cassette tapes prepared from Walton and Lawson 1989) was broadcast from a dual-speaker cassette player (Emerson PD 6509) perpendicular to the trail for 90 s at each sample site. Observations of SWWAs were recorded for 60 s after the broadcast. The cassette player was turned and positioned to the other side of the road or trail and the sequence repeated. In addition to land surveys, sampling along the BNR and the St. Francis River also took place from a canoe between sunrise and 12:00 noon and between 15:00 and 19:00. Broadcasts were directed perpendicular to the river at the shoreline, with sampling sites spaced approximately 400 m apart on both banks of the river.

Coordinates of all SWWA detection sites were recorded with a GPS receiver and their elevation and distance to water measured on DeLorme USA 3-D TopoQuads 3.0 topographic maps (Yarmouth, Maine). Surveyed distances on trails and on water in the BNR area were measured on topographical maps for the west (Trails Illustrated 1999) and east (Trails Illustrated 1997) halves of the BNR. The DeLorme software package was used to measure survey routes on the St. Francis River and in Compartment 22 in SFSL by the use of a digital map wheel. Distance of surveyed trails in SFSL was determined by taking measurements on

USGS 7.5-minute topographic maps of the Hatchie Coon Quadrangle (SFSL).

Vegetation characteristics were measured at BNR, SFNL, and WRNWR between 3 and 21 July 2000 and 28 June and 12 July 2001. Following BBIRD Field Protocol procedures (Martin and Conway 1994), quantitative measures of vegetation characteristics were recorded within 5-m and 11.3-m radius plots located at SWWA detection sites and nearby randomly-located sites.

We divided the 5-m radius plot into four quadrants and within each we estimated the percent cover of leaf litter, green grass, shrubs, forbs, bare ground, logs, fern, moss, dead grass, and water. A mean of the four estimates from each quadrant was used in the analysis. Of all the variables measured, moss cover was encountered only at two sites, fern and dead grass cover on one site, and water cover did not occur on any site in 2001. Therefore, these variables were omitted from the analysis. Depth of leaf litter and organic matter was measured at 1 m, 3 m, and 5 m from the center of the plot in each quadrant only in 2001. A small hole was dug down into the soil to where leaf litter was no longer visible and the height of the decomposed material was measured with a ruler positioned vertically.

To assess percent total canopy closure, four densiometer readings were taken, turning 90º between readings. Plot aspect was determined by taking a compass azimuth reading facing downslope from the highest elevation of the 5-m plot. Using a clinometer, the slope was measured in degrees across the 5-m radius plot from the bottom to top of the plot. Woody stems less than 50 cm in height were counted in 1-m^2 plots 3 m from the center of the plot in each of the quadrants. In each quadrant, ocular estimates of the average top heights of shrubs were made (only in 2001) and a mean of the four estimates used in the analysis. The dominant (≥40 percent) and the subdominant shrub species (≥40 percent) were identified to genus.

Within the 11.3-m radius plot, all trees were identified to genus, diameters measured at breast height (dbh), and recorded in size classes (saplings = <2.5 cm in diameter and >30 cm in height; poles = 2.5-8 cm; tree diameter classes = 8-23 cm, 23-38 cm, and >38 cm). The smallest two size classes were classified as understory and the largest three as overstory. The average crown height of trees was estimated and measured with a clinometer (only in 2001). The dominant (≥40 percent) and the sub-dominant (≥40 percent) tree species were identified. Snags >12 cm dbh and taller than 1.4 m were counted.

The vegetation sampling procedure was undertaken at random plots established 0 to 250 m from the detection sites. To locate plots, a random digit between 0 and 9 selected from a random-number table was multiplied by 36. The resulting number represented the azimuth from the detection site. Three random digits between 0 and 250 were selected for the distances from the detection plot.

In addition to SWWAs detected during our fieldwork, Dawn Dumtra (University of Georgia, pers. comm.) reported a singing SWWA in deciduous forest along a secondary road at the WRNWR. Vegetation measurements were taken at this detection site and the data were included in the analysis.

We first checked vegetation variables for normality by plotting the data and using a Kolmogorov-Smirnov test. If data were normally distributed, we then applied two-sample t-test to compare variables between SWWA detection sites and random sites. A Mann-Whitney U-test was used if data were not normally distributed. However, we presented means for all comparisons because we suggest this measure of central tendency may be more biologically meaningful to SWWAs than medians. To adjust for multiple comparisons, we employed a Bonferroni correction and set significance for statistical tests at $\alpha = 0.025$. A one-way Analysis of Variance (ANOVA) at Tukey's family error rate of 0.05 was used to compare variables between detection and random sites from four different study areas: BNR, SFSL, SFNF, and WRNWR. Because the majority of the variable means were similar between the four study sites, the data were pooled to maximize the sample size. Mean estimates of habitat variables collected at four detection and four random sites at BNR in 2000 were obviously different than estimates based on a larger sample of data collected in 2001. These differences probably reflected unusually high water levels encountered at the BNR in 2000; water levels were relatively normal in 2001. Therefore, 2000 data (4 detection and 4 random sites) from BNR were omitted in the analysis.

A binary logistic regression was performed to predict the probability that SWWAs would use a habitat based on vegetation characteristics. After examination of the data and univariate statistical results, we eliminated all variables that showed a weak relationship ($P > 0.1$) either with plots used by SWWAs or with random plots. Also, highly correlated vegetation variables ($P < 0.05$) were removed. We retained the variable that we felt was most meaningful in terms of providing for the habitat needs of the SWWA based on the literature and our knowledge of the species. After we eliminated the correlated variables, we were left with three variables to include in the logistic regression model: leaf litter cover, stem density, and canopy cover. Initial analyses of vegetation data indicated that candidate models developed to predict SWWA occupancy were only moderately successful. Therefore, we decided to pool the entire data set of 96 sites (48 occupied and 48 random

sites) to develop the best predictive model with the available data. However, in using this approach we could not withhold a sub-sample of the data to test a model developed on another subset of the data. Alternatively, we performed logistic regression analysis on the full model and all subsets of the full model using Minitab. To determine the best habitat model that related habitat variables to occupancy of SWWAs, we calculated Akaike's Information Criterion (AIC) for each model (Christensen 1997). The lowest AIC value should indicate the model that has the best fit with the data.

Results

Distribution

We surveyed 241.9 km of rivers in the Buffalo National River, from Pruitt to Buffalo City, and in the St. Francis Sunken Lands Wildlife Management Area for SWWAs (*table 1*). In addition, we hiked and surveyed with standardized broadcast sampling at locations every 200 m along 230.9 km of primitive roads or trails at our five survey areas (*table 1*). Even though previously-published reports (Widemann 1895, Meanly 1971, James and Neal 1986) indicated that SWWAs were present and relatively common historically at all these study areas, our recent surveys revealed an extremely low frequency of scattered warbler detections (*table 1*).

In the BNR area, 16 SWWAs were detected: 12 detections were in deciduous forest with cane understory, three in deciduous habitat without cane association, and one bird was found in red cedar (*Juniperus* sp.) stands. In SFSL, SWWAs responded at ten sites, seven of which were located in hardwood forests on Hatchie Coon Island. Three detection sites were situated in hardwood-cypress forests near Hatchie Coon Lake on the east side of Hatchie Coon Island. On three occasions in May before fledglings should have been present, when two SWWAs were sighted together, we assumed them to be mated. Each pair exchanged soft "chip" calls and were observed feeding in leaf litter next to each other. Presumed females (not singing) were difficult to follow and we often lost view of them quickly after they were detected. Males, on the other hand, were often observed flying to a perch where they sang, sometimes repeatedly.

We detected 11 SWWAs in the SFNF, all in bottomland forest habitat, with no cane present. No SWWAs responded during our survey of BMWMA. In the WRNWR, we detected 18 SWWAs, 13 in bottomland forest and 5 in canebrakes. On the refuge, the mean elevation of occupied sites ($\bar{x}$ = 49.2 m, se = 0.30, N = 18) was significantly higher ($P < 0.001$) than random sites ($\bar{x}$ = 47.1, se = 0.30, N = 40).

Habitat and Vegetation Characteristics

Vegetation characteristic differences between detection sites and randomly-located sites at the BNR (*table 2*) were only significant ($P < 0.025$) for leaf litter cover ($\bar{x}$ = 59.5 percent at detection sites vs. $\bar{x}$ = 41.1 percent at random sites). We detected no significant differences when comparing other vegetation variables, but some trends were apparent (*table 2*). Limited sample size may have precluded statistical significance in some cases.

In the SFSL, measured characteristics between detection sites and random sites did not show statistically-significant differences (*table 3*). Again, we attribute the lack of statistical trends to small sample sizes.

Two differences were observed in the vegetation characteristics that were measured at SFNF between warbler and random sites. Specifically, shrub cover ($\bar{x}$ = 8.9 percent) and shrub stem density ($\bar{x}$ = 14.1/m^2) were significantly greater at sites with SWWAs compared to random locations (*table 4*).

Table 1— *Distances surveyed and number of detections of Swainson's Warblers within selected study areas in Arkansas.*

Study area	Distance of trails surveyed (km)	Distance of river surveyed (km)	Number of Swainson's Warbler detections
Buffalo National River (BNR)	51.7	226.6	16
St. Francis Sunken Lands Wildlife Management Area (SFSL)	45.2	15.3	10
St. Francis National Forest (SFNF)	13.4	0	11
Bayou Meto Wildlife Management Area (BMWMA)	22.5	0	0
White River National Wildlife Refuge (WRNWR)	98.1	0	18
Cut-off Creek Wildlife Management Area	0	0	1

Table 2— *Mean vegetation characteristics measured at Swainson's Warbler detection sites and random sites at the Buffalo National River, Arkansas in 2001.*

	Detection sites (N = 12)		Random sites (N = 12)			
Characteristics	**Mean**	**se**	**Mean**	**se**	**P-values**	**Test[a]**
Green cover (%)	47.6	8.5	47.8	7.5	0.986	t
Shrub cover (%)	15.6	2.5	19.3	4.2	0.470	t
Grass cover (%)	12.1	4.7	11.4	3.2	0.665	MW
Forb cover (%)	19.9	4.9	16.7	4.5	0.633	t
Leaf litter cover (%)	59.5	8.5	41.1	10.0	<0.001*	MW
Bare ground cover (%)	7.7	2.3	17.5	6.1	0.158	t
Downed log cover (%)	5.6	1.5	5.4	1.7	0.928	t
Canopy cover (%)	90.9	3.3	84.9	5.2	0.073	MW
Leaf litter depth (mm)	21.5	4.7	15.3	4.9	0.298	MW
Stem density (m^2)	8.3	3.4	7.2	2.2	0.840	MW
Understory tree density (ha)	780	231	785	175	0.986	t
Overstory tree density (ha)	584	76	814	126	0.135	t
Snag density (ha)	12.9	6.0	7.8	5.6	0.534	t
Mean shrub height (m)	2.4	0.3	3.2	1.7	0.124	MW
Mean tree height (m)	9.1	0.8	10.5	1.2	0.348	t

*Indicates a significant difference of ($P \leq 0.025$).
[a] t = Two sample t-test, MW = Mann-Whitney U-test.

Table 3— *Mean vegetation characteristics measured at Swainson's Warbler detection sites and random sites in the St. Francis Sunken Lands Wildlife Management Area, Arkansas in 2001.*

	Detection sites (N = 10)		Random sites (N = 10)			
Characteristics	**Mean**	**se**	**Mean**	**se**	**P-values**	**Test[a]**
Green cover (%)	20.6	3.4	24.8	6.5	0.969	MW
Shrub cover (%)	15.3	3.5	17.9	4.8	0.663	t
Grass cover (%)	2.5	0.8	2.9	1.8	0.410	MW
Forb cover (%)	2.9	0.7	4.0	2.2	0.672	MW
Leaf litter cover (%)	82.6	3.7	77.0	5.8	0.427	t
Bare ground cover (%)	2.9	2.1	5.0	2.6	0.871	MW
Downed log cover (%)	7.8	1.0	8.0	1.6	0.897	t
Canopy cover (%)	95.5	0.5	96.0	0.8	0.643	t
Leaf litter depth (mm)	40.3	3.0	33.9	4.0	0.140	MW
Stem density (m^2)	10.6	3.8	4.7	1.2	0.198	MW
Understory tree density (ha)	1135	210	1032	276	0.772	t
Overstory tree density (ha)	784	136	911	159	0.623	MW
Snag density (ha)	12.4	5.1	6.2	4.1	0.473	MW
Mean shrub height (m)	1.6	0.1	1.3	0.2	0.299	t
Mean tree height (m)	13.5	1.7	11.3	1.2	0.345	MW

[a] t = Two sample t-test, MW = Mann-Whitney U-test.

At WRNWR, both green cover ($\bar{x}$ = 31.0 percent) and forb cover ($\bar{x}$ = 49.7 percent) were significantly less at sites with SWWAs than measured in random plots (57.1 percent and 19.6 percent, respectively). Conversely, leaf litter cover (70.0 percent vs. 50.4 percent), canopy cover (88.3 percent vs. 72.0 percent), and shrub stem density (9.6/m^2 vs. 4.7/m^2) were greater at sites with warblers compared to random locations (*table 5*).

Comparison of vegetation characteristics at BNR detection sites with SFSL sites (*table 6*) revealed percent green cover ($\bar{x}$ = 47.6 percent) and percent forb cover ($\bar{x}$ = 19.9 percent) at the BNR were significantly higher than at the SFSL sites ($\bar{x}$ green cover = 20.6 percent and $\bar{x}$ forb cover = 2.9 percent). Also, leaf litter depth ($\bar{x}$ = 21.5 mm, se = 4.7) was significantly lower at BNR detection sites compared with sites at SFSL ($\bar{x}$ = 40.3 mm, se =3.0).

Percent leaf litter cover ($\bar{x}$ = 59.5 percent at BNR vs. $\bar{x}$ = 82.6 percent at SFSL) showed a trend towards statistical significance (P = 0.026; t-test) as did percent

Table 4— *Mean vegetation characteristics measured at Swainson's Warbler detection sites and random sites in the St. Francis National Forest, Arkansas in 2000.*

	Detection sites (N = 10)		Random sites (N = 10)			
Characteristics	**Mean**	**se**	**Mean**	**se**	**P-values**	**Test[a]**
Green cover (%)	31.7	5.2	42.1	8.1	0.299	t
Shrub cover (%)	8.9	2.5	1.1	1.1	0.006*	MW
Grass cover (%)	2.4	1.2	6.6	1.7	0.264	t
Forb cover (%)	21.9	5.7	33.5	7.1	0.222	t
Leaf litter cover (%)	67.1	5.2	43.6	11.1	0.078	t
Bare ground cover (%)	8.8	2.9	25.9	10.2	0.137	t
Downed log cover (%)	2.7	0.7	3.5	2.2	0.741	t
Canopy cover (%)	85.5	2.2	80.6	3.5	0.309	t
Leaf litter depth (mm)	40.3	3.0	33.9	4.0	0.140	MW
Stem density (m^2)	14.1	2.6	3.1	0.7	0.002*	t
Understory tree density (ha)	338	78	262	53	0.484	t
Overstory tree density (ha)	364	31	476	59	0.143	t
Snag density (ha)	5.0	5.0	7.5	5.3	0.448	MW

*Indicates a significant difference of ($P \leq 0.025$).
[a] t = Two sample t-test, MW = Mann-Whitney U-test.

Table 5— *Mean vegetation characteristics measured at Swainson's Warbler detection sites and random sites in the White River National Wildlife Refuge, Arkansas in 2000.*

	Detection sites (N = 14)		Random sites (N = 14)			
Characteristics	**Mean**	**se**	**Mean**	**se**	**P-values**	**Test[a]**
Green cover (%)	31.0	3.9	57.1	5.8	0.005*	MW
Shrub cover (%)	9.2	3.5	3.5	2.4	0.195	t
Grass cover (%)	2.5	1.2	4.1	1.7	0.472	t
Forb cover (%)	19.6	3.5	49.7	5.3	<0.001*	MW
Leaf litter cover (%)	70.0	2.8	50.4	5.2	0.003*	MW
Bare ground cover (%)	3.2	1.0	4.2	1.4	0.574	t
Downed log cover (%)	4.6	1.8	1.6	0.4	0.128	t
Canopy cover (%)	88.3	2.2	72.0	3.5	0.003*	MW
Stem density (m^2)	9.6	1.1	4.7	0.9	0.001*	MW
Understory tree density (ha)	310	70	159	41	0.102	MW
Overstory tree density (ha)	278	31	347	30	0.124	t
Snag density (ha)	14.2	6.2	17.8	4.8	0.448	MW

*Indicates a significant difference of ($P \leq 0.025$).
[a] t = Two sample t-test, MW = Mann-Whitney U-test.

grass cover ($\bar{x}$ = 12.1 percent at BNR vs. $\bar{x}$ = 2.5 percent at SFSL) with P = 0.031 (t-test). When comparing random sites, we found the percent green cover ($\bar{x}$ = 47.8 percent), grass cover ($\bar{x}$ = 11.4 percent), and percent forb cover ($\bar{x}$ = 16.7 percent) were significantly higher ($P < 0.025$) at BNR sites than at SFSL sites ($\bar{x}$ green cover = 24.8 percent, $\bar{x}$ grass cover = 2.9 percent, and $\bar{x}$ forb cover = 4.0 percent). Percent leaf litter cover ($\bar{x}$ = 41.1 percent), canopy cover ($\bar{x}$ = 84.9 percent), and leaf litter depth ($\bar{x}$ = 15.3 mm) were significantly ($P < 0.025$) lower at BNR sites than at SFSL sites ($\bar{x}$ leaf litter cover = 77.0 percent, $\bar{x}$ canopy cover = 96.0 percent, and $\bar{x}$ leaf litter depth = 33.9 mm). The mean shrub height was higher at BNR sites ($\bar{x}$ = 2.4 m) than at SFSL ($\bar{x}$ = 1.6 m; P = 0.033). The mean tree height was lower at BNR ($\bar{x}$ = 9.1 m) than at SFSL ($\bar{x}$ = 13.5 m; P = 0.036).

Several variables were found to differ among study areas sampled in 2000 and 2001. Vegetation characteristics with mean values that most frequently differed among sites included the percent green foliage cover, canopy cover, understory tree density, and overstory tree density for both SWWA detection sites (*table 6*) and random sites (data not shown). However, we only noted consistent patterns among sites for three variables. Specifically, grass cover tended to be greater at BNR ($\bar{x}$ = 12.1 percent) compared to other sites, densities of understory trees (>700 trees/ha) and overstory trees (>550

trees/ha) were greater at BNR and SFSL than at SFNF and WRNWR (means <300 and 450 trees/ha, respectively; *table 6*). Data are not shown for random sites, but patterns were very similar. None of these variables seemed to be related statistically to the presence or absence of SWWAs at a particular habitat. Moreover, we observed none of the mean estimates measured to vary consistently between the two years that we collected vegetation data. Therefore, we suggest that some differences among the different study sites were to be expected and there were no systematic measurement biases among the data collected at the different study areas. We believe the lack of consistent biases in the habitat data among sites and between years allows us to pool the data to look for general patterns.

To maximize the sample size and to identify common characteristics at SWWA detection sites, we pooled the 2001 data (BNR, SFSL, and WRNWR) with the data collected in 2000 (Cut-off Creek Wildlife Management Area, SFNF, and WRNWR). Using the pooled data set, we found significantly greater ($P < 0.05$) percent of shrub cover ($\bar{x}$ = 13.3 percent), leaf litter cover ($\bar{x}$ = 69.5 percent), canopy cover ($\bar{x}$ = 89.3 percent), and stem density ($\bar{x}$ = 10.9/m^2) at SWWA detection sites than at random sites ($\bar{x}$ shrub cover = 10.0%; $\bar{x}$ leaf litter cover = 51.0%; $\bar{x}$ canopy cover = 80.9%; $\bar{x}$ stem density = 5.1/m^2; *table 7*). The mean distance of SWWA detection sites to water was 227 m (se = 56, N = 12) for BNR and 321 m (se = 80, N = 10) for SFSL. The mean elevation of warbler locations was 203.3 m (se = 18, N =12) for BNR and 67.3 m (se = 0.4, N = 10) for SFSL.

Binary Logistic Regression

We evaluated all variables for potential inclusion in a logistic regression model. However, we only retained three uncorrelated variables (see Methods) that based on the literature and our knowledge of the species, were likely important to SWWA habitat selection: leaf litter cover, shrub stem density, and canopy cover. Of all possible model variations with these three variables, the full model including stem density, leaf litter cover, and canopy cover had the lowest AIC value (4.0). This model was significant ($G^2 = 106.64$, $P < 0.001$; *table 8*) and predicted SWWA occupied and random sites correctly in 76.04% of the cases. The Hosmer-Lemeshow lack-of-fit test (Chi-square = 9.63, df = 8, P = 0.292) indicated that the data did not significantly deviate from the model and the Goodman-Kruskal statistic (0.61) revealed a reasonable association between the actual and predicted classification of the 96 samples. The two-variable model that performed almost as well (AIC = 4.8) as the full model included stem density and leaf litter ($G^2 = 109.43$, $P < 0.001$; *table 8*). The Hosmer-Lemeshow lack-of-fit test (Chi-square = 11.24, df = 8, P = 0.189) indicated a more questionable fit between the data and the model, but the association between the actual and predicted classification of sites was relatively good (Goodman-Kruskal statistic = 0.58).

Table 6— *Mean vegetation characteristics measured at Swainson's Warbler detection sites at the Buffalo National River and the St. Francis Sunken Land Wildlife Management Areas, Arkansas in 2001, and in the St. Francis National Forest and the White River National Wildlife Refuge, Arkansas in 2000. Locations with the same letters did not differ significantly (P < 0.05) from each other.*

	Buffalo National River (N = 12)		St. Francis National Forest (N = 10)		St. Francis Sunken Lands (N = 10)		White River National Wildlife Refuge (N = 14)	
Characteristics	**Mean**		**Mean**		**Mean**		**Mean**	
Green cover (%)	47.6	a	31.7	b	20.6	c	31.0	b, c
Shrub cover (%)	15.6	a	8.9	a	15.3	a	9.2	a
Grass cover (%)	12.1	a	2.4	b	2.5	b	2.5	b
Forb cover (%)	19.9	a	21.9	a	2.9	b	19.6	a
Fern cover (%)	0	a	0.6	a	0	a	0	a
Leaf litter cover (%)	59.5	a	67.1	a	82.6	a	70.0	a
Bare ground cover (%)	7.7	a	8.8	a	2.9	a	3.2	a
Downed log cover (%)	5.6	a	2.7	a	7.8	a	4.6	a
Water cover (%)	0	a	0	a	0	a	0.8	a
Canopy cover (%)	90.9	a	85.0	b	95.5	c	88.3	a
Stem density (m^2)	8.3	a	14.1	a	10.6	a	9.6	a
Understory tree density (ha)	780	a	264	b	1135	c	310	b
Overstory tree density (ha)	584	a, b	339	a, c	784	b	278	c
Snag density (ha)	12.9	a	5.0	a	12.4	a	14.2	a

Table 7— *Mean vegetation characteristics measured at Swainson's Warbler detection sites and random sites combined for the Buffalo National River, the St. Francis Sunken Lands Wildlife Management Area, and the White River National Wildlife Refuge, Arkansas in 2001, and for the Cut-off Creek Wildlife Management Area, the St. Francis National Forest and the White River National Wildlife Refuge, Arkansas in 2000.*

	Detection sites (N = 48)		Random sites (N = 48)			
Characteristics	**Mean**	**se**	**Mean**	**se**	**P-values**	**Test[a]**
Green cover (%)	34.6	3.2	43.3	3.7	0.093	MW
Shrub cover (%)	13.3	1.7	10.0	2.0	0.022*	MW
Grass cover (%)	5.0	1.4	6.2	1.3	0.359	MW
Forb cover (%)	16.7	2.2	26.9	3.5	0.085	MW
Fern cover (%)	0.1	0.1	0.3	0.2	0.696	MW
Leaf litter cover (%)	69.5	2.8	51.0	4.4	0.005*	MW
Bare ground cover (%)	5.3	1.0	14.3	3.2	0.281	MW
Downed log cover (%)	5.1	0.7	4.6	0.8	0.430	MW
Water cover (%)	0	0	0.2	0.2	0.356	t
Canopy cover (%)	89.3	1.4	80.9	2.9	0.024*	MW
Stem density (m^2)	10.9	1.3	5.1	0.7	<0.001*	MW
Understory tree density (ha)	578	93	530	93	0.764	MW
Overstory tree density (ha)	482	47	612	61	0.079	MW
Snag density (ha)	10.4	2.7	9.9	2.6	0.890	t

*Indicates a significant difference of ($P \leq 0.05$).

[a] t = Two sample t-test, MW = Mann-Whitney U-test.

Table 8— *Results of logistic regression model comparing 48 sites occupied with Swainson's Warblers to 48 randomly-selected sites in eastern and northern Arkansas (2000-2001).*

Parameter	**Coefficient**	**se**	**P–value**	**Odds ratio**
Full model				
Constant	4.800	1.799	0.008	
Stem density	-0.122	0.045	0.007	0.89
Leaf litter cover	-0.022	0.010	0.027	0.98
Canopy cover	-0.300	0.020	0.138	0.97
Two-variable Model				
Constant	2.460	0.709	0.001	
Stem density	-0.122	0.044	0.005	0.89
Leaf litter cover	-0.025	0.010	0.010	0.98

Discussion

During this study, the entire length of the BNR from Steel Creek to Buffalo City was surveyed at a time when SWWAs should have been active on their breeding grounds. We detected only 16 birds in this large survey area, and the majority of them were concentrated on the downstream portion (between Gilbert, AR and the confluence with the White River) of BNR. Twelve of these 16 birds were located in deciduous forested habitat with a mostly cane understory. Canebrake is considered the primary and "classic" habitat of SWWAs in the river floodplain forests and swamps of the Coastal Plain by many authors (e.g., Meanly 1971; Graves 2001, 2002). Historical records indicate that cane was formerly very abundant in the southeastern U.S. and extended northward as far as Pennsylvania (Marsh 1977). In Arkansas, cane was a conspicuous part of bottomland and riverine landscapes during the 1800s. Early travelers reported an immense quantity in the river bottoms between the St. Francis and Mississippi Rivers (Stoddard 1812) and abundant cane in the areas around Batesville and Helena, AR (Jewell 1892). Stands of cane were described as lining the shores of the Arkansas River for hundreds of miles (Stoddard 1812) and poles reaching tree heights up to 10 m were frequently encountered (e.g., Featherstonhaugh 1844). Since then, loss of canebrakes has been dramatic in the Southeast and the canebrake habitat type is now classified as an endangered ecosystem with less than 2 percent of the original stands remaining (White et al. 1998). The loss of cane habitat might be one of the contributing factors to the current decline of SWWAs. This suggestion is supported by the fact that the present geographic ranges of cane and SWWA coincide very closely (Marsh 1977).

Although SWWAs seem to exhibit a close affinity or as Wheeler (1924:136) states, "cling tenaciously" to cane, they are able to occupy sites with undergrowth structurally similar to "bamboo." These warblers have been found to inhabit forests with understory consisting of sweet pepperbush (*Clethra alnifolia*) in the northern part of the Atlantic Coastal Plain and scrub palmetto (*Sabal minor*) in the southern parts of the Coastal Plain. In the Appalachians, where cane is probably limited by low temperatures (Marsh 1977), SWWAs are associated with rhododendron on the moist slopes in Maryland and rhododendron, mountain laurel, hemlock (*Tsuga canadensis*), and American holly (*Ilex opaca*) in Virginia (Brown and Dixon 1994). Moreover, Graves (2002) argued that the presence of a relatively high density of SWWAs in the Whiskey Bay Pilot Channel in Louisiana, where giant cane is absent, represents strong evidence refuting cane-SWWA association hypothesis.

Mean shrub stem densities (83,000-141,000/ha) in habitats where SWWAs were found in Arkansas were extremely high, whether habitats consisted of understory shrub thickets or cane stands. This is somewhat similar to relatively high stem densities found by Graves (2002) at five locations occupied by SWWAs throughout the Southeastern U.S. However, the maximum count of understory woody stems that he recorded in a core SWWA territory was 104,710 stems/ha and median values from different study areas varied from 31,592-48,281 stems/ha (Graves 2002). Based on these data, Graves (2002) suggested that a relatively narrow range of stem densities (ca. 30,000-50,000 stems/ha) seemed to provide high-quality cover for nesting and foraging SWWAs throughout the Southeast. We suggest that the reason our stem densities are generally greater than those reported by Graves, in part, could be related to different methodology. Specifically, we counted stems in four 1-m^2 plots, whereas Graves (2002) tallied stems in single 12.6-m^2 circular plots, and these larger plots may have included more micro patches with relatively sparse shrub growth. Importantly, more work is required to determine what range of shrub stem densities support populations that are breeding and surviving successfully. Neither our study in Arkansas, or the work reported by Graves related demographic performance to habitat characteristics.

In Arkansas, we found SWWAs primarily inhabiting swampy tangles and shrub thickets along the interface between floodplains and upland forests in the SFNF and the WRNWR. Also, SWWA detection sites in the SFSL were concentrated on the slightly elevated ($\bar{x}$ = 67 m) Hatchie Coon Island, a tract of 13-16 yr old deciduous forest that in most years is not inundated during the spring flood period (C. Wilcoxson, Arkansas Game and Fish Commission, pers. comm.). Such elevated sites in close vicinity to a permanent water source might be a critical factor to the reproductive success of SWWAs (Brown and Dixon 1994). Altered hydrology in many bottomland batture systems in Arkansas and in the southeastern U.S. results in deeper and longer flooding than under natural conditions. Thus, current hydrological conditions probably adversely impact species, including the SWWA, that nest in low vegetation (Brown and Dixon 1994). Importantly, at the higher-elevation locations within bottomland forests, broods are less likely to be destroyed by rising water in the spring or early summer (Graves 2001). In the SFSL, the nearest water to SWWA detection sites was a mean distance of 320 m. Eddlemann (1978) and Thomas (1994) found SWWAs within 200-400 m of water.

In our study, warbler detection sites were characterized by dense shrub cover, high stem density, closed canopy, and well-developed leaf litter cover relative to available random sites (*table 7*). These findings are consistent with reports that SWWAs tend to nest in the densest, darkest areas of their habitat (Meanly 1971, Graves 2001). A canopy cover of 50 percent was regarded as the minimum requirement for SWWA habitat by Eddlemann (1978), with an optimum of 80 percent or higher. Also, Thomas (1994) found warblers at sites with a mean canopy cover of 85 percent. In our study, the mean canopy cover was 89.3 percent (*table 7*). This combination of dense shrub understory and closed canopy contributes to the abundant leaf litter cover measured, that probably supports a rich invertebrate fauna. Morphologically specialized to feeding on subsurface prey, SWWA express a stereotyped method of manipulating leaf litter in search for beetles and spiders (Graves 1998, Strong 2000). Unfortunately, we only began measuring the depth of leaf litter during the second year of this study (2001) and our sample size was very limited for this variable. The data collected, however, did suggest a possible trend of a deeper layer of litter at sites where we detected SWWAs compared to random sites, albeit this pattern was not significant (*tables 2, 3*).

Habitats with deep leaf litter cover are confined to sites with a dense thicket of shrubs. Also natural flooding action in bottomland sites may contribute to the build up of dense leaf litter. In the tropics, leaf litter cover is reduced through increased desiccation resulting from forest fragmentation (Kapos 1989) or from increased radiation reaching leaf litter in early successional habitats (Lee 1989). Desiccation of SWWA habitats due to hydrological alteration in the southeastern U.S. (White et al. 1998) ultimately reducing available invertebrate prey may be another factor contributing to the species' decline. High shrub stem density and leaf litter cover were both important vegetation characteristics in our habitat model (*table 8*). Graves (2001,

2002) also found that extensive understory thickets, greenbriar (*Similax* spp.) tangles, deep shade, including a variety of and an abundance of leaf litter typified SWWA territories in several locations of the southeastern U.S.

Despite the fact that cane shows broad ecological amplitude and can potentially occur in many different community types, including a variety of successional and some climax communities (Marsh 1977), it is increasingly rare and sizeable remaining patches are worthy of protection and in need of management. Frost (1995) has shown fire is a major factor in maintaining canebrakes throughout the southeastern U.S. Thus, carefully-controlled burning may be used to renovate decadent stands. However, Hughes (1957) reported that a completely killed-out canebrake would not restock naturally for several generations, probably due to its rhizomatous vegetative propagation. A reduction in fire frequency leads to the establishment of successional species, such as shrubs and saplings, eventually overwhelming the canebrake. Although this habitat type may not be required by SWWAs (Graves 2002, this study), the historical loss of large cane patches undoubtedly contributed to the decline of this species in the Southeast.

Management Implications

Based on our observations and findings, we propose initiation of small group selection cuts (<0.5 ha) to open up the canopy in combination with prescribed low-heat burns to regenerate remnant cane stands to reestablish potential SWWA habitat. In deciduous habitat, SWWAs have been reported to respond positively to selective cutting as long as cut areas are not excessive in size (Pashley and Barrow 1992). Graves (2002) reported that small clear cuts (as small as 0.25 ha) at a density of 25 clearcuts/km^2 may foster the establishment of SWWAs in marginal habitats in Virginia. The size of a timber harvest that may be too large and would adversely impact the SWWA population is unknown. Although Graves (2002) has suggested that clearcuts as large as 20 ha on a staggered 25-yr cutting rotation could support populations of SWWAs on agroforestry lands. At this point, we suggest that tree harvest operations on SWWA breeding grounds in bottomland hardwood habitats should be limited to individual tree or small group-selection cuts because this method more closely resembles natural disturbances and treefalls (Graves 2001). These light gap areas should promote the development of dense understory vegetation that provides critically important nesting habitat for SWWAs. To prevent direct disturbance of nesting SWWAs, timber cutting should be limited to the non-breeding season (1 October-1 April). Larger cuts could be detrimental as this approach would enlarge forest gaps probably increasing the risk of nest predation and/or brood parasitism (Robinson et al. 1995). This could especially be important for management of forested tracts surrounded by agricultural lands and this situation is characteristic of the bottomland forest remnants throughout the Mississippi Alluvial Valley (e.g., SFNF, SFSL, and WRNWR). Meanly (1971) reported substantial brood parasitism on SWWAs by Brown-headed Cowbirds (*Molothrus ater*) at Pendelton Ferry, Arkansas in 1967. We found a single nest in the SFNF that fledged one cowbird and no warblers. We also observed cowbirds being attracted to SWWAs' primary song on a few occasions in the SFSL, but because we only located one nest, we cannot assess what the impact of cowbird parasitism is on the reproductive success of extant SWWA populations in Arkansas. Although we and others (e.g., Graves 2002) have documented the use of both understory thickets and cane habitats by SWWAs in a variety of circumstances (fragmented patches to contiguous forests), few data are available on what landscape and vegetative structural characteristics support viable vs. sink populations. Therefore, documenting demographic performance (reproductive success and survival) in differing habitat and landscape situations is vital to the development of effective management strategies and conservation policies to avoid further declines in this species.

Acknowledgments

This project was financially supported by the Arkansas Fish and Game Commission (AGFC) and the U.S. Forest Service (USFS). We are grateful to G. Oviatt and C. Bitting of the National Park Service; K. Tinkel and J. Bonnette of the USFS; and B. Rice, L. Moore, K. Rowe, and C. Wilcoxson with the AGFC for their help throughout the study. B. Blakely, J. Millikin, and S. Fowler provided valuable assistance in the field. M. Donaghy Cannon provided statistical input. We greatly appreciate the assistance of P. Hamel, T. Rich, and L. Moore who reviewed and improved this manuscript. Many thanks to S. Vanderpool for help with plant identification, D. Dumtra for sharing information on a SWWA location in the WRNWR, and J. Orr for drafting *figure 1*.

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Conservation of Priority Birds in Sagebrush Ecosystems[1]

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Abstract

Sagebrush ecosystems occupy over 62,000,000 ha of the western US. However, they have been degraded or completely eliminated by agricultural conversion, overgrazing by domestic livestock, invasion of exotic plants, expansion of pinyon and juniper woodlands, uncharacteristic wildfires, and fragmentation. This habitat loss has led to an increasing number of special status species, including 630 plant and animal species of conservation concern. In this paper, we focus on the 22 taxa of sagebrush associated birds that are priorities in Partners in Flight Bird Conservation Plans. These range from sagebrush obligates–Greater Sage-grouse (*Centrocercus urophasianus*), Gunnison Sage-grouse (*C. minimus*), Sage Thrasher (*Oreoscoptes montanus*), Sage Sparrow (*Amphispiza belli*), Brewer's Sparrow (*Spizella breweri*)–to grassland associates such as Short-eared Owl (*Asio flammeus*) and Vesper Sparrow (*Pooecetes gramineus*). Partners in Flight has identified five of these species for the continental Watch List–Swainson's hawk (*Buteo swainsoni*), both sage-grouse, the Short-eared Owl, and Brewer's Sparrow–which places them among the highest priority species for conservation action in North America. We also examine the extent to which sage grouse may serve as classic umbrella species for shrubsteppe avifauna. These species tended to occur together–83 pairwise correlations of relative abundance were significant (8.55 expected). Factor analysis of these data showed that species formed groups based on habitat associations much as expected, although sage-grouse aligned more closely with the Vesper Sparrow than expected. Population trends for three major physiographic strata that encompass sagebrush ecosystems–the Columbia Plateau, Wyoming Basin, and Basin and Range–showed the Columbia Plateau to have many more declining population trends. Habitat associations for declining species included both sagebrush and grassland types. Historic (1850) and current population sizes were estimated for 12 priority taxa in the Interior Columbia Basin based on predicted areas of historic and current source habitat. Estimated current population sizes are, not surprisingly, drastically reduced from historic numbers. The Western Meadowlark (*Sturnella neglecta*) showed the least percent reduction and Grasshopper Sparrow the most. For six species that had significant or near significant declines in the Columbia Plateau since 1966 and for which we had historic and current habitat estimates, the estimated historical declines were all remarkably similar to recent trends. Trends and management activities on public lands in Idaho, Oregon, and Washington that may be contributing to disproportionate declines in priority birds include an increase in the area burned annually by wildfire, an increase in the biomass of grazing cattle, and continued fencing and water development that spread negative impacts over an ever greater portion of the landscape. We suggest that conservation of sage-grouse populations in reasonable numbers well distributed across their historical ranges also will provide substantial benefits for many, or even most, other bird species that co-occur with these grouse. Given that more than 57 percent of this habitat is in public ownership and that concern for the future of sage-grouse continues to build, we have all the information and opportunity we need to take action. Indeed, if we cannot successfully conserve sage-grouse and the sagebrush ecosystem in the US given our theory, our knowledge, and our large blocks of public land, then one wonders how we can succeed for other species elsewhere.

Key words: Artemisia, Columbia Plateau, conservation plans, Great Basin, Greater Sage-grouse, landbirds, Partners in Flight, population trends, public land, sagebrush.

Introduction

In this paper, we summarize species assessments (Carter et al. 2000) and conservation planning for priority birds of sagebrush ecosystems, particularly from Partners in Flight (Bonny et al. 2000, Rich et al. 2004) and the Interior Columbia Basin Ecosystem Management Project (Wisdom et al. 2000). We also present some new analyses on population trends, habitat trends, and the concept of using Greater Sage-

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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grouse (*Centrocercus urophasianus*) and Gunnison Sage-grouse (*C. minimus*) as umbrella species (Caro and O'Doherty 1999) for the sagebrush avifauna. We conclude by suggesting that, because much of the sagebrush ecosystem still exists in very large blocks and is managed by public land agencies, notably the U.S. Bureau of Land Management, and because a substantial amount of planning has already been done using the best available science, we have an excellent opportunity to implement true multi-species, ecosystem management (Odam and Wiens 2002, Groves 2003) to protect and restore portions of this ecosystem and its avifauna.

Sagebrush ecosystems, dominated by various species of woody *Artemisia*, occupy over 62,000,000 ha of the western US (Küchler 1970, West and Young 2000). Losses from the historical extent of these ecosystems have been substantial (Tisdale and Hironaka 1981, Miller and Eddleman 2000, Knick et al. 2003). For example, Hann et al. (1997) estimated that over 30 percent of the sagebrush vegetation in the Interior Columbia Basin has been converted to agriculture, dominated by exotic invasive plants or otherwise lost. West-wide, sagebrush has been degraded or completely eliminated by agricultural conversion (Hann et al. 1997), overgrazing by domestic livestock (Vale 1975, Fleischner 1994, Young 1994, Donahue 1999, West and Young 2000), invasion of exotic plants (Mack 1981, Yensen 1981, Wisdom et al. 2000), expansion of pinyon and juniper woodlands (Miller and Rose 1999), uncharacteristic wild fires (Pellant 1990, Whisenant 1990, Johansen et al. 1993) and fragmentation (Knick and Rotenberry 1995, Hann et al. 1997, Wisdom et al. 2000).

This habitat loss has led to an increasing number of special status species. Rich (unpubl.) compiled a list of 630 plant and animal species of conservation concern that depend on sagebrush ecosystems. These include species identified by the U.S. Bureau of Land Management, Partners in Flight (Paige and Ritter 1999), the Interior Columbia Basin Ecosystem Management Project (Saab and Rich 1997, Wisdom et al. 2000), the Nature Conservancy (Nachlinger et al. 2001) and Defenders of Wildlife (Defenders of Wildlife 1998).

Concern over the status of sagebrush bird communities as the result of multiple impacts was first recognized by Braun et al. (1976). More recently, several species–Greater Sage-grouse, Gunnison Sage-grouse, Columbian Sharp-tailed Grouse (*Tympanuchus phasianellus columbianus*), Mountain Quail (*Oreortyx pictus*) and Loggerhead Shrike (*Lanius ludovicianus*)–have become of great concern to various coalitions of conservation activists. Partners in Flight (PIF) identified five species for the continental Watch List (Rich et al. 2004)–Swainson's Hawk (*Buteo swainsoni*), both sage grouse, the Short-eared Owl (*Asio flammeus*) and Brewer's Sparrow (*Spizella breweri*)–which places them among the highest priority species for conservation action in North America. Rich et al. (2004) also identified six additional Stewardship Species–Gray Flycatcher (*Empidonax wrightii*), Sage Thrasher (*Oreoscoptes montanus*), Green-tailed Towhee (*Pipilo chlorurus*), Black-throated Sparrow (*Amphispiza bilineata*), Sage Sparrow (*A. belli*), and Grasshopper Sparrow (*Ammodramus savannarum*). Stewardship Species have a high percentage of their entire global population within a relatively limited geographic area. Management entities are encouraged to particularly consider needs of these species in land use planning and conservation action.

Management recommendations for birds of sagebrush ecosystems can be found in a variety of recent publications (Dobkin 1995; Paige and Ritter 1998; Bureau of Land Management 2000; Connelly et al. 2000; Wisdom et al. 2002a, 2002b; Knick et al. 2003). Rich et al. (2004) provide continental population estimates and objectives for PIF Watch List and Stewardship Species while PIF Bird Conservation Plans for the western states provide detailed management recommendations at the state level (Neel 1999, Altman and Holmes 2000, Beidleman 2000, Casey 2000, Ritter 2000, Cerovski et al. 2001). Underlying these conservation-oriented accounts is a substantial theoretical base on sagebrush bird populations and ecology (e.g., Rotenberry and Wiens 1980, 1989, 1991; Wiens and Rotenberry 1981, 1985).

In this paper, we focus on the 22 taxa of sagebrush associated birds (*table 1*) identified by Paige and Ritter (1998). These range from sagebrush obligates–Greater Sage-grouse, Gunnison Sage-grouse, Sage Thrasher, Sage Sparrow, Brewer's Sparrow–whose historical ranges were closely tied to the distribution of woody *Artemisia*, to species more typically associated with grasslands and whose historical ranges are very broad in North America, such as the Short-eared Owl and Vesper Sparrow (*Pooecetes gramineus*). Grassland species are of interest because they are widespread in sagebrush vegetation and they help us understand the status of the important grass component of those ecosystems.

Table 1— *Priority bird species of sagebrush habitats and geographic areas where they are a priority.*

Species[a,b]	Scientific name	Birds of North America reference	Sagebrush ecosystems (Paige and Ritter 1998)	Interior Columbia Basin[c] (Wisdom et al. 2000)	Idaho[c] (Ritter 2000)	Montana[c] (Casey 2000)	Nevada[c] (Neel 1999)	Columbia Plateau[c] (Altman and Holmes 2000)	Colorado[c] (Beidleman 2000)	Wyoming[c] (Cerovski 2001)
Swainson's Hawk	*Buteo swainsoni*	England et al. 1997	x		x	x	x		x	
Ferruginous Hawk	*Buteo regalis*	Bechard and Schmutz 1995	x		x	x	x	x	x	x
Prairie Falcon	*Falco mexicanus*	Steenhof 1998	x		x		x		x	
Greater Sage-grouse	*Centrocercus urophasianus*	Schroeder and Braun 1999	x	x	x	x	x	x	x	
Gunnison Sage-grouse	*Centrocercus minimus*	Schroeder and Braun 1999	x	[d]	[d]	[d]	[d]	[d]	x	[d]
Columbian Sharp-tailed Grouse	*Tympanuchus phasianellus columbianus*	Connelly et al. 1998	x	x	x	x	[e]	x		
Long-billed Curlew	*Numenius americanus*	Dugger and Dugger 2002	x		x	x	x		x	x
Burrowing Owl	*Athene cunicularia*	Haug et al. 1993	x	x		x	x	x	x	x
Short-eared Owl	*Asio flammeus*	Holt and Leasure 1993	x	x	x	x	x		x	x
Gray Flycatcher	*Empidonax wrightii*	Sterling 1999	x		x		x		x	
Loggerhead Shrike	*Lanius ludovicianus*	Yosef 1996	x	x	x	x	x	x	x	x
Horned Lark	*Eremophila alpestris*	Beason 1995	x						x	
Rock Wren	*Salpinctes obsoletus*	Lowther et al. 486	x		x					
Sage Thrasher	*Oreoscoptes montanus*	Reynolds et al. 1999	x	x	x	x	x	x		x
Green-tailed Towhee	*Pipilo chlorurus*	Dobbs et al. 1998	x			x			x	
Brewer's Sparrow	*Spizella breweri*	Rotenberry et al. 1999	x	x	x	x		x	x	x

Table 1— *(contd.)*

Species[a,b]	Scientific name	Birds of North America reference	Sagebrush ecosystems (Paige and Ritter 1998)	Interior Columbia Basin[c] (Wisdom et al. 2000)	Idaho[c] (Ritter 2000)	Montana[c] (Casey 2000)	Nevada[c] (Neel 1999)	Columbia Plateau[c] (Altman and Holmes 2000)	Colorado[c] (Beidleman 2000)	Wyoming[c] (Cerovski 2001)
Vesper Sparrow	*Pooecetes gramineus*	Jones and Cornely 2002	x	x			x			x
Lark Sparrow	*Chondestes grammacus*	Martin and Parrish 2000	x	x	x	x		x		x
Black-throated Sparrow	*Amphispiza bilineata*	Johnson et al. 2002	x	x		[d]		x		
Sage Sparrow	*Amphispiza belli*	Martin and Carlson 1998	x	x	x		x	x	x	x
Grasshopper Sparrow	*Ammodramus savannarum*	Vickery 1996	x	x	x	x		x	x	x
Western Meadowlark	*Sturnella neglecta*	Lanyon 1994	x	x						

[a]Species in bold are on the Partners in Flight continental Watch List (Rich et al. 2004).
[b]Species in italics are on the Partners in Flight Stewardship Species list (Rich et al. 2004).
[c]Blanks indicate that species was not listed as a priority in subject reference.
[d]Species or subspecies does not occur in area covered by reference.
[e]Historical occurrence uncertain.

We also examine the extent to which sage grouse may serve as classic umbrella species (Caro and O'Doherty 1999) for shrubsteppe avifauna. Because of long-term population declines and habitat loss, it is likely that significant conservation actions will be taken to conserve the two species of sage-grouse. We believe it is important to understand how many other species of concern might benefit from such actions, and to what degree. Then, actions can be designed to be effective for substantial components of the ecosystem rather than just for single species. Although our interest here is in other bird species, we encourage exploration of multi-species approaches that also benefit other animal and plant taxa.

Finally, opportunities to conserve these birds and their habitats are particularly good because much of the sagebrush ecosystem is public land–land belonging to all American citizens–and is managed by the U.S. Bureau of Land Management (BLM). In fact, BLM manages 22,389,000 ha of sagebrush, which includes 57 percent of the entire ecosystem (Schueck, pers. comm.). We further suggest that the broad scale land management actions of BLM may provide information useful in examining the current condition of sagebrush habitats, particularly in regard to grazing of domestic livestock. The construction of fences and the provision of water through pipelines, for example, reveal the degree to which public land is managed to accommodate livestock in landscapes and habitats where livestock grazing could not otherwise occur. We suggest that the continual expansion of livestock grazing across the public lands of western landscapes has impacted and will continue to impact the quality of those habitats and their ability to support source populations of sagebrush bird species.

Methods

Data used in the analysis of species co-occurrence come from the "State-Province Abundance Checklists" of the Breeding Bird Survey (BBS; Sauer et al. 2001). Data consist of the mean relative abundances of sagebrush-associated bird species over the period 1966-1996 in each state-physiographic unit defined by the BBS. These units consist of that portion of a BBS

physiographic strata, (e.g., Columbia Plateau), that occurred within a given state. There were 52 such units.

Statistical analyses were conducted on the relative abundances of only those species that had sufficient sample sizes. A sample size was considered sufficient if there were non-zero relative abundances in at least 27 of the units. While the non-occurrence of a species in this context does constitute useful information, we wanted to avoid inflating the correlations with large counts of zero relative abundance. This screen excluded the Grasshopper Sparrow and Columbian Sharp-tailed Grouse from this analysis. Data for the newly-described Gunnison Sage-grouse are combined with those for Greater Sage-grouse so no analysis for this species was possible. Nineteen species remained for further analysis.

Inspection of these relative abundance data revealed that the square-root transformation (Zar 1996) was appropriate to produce normal distributions. Variances were approximately homogeneous. A correlation matrix was produced among species with sufficient sample sizes and an exploratory factor analysis with varimax rotation was run in which the factors were defined by the loadings of particular species. Analyses were conducted in which the number of factors was set to 14, 12, 10, 8, 6, and 4, respectively. This approach created progressively fewer groupings of species and allowed the examination of how robust the species associations were as the number of factors was reduced (Rich 2002). Statistical analyses were conducted with Statgraphics® Plus software (Manugistics 1992).

Historic and current population sizes for selected sagebrush steppe bird species in the Columbia Plateau were calculated using historical and current habitat areas from Wisdom et al. (2000). Historical bird population sizes were estimated by multiplying the historical habitat area by the maximum density for the species reported in the Birds of North America series (references in *table 1*) and/or reported by Wiens and Rotenberry (1981). We assumed that during the historic period, population densities for all species were at least as high as the highest densities known from recent studies. Because all habitats are degraded from historic conditions (Wisdom et al. 2000), we reasoned that this was actually a conservative estimate.

Current bird population sizes were estimated by multiplying the current habitat area (Wisdom et al. 2000) by an estimate of current bird density based on BBS data (Sauer et al. 2001) and a method by which BBS data can be converted to densities (Rosenberg and Blancher this volume). Historic population trends (r) were then calculated for those species for which historical and current population estimates could be made for the Columbia Plateau. Trends were calculated using the equation $N_t = N_0 * e^{rt}$ where N_t is the estimated current population size, N_0 was the estimated population size in 1850, e is the base of natural logarithms, r was the annual rate of change, and t was 151 years. Rates also were calculated for changes in the population size both 10 times and one-tenth that estimated to provide perspective on how sensitive r was to the population estimates.

Results

Sagebrush Steppe Species of Concern

Twenty-one species and one subspecies in the western US are priorities in Partners in Flight Bird Conservation Plans (Paige and Ritter 1998) or in regional assessments (see Carter et al. 2000, Panjabi et al. 2001 for assessment methodology) for some part of the sagebrush ecosystem (*table 1*). Although most of these species appear on most state and regional priority lists, only the relatively widespread Loggerhead Shrike was of concern in all eight of the analyses listed. All of the widespread sagebrush obligates–Greater Sage-grouse, Sage Thrasher, Brewer's Sparrow, and Sage Sparrow–were of concern in seven of eight analyses, but there also were four species of grassland birds of concern in seven of eight analyses–Ferruginous Hawk (*Buteo regalis*), Burrowing Owl (*Athene cunicularia*), Short-eared Owl, and Grasshopper Sparrow.

In addition to assessment at the state level, PIF has species assessment scores for the breeding season for each of the relevant Bird Conservation Regions (North American Bird Conservation Initiative (2000). Among the 22 taxa of interest here, none differed by more than 3 points among the three Bird Conservation Regions (BCRs) in question (*table 2*). These scores show the two species of sage-grouse to be of highest concern. Only the widespread grassland species–Vesper Sparrow, Western Meadowlark (*Sturnella neglecta*) and Horned Lark (*Eremophila alpestris*)–scored uniformly lower across the three BCRs.

Co-occurrence of Sagebrush Species

The degree to which species co-occur at spatial scales from the territory to the continent help us determine how to design, or even if we can design, management strategies for multiple species at those different scales. We chose to examine co-occurrence from the perspective of sage-grouse because significant comprehensive conservation actions are likely to be taken for these species. Thus, we need some understanding of how other species co-occur with grouse.

Table 2— *Bird Conservation Region Scores for priority bird species of sagebrush habitats. Maximum possible score is 35; minimum is 7.*

	Bird Conservation Region		
Species	**Northern Rockies**	**Great Basin**	**Southern Rockies/ Colorado Plateau**
Swainson's Hawk	22	21	22
Ferruginous Hawk	23	23	20
Prairie Falcon	22	25	23
Greater Sage-grouse	25	24	22
Gunnison Sage-grouse	[a]	[a]	35
Columbian Sharp-tailed Grouse	[b]	[b]	[b]
Long-billed Curlew	21	21	20
Burrowing Owl	18	17	19
Short-eared Owl	19	21	19
Gray Flycatcher	21	21	22
Loggerhead Shrike	19	19	18
Horned Lark	12	14	13
Rock Wren	18	17	19
Sage Thrasher	19	19	18
Green-tailed Towhee	21	19	21
Brewer's Sparrow	22	24	21
Vesper Sparrow	16	16	16
Lark Sparrow	17	19	18
Black-throated Sparrow	18	20	20
Sage Sparrow	21	22	23
Grasshopper Sparrow	19	19	16
Western Meadowlark	15	16	14

[a]Species does not occur in BCR.
[b]Scoring for subspecies not complete.

At the largest spatial scale, the overlap of the breeding ranges of other priority species with Greater Sage-grouse varied from a maximum of 68 percent for Sage Sparrow and Sage Thrasher to a minimum of 0 percent for Gunnison Sage-grouse (*table 3*). Note that no measurement was available for the Columbian Sharp-tailed Grouse subspecies. Birds with an affinity for sagebrush or other western shrubs had the highest overlaps, but both the Long-billed Curlew (*Numenius americanus*) and Ferruginous Hawk had a greater overlap than Brewer's Sparrow. In the Interior Columbia Basin (Wisdom et al. 2000) overlap of historical source habitats between the Greater Sage-grouse and three other species of sagebrush obligate birds was estimated to be: Sage Sparrow (99 percent), Sage Thrasher (94 percent), and Brewer's Sparrow (94 percent).

At a finer spatial scale, we can examine the co-occurrence of these species in the 52 state/physiographic units defined by the BBS (see Methods). Note that correlations among relative abundances measure overlap of both spatial distribution and frequency of occurrence. Among the 19 species with sufficient sample sizes from the BBS, there was a high level of species co-occurrence over the period 1966-1996. The total number of correlations among species pairs was 171 (19x18/2) and we would expect 8.55 of these to be significant at P = 0.05 by chance alone. The actual number of significant correlations was 83, thereby quantifying the simple fact that these species tend to occur together at a high level.

Of particular interest were the significant correlations between the relative abundances of ten species (with sufficient sample sizes) with the relative abundance of sage-grouse (*table 4*). Grouse often are not considered to be well monitored by the BBS, yet these correlations are all ecologically reasonable. Sage Thrasher and Brewer's Sparrow showed the highest correlations but three species with grassland affinities–Short-eared Owl, Vesper Sparrow, and Western Meadowlark–also co-occurred at a significant level. The significant association with the Green-tailed Towhee also is instructive as that species typically uses mixed shrub habitats with species such as *Artemisia tridentata vaseyena*, *Purshia tridentata*, and *Ceonothus* spp., which are typically found at higher elevations. Notably, Vesper Sparrow–a grassland bird also found at higher elevations–had a higher correlation (r = 0.50) than Sage Sparrow (r = 0.47).

Table 3— *Area of overlap between the breeding range of Greater Sage-grouse and that of other priority sagebrush bird species.*

Species	North American breeding range (km^2)	Area of overlap with Greater Sage-grouse (km^2)	Percent of range overlapped (%)
Greater Sage-grouse	1,407,570	1,407,570	100
Sage Sparrow	1,087,917	738,387	68
Sage Thrasher	1,752,253	1,188,765	68
Gray Flycatcher	1,143,281	701,065	61
Green-tailed Towhee	1,735,138	1,006,463	58
Long-billed Curlew	2,069,362	1,070,270	52
Ferruginous Hawk	2,435,562	1,153,358	47
Brewer's Sparrow	3,221,685	1,392,172	43
Prairie Falcon	3,793,501	1,400,717	37
Rock Wren	5,419,745	1,403,572	26
Lark Sparrow	5,600,839	1,345,393	24
Black-throated Sparrow	2,834,537	679,578	24
Burrowing Owl	5,613,560	1,334,432	24
Western Meadowlark	6,708,163	1,407,570	21
Swainson's Hawk	7,465,918	1,407,570	19
Vesper Sparrow	7,375,124	1,375,608	19
Loggerhead Shrike	8,850,519	1,372,587	16
Grasshopper Sparrow	5,207,266	558,885	11
Sharp-tailed Grouse[a]	6,044,256	574,991	10
Horned Lark	15,593,137	1,405,630	9
Short-eared Owl	12,417,599	964,000	8
Gunnison Sage-grouse		0	0

[a]Measurements are for the full species.

Table 4— *Correlations between the relative abundance of sage grouse and that of other co-occurring sagebrush species in the western US. (N = 52).*

Species	R	P
Sage Thrasher	0.71	< 0.001
Brewer's Sparrow	0.63	< 0.001
Vesper Sparrow	0.50	< 0.001
Sage Sparrow	0.47	< 0.001
Gray Flycatcher	0.38	< 0.01
Green-tailed Towhee	0.37	< 0.01
Rock Wren	0.36	< 0.01
Western Meadowlark	0.31	< 0.05
Prairie Falcon	0.29	< 0.05
Short-eared Owl	0.29	< 0.05

A comparison of the proportion of range overlap (*table 3*) with the correlations of relative abundance (*table 4*) suggests that those correlations are not simply a direct function of area overlap. Proportion of range overlap does not explain a significant amount of the variation in relative abundance correlation ($R^2 = 0.24$, $F = 2.51$, $P = 0.15$).

In the exploratory factor analysis of the relative abundance correlation matrix, species groups were defined by those species that had high loadings (>0.70) on a particular factor. For example, for the analysis with 14 factors, 11 different groups were defined (*fig. 1*). As the number of factors in the analysis was reduced, species were consolidated into progressively fewer groups.

The Burrowing Owl, Short-eared Owl, Prairie Falcon, and Green-tailed Towhee tended to maintain their individual axes. That is, their patterns each maintained a large degree of independence from the other groups. Although three of the sagebrush obligates–Sage Thrasher, Brewer's Sparrow, Sage Sparrow–formed a coherent group from the beginning with Gray Flycatcher and Rock Wren, sage-grouse were not part of that group. Rather, sage-grouse relative abundance aligned more closely with the Vesper Sparrow, repeating an association revealed in previous analyses of these data. The Black-throated Sparrow and Loggerhead Shrike also showed a consistent association, independent of the other groups.

Recent Population Trends

Population trends were available for three major physiographic strata defined by the BBS that encompass sagebrush ecosystems–the Columbia Plateau, Wyoming Basin and Basin and Range (*fig. 2*). None of the species in this analysis showed significant trends in

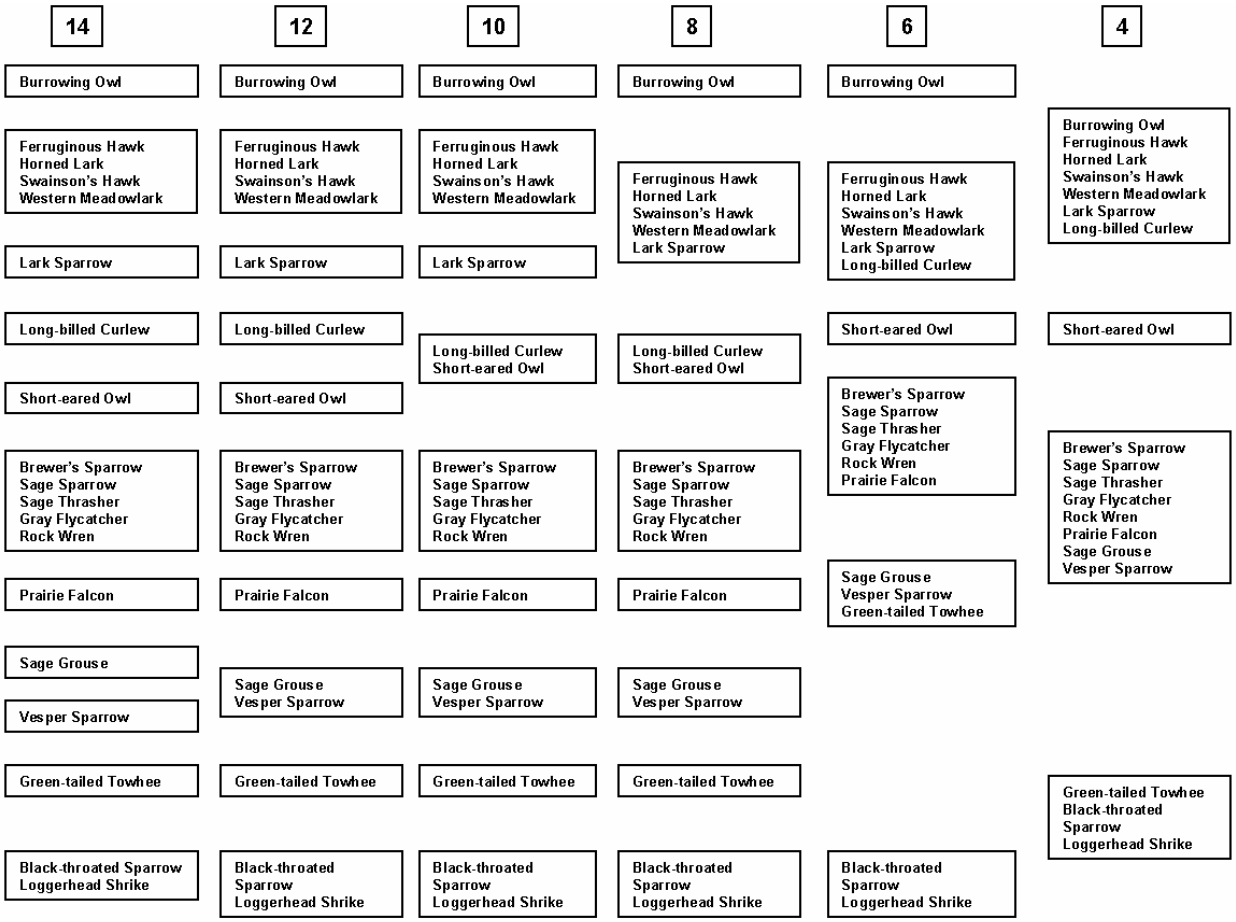

Figure 1— Groups defined by a factor analysis, from 16 to 4 factors, of the relative abundance data from the Breeding Bird Survey for 19 species of sagebrush bird species during the breeding season in the western United States.

all three strata (*table 5*). The Loggerhead Shrike and Grasshopper Sparrow both showed significant or nearly significant declines in two of the strata, although the combination of marginal P values and only fair or poor coverage made those trends weak. The BBS is conventionally not considered to be an effective tool for long-term trend monitoring of grouse, particularly at the finer scales of the physiographic strata, and other sources of data must be used. According to Braun (1998), Schoeder et al. (1999) and Connelly et al. (2000), both species of sage-grouse have declined steadily and have certainly shown significant declines range-wide since 1966.

In the Wyoming Basin, only the Grasshopper Sparrow showed a significant trend. And although that species apparently has had a precipitous decrease, the BBS coverage is rated as poor. In the Basin and Range physiographic strata, both the Short-eared Owl and Sage Sparrow had significant increases while the Loggerhead Shrike showed the only significant decline.

All the other clear trends were in the Columbia Plateau, with 10 of the 21 taxa occurring there–in addition to Greater Sage-grouse–having significant, or nearly significant, population trends. BBS coverage was good for seven species. Eight of the ten showed declining trends and two, increasing. Habitat associations for declining species include both sagebrush and grassland types. Habitat associations for the two increasing species, the Long-billed Curlew and Burrowing Owl, were similar–grassland types with low-stature vegetation and few shrubs.

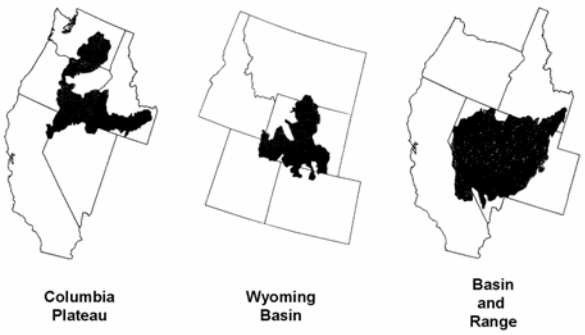

Figure 2— The Columbia Plateau, Wyoming Basin, and Basin and Range physiographic strata from the Breeding Bird Survey.

Table 5— *Population trends (1966-2001), significance and data quality from the Breeding Bird Survey for three physiographic areas.*

	Columbia Plateau			Basin and Range			Wyoming Basin		
Common Name	**Trend (%/yr)**	**P**	**Quality**	**Trend (%/yr)**	**P**	**Quality**	**Trend (%/yr)**	**P**	**Quality**
Swainson's hawk	4.20	0.35	fair	3.80	0.19	fair	-4.60	0.42	poor
Ferruginous hawk	1.80	0.27	poor	5.50	0.28	poor	5.50	0.28	poor
Prairie falcon	-4.10	0.25	poor	-1.30	0.90	poor	19.10	0.20	poor
Greater Sage-grouse	-13.8	0.12	poor	3.50	0.87	poor	2.00	0.62	fair
Gunnison Sage-grouse	[a]			[a]			[a]		
Columbian Sharp-tailed Grouse	[b]			[b]			[a]		
Long-billed curlew	**4.00**[c]	**0.01**	**good**	[a]			26.00	0.50	poor
Burrowing owl	**13.10**	**0.07**	**poor**	11.90	0.17	poor	-24.80	0.56	poor
Short-eared owl	-0.6	0.72	fair	**14.80**	**0.00**	**poor**	[a]		
Gray flycatcher	4.60	0.25	poor	1.00	0.87	poor	[a]		
Loggerhead shrike	**-2.7**	**0.00**	**good**	**-3.00**	**0.09**	**fair**	-7.20	0.14	fair
Horned Lark	**-3.3**	**0.00**	**good**	1.10	0.28	good	-0.90	0.48	good
Rock Wren	**-1.6**	**0.08**	**good**	-0.80	0.78	fair	1.10	0.65	good
Sage thrasher	0.20	0.81	fair	-0.70	0.39	good	0.90	0.62	good
Green-tailed towhee	1.50	0.68	poor	-0.10	0.97	good	-3.20	0.35	fair
Brewer's sparrow	**-3.8**	**0.01**	**good**	-0.50	0.78	good	-0.30	0.78	good
Vesper sparrow	-0.2	0.77	good	-0.50	0.59	good	0.30	0.88	fair
Lark sparrow	**-2.2**	**0.05**	**good**	0.80	0.59	good	-0.60	0.86	fair
Black-throated sparrow	**-10.60**	**0.05**	**poor**	0.50	0.75	good	a		
Sage sparrow	1.90	0.65	fair	**4.10**	**0.10**	**fair**	0.90	0.72	good
Grasshopper Sparrow	**-4.80**	**0.01**	**good**	15.60	0.18	poor	**-41.40**	**0.02**	**poor**
Western Meadowlark	**-0.80**	**0.08**	**fair**	1.90	0.14	good	-0.30	0.87	fair

[a]Taxon does not occur in physiographic strata.
[b]Taxon not sampled by BBS.
[c]Trends at P <= 0.10 are in bold.

Table 6— *Estimated historic and current population sizes and estimated historic population trends (1850-2001) for selected species in the Columbia Plateau physiographic area.*

Species	Maximum historic population size estimate		Current population size estimate	Rate of change (r) based on BNA	For change 10x greater	For change 10x less	Rate of change (r) based on W&R 1981	For change 10x greater	For change 10x less
	Densities from BNA accounts	Densities from W&R 1981[a]							
Greater Sage-grouse	5,183,460		14,533	-0.0389	-0.0542	-0.0237			
Columbian Sharp-tailed Grouse	341,040		5,396	-0.0275	-0.0427	-0.0122			
Short-eared Owl	4,047,936		11,953	-0.0386	-0.0538	-0.0233			
Loggerhead Shrike		1,386,780	39,772				-0.0235	-0.0388	-0.0083
Sage Thrasher	31,083,360	10,949,820	939,786	-0.0232	-0.0384	-0.0079	-0.0163	-0.0315	-0.0010
Brewer's Sparrow		175,282,380	1,077,626				-0.0337	-0.0490	-0.0185
Vesper Sparrow		7,378,644	397,836				-0.0193	-0.0346	-0.0041
Lark Sparrow	61,677,200	10,176,738	100,713	-0.0425	-0.0578	-0.0273	-0.0306	-0.0458	-0.0153
Black-throated Sparrow		31,361,644	69,769				-0.0405	-0.0557	-0.0252
Sage Sparrow		77,423,736	346,940				-0.0358	-0.0511	-0.0206
Grasshopper Sparrow	98,692,800		9,703	-0.0611	-0.0764	-0.0459			
Western Meadowlark		27,969,920	2,584,435				-0.0158	-0.0310	-0.0005

[a]Wiens and Rotenberry 1981.

Historic and Current Population Sizes for the Columbia Plateau

Population size estimation involves many assumptions and we propose the following historic and current estimates only as a starting point for further dialogues. Historic (1850) and current population sizes (*table 6*) were estimated for 12 priority taxa in the Interior Columbia Basin based on predicted areas of historic and current source habitat (Wisdom et al. 2000). The habitat and population estimates should be viewed with caution because an accuracy assessment of the vegetation classification was not conducted. According to these estimates, the largest historic population was for Brewer's Sparrow with an estimated size of 175,282,380 birds (*table 6*). The Columbian Sharp-tailed Grouse had the smallest estimated population–341,040.

Estimated current population sizes (*table 6*) are, not surprisingly, drastically reduced from historic numbers. The Western Meadowlark showed the least reduction with a current population estimate of 2,584,435 birds, about 9 percent of its historic size. It has apparently replaced the Brewer's Sparrow as the most abundant bird in the Interior Columbia Basin, among those species considered here. At the other extreme, the Grasshopper Sparrow was estimated to have been reduced to only 0.000098 of its historic population size. Only the Columbian Sharp-tailed Grouse is estimated to have a lower total population size.

Historic Population Trends for the Columbia Plateau

Historic population declines necessary to produce the changes from estimated historic to estimated current numbers were highest for the Grasshopper Sparrow at -6.1 percent/yr (*table 6*). For a change an order of magnitude less, the rate would have been -4.6 percent/yr, and for an order of magnitude more, -7.6 percent/yr. Declines were estimated to have been least for the Western Meadowlark at -1.6 percent/yr (*table 6*).

For six of the species that had significant or near significant declines in the Columbia Plateau physiographic strata since 1966, and for which we have historic and current habitat estimates–Loggerhead Shrike, Brewer's Sparrow, Lark Sparrow, Black-throated Sparrow, Grasshopper Sparrow and Western Meadowlark – the estimated historical declines were all remarkably similar to recent trends from the BBS (*table 5*). In fact, rates for the Loggerhead Shrike and Brewer's Sparrow were nearly identical. We emphasize that the estimates of current and historical declines were independent.

Habitat Trends for the Columbia Plateau

Public Land Statistics (PLS; e.g., Bureau of Land Management 2001) report several statistics annually that provide some insight into habitat trends on public land in the West and, for this paper, the Columbia Plateau. To our knowledge, the long-term patterns in these statistics have never been examined. Although these statistics are reported by state, rather than by ecoregion, they were nonetheless easily correlated with various physiographic areas for broad-scale considerations. PLS data for "non-forest" BLM lands in the states of Idaho, Oregon, and Washington align well with the Columbia Plateau (*fig. 2*).

Trends in the Area Burned by Fire

The area of non-forest BLM land burned annually provides a strong indication, not only of the loss of sagebrush, but also the spread of exotic cheatgrass (*Bromus tectorum*) and other invasive plants in the region. The area burned has varied greatly from 1946 to 2000 (*fig. 3*), including a minimum of 3,255 ha in 1956 and a maximum of 322,974 ha in 1996. Most importantly, the area burned annually has increased significantly over time ($Y = -2.1*10^6 + 1100X$, $P = 0.02$).

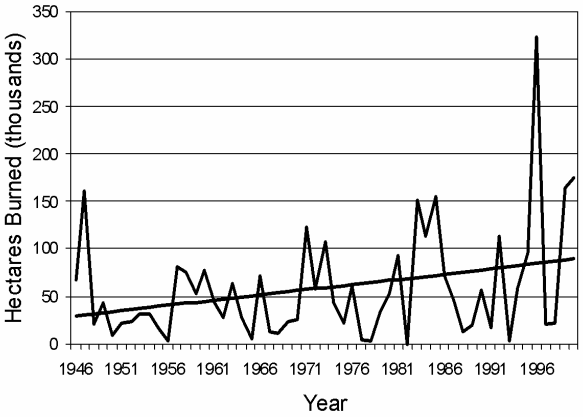

Figure 3— Number of hectares of non-forest land managed by the U.S. Bureau of Land Management that was burned in each year in Idaho, Oregon, and Washington. The linear regression is significant ($Y = -2.1*10^6 + 1100X$, $P = 0.02$).

Trends in Livestock Grazing

The number of livestock on BLM lands is reported in Animal Unit Months (AUMs), which is one cow and one calf for one month. Cattle AUMs in Idaho, Oregon, and Washington on BLM lands have varied little over the period from 1949 to 2000 (*fig. 4*). A low of 1,554,081 AUMs was reported in 1993 while the peak was 2,056,629 in 1985. There were actually more AUMs on the public lands in these states in 2000 than in 1949, when records were begun. The noteworthy point is that AUMs have remained roughly the same for the past half-century, contrary to the conventional wisdom that cattle numbers on public land have steadily decreased. Further, livestock have been selected so that the mean mass of individuals has increased over time (*fig. 5*). Thus, the total grazing impact on the vegetation and other resources is substantially greater than it was historically.

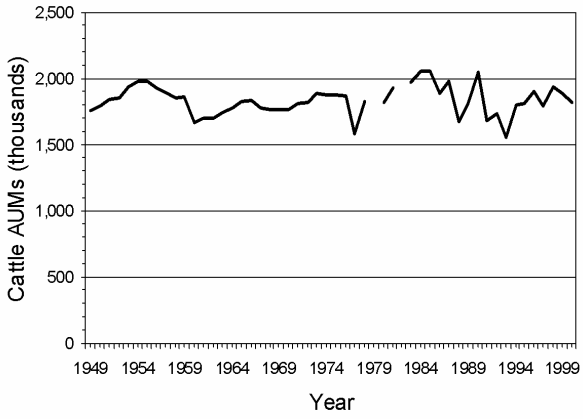

Figure 4— Number of cattle Animal Unit Months (AUMs) permitted each year on land managed by the U.S. Bureau of Land Management in Idaho, Oregon, and Washington.

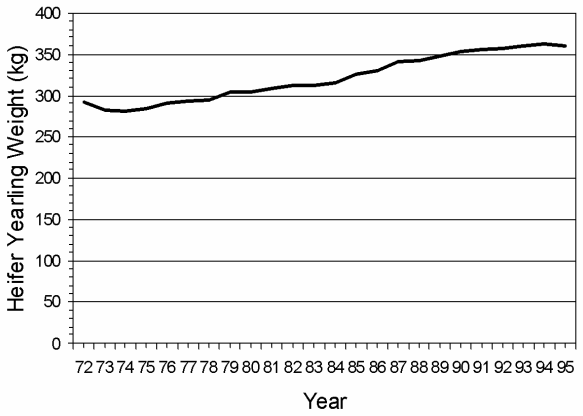

Figure 5— Mean weight of yearling hereford heifers in the Rocky Mountain region from 1972 to 1995. The sample size averages 6250 individuals per year.

Trends in the Supply of Water to Livestock in the Uplands

To maintain the numbers of cattle grazing on public lands at essentially constant levels (*fig. 4*) while implementing a policy to greatly improve the condition of riparian areas (Bureau of Land Management 1993), BLM has spread that grazing more broadly across the landscape. This has been accomplished by two practices–by providing water to upland areas that do not have natural water supplies and by building fences to prevent cattle from leaving those upland areas. The

kilometers of water pipeline built in the three-state area on BLM lands was highest in the 1960s and 1970s (*fig. 6*). However, pipelines continue to be constructed on public lands to date, with over 740 km built over the last decade in Idaho, Oregon and Washington.

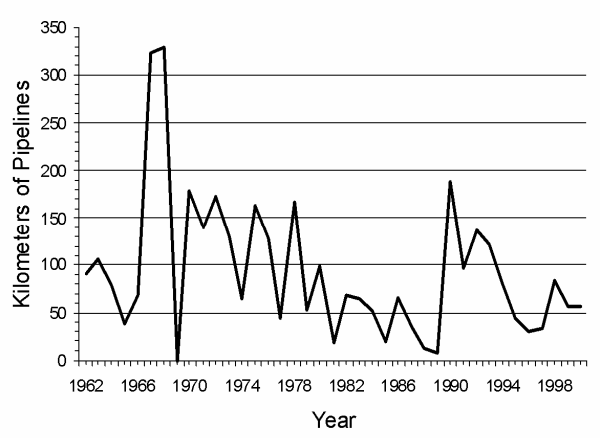

Figure 6— Kilometers of pipeline built each year on land managed by the U.S. Bureau of Land Management in Idaho, Oregon, and Washington.

In a related activity, natural springs have been "developed" to provide water for livestock. This process typically involves installing a structure to capture the natural flow of water to put it into a pipeline or off-site trough for cattle. As with the construction of pipelines, spring development was highest in the 1960s and 1970s but the process continues (*fig. 7*). In the past decade, 1991-2000, 218 springs were developed in the region.

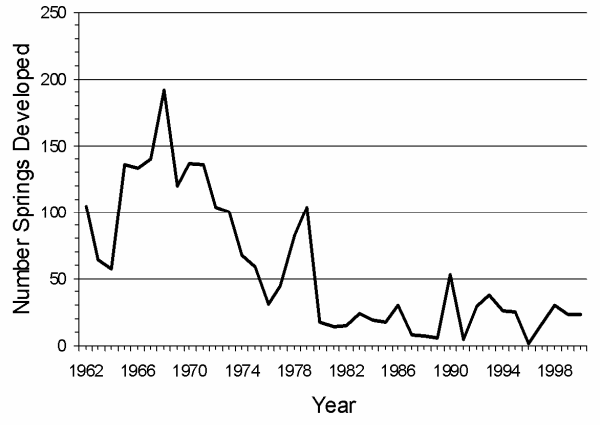

Figure 7— Number of springs developed each year on land managed by the U.S. Bureau of Land Management in Idaho, Oregon, and Washington.

Trends in Fencing

Because cattle are notorious both for staying in the bottoms of valleys and returning to those bottoms once herded higher on slopes, it is necessary to construct fences to keep cattle away from bottoms, streams, and riparian vegetation. As with both the building of pipelines and the development of springs, fence building on BLM lands in Idaho, Oregon, and Washington peaked in the 1960s (*fig. 8*). However, fence building has again increased noticeably over the last decade. The 434 km built in 1998 was the most in a single year since 1973.

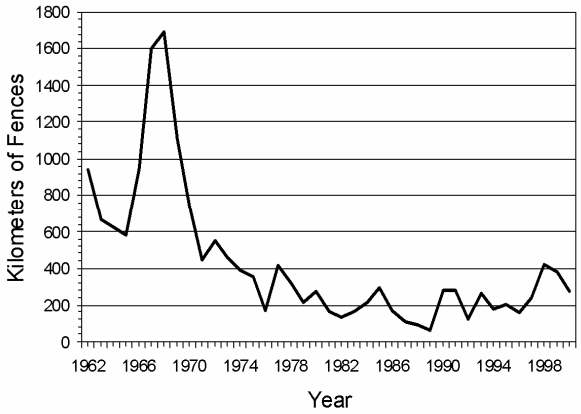

Figure 8— Kilometers of fence built each year on land managed by the U.S. Bureau of Land Management in Idaho, Oregon, and Washington.

Palatability and Conservation Status of Forbs

In sagebrush ecosystems, 431 species of forbs were of management concern to various agencies and non-governmental organizations in 2000 (Rich, unpubl. data). These forbs can be ranked by their palatability to wildlife as good, fair, or poor (Rosentreter, pers. comm.). The null hypothesis was that equal numbers (143.67) of forb species of conservation concern would occur in each of the three palatability categories. However, the distribution of species (*fig. 9*) was significantly different from expected (X^2 = 67.1, P < 0.001). Far more species of conservation concern were of good palatability, and the number of fair palatability exceeded the number of poor.

Discussion

Habitat loss and other adverse impacts to sagebrush avifauna were first recognized as a widespread problem by Braun et al (1976). Although Greater and Gunnison sage-grouse have received the most attention recently (Dobkin 1995; Connelly et al. 2000; Wisdom et al. 2000, 2002a, 2002b; Knick et al. 2003), several other bird species dependent on sagebrush also are of conservation concern more or less across their ranges (Paige and Ritter 1998, Neel 1999, Altman and Holmes 2000, Beidleman 2000, Casey 2000, Ritter 2000, Cerovski et al. 2001, Rich et al. 2004).

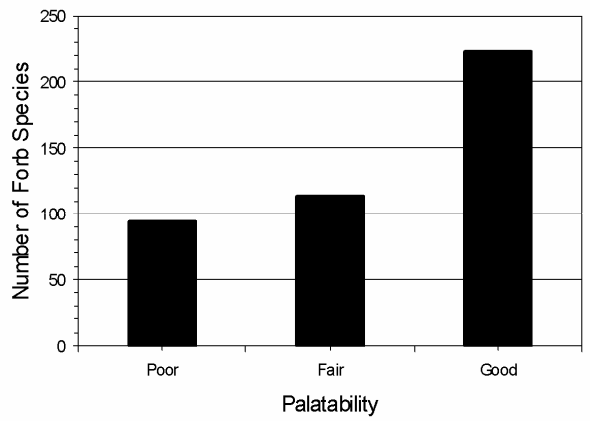

Figure 9—The number of forb species of conservation concern in sagebrush ecosystems with poor, fair, and good palatability to wildlife. The distribution of species is significantly different from the expected even distribution (X^2 = 67.1, P < 0.001).

Sagebrush itself typically provides critical nest sites, perch sites, cover, and even food for these bird species, and thus has been the habitat component most studied over the years. However, it is noteworthy that bird species that depend largely on the grass component of sagebrush systems–Columbian Sharp-tailed Grouse, Long-billed Curlew, Burrowing Owl, Short-eared Owl, Vesper Sparrow, Lark Sparrow, Grasshopper Sparrow, and Western Meadowlark–also are of conservation concern and show clear associations with sage-grouse across the West. Perennial native bunchgrasses such as those in the genera *Agropyron*, *Poa*, *Stipa*, *Festuca*, and *Elymus*, *Pseudoroegneria* and *Oryzopsis* are integral components of sagebrush ecosystems (Vavra et al. 1994, West and Young 2000) that have not always been well examined in bird-habitat relations research. Grasses are important in providing food and cover for birds directly, and in providing a substrate for a volume and diversity of insects which serve as additional food items. The value of grasses in providing cover for successfully nesting sage-grouse has been documented by Connelly et al. (1991).

Data and analysis presented here reveal widespread co-occurrence of sagebrush bird species. Not only do their ranges overlap broadly in western North America, but the relative abundance of various species show high correlations on BBS routes independent of degree of range overlap. This includes the sagebrush obligate and other shrub species as well as those using the grass component of the ecosystem. Even sage-grouse, which are thought to be poorly monitored by the BBS for trend purposes, showed significant correlations with 10 other species, including the grassland species Vesper Sparrow, Western Meadowlark and Short-eared Owl. Perhaps surprisingly, sage-grouse actually aligned most closely with Vesper Sparrow in the factor analysis presented here. Again, this strongly hints at the association of grouse with the grass component of this ecosystem (e.g., Connelly et al. 1991).

Population trend is only one of the seven factors used by PIF to assess the biological status of species in a given geographic area (Carter et al. 2000, Panjabi et al. 2001). Thus, a number of the species of conservation concern (*table 1*) have not necessarily had significantly declining population trends (*table 4*). The Greater Sage-grouse and Loggerhead Shrike are of most concern across the three sagebrush ecoregions (*fig. 2*). But among the other species, there is a clear problem in the Columbia Plateau where eight additional species have declining trends. We believe the reason for this is directly related to the reason that two other species–the Long-billed Curlew and Burrowing Owl–are increasing in the ecoregion. That is the conversion of shrubsteppe habitat to cheatgrass (Wisdom et al. 2000, 2002a, 2002b; Knick et al. 2003). Most native shrubsteppe birds either do not use cheatgrass or occur in much lower densities there (Shaw et al. 1999). Cheatgrass domination produces an open landscape with low-stature vegetation used by the Long-billed Curlew and Burrowing Owl.

The estimates of historical population sizes for selected species presented here for the Columbia Plateau are valuable in helping to establish baseline populations against which to compare current population sizes and future objectives. Not surprisingly, all species' populations are vastly reduced from historic numbers, with the Western Meadowlark declining the least and Grasshopper Sparrows declining the most.

These population estimates also give us an unusual opportunity to estimate historic population trends for these species, trends going back far beyond the 1966-present period of the BBS. These trend estimates depend on the methodology developed to convert BBS data into density estimates (Rosenberg and Blancher this volume) and many assumptions are involved (Rich et al. 2004). Nonetheless, historical trend estimates are perhaps even more valuable than absolute numbers because they provide another baseline with which to compare more recent trends and future trend objectives.

Remarkably, most of the estimated historical population trends are similar to recent trends from the BBS. Because these estimates are independent, they suggest that the trends are real. They also suggest that significant, and relatively steep, declines have been underway for at least 151 years for some species. Doubtless, population trends vary over given periods of time and different factors affecting birds and their habitats come into play. But on the whole, this is not encouraging evidence for these species in this region.

Declines for the Greater Sage-grouse are particularly alarming due to their small current population size (total sage-grouse estimated at 142,000 in 1998 [Braun 1998]) and poor recruitment in recent years. We estimated declines to be 3.89 percent/yr since 1850. This compares to an estimated 1.3 percent/yr for all sage-grouse rangewide over the period 1850-1998 (Braun 1998).

Losses in the historical extent of sagebrush have been estimated for various regions and in various ways (Tisdale and Hironaka 1981, Hann et al. 1997, Miller and Eddleman 2000, Knick et al. 2003). Not only sagebrush itself, but also native grasses have been greatly diminished over the last century by livestock grazing (Mack and Thompson 1982, Fleischner 1994). Negative effects of livestock grazing on birds (Saab et al. 1995) may be substantially due to this impact, although research on the cause-effect relationships is still lacking. Similarly, the fact that at least 431 species of forbs are currently of conservation concern (Rich, unpubl. data, Nachlinger et al. 2001), and that these species tend to be palatable (this paper), suggests that many of these species are far below their historical densities and, possibly, geographic extent. This group of plants has been almost completely ignored by ornithologists in habitat research. The exception is for sage-grouse researchers who have long appreciated the critical role of herbaceous vegetation for food, cover, health of prelaying hens, and juvenile survival (Saab and Marks 1992, Schroeder et al. 1999, Connelly et al. 2000). It seems likely that these forbs also historically provided food and cover directly, and, just as with the perennial bunch grasses, served as substrate for yet another large variety of insects which provide food for adult and young birds of all species.

Data presented here for BLM lands in the Columbia Plateau complement those in Wisdom et al. (2000) which account for the habitat loss and habitat degradation that doubtless continue to contribute to bird population declines. The area of rangeland burned every year is increasing significantly, with a concomitant increase in the area degraded, or completely dominated, by cheatgrass (Hann et al. 1997). The number of cattle AUMs was actually higher in 2000 than in 1949 and the mean weight of these animals has increased by over 20 percent. The evidence suggests that this continuance of livestock grazing is being accommodated by moving cattle out of riparian habitat and into the uplands where impacts on sagebrush birds actually are increasing. BLM has had a policy of improving riparian habitats for many years (Bureau of Land Management 1993). While this goal is critically important and effective for riparian birds (Krueper et al. 2003), we suggest that the steady construction of fences and provision of water through spring development and pipeline construction, is shifting the impacts to the upland habitats where sagebrush species occur. The fact that more palatable species of forbs are more apt to be of conservation concern is consistent with this purported ecological impact.

Many recommendations already have been provided for the conservation of sagebrush landscapes (Mack 1981, Mack and Thompson 1982, Fleischner 1994, Hann et al. 1997, Wisdom et al. 2000, Knick et al. 2003) and birds (Neel 1999, Altman and Holmes 2000, Beidleman 2000, Casey 2000, Ritter 2000, Cerovski et al. 2001). It is not our intent to repeat those here. But of particular interest are recent guidelines for conservation of sage-grouse (Dobkin 1995; Braun 1998; Schroeder et al. 1999; Connelly et al. 2000; Wisdom et al. 2000, 2002a, 2002b). Sage-grouse may serve as classic umbrella species (Caro and O'Doherty 1999) for sagebrush birds and other ecological components of sagebrush ecosystems. According to Caro and O'Doherty (1999), "an umbrella species may be employed as a surrogate to delineate the size of area or type of habitat over which protection should occur." Further, "effective protection of a viable population in this area is assumed to protect populations of other sympatric members of the same guild .... or appreciable parts of the ecosystem..." We suggest that conservation of Greater and Gunnison Sage-grouse populations in reasonable numbers well distributed across their historical ranges also will provide for the conservation of many, or even most, other bird species that co-occur with these grouse.

Sage-grouse populations require expanses of sagebrush habitat with a diverse and substantial understory of native grasses and forbs. Their requirements for lek sites, nesting, brood-rearing and wintering habitat are reasonably well understood (Schroeder et al. 1999, Connelly et al. 2000) and these requirements broadly overlap the requirements for other sagebrush birds (references in *table 1*). Further, sage-grouse need large blocks of these types of habitat in appropriate spatial mixes across the landscape. In one example from Idaho, that area requirement is roughly 2500 km^2 (Connelly, pers. comm.). These spatial requirements are vastly greater than those of any other sagebrush bird population.

Although Caro and O'Doherty (1999) pointed out the umbrella concept remains largely untested, Suter et al. (2002) found some support for the value of Capercaillie (*Tetrao urogallus*) as an umbrella for other forest bird species. We do not suggest that the umbrella effect of sage-grouse conservation will protect all components of all sagebrush ecosystems everywhere. The factor analysis, based on relative abundance correlations, showed a particularly close association between sage-grouse and Vesper Sparrows which suggests that the umbrella effect may be more pronounced in mesic

habitats. Further, Sage Thrashers, Loggerhead Shrikes, and Gray Flycatchers require relatively tall sagebrush plants for nest sites. We can readily imagine a landscape that provides plants tall enough for sage-grouse but that does not provide enough tall sage for these three species. There also could be habitats that supply grouse with sagebrush food during winter but which have an understory of pure cheatgrass. In this case, the value of the site to almost all other species during the breeding season would be very low. Much simpler to envision is how a local, endemic plant population might be left completely outside the umbrella.

Because of the sage-grouse's extensive distribution, large home ranges, and divergent areas of seasonal use (Schroeder et al. 1999, Connelly et al. 2000), conditions necessary to support viable populations of sage-grouse must be assessed at landscape scales that encompass millions of hectares. Wisdom et al. (2002a) evaluated performance of two complementary models designed to assess landscape conditions for sage-grouse across 13.6 million ha of sagebrush steppe in the interior Columbia Basin. *A priori* expectations were that models should predict substantially worse environmental conditions and a substantially higher probability of extirpation in areas where sage-grouse occurred historically but no longer do. Results for both models met these expectations. These results suggest that the models provided reliable landscape predictions for the conditions tested. This finding is important for conservation planning in the Interior Columbia Basin and perhaps in the other sage-dominated ecoregions discussed here–the Great Basin and Wyoming Basin.

In summary, it seems prudent to suggest that use of sage-grouse as an umbrella species for any given geographic area requires that: 1) the species assumed to be protected under the sage-grouse "umbrella" be listed; 2) the specific reasons for sage-grouse functioning as an umbrella be listed for each of those species; and 3) that additional species of concern associated with sagebrush that are not assumed to be protected under the umbrella also be listed.

Knick et al. (2003) provide an excellent assessment of the additional information needed to take the most effective action for the conservation of sagebrush birds and the sagebrush ecosystem. Yet much is already known and detailed recommendations are already available that certainly have not been widely implemented (Dobkin 1995; Paige and Ritter 1998; Neel 1999; Altman and Holmes 2000; Beidleman 2000; Casey 2000; Connelly et al. 2000; Ritter 2000; Wisdom et al. 2000, 2002a, 2002b; Cerovski et al. 2001). Given that more than 57 percent of this habitat is in public ownership under the management of a single agency, and that concern for the future of sage-grouse continues to build, we have all the information and opportunity we need to take action now. Indeed, if we cannot successfully conserve sage-grouse and the sagebrush ecosystem in the US given our theory, our knowledge, and our large blocks of public land, then one wonders how we can succeed for other species, for other land ownerships, and for other regions of the world.

Acknowledgments

We thank P. Blancher for calculating overlap of breeding ranges from digital range map data provided by NatureServe in collaboration with R. Ridgely, J. Zook, The Nature Conservancy/Migratory Bird Program, Conservation International/Center for Applied Biodiversity Science, World Wildlife Fund-US, and Environment Canada/WILDSPACE. Linda Schueck of USGS kindly provided updated calculations of the extent of sagebrush habitats and the amount managed by various entities. This paper was improved by the comments of M. V. Haegen and M. Hilliard. The opinions, suggestions, and conclusions presented here are those of the authors and do not necessarily represent those of the U.S. Fish and Wildlife Service or U.S. Forest Service.

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Occurrence and Density of Breeding Passerine Birds in Shrubland Habitats in Utah[1]

Jimmie R. Parrish,[2] Dan A. Roberts,[3] and Frank P. Howe[3]

Introduction

The Utah Avian Conservation Strategy (Parrish et al. 2002) published by the Utah Partners in Flight (UPIF) Program ranked a total of 24 habitat types and 231 bird species with respect to their need for conservation action. The 24 habitat categories were grouped within five major categories, Riparian, Shrublands, Grassland, Forest, and a collection of additional categories unique to conservation planning efforts in Utah. Shrublands comprise the most abundant of these habitat categories, with sagebrush communities (2.9 million ha) second only to greasewood/halogeton dominant shrublands (5.5 million ha) in total abundance statewide.

Various terminologies have been suggested for referring to western shrublands. The term 'shrubsteppe' technically refers to shrublands that include a substantial portion of native grass (e.g., 'steppe'). However, the term shrubsteppe or 'sagebrush steppe' has more recently been used to refer to sagebrush (*Artemesia* sp.) shrublands only (Paige and Ritter 1999).

In addition, some bird species have been referred to as 'obligates' in sagebrush habitats, including Sage Grouse (*Centrocercus urophasianus*), Sage Thrasher (*Oreoscoptes montanus*), Sage Sparrow (*Amphispiza belli*), and Brewer's Sparrow (*Spizella breweri*) (Braun et al. 1976). Terms such as 'shrub obligates', or 'sage obligates', or 'shrubsteppe obligates' have been applied to these species with the assumption that they are "almost entirely dependent" on sagebrush for their existence (Braun et al. 1976, Knick and Rotenberry 1995, Saab and Rich 1997). On the other hand, Braun et al. (1976) suggested that birds are more adapted to the structure of a shrub community rather than to the particular species of shrub that is present.

Study Area and Methods

We surveyed birds in two shrubland communities in Utah between 1998 and 2002 using sampling protocols modified to allow the collection of distance data (see Ralph et al. 1993, Buckland et al. 2001). Each community was surveyed at least 3 times (i.e., visits) from May through June each year.

Between 1998 and 2002, we surveyed birds in predominantly greasewood/halogeton shrublands in northwestern Utah using point transects (Buckland et al. 2001). The survey area lies within the Utah Test and Training Range (UTTR), an ungrazed area of approximately 405,000 ha used for military training purposes. The UTTR survey area also contains mixed shrub and grassland habitats with the grasslands being comprised of both native and introduced species.

A total of 100 points were spaced approximately 250-300 m apart on either side of existing access roads within the UTTR. Distance from roads to the points varied from a minimum of 50 m to as high as 372 m. Each observer surveyed 10 points for an 8-minute time interval during each visit, and all detections (and their respective distances) were recorded.

Between 2001 and 2002, we concurrently surveyed birds in sagebrush shrublands on lands managed by the U.S. Bureau of Land Management (BLM) in southwestern Utah using line transects (Burnham et al. 1980, Buckland et al. 2001). The southwestern Utah survey area is comprised of 3 large, open blocks of sagebrush (2 blocks approximately 800 ha in size and a third of approximately 500 ha), with limited amounts of additional vegetation types present due to big game and livestock grazing. A total of 16 line transects, each approximately 450 m in length and spaced approximately 250 - 300 m apart, were randomly established in each of the three blocks (e.g., 16 line transects per block).

Distances (measured with laser range finders) to all birds seen or heard were recorded in both survey areas along with species identification, flock size, age/gender, and method of detection (visual, auditory, or both) at each location sampled. Due to the difference in number of years sampled between the two survey areas, we calculated a simple average number of detections recorded for each survey area. Program Distance (Thomas et al. 1998) was used to calculate densities for

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California**.

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Table 1—*Total number of avian detections recorded along point transects in northwestern Utah and line transects in southwestern Utah.*

Greasewood/Halogeton shrublands in NW Utah		Sagebrush shrublands in SW Utah	
Species	Number detected	Species	Number detected
Horned Lark	3,325	Sage Sparrow	473
Western Meadowlark	1,301	Brewer's Sparrow	413
Black-throated Sparrow	418	Lark Sparrow	153
Brewer's Sparrow	341	Pinyon Jay	143
Sage Sparrow	230	Black-throated Sparrow	126
Sage Thrasher	186	Western Meadowlark	42
Loggerhead Shrike	90	Horned Lark	30
Mourning Dove	41	Mourning Dove	29
European Starling	25	Sage Thrasher	13
Rock Wren	22	Chipping Sparrow	11
Lark Sparrow	16	Western Kingbird	7
Burrowing Owl	13	Spotted Towhee	7
Northern Mockingbird	12	Common Nighthawk	7
Blue-gray Gnatcatcher	11	Loggerhead Shrike	6
Say's Phoebe	9	Unidentified Sparrow	4
Common Raven	5	Vesper Sparrow	4
Mountain Bluebird	4	American Kestrel	3
House Finch	4	Red-tailed Hawk	3
Northern Harrier	3	Black-billed Magpie	3
Prairie Falcon	3	Common Raven	2
Common Poorwill	2	Red-winged Blackbird	2
Barn Swallow	2	Northern Harrier	1
Townsend's Solitaire	2	Green-tailed Towhee	1
Western Scrub Jay	2	Canyon Wren	1
Bullock's Oriole	2	Cooper's Hawk	1
White-crowned Sparrow	1	Bullock's Oriole	1
Brown-headed Cowbird	1	Lewis's Woodpecker	1
Brewer's Blackbird	1		
Warbling Vireo	1		
Unidentified Sparrow	1		
Unidentified Flycatcher	1		
MacGillivray's Warbler	1		
Cordilleran Flycatcher	1		
Short-eared Owl	1		
Green-tailed Towhee	1		
Ruby-crowned Kinglet	1		
Chipping Sparrow	1		

two species, Brewer's Sparrow and Sage Sparrow, which have been identified as priority species for conservation action in Utah (see Parrish et al. 2002).

Results and Discussion

Within the UTTR survey area in northwestern Utah, a total of 6,081 detections were recorded representing 37 species (*table 1*). Of these, approximately 84 percent were neotropical migrants. Horned Lark (*Eremophila alpestris*), Western Meadowlark (*Sturnella neglecta*), Black-throated Sparrow (*Amphispiza bilineata*), Brewer's Sparrow, Sage Sparrow, Sage Thrasher, Loggerhead Shrike (*Lanius ludovicianus*), Mourning Dove (*Zenaida macroura*), European Starling (*Sturnus vulgaris*), Rock Wren (*Salpinctes obsoletus*), and Lark Sparrow (*Chondestes grammacus*) comprised approximately 97 percent of the detections, with an average of 1,216 (±111 se) total detections/yr for the northwestern Utah survey area. Horned Lark and Western Meadowlark detections occurred mostly within the grassland portions of the survey area, while Black-throated Sparrow, Brewer's Sparrow, and Sage Sparrow occur-

red primarily in greasewood/halogeton habitat. Loggerhead Shrike and Lark Sparrow were mostly detected in areas with sparse mixed shrub cover.

A total of 1,487 detections were recorded in the sagebrush survey area in southwestern Utah representing 27 species (*table 1*). Of these, approximately 86 percent were neotropical migrants. Sage Sparrow, Brewer's Sparrow, Lark Sparrow, Pinyon Jay (*Gymnorhinus cyanocephalus*), Black-throated Sparrow, Western Meadowlark, Horned Lark, Mourning Dove, Sage Thrasher, and Chipping Sparrow (*Spizella passerina*) comprised approximately 97 percent of the detections in the sagebrush survey area. Detections in the southwestern Utah survey area averaged 743 total detections/yr (±97 se) for each year sampled.

We found that Brewer's Sparrow densities were 55.2 birds/40 ha in sagebrush and 41.6 birds/40 ha in greasewood/halogeton. Sage Sparrow densities in sagebrush were 61.0 birds/40 ha in greasewood/halogeton were 20.7 birds/40 ha. Given these densities, we concluded that both species use greasewood/halogeton habitat in substantial densities as well as sagebrush during the breeding season. Accordingly, considering either species as a 'sagebrush obligate,' particularly Brewer's Sparrow, based on our results appears to be unjustified.

Acknowledgments

Our sampling effort has been made possible through the consistent contributions and support of the Utah Division of Wildlife Resources and numerous cooperators in the Utah Partners in Flight Program, including U.S. Bureau of Land Management, U.S. Fish and Wildlife Service, and the Department of Defense. R. Norvell provided helpful comments on the manuscript.

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Effects of Trail Width on the Densities of Four Species of Breeding Birds in Chaparral[1]

Aaron L. Holmes[2] and Geoffrey R. Geupel[2]

Abstract

We investigated densities of four common species, Wrentit (*Chamaea fasciata*), Spotted Towhee (*Piplio erythrophthalmus*), Bewick's Wren (*Thryomanes bewickii*), and Orange-crowned Warbler (*Vermivora celata*) in relation to trail width in chaparral habitats of Mt. Tamalpais, Marin County, California. Point count sampling stations were assigned to one of three trail width groups—thin (≤2 m), medium (2.1-4 m), and wide (>4 m). We found a marginally significant ($P < 0.1$) negative effect of trail width on the density of Spotted Towhee when thin trails were compared to medium/wide trails. For the other three species our results suggest a trail width effect when thin trails were compared to medium/wide trails ($P < 0.2$), although additional study is needed to confirm or negate these tentative conclusions. Only one species, Orange-crowned Warbler, showed a positive relationship between density and trail width

Key words: Bewick's Wren, chaparral, Orange-crowned Warbler, road, Spotted Towhee, trail, Wrentit.

Introduction

Several studies on the effect of roads show that they may negatively affect the ecosystems and wildlife around them (reviewed in Forman and Alexander 1998). The Marin Municipal Water District conducts limited mechanical clearing of vegetation along fire roads and recreational trails as part of a fuels management program. Potential impacts to songbirds include the direct effect of reduced habitat availability, as well as indirect effects resulting from the creation of long, thin habitat edges within otherwise continuous habitat. To assess if this trail widening impacts songbird abundance we estimated the densities of four species breeding in chaparral habitats with varying trail widths.

Methods

Study Area

The study was conducted on lands managed by the Marin Municipal Water District located on Mount Tamalpais, Marin County, California during the 1999 nesting season.

Mount Tamalpais is located in coastal Marin County, just north of the San Francisco Bay. The study area was comprised of a mosaic of two chaparral habitat associations and ranged in elevation from 350 to 650 m. The chamise association, typically found on xeric south- or west-facing slopes and ridges is typified by dense stands of chamise (*Adenostoma fasciculatum*) interspersed with manzanita (*Arctostaphylos manzanita*) and buckbrush (*Ceanothus cuneatus*), all species that reach heights of 1 to 2 m at maturity. A second association, mixed chaparral, occurs on more mesic sites, often grading into mixed evergreen forest, and is dominated by a mix of manzanita, chamise, buck brush and interior live oak (*Quercus wislizenii*). Coffeeberry (*Rhamnus californica*), blue blossom (*Ceanothus thyrsiflorus*), and chaparral pea (*Pickeringia montana*) also occur in lesser amounts. This community is common along the ridge and on the north-facing slope of Mt. Tamalpais. Sampling points were distributed in both habitat associations. All single-track trails and fire roads within appropriate habitat were selected for study and point counts were established approximately 250 m apart beginning 100 m from the trail or fire road origin. For this analysis we excluded points that fell within the mixed evergreen forest that bordered the chaparral associations. Hiking and mountain biking are the principal uses of all the trails included in this study, although motorized vehicles occasionally used several of the fire roads for maintenance activities.

Bird Surveys

We conducted point count surveys (Ralph et al. 1993) and employed distance sampling at a total of 86 count stations during May and June 1999. All birds detected within 100 m were recorded and distance from the observer was estimated within 10-m bands during a 5-minute period. The type of detection (song, visual, or call) was also noted. Surveys began within a half hour after local sunrise and continued for no more than 4 hours in order to restrict sampling to peak singing hours. Counts were not conducted during excessively

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California**.

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rainy, foggy, or windy conditions where bird activity levels or detection probability may have been reduced. One individual who had multiple years of prior experience conducted all of the surveys. Intensive training in distance estimation occurred prior to the collection of any data.

Trail width was measured perpendicular to the trail, to the nearest 0.5 m, at the center of each point count. Edges were defined by the boundary with shrubby vegetation whether or not trails had been mechanically cleared. These were nearly always discrete and easily determined.

Statistical Analysis

We used the program DISTANCE (Laake et al. 1993) to develop density models for four of the most abundant species occurring in chaparral, Wrentit (*Chamaea fasciata*), Spotted Towhee (*Piplio erythrophthalmus*), Bewick's Wren (*Thryomanes bewickii*), and Orange-crowned Warbler (*Vermivora celata*). We assigned points into three trail width groups—thin (≤2 m), medium (2.1 - 4 m), and wide (>4 m). For most analyses, we combined medium and wide trails in order to compare single track (i.e., thin) to wider trails. Data were summed across two surveys for each count station. We used only song data to model the detection probability as we believed it would be less likely than visual or call detections to be affected by trail width. Because female Wrentits sing (although less often than males), whereas female Spotted Towhees, Bewick's Wrens, and Orange-crowned Warblers do not, the density estimate for Wrentits should be higher relative to true density. Models were selected among alternates based on minimum Akaike information criterion (AIC). Detection models used a half-normal key function with Cosine series expansion (Laake et al. 1993). We then developed density models for each trail width category, and trail effects were tested for significance using a two-tailed t-test.

Results

Mean trail widths at point counts was 3.2 m (N = 86). Mean width was 1.1 m for the thin trail category (N = 31), 3.5 m in the medium width category (N = 37), and 6 m in the wide category (N = 18). Densities of Wrentit, Spotted Towhee, and Bewick's Wren were lower at points in the medium/wide trail category compared to the thin trail category (*table 1*). The index to Wrentit density was 28 percent lower on medium/wide trails (P = 0.13). Spotted Towhee density was 38 percent lower (P = 0.09), and Bewick's Wren density 32 percent lower on medium/wide trails (P = 0.16). The index to Orange-crowned Warbler density was 80 percent higher on medium/ wide trails, although once again the difference was not significant statistically (P = 0.17). For the two species with sufficient data, we split medium from wide trails to see if the magnitude of this effect increases with increasing trail width. There was no difference in densities of either Wrentit ($t_{(53)}$ = 0.04, P = 0.96) or Spotted Towhee ($t_{(53)}$ = 0.02, P = 0.99) between medium and wide trails (*fig. 1*).

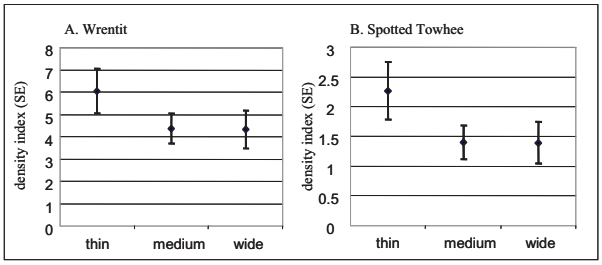

Figure 1— Densities (se) of Wrentit (A) and Spotted Towhee (B) at locations with thin (1 - 2 m), medium (2 - 4 m), and wide (>4 m) trails through chaparral habitats of Mt. Tamalpais, California.

Discussion

This study provides tentative evidence that fragmentation of chaparral habitat by wider trails and fire roads results in a negative effect on the density of some shrub-nesting bird species. The results of our analyses were not statistically significant by conventional measures, but should be considered suggestive and used to guide further studies that will seek a firm conclusion (Robinson and Wainer 2002).

Table 1— *Mean bird density indices with standard errors in relation to thin (≤2 m), medium (2.1–4 m), and wide (>4 m) trails in chaparral habitat, Marin County, California.*

	Density index ± se			
Species	**Thin**	**Medium/wide**	$t_{(84)}$	**P**
Wrentit	6.08 ± 0.99	4.36 ± 0.63	1.54	0.13
Spotted Towhee	2.27 ± 0.49	1.40 ± 0.25	1.77	0.09
Bewick's Wren	3.04 ± 0.59	2.07 ± 0.38	1.43	0.16
Orange-crowned Warbler	0.36 ± 0.12	0.65 ± 0.14	1.38	0.17

We believe that the observed difference in songbird densities is unlikely to stem directly from loss of available habitat. At the scale of the 100-m radius bird survey plots, less than 3 percent of the habitat is removed for the trails. The reductions in songbird densities were of a much greater magnitude (28-38 percent). Our observations suggest similar rates of recreational use on all the trails within the study area. In fact, many trails connect to form discrete loops such that a hiker or mountain biker will often hike a route that combines thin and wider trails within a continuous stand of vegetation. Therefore we do not believe that variable rates or other aspects of recreational use are likely causes of differential use by songbirds.

Other researchers have documented numerous ecological effects of trails (reviewed in Forman and Alexander 1998). Miller et al. (1998) documented negative effects of trails on songbirds in both forest and grassland ecosystems in Colorado. The trails used in their study were 1.25 m, similar in width to our thin trail category. Three of four species in grassland, and five of 11 species in forest were significantly less abundant around trails. Reduced abundance of some forest-nesting songbirds along roads and power lines has been documented in New Jersey (Rich et al. 1994). Haskell (2000) found reduced abundance and species richness of macroinvertebrate soil fauna up to 100 m from forest roads in the Southern Appalachian Mountains. He hypothesized that this may reduce abundance of songbirds near roads, and may serve as an alternative explanation for studies in Europe that have attributed reduced roadside bird abundance to noise levels (Reijnen 1995).

Differential use of surrounding habitat based on trail width could be a functional response related to a species habitat associations and changes in vegetation resulting from the trails themselves. Alternatively differences could be due to a behavioral response to discrete vegetation edges and resulting habitat structure. Only Orange-crowned Warbler demonstrated a positive response in density to trail width, which may relate to an affinity for openings within the shrub canopy not shared by the other species. Independent data in similar habitat is needed to further evaluate this possibility.

Because densities of both Wrentit and Spotted Towhee do not differ between medium and wide trail classes (greater than 2 m), our data suggests mechanical clearing of vegetation on fire roads may not affect the densities of these species if limited to existing trails already wider than 2-3 m. However, clearing vegetation to widen a thin (0.5-2 m) trail may have a negative impact on these species and other wildlife. Although this study offers only limited support for our conclusions, we recommend that only single-track trails <2m wide be established if new recreational trails are developed.

Acknowledgments

D. Dixon conducted bird surveys, for which we are grateful. We thank N. Nur for assistance in the development of density models. M. Swezy and D. Odion of the Marin Municipal Water District provided assistance and logistical support throughout this project. Funding was provided by Marin Open Space and the Marin Municipal Water District. This is PRBO contribution number 1047.

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Two Decades of Change in a Coastal Scrub Community: Songbird Responses to Plant Succession[1]

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Coastal scrub habitats in California are threatened by habitat loss, fragmentation, and degradation. Local and statewide declines have been observed in several birds that breed in coastal scrub, most notably the California Gnatcatcher (*Polioptila californica*; Atwood 1993), but also include more common species such as the White-crowned Sparrow (*Zonotrichia leucophrys;* Trail and Baptista 1993; Sauer et al. 2001; Point Reyes Bird Observatory [PRBO], unpubl. data). While Breeding Bird Survey data can be used to track population trends over larger scales (Sauer et al. 2001), they are not always adequate to monitor trends of distinct breeding populations. Such populations include the *nuttalli* subspecies of the White-crowned Sparrow, which breeds only in the narrow, humid, coastal strip of central and northern California, and the Song Sparrows (*Melospiza melodia*) that breed in northern California coastal scrub habitat. On the other hand, while local monitoring programs have the advantage of being population- and habitat-specific, it is difficult to tell whether trends demonstrated in local study areas are associated with landscape-scale changes or are occurring primarily in response to local changes in habitat characteristics (Holmes and Sherry 2001). We monitored plant succession and associated changes in bird population density in a single study site in northern California coastal scrub habitat. Our objectives were to (1) describe plant succession in coastal scrub over 22 years, and (2) evaluate evidence for population responses to plant succession in three coastal scrub resident birds. Here, we report preliminary results concerning the changes in abundance of three species of coastal scrub-breeding birds.

Bird populations may change in a predictable way as plant succession occurs. However, many studies of this phenomenon have been cross-sectional surveys of multiple sites in various seral stages (Johnston and Odum 1956, Martin 1960, Shugart and James 1973, Morgan and Freedman 1986, Thompson and Capen 1988). A few studies have compared short-term snapshots of bird communities before and after a long period of habitat change (e.g., Kirk et al. 1997). Most rare are studies that have tracked bird populations over long periods (>20 years) as habitat change has occurred (Holmes and Sherry 2001). Holmes and Sherry (2001) found that several forest birds associated with early or midsuccessional forest declined on their study area while other species associated with mature forest increased in abundance. These changes occurred over a period of 30 years, during which the physical structure of the forest changed significantly. To our knowledge, no comparable analysis has been conducted for a shrubland bird community.

The suppression or ignition of fires by humans has a major influence on habitat characteristics throughout the range of coastal scrub habitats. Northern California scrublands may be replaced by forest vegetation in the absence of fire (Heady et al. 1988, Horton et al. 1999). Thus, the process of plant succession in the absence of fire is one possible cause of population changes in northern coastal scrub bird populations. In contrast, southern California coastal scrub has experienced increased fire frequency, which, together with livestock grazing, air pollution, and the invasion of exotic grasses and forbs, has led to the conversion of some scrub habitats into non-native grasslands (Keeley 1995, Minnich and Dezzani 1998). In this study, we tracked changes in plant and bird communities in a northern coastal scrub site in the absence of fire.

Bird responses to plant succession in northern California coastal scrub were monitored intensively for 22 years (1980-2001) at the Palomarin field station of the PRBO, located within the Point Reyes National Seashore. Much of the study site was cultivated until the early 1960's, after which passive regrowth of coastal scrub vegetation began. By 1980, when intensive nest monitoring and territory mapping of all species was initiated, the site supported many breeding pairs of coastal scrub species, including year-round resident Wrentits (*Chamaea fasciata*), Nuttall's White-crowned Sparrows, and Song Sparrows. Density of these three species was monitored by intensive spot mapping of

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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color-banded individuals (March-July; for more details on methods, see Silkey et al. 1999). The number of females breeding on the study area in each year was used as a measure of density. Plant succession was monitored at 40-m line-intercept transects placed at 40 locations in 1981/1982 and 2000 (27 in formerly cultivated, disturbed habitat and 13 in undisturbed habitat). The cover and height of each shrub or tree along the transect was recorded. Plant characteristics were compared between the two sampling periods using two-tailed t-tests. Linear regression was used to analyze trends in bird density.

Vegetation on the study area changed dramatically between 1980 and 2001. Most notably, Douglas-fir (*Pseudotsuga menziesii*) cover and height increased significantly on the study plot (*fig. 1*). Results of territory mapping during this same period showed a large and significant decline in the breeding density of White-crowned Sparrows (*fig. 2A*). The density of Wrentits increased dramatically over most of the study period, but declined slightly in the last three years of the study (*fig. 2B*). Song Sparrow density showed only a weak trend over time (*fig. 2C*).

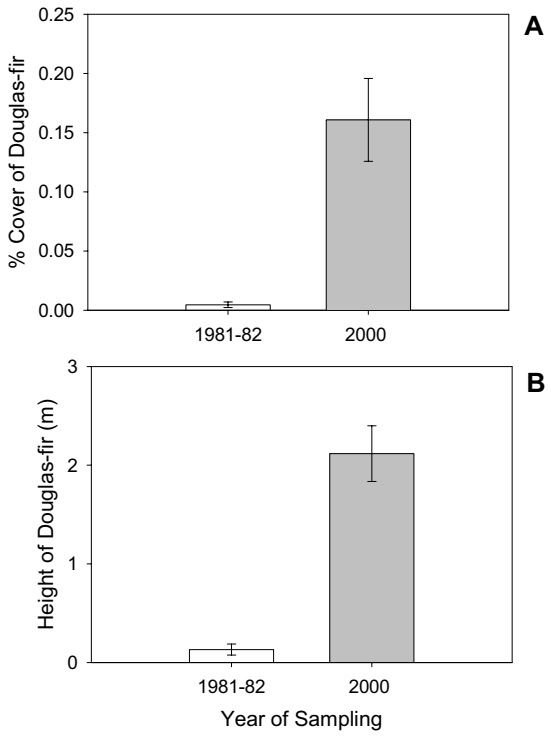

Figure 1— Mean and standard error of Douglas-fir cover (A) and height (B) at 40 transects in the Palomarin study area shortly after the beginning of the study and in 2000 (cover: t = -4.42, df = 78, P < 0.001; height: t = -6.90, df = 78, P < 0.001).

These local trends can be compared with Breeding Bird Survey results for the physiographic area in which our site is located (southern Pacific rainforests; Sauer et al. 2001). During the same period, declines were observed in both White-crowned Sparrows (-2.0 percent annual trend, P = 0.01, N = 56 routes) and Wrentits (-1.6 percent annual trend, P = 0.01, N = 40 routes), while Song Sparrows showed a weak declining trend (-0.7 percent annual trend, P = 0.11, N = 72). Thus, local trends appear to correspond to larger-scale trends for White-crowned Sparrows and Song Sparrows, but not for Wrentits.

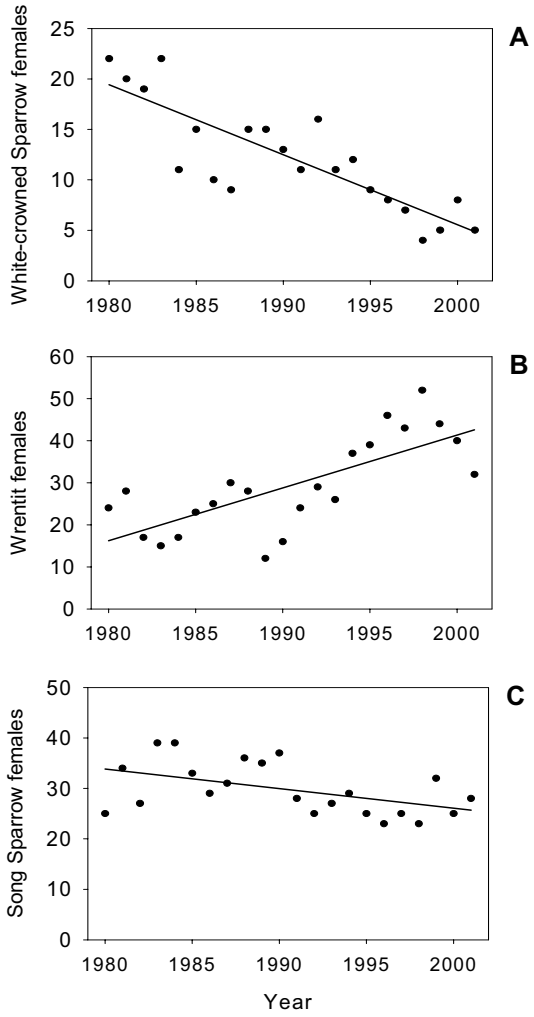

Figure 2— Population trends of three resident coastal scrub birds in the Palomarin study area, 1980-2001. White-crowned Sparrows declined significantly (r^2 = 0.71, F1,20 = 48.97, P < 0.001), Wrentits increased significantly (r^2 = 0.54, F1,20 = 23.54, P < 0.001) and Song Sparrows showed a weak declining trend (r^2 = 0.24, F1,20 = 6.42, P = 0.02). Note differences in scale on y-axes.

In conclusion, Wrentit and White-crowned Sparrow density may have responded to plant succession, while Song Sparrow density did not appear to do so. Although our results are correlational, they are consistent with what is known about the habitat associations of our study species:

- Wrentits are associated with dense shrub cover (Geupel and Ballard 2002) and thus may have responded to the increase in cover by shrubby young Douglas-fir;

- White-crowned Sparrows are associated with more open scrub habitats, containing grass and some bare ground for foraging (Chilton et al. 1995); and

- Song Sparrows are relative generalists, occurring in California in a variety of habitats that are typically moist, with low, dense cover or brushy, weedy edges (Small 1994).

In the future, we plan to evaluate population responses to succession in this site for the entire avian community and to model variation in bird population density in relation to changes in habitat characteristics and weather over time. Preliminary analyses suggest that changes in White-crowned Sparrow and Wrentit density paralleled vegetation change, while variation in Song Sparrow density was more closely related to weather (PRBO, unpubl. data). While plant succession in the absence of fire may have influenced our local populations, more study is needed to evaluate this process as a potential cause of larger-scale bird population trends in northern coastal scrub. However, given the dramatic invasion of trees into our study site, our results suggest that habitat reserves in northern coastal scrub may need active management to retain both early successional scrub habitat, for species such as White-crowned Sparrow, and more mature scrub, for species such as Wrentit.

Acknowledgments

We are grateful to L. R. Mewaldt, C. J. Ralph and D. DeSante for their foresight in establishing the long-term research program at the Palomarin Field Station. This study would not have been possible without the dedicated fieldwork of many interns and staff biologists of the PRBO terrestrial research program. We are indebted to the staff of the Point Reyes National Seashore for their continued cooperation. We are grateful for financial support by the David and Lucile Packard Foundation for PRBO's conservation science and adaptive conservation planning efforts in California. This is PRBO contribution number 1046.

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Diversity Patterns in the Terrestrial Avifauna of the Salton Sea[1]

Mark B. Mendelsohn,[2] William I. Boarman,[2] and Robert N. Fisher[2]

Abstract

We performed bird point counts monthly March-June 2001 and bi-monthly August 2001-February 2002 across a sampling grid of 35 points along the west edge of Salton Sea. We found that landbird species diversity (both in numbers of species, and numbers per species) was dependent on proximity to the sea. Diversity was at a maximum nearest the shore, and was significantly lower farther from the shore. Creosote bush (*Larrea tridentata*) and alkali goldenbush (*Isocoma acradenia*) are the co-dominant plants on the study site, and vary widely in their horizontal and vertical structure. After measuring vegetation cover within the study site, we concluded that avian diversity patterns were caused by these differences in vegetation structure, which also corresponded to proximity to the water's edge. In light of the prevalent debates on potential restrictions of water inflow to the Salton Basin, there is concern that the ecology of the landbirds using this land-shore interface, not to mention the millions of waterbirds and other organisms using the region, may be severely impacted (Shuford et al. 2002).

Introduction

The Salton Sea is a large, saline lake in the counties of Imperial and Riverside, in the Colorado Desert of southeastern California, created in 1905 by flooding of water accidentally diverted from the Colorado River (Redlands Institute 2002). It has become a critical habitat for aquatic and terrestrial fauna alike, especially migrating and wintering birds. More than 400 bird species have been recorded at the Salton Sea, of which about 100 species have established breeding populations (Patten et al. 2003). In the Salton Basin, within desert creosote scrub habitat atop an extensive alkali sink, vertebrate and invertebrate life forms have made homes of this unique and seemingly inhospitable landscape.

However, due to salinity levels approaching toxic concentrations in this biologically and recreationally significant body of water (Shuford et al. 2002), one phase of a multi-dimensional effort to restore the Salton Sea is based on desalinization. Enhanced Evaporation Systems (referred to as "salt blowers"; *fig. 1*) located near the shore are in the testing stage to see if desired results are temporally and financially feasible. As part of a large-scale ecological study designed to monitor the effects of possible particulate deposition from the salt blowers, we gathered baseline count and local distribution data on avian diversity near the southwestern shore of the sea (*fig. 1*). Please see Mendelsohn et al. (2003) for a more detailed manuscript on the research presented here and Redlands Institute (2002) for general information and references therein for research involvements at the Salton Sea.

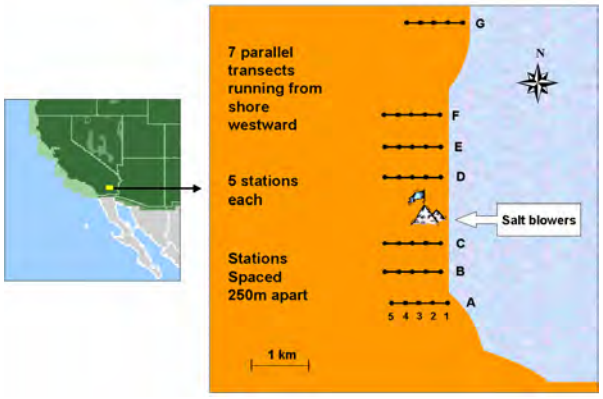

Figure 1— Study design at site located along the southwestern edge of the Salton Sea in southeastern California. Note: transect G is spaced 2 km (vs. 0.8 km distance between other transects) away from the nearest transect because it was intended to serve as a control in the original study plan where the purpose was to study the effect of possible salt deposition on terrestrial fauna.

Currently, challenging issues of the use and fate of this resource are being tossed around between farmers, policy-makers, water district boards, environmental agencies and many other stakeholders. For nearly a century, rivers have fed nutrient-filled water into the sea. At present, talks of redirecting this river water to coastal Southern California for human use are at the forefront. Ecologists and non-scientists alike suggest that this reduction in source water could have direct and far-reaching effects on the Salton Sea ecosystem

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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(D. Barnum, pers. comm.) and surrounding developed areas.

Methods

Our study site lies almost completely within the U.S. Navy's former Salton Sea Test Base, near the southwestern corner of the Salton Sea. The vegetation on this site of extensive alkali sink constitutes primarily Sonoran desert creosote scrub (Redlands Institute 2002). A sampling grid was established along the west edge of the sea with seven transects running perpendicular to the sea and five running parallel to it (*fig. 1*). The five parallel transects were placed across the gradient of distance from the sea edge at 250-m intervals beginning approximately 100 m from the water's edge. Six of the perpendicular transects were placed at 800-m intervals from north to south. A seventh was placed approximately 2 km north of the others. Data were collected at each of the 35 points where the transects intersected.

At each of the 35 points, five-minute counts of individuals of each species of bird seen or heard within a 100-m radius of the count station were recorded, following the methods of Ralph et al. (1993). We did not include as part of the data presented here waterbirds observed on the beach or sea, even if within 100 m of sampling points, nor fly-over observations. Fifteen visits to each station were performed between March 2001 and February 2002, with a sampling period each month during the "spring" (February through June) and every other month in other seasons (i.e., August, October, and December). A variation of a point-intercept vegetation transect (see USDI-NPS 2001 for examples and further references) was performed for each of the 35 nodes to assess cover around each station, to relate to the bird count data.

Systat Version 10 (SPSS Inc. 2000) was used for all statistical analyses. We performed analysis of variance (ANOVA) tests to detect any differences among distances from the shoreline, with respect to total number of birds and total number of species observed. Data from equivalent distances from the shoreline were summed across transects; i.e., transects were treated as the blocking factor, so that values depicted on *figures 2-4* represent the averages across transects. Likewise, vegetation cover was analyzed in the same way. Fisher's Least Significant Difference (LSD) post-hoc tests were used to analyze where the differences among distances, if any, rested. To ease interpretation of *figures 2-5*, we clarify that distance 1 refers to the stations closest to the shoreline, distance 2 is 250 m farther from the shore...until distance 5 which is farthest (just over 1 km) from the sea. Distances 1, 2, 3, 4, and 5 refer to the respective points across all seven transects, i.e., totaled across all transects.

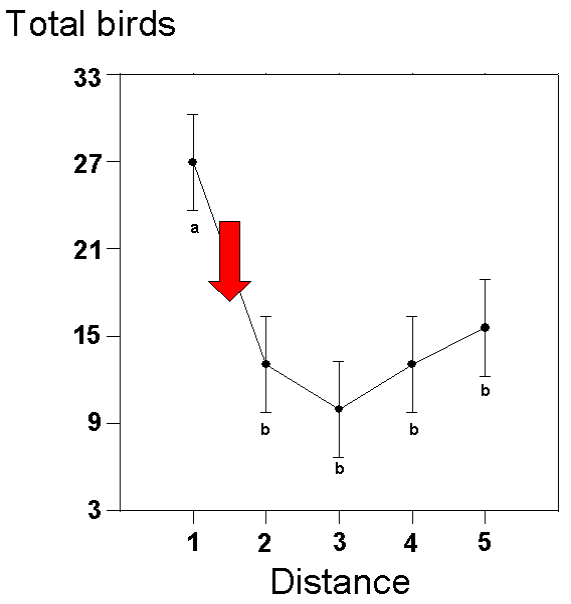

Figure 2— Least squares mean visualization with standard error bars, showing statistically significant differences in individual bird totals between distance 1 and all other distances (group membership from Fisher's LSD signified by the letters "a, b").

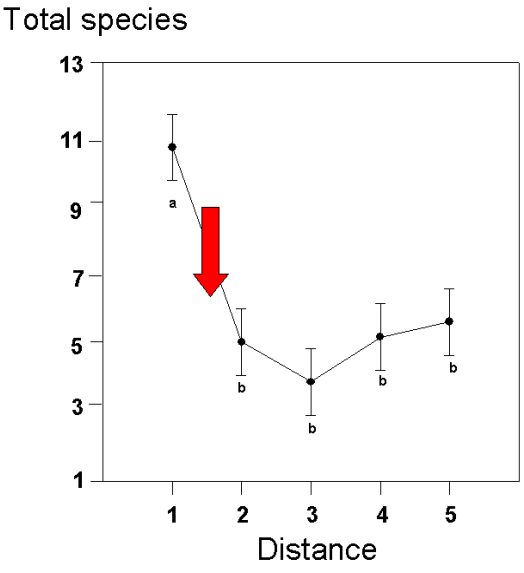

Figure 3— Least squares mean visualization with standard error bars, showing statistically significant differences in total species between distance 1 and all other distances (group membership from Fisher's LSD signified by the letters "a, b").

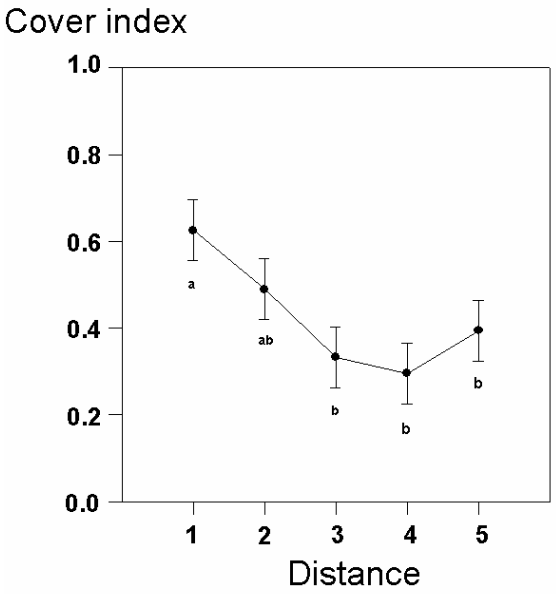

Figure 4– Least squares mean visualization with standard error bars, showing statistically significant differences in vegetation cover between distance 1 and distances 3, 4, and 5; distance 2, however, is not different from 1, nor 3, 4 and 5 (group membership from Fisher's LSD signified by the letters "a, b").

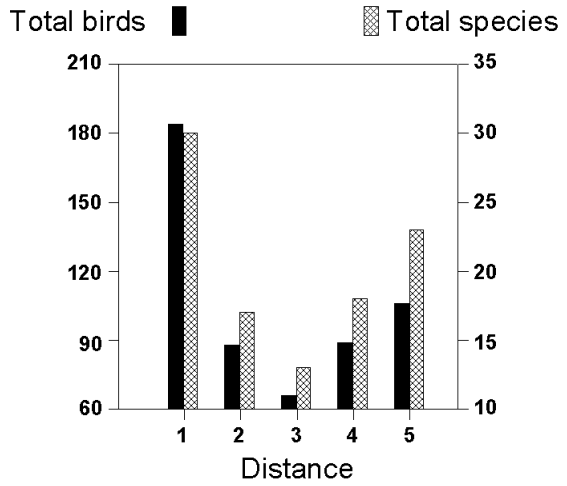

Figure 5– Total numbers of birds and species observed from all stations, showing similar patterns related to distance from the shoreline.

Results

We observed a total of 533 individual landbirds of 44 different species across the whole gradient (i.e., all 5 distances from the shore) and all seven transects (*fig. 5*). The two most commonly encountered species were the Verdin (*Auriparus flaviceps*) with 70 individual observations, and the Loggerhead Shrike (*Lanius ludovicianus*) with 58 individuals. There was a strong effect of distance from the shoreline on both the total number of individuals and species observed. Distance 1, which included the seven stations closest to the sea, had 188 individuals, a significantly higher number of individual observations than any of the other four distances (*fig. 2*; ANOVA: $F_{4,24} = 3.95$, $P = 0.013$). Similarly, the total number of species observed was sensitive to the distance from the shoreline. Distance 1 had 30 species, a significantly higher number than any of the other four distances (*fig. 3*; ANOVA: $F_{4,24} = 7.62$, $P < 0.001$). The effect of distance from the shoreline on the vegetation cover around each station was not as strong as it was with the two preceding variables. However, the stations at distance 1 had significantly more cover than those at distances 3-5 (*fig. 4*; ANOVA: $F_{4,24} = 3.59$, $P = 0.020$). The difference between distance 1's vegetation cover and that of distances 2-5 is less drastic (compared to the patterns seen in total birds and total species with respect to distance) because distance 2 appears to be an intermediary, with respect to cover, between distances 1 and 3-5.

Conclusions

Spatial patterns in landbird diversity—a function of the number of species and number of total individuals—appear to be dependent on proximity to the shoreline near the southwest edge of the Salton Sea. Patterns of vegetation cover by the dominant plant species at the site are also related to proximity to the sea's edge. This reflects a probable correlation between the avian diversity and vegetation cover.

Intuitively, any reduction of source water to the Salton Sea, which is quite possible with future management schemes, will lower the sea's surface and have potentially serious effects on the distribution and cover of the surrounding vegetation. This speculation of vegetative change has two lines of reasoning. First, greater vegetation cover at the sea's edge may be dependent on available ground water and other edaphic features that are not found farther from the shore. Second, the sea floor that will be exposed with a reduced sea level is saturated with saline sedimentation, likely unsuitable for the propagation of any plant species except for the most extreme halophytes. Therefore, the areas of greater vegetative cover may be reduced due to loss of water, and may not be replaced in the newly exposed areas immediately next to the water due to altered substrate conditions.

Thus, avian diversity patterns at this critical migratory and wintering region may be affected at the local, if not landscape (the entire shoreline around the sea), level if the sea's inflow is not maintained at current quantities. Therefore, we extend what Shuford et al. (2002) stated regarding waterbird conservation to landbirds as well: any proposed projects which may directly or indirectly

modify the sea should be carefully evaluated and implemented only if they can provide substantial habitat improvements without negatively impacting the suitability of current habitats.

Acknowledgments

We sincerely appreciate the aid and advice of D. Deutschman (San Diego State University), S. Hathaway, C. Rochester, K. Pease, D. Barnum and B. Kus (all from USGS-WERC), and the US Geological Service, Salton Sea Authority, Bureau of Reclamation and Bureau of Land Management for land access and funding.

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The Importance of Floristics to Sagebrush Breeding Birds of the South Okanagan and Similkameen Valleys, British Columbia[1]

Susan Paczek[2] and Pam Krannitz[3]

Abstract

Habitat associations were determined for five species of songbirds breeding in sagebrush habitat of the South Okanagan and Similkameen valleys, British Columbia. We examined the relative importance of plant species versus "total forbs" and "total grasses" at a local level (<100 m) with point counts and vegetation survey data collected at 245 points. Logistic regression models showed that individual plant species were often more important than variables that grouped species. Habitat associations varied for each species. Brewer's Sparrow (*Spizella breweri*) was associated with parsnip-flowered buckwheat (*Eriogonum heracleoides*) and lupine (*Lupinus sericeus* or *sulphureus*). Lark Sparrow (*Chondestes grammacus*) was positively associated with sand dropseed grass (*Sporobolus cryptandrus*), Grasshopper Sparrow (*Ammodrammus savannarum*) was positively associated with pasture sage (*Artemisia frigida*) and cheatgrass (*Bromus tectorum)*, Vesper Sparrow (*Pooecetes gramineus*) was positively associated with lupine, and Western Meadowlark (*Sturnella neglecta*) was positively associated with needle-and-thread grass (*Stipa comata*). These herb-layer species have strong associations with rangeland management practices; therefore this information can be used to direct management efforts in this highly threatened area.

Key words: Brewer's Sparrow, floristics, Grasshopper Sparrow, habitat associations, Lark Sparrow, Okanagan, sagebrush, Vesper Sparrow, Western Meadowlark.

Introduction

Grasslands and shrubsteppe of British Columbia contain a disproportionately high number of endangered species in Canada relative to the 3 percent of area that these habitat types occupy (Hooper and Pitt 1995). At the northern extent of the Great Basin, the shrubsteppe habitat of the southern Okanagan and Similkameen Valleys (*fig. 1*) supports many species that are at the limit of their range and are unique in Canada. This area contains a high concentration of bird species at risk, including provincially red-listed shrubsteppe birds such as Brewer's Sparrow (*Spizella breweri breweri*), Grasshopper Sparrow (*Ammodrammus savannarum*) and Lark Sparrow (*Chondestes grammacus*). In addition, North American Breeding Bird Survey data compiled for the period 1966 to 1996 showed significant continental decreases in populations of Brewer's Sparrow, Lark Sparrow, Grasshopper Sparrows and Western Meadowlarks *(Sturnella neglecta*; Peterjohn and Sauer 1999), all of which breed in the study area. While the distributions of songbird species are well known within the South Okanagan (Cannings et al. 1987), the specific habitat associations of bird communities within sagebrush habitat of this region are not. Despite recent establishment of parks in the southern Okanagan, between 60-70 percent of potential habitat for the red-listed birds in this study is owned privately or by First Nation reserves (MELP 1998). This habitat is under great threat to irreversible development as the human population of the Okanagan expands. Much of the remaining shrubsteppe habitat is subject to cattle grazing. A good understanding of bird-habitat associations is necessary to guide songbird conservation on public land and to increase the effectiveness of management guidelines for interested private landowners.

Descriptions of bird-habitat associations at a local level have often been made with measures of vegetation such as "total grasses" and "total forbs" and indices of vegetation variables, such as richness and diversity, based on tradition and convenience (Rotenberry 1985). However, breeding songbirds in temperate regions are likely to be insectivorous migrants that are adapted to certain insect prey, and often have better success in the type of vegetation with which abundance of these insects is correlated (Cody 1981). Host specialization is widespread among herbivorous insects (Minckley et al. 2000) and therefore individual plant species could indirectly affect habitat selection of insectivorous songbirds. For example, grasshopper species composition is directly related to plant species composition in some

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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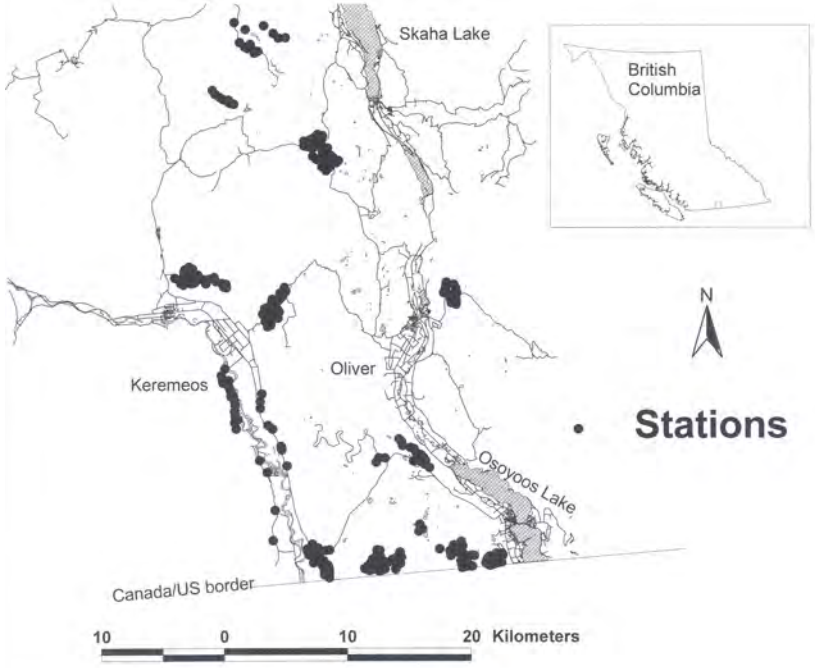

Figure 1— Location of point count stations in the southern Okanagan and Similkameen Valleys for songbird surveys conducted in 1998.

grasslands (Quinn and Walgenbach 1990). In other cases, plant species may reflect environmental variables such as moisture that are directly linked to insect productivity (Dunning and Brown 1982).

The measurement of individual plant species, or "floristics," is of particular value in grazed habitats as grazing impacts both composition and structure of vegetation. While species richness of grassland birds declines in areas of extreme grazing pressure (Bradford et al. 1998), bird species have variable responses to grazing intensities in the middle of this spectrum (Saab et al. 1995). Grazing affects birds indirectly by altering their habitat. For example, litter and cryptogramic crust cover decrease while bare soil increases with grazing (Laycock 1967). Certain plant species are less palatable and/or more robust to livestock grazing and will increase under grazing pressure, while preferred forage or sensitive plant species will decline (Ryder 1980). Insectivorous songbirds can be further affected by grazing, because changes in plant community structure impacts herbivorous insects. Grazing has been positively correlated with increased grasshopper abundance (Smith 1940, Nerney 1958), but has a negative impact on the abundance of small and relatively sedentary insects and arachnids (Dennis et al. 1998). It is difficult to adequately assess grazing effects because of the need for temporal and spatial replication, but the effect of grazing on wildlife can be inferred indirectly from correlations between vegetation and wildlife variables (Hooper and Pitt 1995). Research of this type can produce reliable grazing management prescriptions.

We examined the relative importance of floristics (plant species) versus total grasses or forbs for five shrubsteppe breeding songbird species: Brewer's Sparrow, Lark Sparrow, Grasshopper Sparrow, Western Meadowlark, and Vesper Sparrow. We hypothesized that floristics would have a significant effect on bird distribution, as compared to percent horizontal cover of "total grasses" or "total forbs." Methods, results, and conclusions presented in this paper are summarized from Paczek (2002).

Methods

Study Site Selection

Study sites were located in the lower South Okanagan and Similkameen valleys, British Columbia, between approximately 49° 00' 00" N and 49° 25' 00" N, and 119° 49' 00" W and 119° 27' 00" W (*fig. 1*). Elevations ranged between 345 m and 1200 m, within the Ponderosa Pine (*Pinus ponderosa*) – Bunchgrass and Interior Douglas-fir (*Pseudotsuga menziesii*) biogeoclimatic zones (Medinger and Pojar 1991). All of the survey areas were dominated by big sagebrush, *Artemisia tridentata*. Variation in the herb understory was used to guide point count station selection. Understory types included areas dominated by sand dropseed grass,

needle-and-thread grass and areas with abundant forbs. Understory types were initially categorized by visual observation. Detailed vegetation sampling was then conducted to quantify differences among point count stations. The sites occurred in 15 geographically distinct areas, several of which contained more than one habitat type. Herb understory types were replicated at three or more of these areas. Study sites had a range of sagebrush densities, varied in surrounding landscape characteristics, and included a range of aspects. Point count stations were at least 300 m apart. Within an area, stations were placed so that each plot was in the center of an area of similar sagebrush density and homogeneous understory. The 15 areas had between three and 34 point count stations, depending on the size of the area, for a total of 245 survey stations (*fig. 1*).

Bird Surveys

Point count data were collected by three experienced observers between 12 May and 3 July 1998, within 3 hours of sunrise. Most stations were surveyed four times, with different observers to reduce bias. All birds seen or heard within 5 minutes and within 100 m were recorded to species. Bird counts were averaged across survey dates.

Vegetation Surveys

Habitat measurements were collected at all point count stations between 18 May and 8 August 1988. Two 50-m tapes were laid out to intersect at each station: one tape in a random direction, and the second tape at 90 degrees to the first tape. The line intercept method was used (Brower et al. 1989) to measure percent linear cover of sagebrush and other shrubs.

Twenty Daubenmire (1959) plots (0.5 m x 0.2 m) were placed at 5-m intervals along the tapes to measure ground cover. Percent cover of grasses and forbs were recorded at the species level. Percent cover of bare soil, rocky soil, cryptogamic crust, litter, rock, dead wood, *Selaginella*, rocky soil, and cattle droppings were also recorded. Percent cover for each variable was recorded to 1 percent increments, and was averaged for the 20 plots per station.

We derived elevation, aspect and slope for each station from BC Terrain Resource Inventory Mapping (TRIM) data. An index of moisture was derived from Landsat Thematic Mapper satellite data, taken 6 July 1996.

Statistical Analyses

All statistical analyses were performed in SPSS (version 9). For all species, bird presence versus bird absence was used as the dependent variable for logistic regression models (*table 1*). Logistic regression was used for analysis because most of the habitat and bird variables were not normally distributed, and this could not be remedied with transformations. Logistic regression is robust with non-normal data (Menard 1995), but because of its requirement of a binary response variable it is difficult to assess the relative quality of habitat. For the three most abundant species, Vesper Sparrow, Western Meadowlark, and Brewer's Sparrow, additional binary models were created to explore the value of different habitats (Begg and Gray 1984, Bender and Grouven 1998). In these models, presence data were further divided into low versus high abundance (*table 1*). As there was no biologically meaningful reason to choose a particular cut off between low and high abundance, cut-offs were calculated within the presence sites for all species that would give an equal number of stations in the low and high classes. Because Vesper Sparrow was highly abundant, few point count stations were surveyed where they were absent. This species was categorized as having low abundance (<1.33 birds), moderate abundance (>1.33 birds <2.66) and high abundance (>2.66 birds).

Vegetation data were analyzed at species level, but some of the less abundant forb species were grouped to genus or family (e.g. pussytoes, *Antennaria*). Data were sorted by frequency and abundance. Plant species or groups of species occurring at fewer than 50 stations were excluded. Floristic independent variables that were used are listed with taxonomic names (*table 2*). Plant species that were highly correlated with more abundant species were not included (i.e.: *Aristida longiseta* was consistently found with the more abundant *Sporobolus cryptandrus*). To examine the relative

Table 1— *Dependent variables used in logistic regression models of songbird habitat association. N is number of survey stations (total 245).*

Species	Dependent variables to measure occurrence	Dependent variables to measure habitat quality
Brewer's Sparrow	presence (N = 105) vs. absence (N = 140)	low (N = 70) vs. high abundance (N = 70)
Lark Sparrow	presence (N = 69) vs. absence (N = 176)	
Grasshopper Sparrow	presence (N = 52) vs. absence (N = 98)	
Western Meadowlark	presence (N = 49) vs. absence (N = 196)	low (N = 102) vs. high abundance (N = 94)
Vesper Sparrow	low (N = 79) vs. moderate and high abundance (N = 166)	moderate (N = 77) vs. high abundance (N = 89)

Table 2— *Floristic independent variables initially used in individual logistic regression models for songbird habitat association analyses*

Common Name	Taxonomic Name
Grasses	
Bluebunch wheatgrass	*Agropyron spicatum*
Cheatgrass	*Bromus tectorum*
Junegrass	*Koeleria macrantha*
Kentucky bluegrass	*Poa pratensis*
Needle-and-thread grass	*Stipa comata*
Sand dropseed grass	*Sporobolus cryptandrus*
Sandberg bluegrass	*Poa secunda*
Spreading needlegrass	*Stipa richardsonii*
Six weeks fescue	*Vulpia octoflora*
Forbs	
Balsamroot	*Balsamorhiza sagittata*
Cactus	*Opuntia fragilis*
Dandelion	*Taraxacum officinale*
Desert-parsley	*Lomatium* spp.
Fleabane (daisies)	*Erigeron* spp.
Knapweed	*Centaurea diffusa*
Knotweed	*Polygonum majus*
Lemonweed	*Lithospermum ruderale*
Lupine	*Lupinus sericeus* or *sulphureus*
Milk-vetches	*Astralagus* spp.
Mullein	*Verbascum thapsus*
Parsnip-flowered buckwheat	*Eriogonum heracleoides*
Phlox	*Phlox longifolia*
Pussytoes	*Antennaria* spp.
Snow buckwheat	*Eriogonum niveum*
Woolly plantain	*Plantago patagonica*
Yarrow	*Achillea millefolium*
Yellow salsify	*Tragopogon dubius*
Shrubs	
Big sagebrush	*Artemisia tridentata*
Pasture sage	*Artemisia frigida*
Rabbit-brush	*Chrysothamnus nauseosus*
Snowberry	*Symphoricarpos albus*
Three-tip sagebrush	*Artemisia tripartita*

importance of floristics, all forbs and all grasses were combined into two additional variables: "total forbs" and "total grasses." Other independent variables included were percent cover of cow dung, cryptogramic crust, dead wood, litter, moss, rock, rock/*Selaginella*, rocky soil, soil, aspect, elevation, moisture and slope.

To screen data for the selection of variables for stepwise models, individual logistic regressions were performed for each bird species dependent variable (*table 1*) with each of the independent variables (Hosmer and Lemeshow 1989). This step was used to prioritize variables, since sample size was not sufficient for all independent variables to be entered into a single stepwise regression. Variables were retained if the individual model was significant ($P<0.05$). Data were log transformed where this improved the fit of these regressions (Menard 1995). Where this was the case, the log-transformed variables were included in the models.

After the screening process determined which independent variables had significant associations and should be retained, all habitat associations were modeled using stepwise logistic regression. This allowed us to determine the relative importance of the different variables including plant species versus "total forbs" or "total grasses." We used backward elimination to reduce the risk of excluding variables that had a significant relationship to the dependent variable (Menard 1995). The maximum likelihood ratio was used to decide which variables to retain. Alpha levels used in all models were $P < 0.05$ for entry and $P > 0.10$ for removal of variables. A higher P value (such as $P >$

0.10) is recommended for removal to prevent the elimination of important variables (Menard 1995).

Results

In initial logistic regression analyses, all dependent variables were significantly associated, either positively or negatively, with six or more independent variables. In most cases, significant associations occurred between bird species and plant species (*table 2*) rather than "total forbs" or "total grasses." Significant variables from individual regressions were entered into the stepwise models for each species. The direction of an association was only interpreted if it was supported by regression results from individual models, to ensure that the direction of association did not change when variables were used in a group. All variables listed below were significant, and had the same directional relationship as in the single regressions. Values of r, the partial correlation coefficient, are provided.

Probability of Brewer's Sparrow presence was higher at sites having higher elevations, and at sites with more parsnip-flowered buckwheat (r = 0.08, P = 0.03), junegrass (*Koeleria macrantha*; r = 0.06, P = 0.04), litter (r = 0.10, P = 0.02) and cryptogramic crust (r = 0.06, P = 0.07). Brewer's Sparrow seldom occurred at sites with a north aspect (r = -0.05, P = 0.02), cactus (*Opuntia fragilis*; r = -0.07, P = 0.02) and sand dropseed grass (r = -0.04, P = 0.09; *table 3*). Although "total forb" was positively associated with Brewer's Sparrow at the individual model level, this variable was not significant in either the presence vs. absence or low vs. high stepwise models, while particular plant species were. Within occupied sites, high relative abundance of Brewer's Sparrow was positively associated with parsnip-flowered buckwheat (r = 0.10, P = 0.02), lupine (r = 0.13, P = 0.04), sagebrush (r = 0.06, P = 0.09) and litter (r = 0.09, p = 0.06; *table 3*). Elevation was not significant, meaning that for occupied sites at a given elevation, Brewer's Sparrow relative abundance was predicted by parsnip-flowered buckwheat, lupine, sagebrush and litter.

Lark Sparrow presence was positively associated with bare soil (r = 0.14, P = 0.00) and sand dropseed grass (r = 0.07, P = 0.06), and negatively associated with total forbs (r = -0.10, P = 0.03) and elevation (r = -0.09, P = 0.04; *table 3*).

Grasshopper Sparrow was positively associated with cheatgrass (r = 0.15, P = 0.01) and pasture sage (*Artemisia frigida*; r = 0.20, P = 0.00), and negatively associated with spreading needlegrass (*Stipa richardsonii*; r = -0.13, P = 0.00), sagebrush (r = -0.29, P = 0.00) and north aspects (r = -0.12, P = 0.07; *table 3*). 'Total grass' was not important to this species in either individual or stepwise regressions.

Western Meadowlark presence was positively associated with pasture sage (r = 0.07, P = 0.04), total grasses (r = 0.20, P = 0.00) and knapweed (*Centaurea diffusa*; r = 0.09, P = 0.03), and negatively associated with moisture (r = -0.18, P = 0.00), elevation (r = -0.09, P = 0.04) and balsamroot (*Balsamorhiza sagittata*; r = -0.18, P = 0.00; *table 3*). Within occupied sites, higher abundance was more likely at drier sites (moisture r = -0.23, P = 0.00) with needle-and-thread grass (r = 0.05, P = 0.04) and negatively associated with three-tip sage (*Artemisia tripartita*; r = -0.13, P = 0.01; *table 3*).

Vesper Sparrow presence was positively associated with lupine (r = 0.09, P = 0.03) and pasture sage (r = 0.10, P = 0.01), and negatively associated with pussytoes (r = -0.07, P = 0.06), dead wood (r = -0.18, P = 0.00) and the combination of rock and *Selaginella* species (r = -0.07, P = 0.06; *table 3*). "Total forbs" was not a significant predictor in either individual or stepwise models. Within occupied sites, higher abundance of Vesper Sparrow was positively associated with yarrow (*Achillea millefolium*; r = 0.12, P = 0.02) and pasture sage (r = 0.08, P = 0.08), and negatively associated with sand dropseed grass (r = -0.20, P = 0.00), sagebrush (r = -0.18, P = 0.01) and moisture (r = -0.14, P = 0.02; *table 3*).

Discussion

By considering broadly distributed occupied and unoccupied survey stations within big sagebrush habitat, we were able to confirm the suggestion that floristics play an important role in habitat associations (Tomoff 1974, Rotenberry 1985). All five focal songbird species had significant associations with particular understory plant species. Our approach of using binary logistic regressions to assess habitat quality undoubtedly resulted in the loss of information as dependent variables were collapsed into "presence versus absence" and "high and low" abundance classes for bird species. Despite the limitations of this method, in many cases individual understory species were more important than "total forbs" and "total grasses," highlighting the importance of measuring individual understory species. Inclusion of plant species improved the description of habitat associations, as compared to associations identified by Wiens and Rotenberry (1981) whose study included all of our focal bird species except Grasshopper Sparrow. By looking at habitat associations within shrubsteppe at a regional level, they found that many of the correlations to habitat features were weak, with the strongest associations occurring between songbirds and shrub species (Wiens and Rotenberry 1981). The associations

Table 3— *Results of stepwise logistic regressions for the focal songbird species. Only significant variables are listed, (P < 0.10). "L." before a variable means that it was log-transformed for better model fit. All models are significant (P < 0.05).*

Species	Model	Variable	Significance[1]
Brewer's Sparrow	presence vs. absence	L. Litter	(+)**
		Elevation	(+)**
		L. Parsnip buckwheat	(+)**
		Crust	(+)*
		L. Junegrass	(+)**
		L. Sand dropseed	(-)*
		Aspect	(-)*
		L. Cactus	(-)**
Brewer's Sparrow	low vs. high abundance	L. Lupine	(+)**
		L. Parsnip buckwheat	(+)**
		L. Litter	(+)*
		L. Sagebrush	(+)*
Lark Sparrow	presence vs. absence	Bare soil	(+)***
		L. Sand dropseed	(+)*
		Elevation	(-)**
		L. Total forbs	(-)**
Grasshopper Sparrow	presence vs. absence	L. Pasture sage	(+)***
		L. Cheatgrass	(+)***
		Aspect	(-)*
		L. Spreading needle	(-)***
		L. Big sagebrush	(-)***
Western Meadowlark	presence vs. absence	L. Total Grasses	(+)***
		L. Knapweed	(+)**
		L. Pasture sage	(+)**
		Elevation	(-)**
		Moisture	(-)***
		L. Balsamroot	(-)***
Western Meadowlark	low vs. high abundance	L. Needle-and-thread	(+)**
		L. Three-tip sagebrush	(-)***
		L. Big sagebrush	(-)***
		Moisture	(-)***
Vesper Sparrow	low vs. moderate/high abundance	L. Pasture sage	(+)***
		L. Lupine	(+)**
		L. Pussytoes	(-)*
		Rock/Selaginella spp.	(-)*
		L. Dead wood	(-)***
Vesper Sparrow	moderate vs. high abundance	L. Yarrow	(+)**
		L. Pasture sage	(+)*
		Moisture	(-)***
		L. Big sagebrush	(-)***
		L. Sand dropseed	(-)*

[1](*) indicates 0.05 < P < 0.10; (**) indicates P < 0.05; (***) indicates P < 0.001; (+/-) is direction of association.

Notes: Aspect was the sole categorical variable, north (315° - 44°), east (45° - 134°), south (135° - 224°) or west (225° - 314°). The significant response to aspect represented a negative relationship with north aspects relative to east, south, and west.

we have observed among songbirds and grass and forb species within big sagebrush habitat help to explain the patchy distribution of sagebrush breeding songbird species in our study area, and possibly reflect dietary preference of adult birds, habitat for insect prey, or structural requirements for nesting.

Previous studies have shown that Brewer's Sparrow is positively associated with shrub cover (Knick and Rotenberry 1995). Although Brewer's Sparrow usually nests in big sagebrush in our study area, big sagebrush density was not associated with presence of this species, but was only associated with high abundance within occupied sites. In contrast, Brewer's Sparrow presence was predicted by elevation, parsnip-flowered buckwheat abundance and other variables. Both parsnip-flowered buckwheat and lupines were further associated with high Brewer's Sparrow abundance. This association may be related to foraging habitat. The areas that Brewer's Sparrow select had high abundance of herbaceous perennial forbs, and had three times the abundance and twice the species richness of arthropods compared to sites not selected by Brewer's Sparrow sites in our study area (P. Krannitz, unpubl. data). Lepidopteran larvae make up 72 percent of nestling Brewer's Sparrow diet (Petersen and Best 1986), and adult Brewer's Sparrow have been observed feeding their chicks large lepidopteran larvae collected from lupines from areas of our study sites (N. Mahony, pers. comm.). Lepidopterans often have association with specific 'host plants', including plants for larval food (Swengel and Swengel 1999). Herbaceous perennial forbs have also been used as nesting substrate in burned areas (N. Mahony, unpubl. data).

The association of Brewer's Sparrow abundance with forb species has management implications, as many of these species are affected by grazing and burning. Lupines, for example, are reported to increase after fires (Grigore and Tramer 1996). Although not all of the burn histories of our point count stations are known, some of the areas of greatest forb productivity had been recently burned. Lupines are toxic to cattle and thought to increase under grazing pressure although in overgrazed areas they may still be used as forage by cows. Cows often eat lupines at our sites (N. Mahony, pers. comm.) and lupines are highly abundant in a grazing exclosure in this area, relative to the surrounding grazed pasture.

A marked spatial separation in the distribution of Lark and Brewer's Sparrow was obvious throughout our study sites. This pattern was reflected by differences in habitat associations for these species with Brewer's Sparrow being negatively associated with sand dropseed grass while Lark Sparrows occurred in areas with high sand dropseed grass abundance and few forbs. Sand dropseed grass is a native species that is commonly associated with disturbance and overgrazing (Archer 1953). Local-scale plant variables were similarly important to Lark Sparrow in Colorado, where they preferred shale plant communities (Haire et al. 2000). As in Arizona (Bock and Bock 1992), Lark Sparrow at our sites was positively associated with bare soil. Bare soil is positively associated with grazing (Milchunas et al. 1989), which could further indicate an association between Lark Sparrow and disturbed areas.

Other studies have shown that Grasshopper Sparrow is associated with 'total perennial grasses' (Vander Hagen et al. 2000). We did not observe a relationship between Grasshopper Sparrow occurrence and total grasses at the individual logistic regression model level; therefore this variable was not entered into the stepwise regression. However, the individual logistic regression models showed a strong relationship between this bird species and needle-and-thread grass. Grass cover is important for concealing nests (Vickery 1996), although Grasshopper Sparrow also select areas with bare soil, presumably to aid in foraging on the ground for insects (Whitmore 1981, Vickery 1996). Grasshopper Sparrow was more abundant in areas with abundant Eurasian weeds relative to native plants, in Manitoba, Illinois and Colorado (Wilson and Belcher 1989, Haire et al. 2000, Walk and Warner 2000). The positive association between Grasshopper Sparrow with cheatgrass and pasture sage, both weedy species, may be because these plants are widespread in the dry, open areas of my study sites which this species preferred. However, grasshopper abundance, an important component of Grasshopper Sparrow diet (Vickery 1996), tends to increase on overgrazed rangeland invaded by exotic species (Smith 1940, Nerney 1958). It is possible that Grasshopper Sparrow responds more to plant structure rather than to floristics (Walk and Warner 2000), as supported by the strong negative association we observed between this species and abundance of big sagebrush. A landscape level analysis of habitat associations in these areas suggests that Grasshopper Sparrow presence is mainly dependent on the availability of large areas of shrubsteppe with low density of big sagebrush (Paczek 2002).

A positive association of Western Meadowlark presence with total grass abundance has been found in previous studies (Wiens and Rotenberry 1981, Knick and Rotenberry 1995, Krannitz and Rohner 2000). However, within occupied sites in our study, Western Meadowlark abundance was positively associated with abundance of needle-and-thread grass, rather than total grass cover, implying that presence of this native grass may be important to this species. In other studies, Western Meadowlark was positively correlated with native grass species, and negatively associated with Eurasian weeds (Wilson and Belcher 1989, Haire et al.

2000). The reason for this association is not clear. Seeds are a minor part of Western Meadowlark diet during breeding season (Kaspari and Joern 1993), but grass is important in nest cover (Lanyon 1994), and native grasses could provide habitat for insect prey.

Although Vesper Sparrow was highly abundant throughout our study area, they shared similar associations to Brewer's Sparrow, occurring in highest numbers in areas with abundant lupines, and low abundance of sand dropseed grass. Structure also appeared to be important for this species, as Vesper Sparrow were associated with dry open sites with sparse cover of big sagebrush, as has been previously observed (Kantrud and Kogoloski 1983).

The relationships that we have identified between birds and floristics provides more information on bird distribution than the measurement of total forb and grass cover alone. These associations further provide a means by which wildlife managers can communicate with range managers in order to ensure the protection of songbird habitat, both on public and private land. The associations that we observed are supported by what is known about our focal species in the literature, however further research is required to tease apart the relative importance of floristics from vertical structure and to identify the roles that different plant species may play in songbird foraging.

Acknowledgments

Funding for this study was provided by HCTF, NSERC, Environment Canada and Career Edge. T. Rich, K. Martin, B. Klinkenberg, D. Smith, V. Lemay and S. Melles provided useful editorial and statistical advice. The following people and organizations allowed bird surveys on their land: Osoyoos First Nations Band, Penticton First Nations Band, Lower Similkameen First Nations Band, the Nature Trust, B. Clements, W. Clifton, B. Ellis, D. Francis, L. and N. Kusler, L. McFayden, C. Schneider and J. McGibbon. Assistance with field work was provided by K. Dust, L. Stepnisky, K. Lisgo and P. Williams.

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Using Survival Analysis of Artificial and Real Brewer's Sparrow (*Spizella breweri breweri*) Nests to Model Site Level and Nest Site Factors Associated with Nest Success in the South Okanagan Region of Canada[1]

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Abstract

Predation is the predominant cause of nest failure for the Brewer's Sparrow (*Spizella breweri breweri*), a provincially red-listed shrub-steppe species that has experienced significant declines throughout most of its range. We monitored Brewer's Sparrow nests and conducted an artificial nest experiment, in the South Okanagan Valley, British Columbia (B.C.), to investigate factors associated with nest predation. Avian predation of artificial nests was higher when nests were placed in smaller shrubs, set out earlier in the season and when corvid numbers were high. Predator imprints on clay eggs in the artificial nest experiment showed that rodent predation increased through the season. Results from real nests indicate that nest initiation date was also an important predictor of nesting success with more predation by all predators later in the season. Nesting density was lower at sites with more corvids, and much higher at similar sites with low corvid numbers. Our results suggest that Brewer's Sparrows select sites lower in avian nest predator activity and that this results in the effect of other predators such as rodent becoming more apparent.

Keywords: artificial nests, Brewer's Sparrow, corvids, depredation, predator avoidance, *Spizella breweri breweri*, survival analysis, timing.

Introduction

Like many other species in shrub-steppe habitat, Brewer's Sparrow numbers are declining at an estimated 3.2 percent per year range wide (Sauer et al. 2001). Brewer's Sparrow is red-listed in British Columbia (BC), due to small population numbers and threatened sagebrush habitats (Sarell and McGuiness 1996). The BC population is at the northern extent of the species' range and may play a crucial role as a source population for declining populations in the south. It is therefore important to understand the factors that affect this population and to address problems that may further reduce population size.

Several studies have assessed nest placement and nest site characteristics for Brewer's Sparrows (Petersen and Best 1985, Knick and Rotenberry 1995). Only a few studies have attempted to determine what influence habitat differences have on Brewer's Sparrow nesting success (Reynolds 1981, Mahony unpubl. ms.). However, in these studies, sample sizes were small and associations were only tested at the nest shrub or nest patch level. Our objectives are to examine the relative importance of site level and individual nest variables on the nesting success of artificial nests and then to compare the results to those from real Brewer's Sparrow nest survival. Site level factors tested in this study include the associations of nest survival with nesting density and predator activity. Individual nest variables modeled using survival analysis are nest concealment, distance to nearest tree, density of trees, distance to the nearest neighbour and timing.

Methods

Artificial nest experiments and real nest monitoring were conducted simultaneously to determine factors associated with nest survival during the summer of 2000, from 1 May to the end of July, coinciding with Brewer's Sparrow's breeding season (Cannings et al. 1987). The six sites used for the artificial nest experiment were located in the shrub-steppe habitat of the South Okanagan region, British Columbia, Canada, in the region between the villages of Keremeos (49° 12'N, 119°49'E) and Okanagan Falls (49°20'N, 119°

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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34'E). Using survey data from Paczek (2002), we were able to select six sites with known Brewer's Sparrow relative abundance and comparable characteristic known to be associated with Brewer's Sparrow abundance. Because these characteristic were selected based on correlations with abundance it was difficult to obtain constant sites, however all our sites were had comparable lupine, parsnip buckwheat, and sagebrush cover but varied in litter cover. Litter cover was assumed not to affect the distribution of corvids or nest predation rate. Rather, its influence would primarily be in site selection for food availability.

Artificial Nests

We compared the nest predation rates in three sites with low relative abundance to three sites with high relative abundance. We established eight transects of artificial nests at each of the six sites. Each transect consisted of six artificial nests placed at 5, 30, 55, 80, 105, and 130 m (25 m increments) from the base of isolated conifer trees. Trees had a mean height of 16 meters (range 5-30 m).

Every attempt was made to mimic the dimensions and construction of the Brewer's Sparrow nest to provide a similar search image for predators. We used commercially purchased realistic woven-grass canary nests (approximately 10 cm in diameter and 4 cm deep; Hagen© item B-1980) and two colored clay eggs for artificial nests. Two kinds of non-toxic clay with negligible odor were used to make the eggs: 1) Sculpey II©, which can be permanently hardened by baking. This is useful because it provided a permanent record, and 2) Aken plastaline© (Plastaline modeling clay; Van Aken international, Rancho Cucamonga, CA) was also used as it was the clay most commonly used in artificial nest experiments. Modeling clay provided an excellent substrate for recording tooth or beak imprints. Clay eggs were placed in nests for a 12-day cycle, based on the approximate incubation period of Brewer's Sparrows of 11 days (Rotenberry and Wiens 1991). The nests were checked between sunrise and 12:00 on the 3rd, 6th, and 12th day of each trial. A nest was considered depredated if one or both eggs were missing, or marked with direct evidence of predation such as beak, tooth, or scratch marks. Untouched eggs were removed on the last (12th) day. After being left empty for 8 days, the nests were moved at least 5 m in random directions and reset for another 12 days, three trials in total were run.

Real Nests

Real nest searching and survival monitoring was conducted at 10 sites, six of which overlapped the artificial nest experiment sites. Real nest monitoring was conducted on a three-day rotation for six sites and a four-day rotation for the remaining four sites. Nests were considered successful if they were found empty after the expected fledging date (8-9 days after hatching), and signs of a successful fledge were observed. Nests that were abandoned with all the eggs intact were removed from the analysis. To avoid pseudo-replication (Hurlbert 1984), only first nesting attempts were used in the data analysis, and renests were disregarded.

Multivariate Analysis to Model Predation Patterns for Each Predator Type

To assess factors that are associated with nest survival we modeled the follow individual nest variables using survival analysis; nest concealment, distance to the nearest neighbour, tree encroachment predictors (distance to nearest tree, density of trees) and timing.

Characteristics of nest placement were measured: height of above the ground (m), plant height (m), plant species in which the nest was built or placed, number of supporting branches, and percentage overhead cover. These characteristics were measured for every real and artificial nest. To prevent abandonment, measurements were taken once a nest became inactive. Nest height was measured from the ground to the rim of the nest with a meter stick. Plant height was measured from the ground to the top of the plant that the nest was built or wired in. Cover height was calculated by subtracting the difference between plant height and nest height. Percent overhead cover was estimated from the amount of vegetation covering the nest one meter above the nest. To avoid observer bias, one person estimated percent overhead cover and counted the number of supporting branches for all of the nest sites. However, percent cover estimates and branch counting were prone to measurement error and were not used in the model building process; rather they were used to compare general nest characteristics between real and artificial nests.

Nearest neighbour distances or the distances between nests were estimated using precise geographical locations of all nests were measured and mapped in AutoCAD© (Autodesk 2002). Nearest neighbour was used as an individual nest variable in the analysis of real nests only. It was not used in the artificial nest analysis because the artificial nests were all placed equal distances apart, at 25 meters increments.

To determine the effect of tree encroachment on nest predation, tree density and horizontal distance to the closest tree were measured using a Nikon Laser 800 Rangefinder directed perpendicularly to the trunk of a tree. Tree density was the count of all trees greater than five meters high (conifer and deciduous) within 100 meters of the nest. Tree density estimates were grouped categorically; 0-5 trees was low tree density, 6-10 trees

was medium density and high tree density was greater than or equal to 11 trees within 100 m. Measurements were recorded for all artificial and real nests.

Clutch initiation date was determined from either nest observations or counting backwards from the hatching or fledging date. The hatching date for Brewer's Sparrow eggs is 10-12 days with a mean of 11 days (Reynolds 1981, Rotenberry and Wiens 1991) and was used to calculate laying date or the start of the egg stage. Fledging was expected to occur between 7-9 days after hatching. Thus, an eight day (Rotenberry and Wiens 1991) mean fledging time was used to calculate hatching date, the start of the nestling stage.

Model building using survival/failure time analysis under Cox's Model, in combination with forward stepwise selection process, was used to determine which factors most strongly influenced nest predation rate. Akaike Information Criterion (AIC) (Burnham and Anderson 1998) was used at each step of the modeling process to evaluate and select the most parsimonious model that best fit the data, and to determine the contribution of each variable to the model, using methods suggested by Collett (1994). Because, there were several cases where the models were tied for best fit (AIC within 1 or 2 units), we assessed the uncertainty around the models selected using Akaike Weights (w) (Burnham and Anderson 1998) of models. The variables entered into the Cox's regression models were: distance from tree; tree density within 100 meters from the nest; plant height (correlated with height of nest placement); distance to the nearest neighbour for real nest predation only; and clutch initiation date (time).

Site Level Variables for Univariate Analysis

To assess the importance of nest patch area, predator abundance, predator activity, breeding pair density, and nest density estimates, the Mayfield daily survival rate was calculated for each site by grouping all nests at each site. Appropriate modifications were made (maximum likelihood estimator of survival rate; MLE) as nests were visited periodically and the exact date of depredation is unknown (Bart and Robson 1982, Krebs 2000).

Each predator type was analyzed separately for artificial nests; avian, mammalian, and pooled predators. The daily survival rate (DSR) for real nests includes all predator types, as the predator type cannot be determined with confidence (Pietz and Granfors 2000). Univariate correlation statistical tests were preformed using STATISTICA© (Statsoft Inc. 1999). MLE was calculated using the program SURVIVAL (Krebs 2000). All correlation analyses are Spearman Rank correlation (r_s).

The effects of population size and density of Brewer's Sparrows on nest predation were investigated using two measures of density: 1) nest density (number of nests per ha) and 2) breeding pair density (number of singing males/area), estimated using a combination of line and point count survey procedures (Recher 1988, Zanette and Jenkins 2000). Additionally, the area occupied by the population was calculated to determine the potential effects of nesting patch size on the nesting success.

Potential nest predators were monitored throughout the study at six sites using a measure of activity level. To produce an avian nest predator activity index, each observer independently recorded potential predators encountered while conducting fieldwork, the frequency of observations, and the number of hours spent in the area. Moving predators were recorded only where first seen, and repetitive daily sightings of the same species in the same place were recorded only once by that person for that day. To avoid overestimates, duplicate auditory or visual detections coming from the same direction were omitted. Results for all observer-days were combined to calculate the average number of predators seen per hour (encounter rate). Counts were not conducted during inclement weather. Predator activity was compared to the number of Brewer's Sparrow nests present at the site to determine if there were fewer predators at sites 'high' in Brewer's Sparrows. Sites designated as 'low' Brewer's Sparrow sites had less than five nests per site and 'high' Brewer's Sparrow sites had greater than five nests.

Results

Multivariate Analysis

For real nests, clutches initiated earlier in the season had a greater chance of survival than later nests ($\Delta AIC_c = 0.00$, $w = 0.36$, $p < 0.05$). Artificial nests showed a similar trend for predation by pooled predators ($\Delta AIC = 1.62$, $w = 0.26$, $p < 0.01$), and by mammals ($\Delta AIC = 0.00$, $w = 1.00$, $p < 0.00$). Avian predation of artificial nests decreased through the season, but not significantly ($\Delta AIC = 7.40$, $w = 0.02$, $p = 0.12$).

The effect of plant height on nest survival differed between real and artificial nests. Plant height did not influence survival of real nests. However, artificial nests placed in taller shrubs experienced less avian predation ($\Delta AIC = 1.82$, $w = 0.26$, $p < 0.01$). Plant height in combination with time was a competing model, as artificial nests placed in taller shrubs and initiated later experienced less avian predation risk ($\Delta AIC = 0.00$, $w = 0.66$, $p < 0.00$). Predation of artificial nests by pooled predators also decreased with

increased plant height, but only in combination with time (ΔAIC = 0.00, w = 0.59, $p < 0.01$).

Plant height was not an important variable for real nest survival, perhaps because plant height was associated with cover ($r_s = 0.79$, $p < 0.00$, n = 122). There were significant differences between plant heights, percent overhead cover and cover height between real and artificial nests (Mann-Whitney U-test; $z = 5.82$, $p < 0.00$, $z = 10.64$, $p < 0.00$, and $z = 7.02$, $p < 0.00$, respectively). Despite placing artificial nests at previously reported nest heights for Brewer's Sparrows, real nests were placed in plants with a higher mean height (mean 87.39 ± 25.4 SD) than artificial nests (mean 72.88 ± 26.5 SD). The mean cover height for the real nests was 55 cm whereas for artificial nests the mean cover was much less at 42.5 cm).

Univariate Analysis

Potential avian nest predators were mostly within the family Corvidae and included the American Crow (*Corvus brachyrhynchos*), Common Raven (*Corvus corax*), and Black-billed Magpie (*Pica pica*). Nesting density had no effect on nest survival. Predator activity was significantly higher in sites that were lower in Brewer's Sparrow abundance, when compared to the other higher abundance sites (n = 6, $r_s = -0.81$, $p < 0.05$). Avian nest predator activity was associated with reduced survival of real nests (n = 4, $r_s = -1$, $p < 0.00$) and reduced artificial nest survival attributable to avian predators (n = 6, $r_s = -0.83$, $p < 0.04$), which provides evidence that when avian nest predator activity is high nest survival decreases. In contrast, mammalian predation did not vary significantly between high and low Brewer's Sparrow abundance sites (Mann-Whitney U-test $z = -0.77$, $p = 0.44$).

Discussion

Temporal Changes

Increased predation later in the season was the most important factor affecting nest predation of real nests. Artificial nests indicated that mammalian predation rate also increased through the season. A similar increase in mammalian predation has been associated with a seasonal increase in abundance and dispersal of hungry juveniles (Briese and Smith 1974) and is likely to case at our sites (Klenner, pers. comm.[1]). Snakes have been documented as important predators in shrub lands (Best 1978, Thompson et al. 1999), but were rarely attracted to artificial nests (Marini and Melo 1998). Thus, increased predation in real nests over time might have been attributable to snakes as well as small mammals, but this could not be documented using artificial nests.

In contrast to our results, the reverse pattern of decreased predation through time has been documented elsewhere. Increased nest predation early in the season has been linked with the dispersal of juveniles and fledging avian predators (Zimmerman 1984, Patnode and White 1992, Sloan et al. 1998). Corvids breeding in the spring are known to use the eggs of other species to supplement the diet of their weaning or fledging young (Boarman and Heinrich 1999). This explanation does not seem probable for this study, although many of the nest predators were corvids, timing did not have a strong effect on the avian predation rate of artificial nests. Additionally, avian predation of real nests might have been minimized, if Brewer's Sparrows avoided sites high in corvids when selecting sites. Our results suggest that birds were the primary predators for artificial nests but mammalian predation might have been the dominant predator of real nests (Willebrand and Marcstrom 1988, MacIvor et al. 1990).

Plant height and nest height were strongly associated and provided an index of nest concealment. Concealment was not related to the survival of real Brewer's Sparrow nests but was for artificial nest. Our results are contrary to those in Martin's (1992) review, which found that artificial and real nests that are more concealed were less likely to be depredated. However, several studies have found an effect of nest concealment on artificial nests but failed to find one for in real nests (Storaas 1988, Cresswell 1997). There are three plausible explanations for this contradiction:

1) Concealment may be important for Brewer's Sparrows but they were selecting for overall cover at the nest-patch scale (Martin and Roper 1988, Martin 1992), which was not measured in this study.

2) Shrub cover was already at an optimal level so that the range in cover did not provide enough statistical evidence of minor changes in predation rate.

3) Avian predation was not as important as ground-dwelling predators, making the influence of overhead cover negligible.

Real nests found in this study were placed in plants with a higher mean height than what has been documented in other studies (69 cm ± 15 SD, n = 58 [Petersen and Best 1985], 66.9 cm ± 11.3 SD, n = 27 [Rich 1980], 71.36 cm ± 1.23 SD, n = 89 [Rotenberry

[1]Walt Klenner is a wildlife biologist at British Columbia Ministry of Forests and works on small mammals in the South Okanagan.

et al. 1999]). This may be an indication that mammal and snake predation may have been more important than that of avian predation. Additionally, Sullivan and Dinsmore (1990) found that cover height reduced crow predation of egg up until 20cm, but beyond 20 cm there was no substantial reduction in predation. The majority of real nests at our sites had more than 20 cm of cover height with an average of 55 cm (range 17-164 cm). Brewer's Sparrows at our sites may be nesting under an optimal amount of cover, thus the changes within the range of cover may not be extreme enough to alter predation rates.

Predator Avoidance through Site Selection

Our results suggest that Brewer's Sparrows prefer to nest in sites that are lower in corvid numbers. Nest predator avoidance can be identified by a reduction in the number of nests found at these sites. Only four real nests where found at sites high in avian predators and these nests were distributed at a lower mean density. This suggests that Brewer's Sparrows may avoid nesting in areas high in corvid numbers. The relationship between nest predator activity and nest predation rates is not surprising and is consistent with other studies (Zanette and Jenkins 2000). Increased predator activity and predation should result in a selective force for Brewer's Sparrows to nest in areas that are lower in nest predator activity. Paczek (unpubl. data) also suggests that Brewer's Sparrows were negatively correlated with avian nest predators ($n=159$, $r_s = -0.48$, $p = 0.00$).

Our artificial nest results support research that found predator presence was correlated to the potential rate of predation by that predator (Angelstam 1986, Andrén 1992). This supports that notion that surveys of nest predators can increase the understanding of predation risk and particular sites (Sloan et al. 1998). Andrén (1995) stresses the importance of knowing predator community composition for understand changes in predation patterns. For instance, mammalian predation did not differ between high and low Brewer's Sparrow density (see Welstead 2002 for details). These differences in spatial patterns of nest predation with predator types have been well documented (Nour et al. 1993, Haskell 1995, Hannon and Cotterill 1998).

Management Implications

It is advised that long term monitoring of corvid populations be conducted and the influence of avian nest predator numbers be a consideration when investigating the impacts of urban sprawl and agricultural conversion in the South Okanagan. Density of corvids tended to increase proportionally with the encroachment of agricultural land into to natural habitat (Andrén 1992). If Brewer's Sparrows require sites that are low in corvid numbers for nesting and if corvid numbers increase in the South Okanagan, it maybe hard for Brewer's Sparrows to select sites low in corvid numbers.

Additionally, tree encroachment, which is a concern in the South Okanagan due to fire suppression (Turner and Krannitz 2001), may be a contributing factor to the increase in density of nest predators (Krannitz and Rohner 2000). Encroaching trees provide perching and nesting sites for a number of avian nest predators such as corvids (Loman and Göransson 1978, Sullivan and Dinsmore 1990).

Acknowledgments

This research was made possible through funds from Environment Canada (Science Horizon + operating funds); ESRF (Endangered Species Recovery Fund). Thanks to P. Arcese, P. Marshall, A. R. E. Sinclair, T. Rich, S. Paczek, R. Vennesland, D. Cunnnington, S. Leckie, D. Dagenais, P. Ramsay, D. Haag, V. Lemay, M. Sarell, S. Parken, P. Sandiford, D. Higgins, and R. Gill.

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Community-Based Restoration of Desert Wetlands: The Case of the Colorado River Delta[1]

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Abstract

Wetland areas have been drastically reduced through the Pacific Flyway and the Sonoran Desert, with severe consequences for avian populations. In the Colorado River delta, wetlands have been reduced by 80 percent due to water management practices in the Colorado River basin. However, excess flows and agricultural drainage water has restored some areas, providing habitat for several sensitive species such as the Yuma Clapper Rail (*Rallus longirostris yumanensis*). This has sparked community interest to explore different scenarios for the restoration of bird habitat. Three community-based restoration projects are currently underway in the delta, focusing on the restoration of marshlands, riparian stands, and mesquite bosque. The goal of these projects is to reestablish the ecological functions of the Colorado River delta, through an efficient use of available water for the conservation of biodiversity and the preservation of social and cultural values in the region.

Key words: birds, Colorado River, Hardy River, water management, wetland restoration.

Introduction

Wetland restoration has become a critical requirement to achieve conservation and recovery goals of many bird species. This need has become more evident as we have realized that wetland dependent birds have suffered population declines over the last century (Rosenberg et al. 1991, Davis and Ogden 1994, DeGraff and Rappole 1995). Causes for these declines are related to the dramatic rate at which wetlands have been destroyed in North America (Dahl 1990, National Research Council 1995), diminishing the area and quality of breeding grounds, wintering areas, and migratory stopover habitat (Weller 1999). In western North America, the patterns are shocking: wetland loss in the California Central Valley is estimated at 95 percent (Zedler 1988), and loss along the U.S. Pacific coast has been 50 percent (Helmers 1992).

This trend has been particularly critical in the Sonoran Desert, where the struggle for water between human uses and the environment has dried up most of the riparian forests and wetlands (Brown 1985). The Lower Colorado River basin is a clear example where the Colorado delta has lost over 80 percent of its wetland area over the last 80 years (Valdés-Casillas et al. 1998).

Worldwide, loss of wetlands is often related to water management practices (Lemly et al. 2000), and this certainly is the case in the Lower Colorado Basin (Lemly 1994, Morrison et al. 1996), where water diversions for human activities have negatively impacted the delta region (Glenn et al. 1996). Nevertheless, agricultural runoff, sporadic flood flows, and their interaction with the tidal regime from the Upper Gulf of California have restored and maintained part of these wetlands, showing that environmentally sound water management could help restore and conserve some avian habitats in the delta (Glenn et al. 2001, Zamora-Arroyo et al. 2001).

The interest in restoring wetlands in the Colorado River delta and allotting water for the environment has been increasing on both sides of the border (Valdés-Casillas et al. 1998, Pitt 2001). Opportunities for restoration have been identified (Briggs and Cornelius 1998, Luecke et al. 1999) and these ideas have been discussed in public forums incorporating environmental considerations into the political, social, and economic framework (Varady et al. 2001). An important result is a binational consensus among stakeholders, agencies, environmental groups, and academia on the importance of developing and implementing a binational conservation/restoration program, based on

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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robust scientific information, which would consider water requirements for wildlife conservation.

The long-term success of restoration and conservation efforts is linked strongly to the support of local communities (Little 1994). In this sense, wetlands of the Colorado River delta provide one of the greatest opportunities for restoration in the Sonoran Desert. As local communities are strongly connected to wetland resources, they are committed for the long-term conservation and recovery of these resources, and they have joined efforts to form a local association to achieve these goals (Valdés-Casillas et al. 1999, Carrillo-Guerrero 2002).

In this paper we discuss the opportunities for restoration in the Colorado River delta, initial restoration projects, and the critical role that local communities can play in the long-term success of such efforts.

The Colorado River Delta

The Colorado River delta is located in the western edge of the Sonoran Desert, at the common border of the Mexican states of Baja California and Sonora, surrounded by the driest biomes of the ecoregion (*fig. 1*). The delta ecosystem covers 169,000 ha, providing critical linkage among deserts, freshwater/riparian areas, brackish marshes, tidal flats, and the Upper Gulf of California.

Prior to the dam era, the cottonwood (*Populus fremontii*) – willow (*Salix gooddingii*) forest was very common in the Colorado River delta, extending over tens of thousands of hectares throughout the Mexicali Valley (Sykes 1937). Thick mesquite (*Prosopis* spp.) bosque dominated the upland terraces, in association with arroweed (*Pluchea sericea*) and quail bush (*Atriplex lentiformis*) (Mearns 1907). Oxbows, backwaters, and seepage were common, and provided for vast extensions of marshlands (Sykes 1937).

Eighty years later, only 1,500 ha of cottonwood-willow remain, regenerated after excess flows reached the delta, and maintained with "administrative losses" from the irrigation systems (Glenn et al. 2001). The extent of mesquite bosque has been largely diminished, as upland areas have been cleared for agriculture development (Valdés-Casillas et al. 1998). Marshlands have been reduced as well, but significant areas have been maintained with agricultural drainage and brackish water. The Ciénega de Santa Clara, the largest marsh in the Sonoran Desert and a protected natural area, extends over 6,000 ha (Glenn et al. 1992; *fig. 1*). The Ciénega is maintained by brackish agricultural drainage from the Wellton-Mohawk Valley in Arizona, but there are still plans to divert this water for human consumption (Glenn et al. 2001).

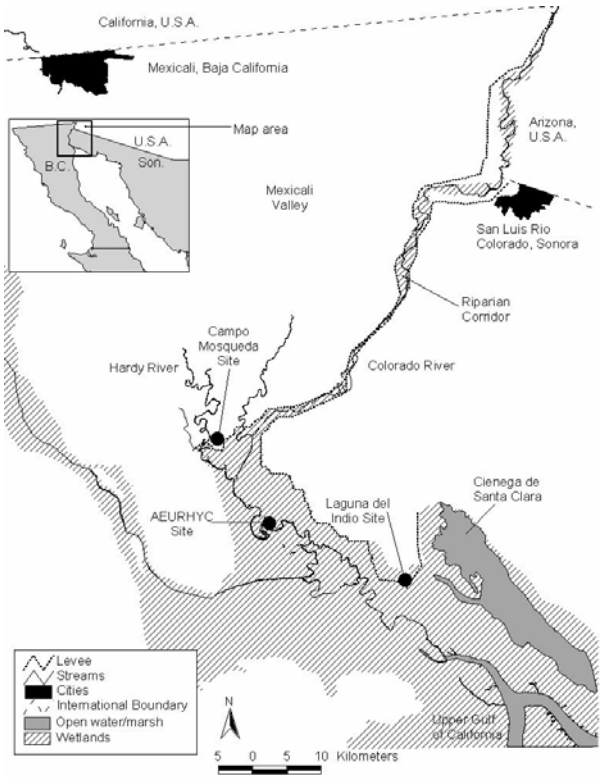

Figure 1— Wetland areas and restoration projects in the Colorado River delta, México. Black dots indicate the location of the restoration sites.

Despite these changes, many species still thrive in the region and the Colorado River delta remains one of the best opportunities for binational collaboration for biodiversity conservation along the border. The importance of the delta for the conservation of birds has been recognized both nationally and internationally. In México, a portion of the delta wetlands is part of the Upper Gulf of California and Colorado River Delta Biosphere Reserve (SEMARNAP 1995). The delta also is an Important Bird Area in México (AICA), and a priority site for the conservation of biodiversity as decreed by the National Commission on Biodiversity (CONABIO; Cervantes et al. 1999). The Colorado River delta also is recognized as a wetland of international importance by the Ramsar Convention (Ramsar Convention Bureau 1998), and is part of the Western Hemisphere Shorebird Reserve Network (WHSRN 1998).

Between 1993 and 2002, 353 bird species have been detected in the Colorado River delta in México (Patten et al. 2001, Hinojosa-Huerta et al. in press). The delta provides habitat for 24 protected Mexican species, for migratory and wintering waterbirds along the Pacific Flyway, and for neotropical migrant landbirds (Mellink and Ferreira-Bartrina 2000; García-Hernández et al.

2001; Hinojosa-Huerta et al. 2001a, 2001b; Diario Oficial de la Federación 2002). Nearly 200,000 shorebirds and 60,000 ducks and geese use the delta wetlands as wintering grounds or for stopover habitat during migration (Morrison et al. 1992, Mellink et al. 1997), and at least 110 species of neotropical migratory landbirds visit the delta during their migratory movements (Patten et al. 2001).

Restoration Needs in the Colorado Delta

The root causes of ecological decline in the Colorado River delta are the fundamental changes in water and sediment movement brought on by river impoundment and water diversions all along the Colorado River. These have significantly impacted the local avifauna. Ten species of breeding birds and fourteen species that use this area as stopover or wintering ground have required a status of legal protection under Mexican laws (Endangered, Threatened, or Special Protection; Diario Oficial de la Federación 2002; *table 1*).

Populations of many species have declined regionally, and some have been extirpated locally, including populations of five breeding and two wintering species (Hinojosa-Huerta et al. in press; *table 1*). Most affected have been riparian-obligate breeders, waterfowl, and marshbirds. There is major concern for the endemic subspecies of Yuma Clapper Rail (*Rallus longirostris yumanensis*) and Large-billed Savannah Sparrow (*Passerculus sandwichensis rostratus*; Mellink and Ferreira-Bartrina 2000, Hinojosa-Huerta et al. 2001a).

To significantly improve the delta's wetland, riparian, and inter-tidal areas, the management of the Colorado River must meet the ecological needs of these ecosystems. This means allowing the occasional large spring flow to pass through the delta to re-work sediments and create conditions ideal for natural regeneration, and to guarantee smaller, yet consistent flows that keep the wetland and riparian ecosystems moist during the hot, dry months of the summer.

Pulse floods and almost continuous instream flows during the last 5 years have brought significant revegetation of native riparian plants along the Colorado River in México (Zamora-Arroyo et al. 2001). These events, along with others such as the regeneration of marshlands in the Ciénega de Santa Clara, have shown that water management practices can be implemented to restore and protect biodiversity and sensitive species in the region (Glenn et al. 2001, Hinojosa-Huerta et al. 2001a).

Calculations based on vegetation analysis suggest that even 1 percent of the natural flow of the Colorado River could provide the means for conserving and enhancing riparian and wetland areas in the delta.

The required water is a continuous flow managed to maximize the number of days with discharge larger than 2 m^3/s (4 X 10^7 m^3/year). This should be complemented with pulse floods every 4-5 years at 80-120 m^3/s (3 X 10^8 m^3/year) to foster recruitment of native plants, wash salts, and rework sediments in the floodplain (Glenn et al. 2001, Zamora-Arroyo et al. 2001). However, achieving even these relatively modest flows will be challenging.

Numerous steps involving social, political, and ecological considerations will have to be taken before the United States and Mexican governments, delta residents, and other stakeholders can agree on what the overarching goal of restoration is, and which strategies would be most effective in accomplishing the restoration goals.

One of the major milestones towards these goals has been the incorporation of local communities in the process, in particular through the representation of the Ecological Association of Users of the Hardy and Colorado Rivers (AEURHYC). The organization was formed in 1998 by different sectors of the local communities of the Río Hardy to work together toward the restoration of the Colorado River delta. The association includes fishermen, farmers, the Cucapá tribe, aquaculturists, and the tourist sector. In particular, they call for 1) a reconsideration of water treaties, which will include considering the environment as another user of river water, 2) the designation of all delta wetlands under a protection status, and 3) the implementation of restoration projects (AEURHYC 2001).

Community support for wetland conservation also extends to farmers and landowners located close to the riparian areas. These farmers have shown their interest in maintaining native riparian vegetation, allotting water for the environment, protecting the Colorado River floodplain with a conservation designation, and in participating in active restoration projects by leasing land and water (Carrillo-Guerrero 2002). These community activities show that long-term restoration and conservation projects for wetlands can be implemented successfully in the Colorado River delta.

Community-Based Restoration Projects

Delta communities have witnessed environmental changes in the wetlands and negative impacts to their livelihoods over the past decades (Valdés-Casillas et al. 1998). Nevertheless, the natural revegetation and the

Table 1— *Bird species under a protection category in México or of conservation concern in the Colorado River delta. Four codes are given for each species: protection category (SP – Special Protection, TH – Threatened, EN – Endangered, NP – No Protection), breeding status (NB – Non-breeding, BR – Breeding), relative abundance (EX – Extirpated, CA – Casual, RA – Rare, UN – Uncommon, CO – Common), and temporal presence (WI – Winter, SP – Spring, SU – Summer, PE – Perennial). Abundance categories follow Patten et al. (2001).*

Species	Protection category	Breeding status	Relative abundance	Temporal presence
Least Grebe (*Tachybaptus dominicus*)	SP	NB	CA	SU
Laysan Albatross (*Phoebastria immutabilis*)	TH	NB	RA	SP
Black Storm-Petrel (*Oceanodroma melania*)	TH	NB	CO	PE
Least Storm-Petrel (*Oceanodroma microsoma*)	TH	NB	CO	PE
Reddish Egret (*Egretta rufescens*)	SP	BR	RA	SU
Roseate Spoonbill (*Ajaia ajaja*)[1]	NP	NB	EX	WI
Fulvous Whistling-Duck (*Dendrocygna bicolor*)[1]	NP	BR	EX	SU
Brant (*Branta bernicla*)	TH	NB	UN	WI
Bald Eagle (*Heliaeetus leucocephalus*)[2]	EN	NB	UN	WI
Sharp-shinned Hawk (*Accipiter striatus*)	SP	NB	UN	WI
Cooper's Hawk (*Accipiter cooperi*)	SP	NB	UN	WI
Harris' Hawk (*Parabuteo unicinctus*)	SP	NB	UN	WI
Red-shouldered Hawk (*Buteo lineatus*)	SP	NB	CA	WI
Swainson's Hawk (*Buteo swainsoni*)	SP	NB	UN	WI
Ferruginous Hawk (*Buteo regalis*)	SP	NB	RA	WI
Peregrine Falcon (*Falco peregrinus*)	SP	NB	UN	WI
Prairie Falcon (*Falco mexicanus*)	SP	NB	RA	WI
California Black Rail (*Laterallus jamaicensis coturniculus*)	EN	BR	RA	PE
Yuma Clapper Rail (*Rallus longirostris yumanensis*)[2,3]	TH	BR	CO	PE
Virginia Rail (*Rallus limicola*)	SP	BR	CO	PE
Sandhill Crane (*Grus canadensis*)[1]	NP	NB	EX	WI
Snowy Plover (*Charadrius alexandrinus nivosus*)[2]	TH	BR	UN	SU
Heermann's Gull (*Larus heermanni*)	SP	NB	CO	PE
Gull-billed Tern (*Sterna nilotica vanrossemi*)[1]	NP	BR	CO	PE

Table 1 (contd.).

Species	Protection category	Breeding status	Relative abundance	Temporal presence
Elegant Tern (*Sterna elegans*)	SP	BR	RA	SU
Least Tern (*Sterna antillarum*)[2]	SP	BR	UN	SU
Yellow-billed Cuckoo (*Coccyzus americanus occidentalis*)[1]	NP	BR	UN	SU
Western Screech-Owl (*Otus kennicottii*)[1]	NP	BR	RA	SU
Short-eared Owl (*Asio flammeus*)	SP	NB	RA	WI
Gilded Flicker (*Colaptes chrysoides*)[1]	NP	BR	EX	SU
Southwestern Willow Flycatcher (*Empidonax traillii extimus*)[1,2,4]	NP	BR	EX	SU
Bell's Vireo (*Vireo bellii*)[1]	NP	BR	RA	SU
Lucy's Warbler (*Vermivora luciae*)[1,4]	NP	BR	EX	SU
Summer Tanager (*Piranga rubra*)[1,4]	NP	BR	EX	SU
Large-billed Savannah Sparrow (*Passerculus sandwichensis rostratus*)[3]	SP	BR	CO	SU

[1] Species not under a protection category, but has experienced sharp population declines in the region.
[2] Species also under federal protection in the US.
[3] Species endemic to the Colorado River delta.
[4] Breeding population has been extirpated, but still present as transient.

maintenance of wetland areas with agricultural drainage water have maintained community interest and hope for conserving a functional ecosystem. Community support has sparked interest in starting restoration efforts that could function as models to obtain information for management of the delta ecosystem, and that could explore the possibilities of using agricultural drainage water, irrigation water, private and ejido lands, and marginal fields for environmental purposes.

Three restoration projects are currently operating in the delta, with the participation of local communities, environmental groups, government agencies, universities, and research institutions from the United States and México. Each one of these projects has different specific objectives and is focused on a different type of ecosystem. However, the common goal is to reestablish some of the ecological functions of the Colorado River delta, through a more efficient and environmental use of the available water, which allows for the conservation of biodiversity and the preservation of social and cultural values of the region.

The Projects

A riparian/mesquite restoration project is being developed by a binational team of environmental and scientific institutions in the northern area of the Río Hardy, in coordination with a local tourist camp (Campo Mosqueda). South from there, the Ecological Association of Users of the Hardy and Colorado Rivers has been working on the restoration of marsh wetlands in the Río Hardy. Finally, restoration activities have continued at the Laguna del Indio, in the eastern part of the delta since 1998.

Mosqueda Restoration Project

The Campo Mosqueda site is in the Río Hardy wetland system, on the western side of the Colorado River delta, and at the southern portion of the Mexicali Valley (*fig. 1*). The Río Hardy is a tributary that drains much of the Mexicali Valley agricultural area as it makes a sinuous 26-km journey to the confluence with the Colorado River.

As with much of the Colorado River delta, extensive areas of riparian vegetation and dense forests of mesquite covered the Río Hardy area before dams were constructed. Today, much of the Hardy complex is hydrologically isolated from the Colorado floodplain, with limited remnant patches of wetland and mesquite plant communities persisting due to agricultural return flows.

The objective of the Mosqueda restoration effort is to re-establish 10 ha of wetland, mesquite and riparian habitat types on lands that were formerly used for agriculture. The overall focus and long-term goal of the restoration design is on providing habitat for migratory waterfowl and neotropical migratory birds and on providing opportunities for local residents to develop an ecotourism enterprise. A nursery of native plants also has been established to provide materials for the Mosqueda project as well as for subsequent riparian revegetation efforts.

The Mosqueda restoration effort is establishing three types of plant communities: a 0.5-ha open water zone with intermixed marsh areas dominated by cattails (*Typha domengensis*), bulrush (*Scirpus americanus*), and sedges (*Juncus* spp.); a 0.5-ha hectare riparian woodland dominated by cottonwoods and willows; and a 10-ha mesquite zone dominated by screwbean (*Prosopis pubescens*) and honey mesquite (*Prosopis glandulosa*).

The restoration design includes considerations for the restoration of breeding habitat for at least 10 bird species dependent on woody vegetation and 9 species dependent on aquatic and marsh areas. We expect that the restored plot will also benefit over 50 species of migratory and wintering birds as well as other wildlife.

Laguna del Indio

El Indio wetland is located at the lower end of the Mexicali Irrigation District, in the buffer zone of the Upper Gulf of California and Colorado River Delta Biosphere Reserve, within Ejido Indiviso, Baja California (*fig. 1*). El Indio is a 100-ha subtropical floodplain dominated by saltcedar, but includes other species of smaller stature, including arroweed (*Pluchea sericea*), seep willow (*Baccharis salicifolia*), saltbush (*Atriplex* spp.), and iodine bush (*Allenrolfea occidentalis*). In addition, pockets of cattail, bulrush, and other hydrophytes persist in areas where soils remain saturated throughout the year. Salt grass (*Distichlis palmeri* and *D. spicata*) forms significant patches on the salt-affected wetland fringes at the south end of El Indio.

These lagoons are part of an old stream of the Colorado River on the eastern delta; now they are supported by agricultural run-off water from the Mexicali Valley. These wetlands were created when a drain broke in 1993, flooding about 90 hectares as water was retained between a flood control levee and an agricultural drain. The restoration project is focusing on a rectangular portion of El Indio (roughly 1,650 m long and 220 m wide) that occupies about 36 ha.

El Indio is an important area for migratory waterfowl, wading birds, shorebirds, and marshbirds, with more than 100 avian species recorded in these wetlands. They provide important habitat for several endangered or sensitive species, including the Yuma Clapper Rail (Hinojosa-Huerta et al. 2001), and are considered one of the restoration priorities of the Upper Gulf of California and Colorado River Delta Biosphere Reserve.

Reuse of water for environmental purposes in El Indio will provide an important example of how agricultural return flows can be used for the benefit of both the community and the environment. By implementing this effort in an agricultural area, we hope that project results will serve as a model that other delta communities can follow for developing alternative uses for marginal agricultural lands.

Currently, the activities at El Indio are aimed at securing a source of water for these wetlands, and exploring the opportunities of water re-use for environmental purposes and some economic activities, in particular ecotourism and small-scale aquaculture. Key elements of this project include 1) management of agricultural drains to enhance water availability in the lagoon; 3) saltcedar removal in areas that contain significant amounts of native wetland species; and 3) community participation in the restoration design and in the development of local backyard projects that will address both community and environmental issues.

Wetland Restoration at the Río Hardy – AEURHYC

The Ecological Association of Users of the Hardy and Colorado Rivers (AEURHYC) has united several sectors of the community to channel restoration efforts in the delta. One of the main objectives of the association is to efficiently manage the water of the Río Hardy, in order to optimize its environmental benefits and the functions it provides to the communities.

The current appearance of the Hardy wetlands began to be shaped during the 1930's, when several consecutive flooding events created a natural dam or sandbar 35 km upstream from the Gulf of California that blocked the flow of water from the western delta (Glenn et al. 1996). The sandbar maintained a 20,000 ha marsh in the Río Hardy even during the 50-year period when Lake Mead and Lake Powell were filling and there were few or no flows to the region (Glenn et al. 1996).

After the major flooding on the Colorado in 1983, and until 1989, the delta received significant flows, and the Hardy/Colorado Wetlands grew to some 66,400 ha. Since then, the Hardy wetlands have shrunk to approximately 2,000 ha dominated by saltcedar. Aside from the lack of flows, the shrinkage of the Hardy

complex also was due to the destruction of the natural dam by flooding in 1987 and the subsequent drainage of the wetlands (Glenn et al. 1996).

Due to the significant amounts of agricultural return flows that accumulate in the Río Hardy area, this wetland complex still supports considerable native wetland plant communities that provide habitat to a large number of bird species. In particular, the Río Hardy provides habitat for wintering and migratory waterfowl, piscivorous birds, and marshbirds. Migratory landbirds also stopover at the banks of the Hardy, en route north through the Colorado River corridor.

One of the activities of AEURHYC is the construction of a dike in the lower part of the Río Hardy, that would maintain a larger wetland area, increase river depth, and restore habitat for migratory waterbirds and associated wildlife. The general idea of the AEURHYC project is to simulate the functions of the sandbar, evaluate the feasibility and potential environmental benefits of the project, and to generate information on the hydrologic variables of the river in relation to the dike. The 120-m dike will restore approximately 1,500 ha of marsh, extending over 25 river kilometers.

The first phase of the dike was built during July and August 2001, using sandbags as the main material. The primary force was the participation of more than 80 volunteers from different communities on the delta, and the continuous involvement of the Indigenous Cucapá Community. A second phase was finished in August 2002, in which the dike was extended to reach higher terraces and increase the area to be restored.

The Association was in charge of coordination and fundraising to finish the project, most of which were provided by the tourist camps of the Río Hardy. Other sectors of the community provided equipment and materials.

This project will provide short-term benefits in terms of restored habitat for waterbirds and for the activities of tourist camps and fishermen. In the long-term, the Hardy communities hope that this effort could be a spark that starts a large-scale movement to restore and conserve the wetlands of the Hardy and Colorado Rivers.

Conclusions

The drastic rate at which wetlands have been degraded within the Pacific Flyway and the Sonoran Desert call for an urgent reconsideration of water policies and for restoration actions to recover these ecosystems. This process is critical for the recovery and conservation of many bird species of northwestern México and southwestern United States. The resilience and remnant biological richness of the Colorado River delta provides unique opportunities for conservation and restoration of riparian and wetland areas within this ecoregion. The community-based projects in the Colorado River delta show that diverse habitat types can be recreated or improved through restoration work. These restoration efforts should be expanded as part of an overall conservation strategy for the Colorado River delta. However, it is unlikely that bird populations can be sustained through localized restoration actions only. The ecological integrity of the riparian and wetland ecosystems of the delta needs to be maintained as well. An overall bird conservation strategy for the delta should find alternatives to large-scale destruction of wetlands and riparian forests while creating islands of high-quality habitat at suitable sites through restoration projects. These efforts should be coupled with the support and interest of local communities, which are working toward the long-term recovery and conservation of the desert wetlands of the Colorado River delta.

Acknowledgments

The restoration projects at Campo Mosqueda and Laguna del Indio have been funded in part by the North American Wetlands Conservation Council. We thank the National Fish and Wildlife Foundation, the Sonoran Joint Venture (U.S. Fish and Wildlife Service), the Sonoran Institute, the Upper Gulf of California and Colorado River Delta Biosphere Reserve, Campo Mosqueda, AEURHYC, the Cucapá Community, and Ejido Johnson for their help to carry on these projects. We thank J. García-Hernández, J. Campoy-Favela, F. Zamora-Arroyo, S. Cornelius, E. Zamora-Hernández, P. Nagler, V. Gerhardt, C. Valdés-Casillas, M. de la Garza, R.l Castro, the Mosqueda Family, the Butrón Family, the González Family (Cucapá El Mayor) and all others who have devoted their time for the conservation and restoration of the Colorado River delta.

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Timing of Hummingbird Migration in Southeastern Arizona: Implications for Conservation[1]

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Abstract

We examined the distribution and abundance of hummingbirds at three study sites in southeastern Arizona, where over 8,000 individuals of twelve species were banded. Banding occurred at two sites in the early 1990s and is currently active at the third. Anna's (*Calype anna*), Black-chinned (*Archilochus alexandri*), and Rufous (*Selasphorus rufus*) Hummingbirds were the most abundant species. A massive southbound fall migration occurred at the study sites with fewer hummingbirds moving northward in spring. The large numbers of migrants were spaced over time within seasons, and the timing of peak migration for a species varied among years. Fall-migrant Black-chinned peaked earliest, followed by Rufous (predominantly juveniles), then Anna's. Of these species, Rufous used the sites during migration only while the other species bred at one or more sites. Because the timing of migration differed among species, the resources critical for migration of each species likely differed as well. The implications for hummingbird conservation are discussed.

Key words: Anna's Hummingbird, Black-chinned Hummingbird, conservation, hummingbird, migration, Rufous Hummingbird, southeastern Arizona.

Introduction

Migration patterns are poorly known for hummingbirds. Most of the more than 300 hummingbird species do not migrate and those that do migrate breed farthest north or south of the tropics (Schuchmann 1999). Our knowledge about the routes and timing of migration is based mainly on a few North American species that include Rufous (*Selasphorus rufus*), Allen's (*Selasphorus sasin*) and Calliope (*Stellula calliope*) hummingbirds (Phillips 1975, Calder 1993, Calder and Calder 1994). These species breed in the higher latitudes of North America and traditionally migrate in an elliptical route. In late summer and early fall, they fly south following the Rocky Mountains and in late winter and early spring, their northbound migration usually occurs farther west and at a lower elevation (Phillips 1975, Calder 1993, Calder and Calder 1994).

The timing of southbound migration varies among these species with the age and sex of individuals. Typically, adult males migrate before adult females, which in turn precede the juveniles (Stiles 1972, Phillips 1975, Calder 1987). This pattern has also been documented for Ruby-throated Hummingbirds (*Archilochus colubris*) (Mulvihill and Leberman 1987). A slight variation of the pattern has been documented for other species such as Black-chinned Hummingbird (*Archilochus alexandri*) and Costa's Hummingbird (*Calypte costae*), in which males precede females and young of the year, the latter two groups migrating at similar times. It has been documented for both north- and south-bound migrations in Black-chinned, but only in late summer movement patterns for Costa's (Baltosser and Scott 1996, Baltosser and Russell 2000, Wethington and Russell 2003).

In this paper we compare temporal migration patterns for three common hummingbird species: Black-chinned, Anna's (*Calypte anna*), and Rufous at three sites in southeastern Arizona. The general shapes of these patterns was previously described for two sites, where banding occurred in the early 1990s (Wethington and Russell 2003). Ten years later, we compare these temporal patterns from those sites to another site, which is to the east and at a higher elevation. The consistency of these temporal patterns may suggest factors important for the conservation of North American hummingbirds.

Study Areas and Methods

The Sonoita study site (31°038'51"N, 110°039'18"W, elevation 1530 m, 2 km south of Sonoita, Arizona) lies in an intermontane valley between the Santa Rita and Huachuca mountains in oak (*Quercus emoryi* and *Q. arizonica*) woodland at the southern end of open grasslands. Bock and Bock (1986, 1988) have described the

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference**, March 20-24, 2002, Asilomar Conference Grounds, California.

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area's vegetation. Flowers used by hummingbirds are scarce during all seasons. After a pilot study in 1987, we banded approximately every week while birds were present, from the first part of April to the end of October for five years (1988-1992).

In 1991, we established a second site along Harshaw Creek (31°030'00"N, 110°040'50"W, elevation 1370 m) approximately 16 km south of the Sonoita site, and operated it concurrently in 1991 and 1992. Banding continued there in 1993. This study site lies within a riparian zone bounded by oak and mesquite woodlands. Desert willow (*Chilopsis linearis*), Arizona sycamore (*Platanus racemosa*), Fremont cottonwood (*Populus fremontii*), Arizona walnut (*Juglans major*), willows (*Salix* spp.), and seep willow (*Baccharis salicifolia*) grow within the riparian zone. Surface water flows intermittently at the site.

In 2000, a third banding site was established at Miller Canyon in the Huachuca Mountains (31°030'N, 110° 015'W, elevation 1780 m) on the border of a 4 ha apple orchard. The neighboring woods are dominated by several species of oak and Manzanita (*Arctostaphylos pungens*) with Arizona sycamore along the creek. Banding occurred once every two weeks from late March to mid-October.

Commercial hummingbird feeders were maintained at all sites, providing an unlimited food supply and may have increased the number of hummingbirds in the area. We used a sugar solution of 1 part sugar to 4 parts water. At the Sonoita and Miller Canyon sites, feeders had been maintained for many years. We introduced feeders at the Harshaw Creek site in 1991 where other feeders were more than 2 km away.

At Sonoita and Harshaw Creek, we captured hummingbirds using a trap (Russell and Russell 2001) made from a 6-m long mist net with a 24-mm mesh, arranged as an open-ended box and baited with one or two feeders on poles inside. Another mist net covered the top. At Miller Canyon, two Hall traps were used (Russell and Russell 2001). At all sites, we trapped hummingbirds during the morning hours. At Sonoita and Harshaw Creek, we began approximately 30 min before sunrise and usually continued until the first of three ending conditions occurred: we had captured 100 birds; an hour had passed with no new birds captured; or the hour of 1100 was reached. At Miller Canyon, trapping began approximately 30 min after sunrise and continued for at least 5 hrs.

We banded all hummingbirds with U.S. Fish and Wildlife Service bands and aged and sexed individuals using plumage and flight feather characters (Stiles 1972, Baltosser 1987) and bill corrugations (Ortiz-Crespo 1972). We also weighed each individual to 0.1g.

For site comparisons, we standardized the data by matching 15 dates from each site. The matched dates typically occurred within 5 days of each other. Seven days was the maximum number of days separating paired banding days.

To determine if the abundance for each age-sex class per species differed among sites, we used the Friedman rank sum test. In these analyses, the grouping factor was the site, the blocking factor was the banding day, and the response variable was the number of birds captured. For Sonoita and Harshaw Creek, we averaged each banding day's capture across years of the study and used the average in the analyses. Sonoita's average contained five years of data, Harshaw Creek three. Miller Canyon had one. If a significant difference in abundance was detected, we then used the Wilcoxon rank-sum test to determine which pairs of sites differed. Because the number of birds captured each banding day fluctuated, we used Friedman's super smoothing algorithm (Friedman 1984) to show a smoothed pattern to the abundance data.

We used a standard $P < 0.05$ to indicate statistical significance. Values presented are means ± SD. All analyses were done with AXUM 6.0 (Mathsoft Inc. 1999). Because the number of birds captured each banding day varied, we used Friedman's super smoothing algorithm (Friedman 1984) to display a smoothed pattern to the abundance data.

Results

During the study at Sonoita and Harshaw Creek, peak numbers of the three species during fall migration occurred at different times, Black-chinned in late August to early September, followed by Rufous and then Anna's (*fig. 1*). For these species, migration times also varied among years. We identified the date for the median hummingbird captured from July through October for each year at each study site (*table 1*). In some age-sex classes, these dates varied by over four weeks. Ten years later, the same temporal patterns for these species is documented at Miller Canyon ($Z < 0.8$, $P > 0.44$ for three pair-wise comparisons; *fig. 2*, *table 1*).

Black-Chinned Hummingbird

Black-chinned Hummingbird was the most abundant species (*fig. 3*). Males arrived between late March and early April. By mid-April, adults of both sexes were present. Juveniles first appeared at the feeders in mid-June. The abundance of juvenile females differed significantly among sites (Friedman $\chi^2_2 = 14.5$, $P < 0.01$) and the difference in abundance was almost significant for adult males (Friedman $\chi^2_2 = 5.9$, $P < 0.06$). During the time in which juveniles were present, the

average number of juvenile females per banding day at Miller Canyon was 1.3 ± 2.5, at Sonoita 3.6 ± 3.5, and at Harshaw Creek 6.4 ± 6.4. The abundance at Miller Canyon differed significantly between Sonoita ($Z = 2.2$, $P < 0.03$) and between Harshaw Creek ($Z = 2.4$, $P < 0.02$).

The abundance of adult males differed significantly between Sonoita and Harshaw Creek ($Z = 2.4$, $P < 0.02$) only. The ratio of adult males to adult females differed significantly between these sites ($\chi^2_1 = 80.5$, $P < 0.01$). Males averaged 72 ± 5 percent of the adult population in Sonoita but only 37 ± 2 percent in Harshaw Creek. These percentages remained consistent throughout the season. Males averaged 62 percent at Miller Canyon.

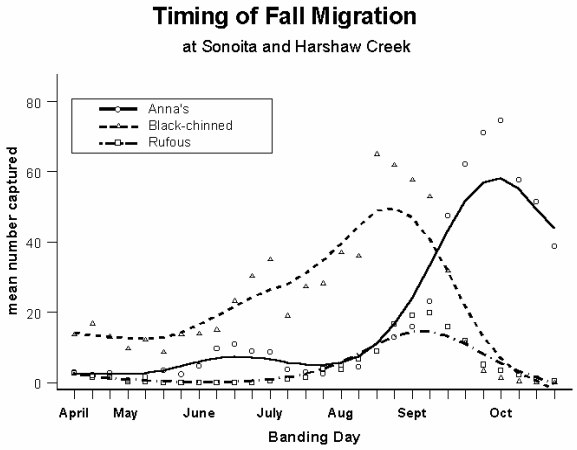

Figure 1— The smoothed seasonal distribution of the three most commonly captured hummingbird species. Point values are average number of hummingbirds per species per banding day from Sonoita and Harshaw Creek.

Anna's Hummingbird

Anna's Hummingbird was the most abundant species during September and October (*fig. 4*). The abundance for both age-sex classes of females differed significantly among sites (Friedman $\chi^2_2 > 7.1$, $P < 0.03$). At Harshaw Creek, adult females occurred throughout the banding season. At Sonoita, adult females did not consistently occur until August and then they stayed later in October than at Harshaw Creek. This pattern likely explains the significant difference for adult females between these two sites ($Z = -2.1$, $P < 0.04$).

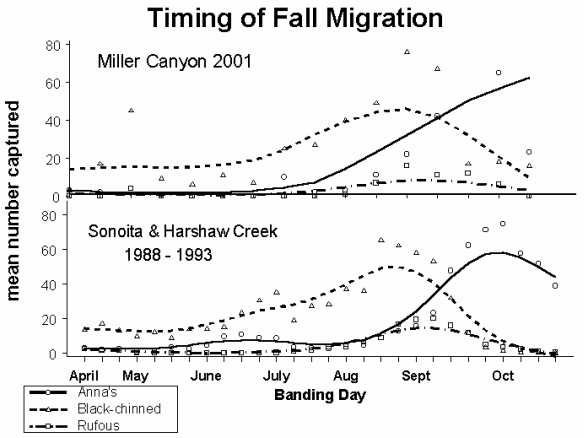

Figure 2— Comparison of one year of data from Miller Canyon with the smoothed seasonal distribution of the three most commonly captured hummingbird species from Sonoita and Harshaw Creek. Although the number of Anna's had declined at the end of banding at Miller Canyon, the smoothing algorithm does not show it.

Table 1— *Dates for capture of the median hummingbird for each age-sex class during migration (July-October).*

Species	Sonoita					Harshaw Creek			Miller Canyon
Age/sex classes	**1988**	**1989**	**1990**	**1991**	**1992**	**1991**	**1992**	**1993**	**2001**
Anna's Hummingbird									
Juvenile male	29 Sept	14 Sept	29 Sept	3 Oct	25 Sept	28 Sept	20 Sept	12 Sept	18 Sept
Juvenile female	12 Oct	25 Sept	24 Sept	26 Sept	25 Sept	5 Oct	27 Sept	25 Sept	2 Oct
Adult male	29 Sept	25 Sept	29 Sept	3 Oct	25 Sept	28 Sept	20 Sept	19 Sept	18 Sept
Adult female	29 Sept	7 Oct	29 Sept	3 Oct	3 Oct	28 Sept	20 Sept	25 Sept	18 Sept
Black-chinned Hummingbird									
Juvenile male	31 Aug	18 Aug	27 Aug	19 Aug	31 Aug	1 Sept	15 Aug	15 Aug	21 Aug
Juvenile female	9 Sept	27 Aug	12 Sept	10 Aug	19 Aug	1 Sept	15 Aug	15 Aug	6 Sept
Adult male	22 Aug	25 July	17 Aug	10 Aug	19 Aug	24 Aug	15 Aug	8 Aug	9 Aug
Adult female	26 Aug	27 Aug	17 Aug	25 Aug	27 Aug	24 Aug	23 Aug	15 Aug	21 Aug
Rufous Hummingbird									
Juvenile male	9 Sept	31 Aug	12 Sept	10 Sept	31 Aug	8 Sept	4 Sept	5 Sept	6 Sept
Juvenile female	9 Sept	10 Sept	12 Sept	10 Sept	10 Sept	15 Sept	4 Sept	29 Aug	21 Aug
Adult male									
Adult female									

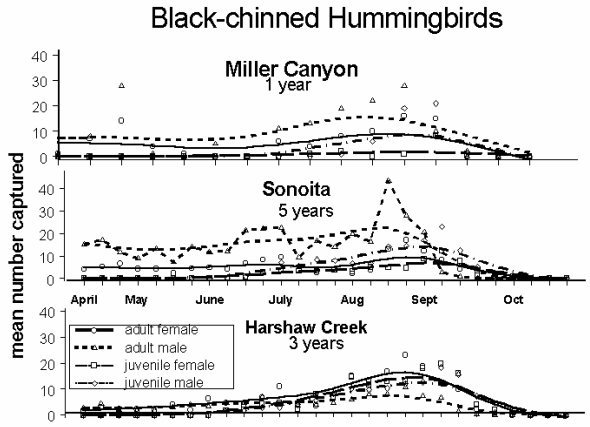

Figure 3— The smoothed seasonal distribution of Black-chinned Hummingbird (Archilochus alexandri) captured at each study site. Values are averaged across years with five years of data from Sonoita, three years of data from Harshaw Creek, and one year of data from Miller Canyon. The unsmoothed line on the Sonoita graph indicates, on average, a significant increase in adult males occurs in the third week of August. The data from Miller Canyon shows a similar pattern.

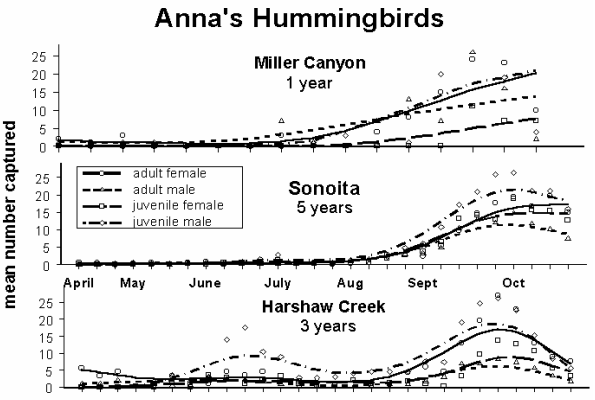

Figure 4— The smoothed seasonal distribution of Anna's Hummingbirds (*Calypte anna*) captured at each study site. Values are averaged across years with five years of data from Sonoita, three years of data from Harshaw Creek, and one year of data from Miller Canyon.

The abundance of juvenile females differed significantly between Miller Canyon and Sonoita ($Z = -2.3$, $P < 0.02$) and between Miller Canyon and Harshaw Creek ($Z = -2.3$, $P < 0.03$). At Miller Canyon, juvenile females were not captured until the middle of September. At both Sonoita and Harshaw Creek, juvenile females occurred in small numbers from May through August.

Rufous Hummingbird

Rufous Hummingbird, which does not breed in the Southwest, was most numerous during fall migration

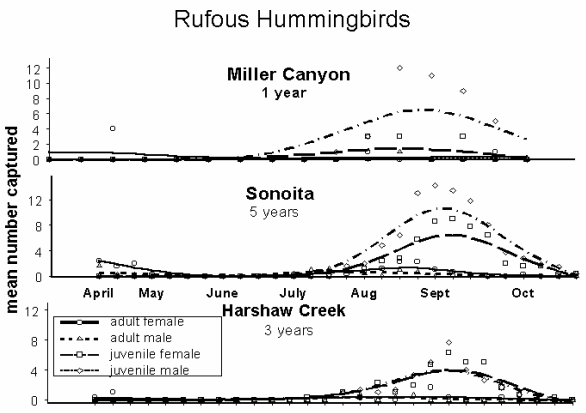

Figure 5— The smoothed seasonal distribution of Rufous Hummingbird (*Selasphorus rufus*) captured at each study site. Values are averaged across years with five years of data from Sonoita, three years of data from Harshaw Creek, and one year of data from Miller Canyon.

(*fig. 5*). Approximately 90 percent of the migrating Rufous was juveniles. Because adults occur in low numbers during spring and fall, we compared only the juveniles' abundance. No significant differences occurred between site comparisons for either sex class ($Z < 0.88$, $P > 0.38$ for males, three pair-wise comparisons, $Z < 0.8$, $P > 0.13$ for females, three pair-wise comparisons).

Discussion

A massive southbound migration of hummingbirds has been documented at two study sites in southeastern Arizona (Wethington and Russell 2003) and now, confirmed at a third site. Migration begins in July and lasts through October. Black-chinned Hummingbird migration peaks earliest followed by Rufous Hummingbird (predominantly juveniles), and then Anna's Hummingbird. Factors affecting the timing of migration probably vary for each species. These factors are unknown but likely include geographical locations of breeding sites and conditions affecting food resources along the migration routes (Russell et al. 1993).

The lack of migrating adult Rufous Hummingbirds at these mid-elevation sites is puzzling. The difference in timing of migration for different age groups could cause such a pattern. With the later migration times of juveniles, it is possible that southeastern Arizona provides more food resources than the expected adult route through the Rocky Mountains. Another possible factor is elevation. Rufous Hummingbirds have been documented migrating through sites at much higher elevations than our study sites (Kodric-Brown and Brown 1978, Calder 1993). If adult Rufous migrate through Arizona at higher elevations, our study would miss this migration. Alternatively, juveniles may be

forced to use suboptimal habitats because they are less successful at maintaining territories along their migration routes than adults (Gass 1978). Whether our study sites represent sub-optimal habitats for migrating Rufous or a better food source at the later migration time of juveniles is unknown.

Black-chinned Hummingbird migration patterns at our study sites are confounded because the influx of southbound migrants begins when individuals in the breeding populations are still at our sites. Consequently, the pattern of adult males arriving first at a site, then adult females and juveniles, is not easily detected. We determined the date when we captured the median bird in each age-sex group as an alternative to first occurrence (*table 1*). In five of the nine years, the median adult male occurred at the same time as the median of another age-sex group and in the remaining four years, the median adult male occurred earlier. Southern Arizona is at the southern end of the breeding range for Black-chinned and their range is large. Migrants are joining the southward movement over a large geographic area, at different times because of the differences in breeding seasons at different latitudes. We think the pattern exists, but it is not always detected here.

Another confounding factor in Black-chinned migration patterns is the consistent differences in sex ratios among the sites. The sex ratios varied significantly between Harshaw Creek and Sonoita but remained consistent at each site throughout the breeding season and migration. The causes of the sex ratio difference are unknown. One hypothesis suggests the quality of habitat for breeding could be reflected in sex ratios but this does not suggest a reason for the pattern to continue through migration.

The migration route of Anna's Hummingbirds is fundamentally different from the previous two species. Anna's follow an east-west migration route instead of the more typical north-south route (Russell 1996). Of the species discussed here, it is likely that the number of migrating individuals in each age-sex class peaks at about the same time (*fig. 3, table 1*).

The identification of factors that improve hummingbird survivorship along their migration routes is critical for effective conservation of hummingbirds. The extended length of time in which migration occurs in southeastern Arizona suggests that hummingbirds here do not migrate in synchrony with peak flowering of any particular plant species. This lack of synchrony has been documented for Ruby-throated Hummingbird migration (Bertin 1982). Consequently, an area that provides a continuous supply of nectar throughout the migration period is likely an important area for improving survivorship along the migration route.

Southeastern Arizona, the Sky Island region in the state, supports a large diversity of vegetation types that occur in the isolated mountain ranges and in the desert valleys. Consequently, migrating hummingbirds have a choice of habitats in which to stopover. Our mid-elevation sites document the importance of these habitats to migrating hummingbirds but the importance of other elevations is virtually unknown here. Earlier, we hypothesized that elevation could be important for determining migration routes for adult Rufous Hummingbirds. If so, it becomes important for hummingbird conservation to identify these routes. It is also unknown if hummingbirds use any physiographic features such as corridors within elevational ranges or river drainages to guide their migration. Some evidence suggests that hummingbird migration does not occur at all locations in southeastern Arizona but that some river drainages could be important routes (Wethington and Russell 2002).

Southeastern Arizona supports the greatest diversity (Johnsgaard 1997) and likely the highest density of migrating hummingbirds in the United States and Canada. Here, the isolated mountain ranges provide a natural experimental arena for testing effects of elevation and vegetation type on hummingbird migration. In addition, the methodologies of our studies provide a framework on which to build a protocol that would monitor hummingbird migration, productivity, and survivorship. This is an area of concern. While the productivity and survivorship of other landbirds have nationwide attention, the methodology used by programs such as MAPS does not include hummingbirds. Their mist nets rarely catch hummingbirds and when caught, few bird banders have the permission or the ability to band them. We use the same methodology for studying hummingbird migration as we do for studying their productivity and survivorship. Without a separate methodology, specifically focused on hummingbirds, the productivity and survivorship of species in the avian family, *Trochilidae*, remain unstudied in the United States. We are encouraging hummingbird banders to adopt a standardized protocol that would allow us to gather the information needed to identify factors important for hummingbird conservation.

Acknowledgments

We thank J. P. Church and T. and E. Beatty for maintaining the banding sites, R. O. Russell, L. A. Rogers, and E. West for their involvement in every phase of our studies, and the multitude of volunteers that helped during the banding sessions. We also thank T. Rich and C. Beardmore for their constructive comments on earlier drafts of the manuscripts.

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Addressing Conservation Needs of Birds During the Migratory Period: Problems and Approaches[1]

Mark S. Woodrey,[2] Dean Demarest,[3] and Ernesto Ruelas Inzunza[4]

The conservation of declining intercontinental landbird and shorebird migrants is complicated by the migratory nature of these organisms. Although debate over the causes of declines in most species will no doubt continue for some time, continued attention has focused largely on events associated with the breeding and wintering phases of the migrant's annual cycle. What has been largely overlooked in our developing conservation strategy is the importance of the migratory period and the issues associated with conserving these diverse and often sporadically used stopover habitats throughout the hemisphere (e.g., Moore and Woodrey 1993, Moore 2000). Although we have learned much recently, we still lack fundamental data regarding issues such as species-specific migration routes, which habitats are most important at various locations along the migratory route, where these critical habitats occur, and how their distribution and abundance are changing as a result of development and land conversion. The importance of these data gaps in our knowledge, and thus our ability to develop comprehensive bird conservation plans, are highlighted in two recent North American bird plans: the United States Shorebird Conservation Plan (Brown et al. 2000) and the North American Landbird Conservation Plan (Rich et al. 2004). Although we currently know little about migrant-habitat relations for many of these species, increased attention in both the research and conservation communities are focused on gathering these types of data.

Given the recent attention to the importance of migration ecology in the development of bird conservation plans, we organized this session to consider aspects of migration ecology that have direct application to planning and implementation of conservation efforts (e.g., identification, protection, management, restoration, or creation of stopover habitats) and to assess current planning and delivery efforts in addressing the unique demands imposed by migration. Specifically, this series of papers addresses the importance of spatial aspects of stopover habitats; discusses methods for the identification of important stopover/staging sites and migration routes; provides an assessment of how well existing conservation planning and delivery programs address migratory periods; and provides information on how to better integrate needs of *en-route* migrants into current conservation efforts.

One of the most important biological and conservation related issues when developing conservation plans for migratory birds is migrant-habitat relations. Although we have a general understanding of these relationships for land- and shorebirds, what the conservation community is lacking is a more comprehensive strategy for addressing these relationships at various ecological scales. Moore et al. (this volume) provide a scale dependent approach consisting of four components for understanding migrant-habitat relations: (1) radar, (2) census, (3) telemetry, and (4) behavioral or direct observation. Using published and unpublished data, Moore and his colleagues provide examples illustrating the importance of both the census and direct observation components of their framework. In addition, they briefly discuss the utility of their framework in that it provides a broader context for the interpretation and understanding of the behavioral ecology and conservation biology of migrants during the en-route period.

One of the biggest obstacles facing the avian conservation community involves the development of an understandable and practical approach for explaining the importance of stopover sites which incorporates the extreme daily and annual fluctuations in migrants using a particular area. The senior author has found himself, on several occasions, in a situation where he is asked whether a particular stopover site warrants protection, either through direct purchase or some type of conservation easement. Often, recommendations are made with little or no information and can be hard to explain to individuals not familiar with the ecology of migratory birds, particularly when they see few migrants during a site visit to an area they have worked hard to protect. This is exactly the issue addressed by one presentation of this session. Duncan et al. (2002), in a

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California**.

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Nature Conservancy Issue Paper, outline a practical approach to protecting stopover sites as part of The Nature Conservancy's (TNC) *Conservation by Design* planning process. Although based on this TNC process, this work is applicable to anyone interested in the conservation and protection of stopover sites. Interestingly, the basis of their approach is scale-dependent, an approach proposed by Moore et al. (this volume). In addition, they define three types of stopover sites – "Fire Escapes," "Convenience Stores," and "Full-service Hotels" – and provide a list of functional attributes for each category.

Technological advances over the past three decades have provided fertile ground for the development of hi-tech tools by scientists interested in avian research and conservation. Perhaps the most recent influential technological advance in the identification of stopover sites and migration routes has been the development of the WSR-88D (NEXRAD) Doppler weather surveillance radars (Diehl and Larkin this volume). As with any new technique, an understanding of the applications and limitations of the technology are critical. These researchers address several of the issues associated with the interpretation of WSR-88D imagery and quantification of data. In particular, they discuss some of the challenges associated with relating bird numbers from radar imagery to specific habitats or landscape features.

Another key component in the identification of stopover sites for migratory birds involves determining the availability of suitable habitat. Many of the bird conservation plans have developed population objectives which in turn are based on an estimate of the number of individuals supported by a habitat type (e.g., Loesch et al. 2000). Thus, these models assume that we know how much and what kinds of habitats are available to birds (and other organisms). However, it is obvious to those of us within the bird conservation community that we often lack this critical information (e.g., Woodrey et al. 2000). Using ground surveys of field conditions and shorebird counts correlated with spectral signatures, Jeske et al. (this volume) discuss the utility of aerial video as one tool useful for assessing availability of highly ephemeral wetland habitats. The authors note several advantages in using an aerial video system, including a reduction in labor required for ground-based surveys, reduction in the costs associated with these surveys, and the elimination of access to private lands, which can make broad-scale statistical approaches to habitat sampling nearly impossible. Further, they suggest a major advantage of using a digital aerial video system is the short-duration repeatability of surveys in highly ephemeral wetland habitats utilized by shorebirds.

There are many possible measures which could be used to determine the "importance" of a stopover site. However, to define what is meant by "important" is almost certainly problematic. For instance, is a small patch of coastal maritime forest, which is used very infrequently, maybe only once a migration season, considered important, as compared to a large forested wetland system which is used regularly by a large number of migrants? Although some would argue that the larger forested system is more important than the smaller woodland, the availability of this smaller site is likely critical to the survival of migrants using the area on a given day (*sensu* "Fire Escapes" as discussed in Duncan et al. 2002). However, at the level of the migrant, there are some measures which one could argue are related to its survival, and ultimately, the fitness of the individual. These measures could include, but are not limited to body mass change (e.g., Dunn 2001) and stopover length (Morris et al. this volume). Morris et al. (this volume) address the difficult issue of using stopover length to evaluate the importance of a stopover site. Traditionally, studies have reported minimum length of stopover, using the difference between the date of initial and final capture. However, recent studies have demonstrated that estimation of stopover length based on mark-recapture models, such as stopover duration analysis (SODA), are likely to provide a better overall estimate of the stopover length of migrants (Schaub et al. 2001). Based on the results of both empirical data and computer simulations, Morris et al. (this volume) suggest that SODA methods are not without problems and biases and recommend that care be used when analyzing and interpreting stopover data based on mark-recapture models, especially with regards to pooling data.

Integration of conservation actions relating to the migratory period for both shorebirds and landbirds is complicated by their migratory nature. Because we are dealing with several hundred species of migratory birds, a "cookie-cutter" or "one-size-fits-all" approach to conservation action will not lead to successful bird conservation. Various groups of migrants often exhibit different migration strategies which can have profound consequences for developing our conservation efforts. Traditional programs such as the Western Hemisphere Shorebird Reserve Network have been extremely successful at protecting shorebird species that stage in traditional areas. However, recent attention has been focused on species and populations that disperse broadly on the landscape and are opportunistic in their use of dynamic ephemeral wetlands. Unfortunately, this unpredictability makes the conservation of these wetland systems challenging. Skagen et al. (this volume) note that site based approaches are less effective in prairie wetland systems where habitats are dynamic, and thus difficult to predict their availability as suitable shorebird stopover habitat. Based on some modeling efforts, they suggest that wetland complexes

be considered as a single unit and that these complexes be extensive to account for shifting distributions of habitat conditions and migrant densities.

Finally, in a case study of the stopover ecology of neotropical migrants in Mexico, Ruelas et al. (this volume) provide data on species occurrence, review prevailing weather patterns which influence bird behavior and their ecology during spring and fall migration, and use a landscape analysis approach to better understand the relationship between migrants and the factors which affect their migration. Using the relationships they identified, they provide specific recommendations for future stopover ecology research and define the conservation priorities for the continued protection of these long-distance migrants. Case studies such as this one, where the local factors influencing the behavior and ecology of migrants are described, provide the kind of insight which, when combined with similar studies covering a broader geographic area, can provide a regional understanding of the factors which are impacting migrant populations. This regional understanding can be used to develop effective conservation practices which can, in turn, be integrated into bird conservation plans, leading to the full implementation of a truly comprehensive bird conservation strategy.

Acknowledgments

We would like to thank the organizers of this conference for inviting us to organize a stopover ecology session. We also would like to thank each of the participants who contributed to the oral presentation portion of the workshop which formed the basis for these published manuscripts: F. Moore, J. Buler, B. Abel, C. Duncan, D. Ewert, D. Mehlman, R. Sutter, R. Diehl, R. Larkin, C. Jeske, S. Wilson, W. Barrow, P. Chadwick, S. Morris, D. Sheets, E. Turner, D. Leibner, A. Larracuente, S. Skagen, S. Brown, R. Johnson, J. Corven, and B. Harrington. This manuscript was improved by the valuable comments provided by W. Barrow, C. J. Ralph, and L. Yates.

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Stopover Ecology of Neotropical Migrants in Central Veracruz, México[1]

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Abstract

Available information on the ecology of neotropical migrants during the winter season and especially during migration is far behind the existing knowledge of birds during the breeding season. This paper presents a stopover ecology case study. We document the occurrence of species, outline the prevailing weather patterns during spring and fall migration seasons, and present an analysis of the landscape and land use indices from central Veracruz, México, to better understand the relationship between birds and some of the variables that model their migration strategies.

The central Veracruz region has a large altitudinal gradient and habitat types vary from coastal to alpine. Forty-four localities of central Veracruz were extensively surveyed between 1991-2003, using field techniques such as migration counts, mist nets, and fixed-radius point counts. Prevailing weather during migration seasons consists of fronts called 'Nortes' in the fall and 'Suradas' in the spring.

The area has a high diversity of neotropical migrants with 239 species recorded, representing over 44 percent of the regional avifauna. Migrant bird species decrease in both quantity and relative proportion of local avifaunas as elevation increases. Lowland habitats are of conservation concern, while highland habitats are better preserved. Migrants seem to first occupy lowland habitats and then spread out to locations with a more specific habitat type and altitude. The relative importance of habitat patches in this fragmented landscape is believed to be influenced by weather regimes and vary temporally. We make specific recommendations on future stopover ecology research with immediate applications and recommendations for conservation measures.

Key words: neotropical migrant birds, stopover ecology, Veracruz, México.

Introduction

During the spring of 1992, the senior author was attending a tropical ornithology course in southern México taught by instructors from the Point Reyes Bird Observatory. There, Steve N. G. Howell used the term "White Map Syndrome" to explain how the lack of information on tropical birds, and that of neotropical migrants outside their breeding range, was reflected in many distributional works by leaving the section of the map corresponding to México (or any other area outside the United States and Canada) colored in white (*fig. 1*). This syndrome continues to be present in many recent publications, although our understanding of the winter ecology of neotropical migrants – and more recently of the conservation issues of wintering areas and stopover sites – has improved significantly within the last 25 years (e.g. Keast and Morton 1980, Rappole et al. 1983, Hagan and Johnston 1992, Finch and Stangel 1992).

The original interest in neotropical migrant ecology outside the breeding season, was primarily focused on habitat relationships and species distribution on their non-breeding range (e.g. Lowery and Dalquest 1951; Andrle 1966; Greenberg 1980; Lynch 1989, 1995; López-Ornat and Greenberg 1990; Hutto 1992; Greenberg et al. 1997, 2001). More recently, the ecology of migrants at stopover sites has been recognized by the scientific and conservation community as a period of critical importance (Moore 2000, Yong and Finch 2002). However, information on neotropical migrants continues to be lacking outside the breeding period.

Researchers and conservationists are recognizing the need to look at a larger scale than individual species, such as the physiographic regions described in the Partners in Flight Bird Conservation Plans (Rich et al. 2004). Recently, conservationists have turned their

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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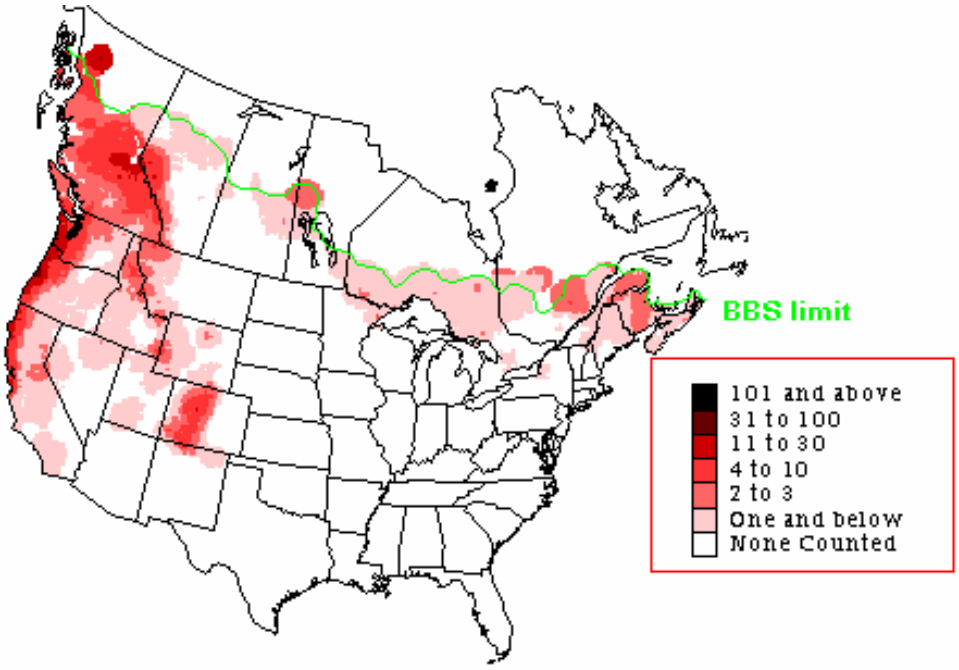

Figure 1— The White Map Syndrome. The lack of information about the status of migrant birds outside the well-studied area of the United States and Canada is frequently depicted in maps as a white area. Winter distribution of Neotropical migrants is roughly understood, but the level of information is far from parallel to the one available on the breeding season. Stopover areas information is only recently being explored. Source: Breeding Bird Survey data for the Wilson's Warbler (*Wilsonia pusilla*) (Sauer et al. 2003 [on-line]).

attention to the identification and protection of important sites for en-route migrants, reviewing existing bird conservation and land protection plans, and adding stopover areas not encompassed in current conservation initiatives (e.g. Duncan et al. 2002). However, the interface between bird migration strategies, geography, and climate is a complicated topic, and even basic criteria to define what makes a stopover site a conservation priority are still debated.

This paper provides a descriptive account of (1) the species of neotropical migrant birds present in central Veracruz, their seasonal occurrence, and altitudinal distribution; (2) the effect of weather regimes on bird migrations during spring and fall migration seasons; and (3) the landscape features, habitats, and regional land use practices of importance to neotropical migrants. We also identify key issues for ecological research and provide a list of local conservation priorities.

Methods

Study area

Central Veracruz, México, lies at the intersection of the Central Volcanic Belt and the Sierra Madre Oriental. The lowlands of the wide Gulf coastal plain narrow to its minimum at around 19° 30' of North latitude, and this geographic feature constrains the width of the migration front for many species (*fig. 2*). We arbitrarily selected field work localities within a rectangle of 1 degree of latitude by 1.5 degrees of longitude (19 to 20°N, and 96 to 97°30'W), an area of roughly 10,059 square kilometers (*table 1*, *fig. 2*). Within that geographic area, the variation in altitude ranges from sea level to 5,747 meters above sea level (mASL) at the summit of the Pico de Orizaba volcano. All the observations were made in localities below 3,500 mASL and most were below 2,400 mASL (*table 1*).

As suggested by the altitudinal variation, the vegetation of the area is diverse. Gómez-Pompa (1973) has described 15 major vegetation associations for this region, from coastal scrub to alpine meadows. The most representative vegetation types are (in approximate order of regional coverage) tropical deciduous forest, tropical evergreen forest, cloud forest, oak forest, pine-oak forest, pine forest, and fir forest.

Very few of these habitats remain in a pristine condition and natural communities continue to be under strong anthropogenic pressure. Many different agricultural practices have largely replaced natural habitats (Hoffman and Velázquez 1995). This mosaic of variation in altitude, vegetation types, and location in the transition area between the nearctic and the neotropic has resulted in a high regional bird diversity

Table 1— *List of localities of study of neotropical migrants in central Veracruz, México, 1991-2003 and survey techniques used.*

	Locality	Coordinates	Elevation (mASL)[1]	Survey technique(s) used[2]
1	Acajete	19º35'N 97º07'W	2,010	MICT, NSYO
2	Actopan	19º30'N 96º37'W	380	MICT, NSYO
3	Antigua	19º17'N 96º17'W	10	MICT, NYSO
4	Cardel	19º22'N 96º22'W	29	MICT, MSNT, PTCT, BNDS (El Palmar), NSYO
5	Cerro Gordo	19º26'N 96º42'W	660	MICT, MSNT, NSYO
6	Chachalacas	19º25'N 96º19'W	10	MICT, NSYO
7	Chichicaxtle	19º21'N 96º28'W	120	MICT, MSNT, NSYO
8	Coatepec	19º27'N 96º57'W	1,225	MSNT, NSYO
9	Cumbre del Español	18º29'N 97º08'W	1,990	PTCT
10	El Aserradero	18º31'N 97º07'W	3,100	PTCT, NSYO
11	El Castillo	19º35'N 96º52'W	1,180	NSYO
12	El Rincón	18º34'N 97º04'W	1,415	PTCT
13	Fortín (El Corazón)	18º54'N 97º01'W	700	PTCT, MSNT, NSYO
14	Jilotepec	19º36'N 96º57'W	1,380	NSYO
15	La Joya	19º36'N 97º02'W	2,230	MSNT, PTCT, NSYO
16	La Mancha	19º35'N 96º23'W	10	MICT, MSNT, BNDS, NSYO
17	Las Torres	18º54'N 97º01'W	815	PTCT, NSYO
18	Las Vigas	19º38'N 97º06'W	2,485	MSNT, PTCT, NSYO
19	Macuil Acatl	18º29'N 97º03'W	2,350	PTCT
20	Matalarga	18º52'N 96º58'W	700	PTCT, MSNT, NSYO
21	Metlac Primero	18º28'N 97º03'W	1,960	PTCT, NSYO
22	Miradores	19º28'N 96º47'W	925	MICT, MSNT, NSYO
23	Monte Blanco	18º57'N 97º00'W	1,300	PTCT, MSNT, NSYO
24	Monte Salas	18º55'N 97º01'W	1,020	PTCT, MSNT, NSYO
25	Naolinco	19º39'N 96º52'W	1,605	MICT, MSNT, NSYO
26	Palma Sola	19º46'N 96º26'W	90	MICT, NSYO
27	Peña Blanca	18º03'N 97º07'W	1,825	PTCT, NSYO
28	Perote	19º34'N 97º15'W	2,420	NSYO
29	Plan de las Hayas	19º45'N 96º40'W	1,080	MICT, NSYO
30	Playa Juan Angel	19º30'N 96º20'W	10	NSYO
31	Potrero Nuevo	18º34'N 97º05'W	3,490	PTCT
32	Rinconada	19º21'N 96º34'W	254	MICT, NSYO
33	Rio Escondido	19º20'N 96º32'W	160	MICT, MSNT, NSYO
34	San Julián	19º14'N 96º15'W	45	NSYO
35	Teocelo	19º23'N 96º58'W	1,240	MSNT, NSYO
36	Tetla	18º59'N 97º03'W	1,400	PTCT, NSYO
37	Tocuila	18º31'N 96º54'W	1,310	PTCT, NSYO
38	Totalco	19º30'N 97º21'W	2,380	NSYO
39	Veracruz City	19º13'N 96º08'W	20	NSYO
40	Villa Rica	19º41'N 96º24'W	25	NSYO
41	Xalapa	19º32'N 96º55'W	1,440	MICT, MSNT, PTCT, NSYO
42	Xocotla	18º32'N 97º05'W	1,950	PTCT, NSYO
43	Xometla	18º31'N 97º31'W	2,550	PTCT, NSYO
44	Zapoapan	18º50'N 97º58'W	700	PTCT, NSYO

[1]mASL: meters above the sea level.
[2]Codes for survey techniques: PTCT: point counts; MSNT: mist net survey; BNDS: banding station; MICT: counts of migrants; NSYO: non-systematic observations.

of over 500 species (Ruelas and Montejo 1999, R. Straub unpubl. data, E. Ruelas I. unpubl. data).

Each fall, a series of fronts move across the central Veracruz area from the north. Between the period of mid-August and mid-November each year (the height of the migration season) between 11 and 15 fronts, locally called 'Nortes', modify the seasonal rhythm of the migration. Nortes last between 2 and 7 days, the first day usually has the strongest winds (as strong as 75 kph) that decrease as the front passes through. For a day or two following a Norte, the winds have a reduced and southerly component. Precipitation ranges from 550 to 715 mm during the period 20 August through 20 November of each year (SEMARNAT 2004).

During spring migration, the weather is similar, but southerly winds of lesser speeds dominate the region and alternate with fewer days of winds of a northerly component. These fronts, locally called 'Suradas', are more diffuse and about 8 to 12 of these fronts are reported between the 1 March and 15 May of each year (Servicio Meteorológico Nacional 2004) (*fig. 3*).

Bird Surveys

Our inventory of neotropical migrants is the result of several studies carried on between 1991 and fall 2003 in 44 localities. Four main field methodologies were used in these surveys:

(1) *Fixed-radius point counts of winter residents.* We used 10 min, 25-m radius point counts spaced at 200 m (Hutto et al. 1986, Ralph et al. 1995) to survey winter residents during the fall of 1993 in the lowlands around Cardel and La Antigua, and around Fortín and Coscomatepec in 1995 (N = 21 localities) (López-Portillo et al. 1993, Ruelas 1995, E. Ruelas I. unpubl. data).

(2) *Mist nets.* An array of five to ten 2.5-m by 12-m, 25-mm mesh mist nets were used in 16 localities to survey local avifaunas (sensu Ralph and Scott 1981, Ralph et al. 1993). Mist nets were used during breeding and non-breeding season.

(3) *Operation of banding stations.* Migrant species records have also been obtained during the operation of banding stations for raptors in El Palmar and La Mancha (Ruelas 1993, Scheuermann and Ruelas 2003) and for passerines (E. Martínez L. pers. comm., R. Straub pers. comm.).

(4) *Diurnal counts of migrants.* Counts have been performed in 16 localities following standard procedures described by Kerlinger (1989:30) and HMANA (2004). The protocol locally in use is focused on raptors, vultures, and wading birds, but includes any other species recorded.

In addition to the four methods outlined above, we also included daily observations collected as part of non-systematic field work at 39 locations (*table 1*).

Landscape Feature Analysis

Rather than attempting a thorough analysis of the 42 different land use categories that can be differentiated in satellite imagery available, we calculated a series of landscape indices (O'Neill et al. 1988) to understand general patterns of land use. The landscape analysis was done using a commercially available satellite image from 1994 and a 1:250,000 spatio-map with pixels of 30-m resolution (INEGI 2004a). The 1x1.5 degree study area was divided into three arbitrary altitudinal categories we considered to be a good representation of altitudinal variation of the local distribution of bird species (*fig. 4*). Bird species records were assigned to the altitudinal category where they had been collected to determine relative importance of different altitudinal categories.

Landscape indices were obtained using the raster version of Fragstats 2.0 (McGarical and Marks 1994). The landscape metrics obtained are typically used to characterize the geometric and spatial properties of fragments in a map (Fortin 1999), and include: (1) the proportion of non-forested grid cells; (2) the proportion of forested grid cells; (3) dominance or the extent to which one or several similar land uses dominate the region (low values = few land uses); (4) a measure of the complexity of shapes in the landscape, an index that incorporates perimeter-area information (low values = low variation in fragment shapes, e.g. mechanized agriculture which uses square-shaped fields; and (5) mean patch size which is the average size of fragments over 0.81 hectares (three by three grid cells).

Results

We recorded 239 species of neotropical migrants (39 families) (*Appendix 1*). These represent ~44 percent of all the species of birds recorded in the area to date (Ruelas and Montejo 1999, E. Ruelas I. unpubl. data, R. Straub unpubl. data) (*table 2*). Most species of migrants (N = 146) have overwintering populations, while relatively fewer species have both wintering and resident populations, or are purely transient (*fig. 5*).

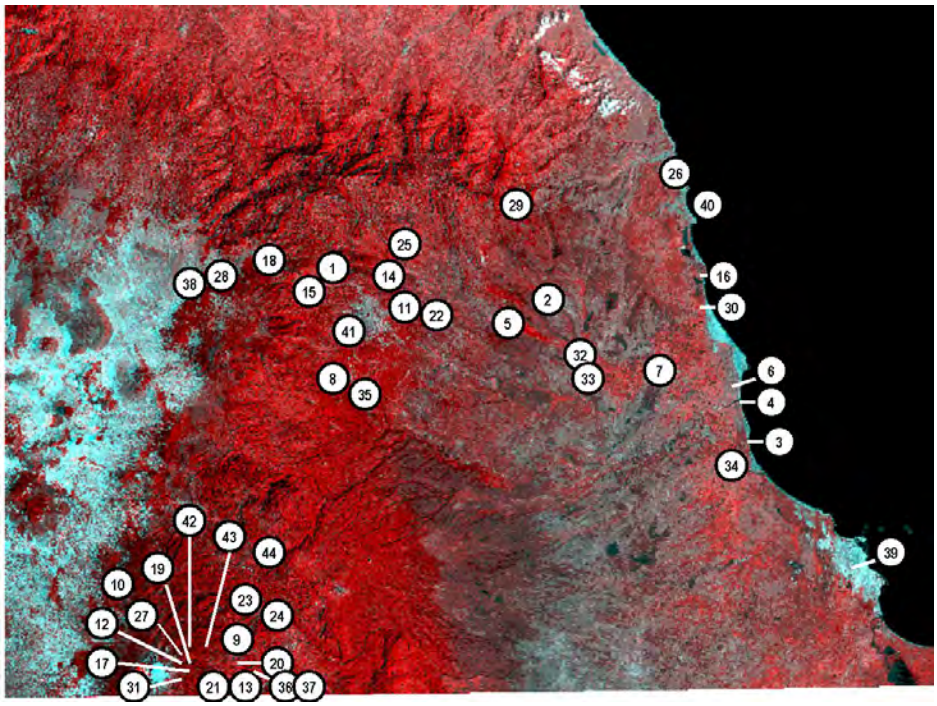

Figure 2— Topographic and land use features of the central Veracruz landscape. Source: INEGI spatio-map scale 1:250,000 (INEGI 2004a) from a 1994 satellite image. Localities of field work are numbered as in *table 1*.

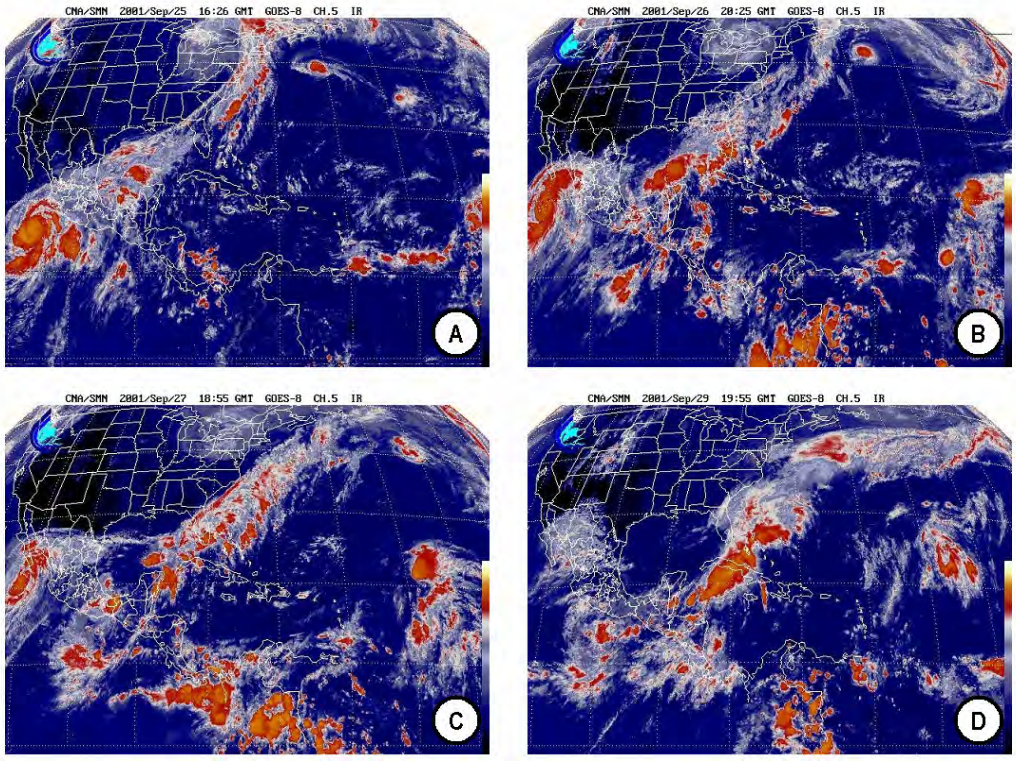

Figure 3— The typical sequence of a Norte during the fall migration season in central Veracruz, México. (A) A clearly defined Norte with winds of 55 kilometers per hour is recorded from northern Tamaulipas to Veracruz. (B) A Norte finds opposition as it encounters a low pressure system with eastern and southern winds. Winds reduce their speed to 35 kilometers per hour in central Veracruz. (C) Mean wind speed for the day is 12 kilometers per hour in central Veracruz, from the northeast and shifting to the east around 1700 CST. (D) The prevailing winds are east in the morning hours. Low wind speed (6 kilometers per hour) from the southeast is recorded in the afternoon hours in central Veracruz. Source: satellite GOES 10 and GOES 12 images of the Servicio Meteorológico Nacional (2004).

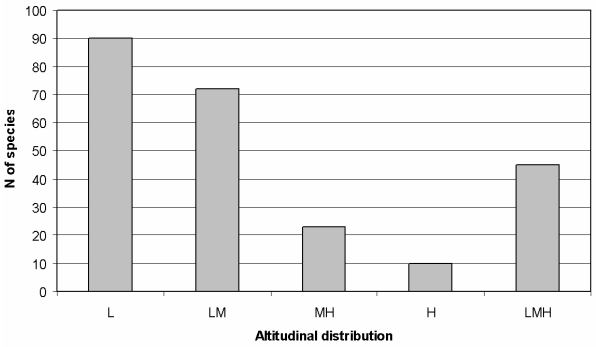

Figure 4— Altitudinal distribution of neotropical migrants recorded in central Veracruz, México. Excluding the nearly 18 percent of the species with altitudinally widespread distributions, the number of species decreases dramatically as altitude increases. Key to altitudinal distribution codes: (L) lowlands below 500 mASL; (LM) lowlands-mid-elevations between 0-1,500 mASL; (MH) mid-elevations-highlands, between 500 and 1,500 mASL; (H) highlands above 1,500 mASL; and (LMH) altitudinally widespread migrants.

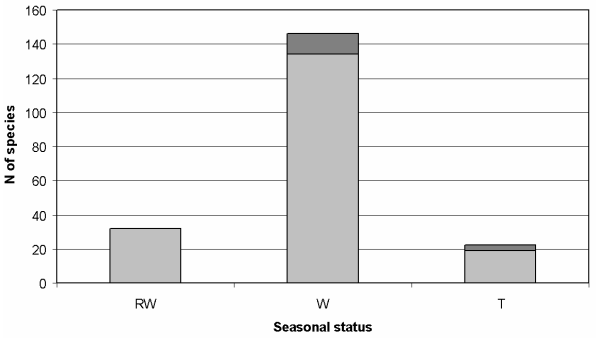

Figure 5— Seasonal status of neotropical migrants recorded in central Veracruz, México. Key to seasonality codes: (RW) species with year-round resident and wintering populations; (W) species with only wintering populations (light gray), and wintering species with accidental records in the area (dark gray); (T) species with transient populations (light gray), which includes (t) species of transient species that might have wintering populations (dark gray), and three records of accidental transient migrants.

Altitudinal distribution

The flux of incoming migrants appears to occur first in the lowlands and spread across the study area at a later time. This idea is supported by the fact that most species (N = 162) can be found in the lowlands throughout the northern winter season, where it is frequent to find species of mid-elevation and highland birds [e.g. Black-throated Green Warbler (*Dendroica virens*), Hermit Warbler (*D. occidentalis*), and Townsend's Warblers (*D. townsendi*)] that settle in higher altitudinal habitats as the winter season advances (*fig. 4*).

Except for the 45 species of altitudinally-widespread migrants, migrant birds are overall more abundant and encompass a larger proportion of the local avifauna in lowland elevations. Migrant species decrease both in quantity and total proportion of the avifauna as altitude increase ($r^2 = 0.947$, $P < 0.01$, $df = 3$) (*fig. 4*), despite the relatively better condition of forest habitats in the highlands (*table 3*).

Weather and Migration

During fall migration, diurnal migrants (e.g. vultures, hawks, storks, ibises) cease their flights during the start of the fronts, when wind speed can reach up to 75 kph. In the days after the beginning of a Norte, winds slow down and the migration continues its pace for periods of two to five days until the front is followed by a few days of winds with a southerly component. The number of birds recorded daily at a migration count site varies and it is highly weather-dependent (i.e. high numbers with Nortes and low numbers with Suradas).

It is unclear what the effect of Nortes might be on nocturnal migrants, but we suspect that they respond in a similar way to the diurnal migrants, since large numbers of passerine migrants often are found foraging in all habitats following the start of Nortes. When fronts are very strong, events of moderate mortality are not infrequent. Nortes provoke overcast, windy weather in the lowlands and days with heavy precipitation in the highlands, possibly reducing foraging or making adequate shelter for migrants harder to locate.

Table 2— *Neotropical migrants present in central Veracruz, México, by ecological/taxonomic groups. The base inventory of birds is taken from Ruelas and Montejo (1999) and R. Straub and E. Ruelas I. (unpubl. data).*

Ecological / taxonomic group	Total N of species	Species of neotropical migrants
Waterbirds (Grebes to Ducks, Rails to Cranes)	60	44
Shorebirds (Plovers to Gulls)	51	46
Non-passerine landbirds (New World Vultures to Falcons, Pigeons to Woodpeckers)	64	40
Suboscine passerines (Flycatchers to Swallows)	45	25
Oscine passerines (Wrens to Orioles)	176	84
Total	528	239

Table 3— *Indices of landscape use for central Veracruz, México. These include: (P1) the percentage of non-forested grid cells; (P2) the percentage of forested grid cells, including primary vegetation types and second growth; (D1) dominance (high values= one land use type dominates others); (D3) complexity of shapes in the landscape (high values= higher variation of shapes in the landscape); and (MPS) mean patch size, average area of forested habitat patches over 0.81 hectares.*

	Index				
Elevational category	**P1**	**P2**	**D1**	**D3**	**MPS (ha)**
Lowlands (0 to 500 mASL)	89	11	1.25	0.84	6.5
Mid-elevation (500 to 1,500 mASL)	62	38	0.80	1.16	27.8
Highlands (>1500 mASL)	42	58	0.65	1.11	33.5

The system observed in spring migration is similar, although the alternating Suradas are not as strong as Nortes and Suradas usually last fewer days and show a less marked effect on the seasonal timing of migration. Hurricanes are infrequent in this area because of the protection of the Yucatán Peninsula that blocks their trajectory.

Landscape Attributes and Migration

The lowlands of central Veracruz have lost more of the original habitat cover than the mid-elevation and highland localities. Land uses in lowlands below 500 mASL include primarily sugar cane plantations and cattle pastures and the remaining forested area is highly fragmented (mean patch size < 6.5 ha) and restricted to short riparian corridors and inaccessible terrain (*table 3*).

Non-forested, mid-elevation landscapes (500 to 1,500 mASL) are utilized mainly for cattle pastures and shade coffee plantations, among many other crop types. Average patch size is over four times that found in the lowlands (*table 3*). Land use systems of mid-elevations are more dynamic that lowland and highland landscapes, and land use can change dramatically within a few years resulting in a heterogeneous mosaic of land uses.

The highlands are the best preserved altitudinal zone, with less than half of the original landscape converted into agricultural production. Cattle production is the dominant use in this landscape, although corn, wheat, potatoes, and other high elevation crops are found as well. Second-growth forest is abundant despite long-term forestry practices for lumber and charcoal. The lower human population densities may be responsible for the overall better preserved landscape (*table 3*). Forested patches have the largest average size of any in the region.

Discussion

Relative Importance

The large number of migrant species recorded wintering in central Veracruz represents nearly two-thirds of the species involved in the nearctic-neotropic avian migration system (Partners in Flight 2004). To our knowledge, this is the highest diversity of neotropical migrant species recorded for a given area (Rappole et al. 1983, Yong and Finch 2002).

Distribution by Altitude and Habitat

The altitudinal distribution patterns of migrants support the idea of a hierarchical mode for habitat selection in Veracruz. Migrants appear to be more plastic and to select a wider variety of habitats and altitudinal ranges early in the migration season. Habitats may be selected first by landscape attributes, e.g. forested vs. non-forested habitats, and as the winter season advances the migrants seem to confine themselves to more specific habitats, supporting the observations of Hutto (1985) for western México and the scale-dependent model of Moore et al. (this volume).

Some species of migrants requiring high quality or very specific habitats, such as Marsh Wrens (*Cistothorus palustris*), Hooded Warblers (*Wilsonia citrina*), and Worm-eating Warblers (*Helmitheros vermivorus*), have been recorded in Veracruz in the past (Sclater 1857, 1859; Chapman 1897; Davis 1945). Despite extensive field work, they appear to either occur in low numbers or be absent as over-wintering migrants. Because most of the pristine or well-preserved habitats in the lowlands have largely vanished, local and regional bird distributions seen today are principally a human-influenced phenomenon. Habitat use patterns observed for residents and migrants must be interpreted within these constraints.

Weather and its Influence in Selection of Habitat and Altitude

Bird migrations are largely modeled by prevailing wind conditions and habitat availability (Berthold 2003). The

local weather regimes described here, with alternating front systems, affects bird abundance and results in selection of different habitat patches. These patches may have a different relative importance as stopover habitat in years with different weather regimes (Moore 2000).

Between-year variation of precipitation and distribution of fronts is relatively high (coefficient of variation 25-36 percent, Servicio Meteorológico Nacional 2004) and habitat use in small fragments of vegetation can not be considered 'traditional' due to the patchy nature of its distribution. Large expanses of forest are consistently used by migrants, such as those in the Sierra de Manuel Díaz and the higher-elevation Sierra de Misantla (parallel to the 19° 30'N line). The conservation of stopover habitats in such a region needs to be considered a dynamic process with ample spatial and temporal flexibility. We suggest that a classification of stopover habitats which assign a fixed label of relative importance in such highly-fragmented areas should be discouraged.

Role of Land Use in Regional Bird Distribution and Seasonality

Lowland habitats have historically had a much higher human population density than mid-elevation and highland areas and land uses have remained relatively unchanged for many years (Hoffman and Velázquez 1995). Mid-elevation habitats, formerly dedicated to agriculture are reverting to habitats more suitable for birds through secondary succession. The areas around large cities such as Xalapa, Córdoba, Fortín, Huatusco, and Orizaba have shifted large proportions of their human population from primary production to industrial and commercial activities within the last 20 years resulting in a net increase in forested area in recent years (INEGI 2004b).

Solving the White Map Syndrome: Further Avenues of Research and Conservation

Recommendations for further work in the region can be classified in two types: research directions, and conservation priorities. Since the base for most conservation suggestions rests on further knowledge of migration ecology, we will start outlining what we consider the most important research topics for the region:

Research Priorities

(1) Determine species and populations involved in migrations; conduct an assessment of the geographic origin and the relative importance of the region for each species' populations;

(2) Define species-specific patterns of the timing of migration and geographic distribution;

(3) Identify stopover and wintering areas. Once identified, determine migrant use of stopover habitat, length of stopover, relative importance of available vegetation types, and survivorship and health of migrants using habitat fragments as stopover and wintering sites;

(4) Determine the influence of weather on the timing, geographic distribution and habitat use by migrants; and

(5) Investigate diet and food resources used by neotropical migrants.

Conservation Issues

(1) Identify of populations, species, and habitats that need critical conservation attention;

(2) Assess and rank human activities influencing (positively, negatively) migratory birds;

(3) Identify conflicts with agricultural and other human activities and generate possible solutions;

(4) Evaluate the role of preserving habitat versus promotion of land use practices that have little or no conflict with habitat use by migrants (e.g., shade coffee) or recovery of altered habitats;

(5) Increase funding available for neotropical migratory bird research, public outreach, and habitat conservation in Veracruz; and

(6) Develop local capable, sustainable human resources to implement research and conservation priorities.

Acknowledgments

We thank R. Rodríguez, J. Montejo, R. Tingay, Z. Smith, O. Cruz, E. Castillejos, E. Martínez, R. Straub, K. Scheuermann, F. Rincón, S. Aguilar, and C. Tejeda for dedicated fieldwork and as field crew leaders, as well as the assistance of many field crew members for their high quality work. Funding for this project has come from National Fish and Wildlife Foundation, U.S. Fish and Wildlife Service, Lannan Foundation, The John D. and Catherine T. MacArthur Foundation, American Bird Conservancy, Lincoln Park Zoo - Scott Neotropic Fund, Hawk Mountain Sanctuary Association, HawkWatch International, Pronatura Veracruz,

Fondo Mexicano para la Conservación de la Naturaleza, Center for the Study of Tropical Birds, The Nature Conservancy, members of Amigos del Río de Rapaces, and private donors. J. Faaborg and the University of Missouri - Columbia supported ERI during the preparation of this manuscript. M. S. Woodrey, L. L. Long, and C. J. Ralph provided valuable comments to this paper. This is Hawk Mountain research contribution number 106.

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Appendix 1— *A list of the neotropical migrants of central Veracruz, México. Taxonomy and nomenclature follows Howell and Webb (1995). Key to seasonal status codes: (RW) a species with resident and wintering populations; (W) a species with wintering populations only (includes WA, accidental in the area); (T) a species with transient populations [includes (t), species with transient populations which could have unconfirmed (W) populations, and (tA), accidental in the area]. Elevation records codes: (L) lowlands between 0-500 mASL; (M) mid-elevation, 500-1,500 mASL; and (H) highlands, >1,500 mASL.*

Species		Seasonal status	Elevation records
Grebes (Podicipedidae 2)			
Pied-billed Grebe	*Podilymbus podiceps*	RW	LM
Eared Grebe	*Podiceps nigricollis*	t	L
Boobies and gannets (Sulidae 1)			
Northern Gannet	*Morus bassanus*	W?A	L
Pelicans (Pelecanidae 1)			
American White Pelican	*Pelecanus erythrorhynchos*	t	LM
Cormorants (Phalacrocoracidae 2)			
Double-crested Cormorant	*Phalacrocorax auritus*	W	L
Neotropic Cormorant	*Phalacrocorax brasilianus*	RW	LM
Anhingas (Anhingidae 1)			
Anhinga	*Anhinga anhinga*	RW	LM
Herons (Ardeidae 8)			
American Bittern	*Botaurus lentiginosus*	W	L
Least Bittern	*Ixobrichus exilis*	t	L
Great Blue Heron	*Ardea herodias*	W	LMH
Great Egret	*Egretta alba*	RW	LMH
Snowy Egret	*Egretta thula*	RW	LM
Little Blue Heron	*Egretta caerulea*	W	LM
Tricolored Heron	*Egretta tricolor*	W	L
Reddish Egret	*Egretta rufescens*	R?W	L
Ibises and spoonbills (Threskiornithidae 3)			
White Ibis	*Eudocimus albus*	W	L
White-faced Ibis	*Plegadis chihi*	W	L
Roseate Spoonbill	*Platalea ajaja*	W	L
Storks (Ciconiidae 2)			
Jabiru	*Jabiru mycteria*	tA	L
Wood Stork	*Mycteria americana*	t	L
Geese and ducks (Anatidae 18)			
White-fronted Goose	*Anser albifrons*	W	L
Snow Goose	*Anser caerulescens*	W	L
Canada Goose	*Branta canadensis*	WA	L
Wood Duck	*Aix sponsa*	WA	L
Green-winged Teal	*Anas crecca*	W	LMH
Mallard	*Anas platyrhynchos*	WA	L
Northern Pintail	*Anas acuta*	W	L
Blue-winged Teal	*Anas discors*	W	LM
Cinnamon Teal	*Anas cyanoptera*	W	LM
Northern Shoveler	*Anas clypeata*	W	L
Gadwall	*Anas strepera*	W	L
American Wigeon	*Anas americana*	W	L
Canvasback	*Aythya valisineria*	W	L
Redhead	*Aythia americana*	W	L
Lesser Scaup	*Aythya affinis*	W	LMH
Hooded Merganser	*Mergus cucullatus*	t?A	LM
Red-breasted Merganser	*Mergus serrator*	WA	L
Ruddy Duck	*Oxyura jamaicensis*	t?	L

Appendix 1. *continued.*

Species		Seasonal status	Elevation records
New world vultures (Cathartidae 1)			
Turkey Vulture	*Cathartes aura*	RW	LM
Kites, hawks, eagles, and allies (Accipitridae 18)			
Osprey	*Pandion haliaetus*	W	LMH
Hook-billed Kite	*Chondrohierax uncinatus*	W	LM
Swallow-tailed Kite	*Elanoides forficatus*	T	LM
Mississipi Kite	*Ictinia mississippiensis*	T	LM
Plumbeous Kite	*Ictinia plumbea*	T	L
Bald Eagle	*Haliaetus leucocephalus*	WA	L
Northern Harrier	*Circus cyaneus*	W	LMH
Sharp-shinned Hawk	*Accipiter striatus*	W	LMH
Cooper's Hawk	*Accipiter cooperii*	RW	LMH
Common Black Hawk	*Buteogallus anthracinus*	RW	L
Harris's Hawk	*Parabuteo unucinctus*	W	LM
Grey Hawk	*Buteo nitidus*	RW	L
Red-shouldered Hawk	*Buteo lineatus*	W	L
Ferruginous Hawk	*Buteo regalis*	WA	LM?H
Broad-winged Hawk	*Buteo platypterus*	t	LMH
Swainson's Hawk	*Buteo swainsoni*	T	LMH
Zone-tailed Hawk	*Buteo albonotatus*	W	LM
Red-tailed Hawk	*Buteo jamaicensis*	W	LMH
Golden Eagle	*Aquila chrysaetos*	WA	L
Falcons and allies (Falconidae 3)			
American Kestrel	*Falco sparverius*	W	LMH
Merlin	*Falco columbarius*	W	LM
Peregrine Falcon	*Falco peregrinus*	W	LMH
Rails, gallinules, and allies (Rallidae 5)			
Virginia Rail	*Rallus limicola*	W	L
Sora	*Porzana carolina*	W	L
Purple Gallinule	*Porphyrula martinica*	RW	L
Common Moorhen	*Gallinula chloropus*	RW	L
American Coot	*Fulica americana*	RW	LMH
Cranes (Gruidae 1)			
Sandhill Crane	*Grus canadensis*	WA	L
Plovers (Charadriidae 7)			
Black-bellied Plover	*Pluvialis squatarola*	W	L
American Golden Plover	*Pluvialis dominica*	T	L
Snowy Plover	*Charadrius alexandrinus*	W	L
Wilson's Plover	*Charadrius wilsonia*	W	L
Semipalmated Plover	*Charadrius semipalmatus*	W	L
Piping Plover	*Charadrius melodus*	W	L
Killdeer	*Charadrius vociferus*	RW	LMH
Oystercatchers (Haematopodidae 1)			
American Oystercatcher	*Haematopus palliatus*	W	L
Stilts and avocets (Recurvirostridae 2)			
Black-necked Stilt	*Himantopus mexicanus*	RW	LM
American Avocet	*Recurvirostra americana*	W	LM
Sandpipers and allies (Scolopacidae 24)			
Greater Yellowlegs	*Tringa melanoleuca*	W	L
Lesser Yellowlegs	*Tringa flavipes*	W	LM
Solitary Sandpiper	*Tringa solitaria*	W	L
Willet	*Catoptrophorus semipalmatus*	W	L
Spotted Sandpiper	*Actitis macularia*	W	LMH
Upland Sandpiper	*Bartramia longicauda*	T	L

Appendix 1. *continued.*

Species		Seasonal status	Elevation records
Sandpipers and allies (Scolopacidae 24) (*contd.*)			
Whimbrel	*Numenius phaeopus*	W	L
Long-billed Curlew	*Numenius americanus*	W	L
Marbled Godwit	*Limosa fedoa*	W	L
Ruddy Turnstone	*Arenaria interpres*	W	L
Red Knot	*Calidris canutus*	W	L
Sanderling	*Calidris alba*	W	L
Semipalmated Sandpiper	*Calidris pusilla*	T	L
Western Sandpiper	*Calidris mauri*	W	L
Least Sandpiper	*Calidris minutilla*	W	L
White-rumped Sandpiper	*Calidris fuscicollis*	T	L
Baird's Sandpiper	*Calidris bairdii*	T	L
Pectoral Sandpiper	*Calidris melanotus*	T	L
Stilt Sandpiper	*Calidris himantopus*	W	L
Buff-breasted Sandpiper	*Tryngites subruficollis*	T	L
Short-billed Dowitcher	*Limnodromus griseus*	W	L
Long-billed Dowitcher	*Limnodromus scolopaceus*	W	L
Common Snipe	*Gallinago gallinago*	W	LM
Wilson's Phalarope	*Steganopus tricolor*	T	L
Gulls, terns, and skimmers (Laridae 12)			
Laughing Gull	*Larus atricilla*	RW	LM
Franklin's Gull	*Larus pipixcan*	T	LM
Ring-billed Gull	*Larus delawarensis*	W	L
Herring Gull	*Larus argentatus*	W	L
Gull-billed Tern	*Sterna nilotica*	R?W	L
Caspian Tern	*Sterna caspia*	W	L
Royal Tern	*Sterna maxima*	W	L
Sandwich Tern	*Sterna sandvicensis*	W	L
Forster's Tern	*Sterna forsteri*	W	L
Least Tern	*Sterna antillarum*	RW	L
Black Tern	*Chlidonias niger*	t	L
Black Skimmer	*Rynchops niger*	W	L
Pigeons and doves (Columbidae 2)			
White-winged Dove	*Zenaida asiatica*	W	LMH
Mourning Dove	*Zenaida macroura*	W	LM
Cuckoos (Cuculidae 2)			
Black-billed Cuckoo	*Coccyzus erythropthalmus*	T	LM
Yellow-billed Cuckoo	*Coccyzus americanus*	T	LM
Owls (Strigidae 2)			
Burrowing Owl	*Athene cunicularia*	W	LMH
Short-eared Owl	*Asio flammeus*	W	LM
Nighthawks and nightjars (Caprimulgidae 4)			
Lesser Nighthawk	*Chordeiles acutipennis*	W	LM
Common Nighthawk	*Chordeiles minor*	RW	LM
Chuck-Will's-Widow	*Caprimulgus carolinensis*	W	L
Northern Whip-poor-will	*Caprimulgus vociferus*	W	LM
Swifts (Apodidae 2)			
Chimney Swift	*Chaetura pelagica*	T	LM
Vaux's Swift	*Chaetura vauxi*	R?W?	MH?
Hummingbirds (Trochilidae 4)			
Ruby-throated Hummingbird	*Archilochus colubris*	t	MH
Black-chinned Hummingbird	*Archilocus alexandri*	t	MH
Broad-tailed Hummingbird	*Selasphorus platycercus*	W?	MH
Rufous Hummingbird	*Selasphorus rufus*	t?	LMH

Appendix 1. *continued.*

Species		Seasonal status	Elevation records
Kingfishers (Alcedinidae 1)			
Belted Kingfisher	*Ceryle alcyon*	W	LM
Woodpeckers (Picidae 1)			
Yellow-bellied Sapsucker	*Sphyrapicus varius*	W	MH
Flycatchers (Tyrannidae 15)			
Olive-sided Flycatcher	*Contopus borealis*	t	MH
Eastern Pewee	*Contopus virens*	T	LM
Yellow-bellied Flycatcher	*Empidonax flaviventris*	t?	LM
Acadian Flycatcher	*Empidonax virescens*	T	LM
Alder Flycatcher	*Empidonax alnorum*	T	L
Willow Flycatcher	*Empidonax trailli*	T	LM?H?
White-throated Flycatcher	*Empidonax albigularis*	W	LM
Least Flycatcher	*Empidonax minimus*	W	LM
Hammond's Flycatcher	*Empidonax hammondi*	W	MH
Buff-breasted Flycatcher	*Empidonax fulvifrons*	R?W?	H
Eastern Phoebe	*Sayornis phoebe*	W	LMH
Say's Phoebe	*Sayornis saya*	RW	H
Vermillion Flycatcher	*Pyrocephalus rubinus*	W	LMH
Ash-throated Flycatcher	*Myiarchus cinerascens*	W	LM
Great Crested Flycatcher	*Myiarchus crinitus*	tA	LM
Brown-crested Flycatcher	*Myiarchus tyrannulus*	RW	LM
Western Kingbird	*Tyrannus verticalis*	tA	L?M
Eastern Kingbird	*Tyrannus tyrannus*	T	L
Scissor-tailed Flycatcher	*Tyrannus forficatus*	t	L
Swallows (Hirundinidae 6)			
Purple Martin	*Progne subis*	T	L
Tree Swallow	*Tachycineta bicolor*	W	LM
Northern Rough-winged Swallow	*Stelgidopteryx serripennis*	RW	LMH
Bank Swallow	*Riparia riparia*	T	L
Cliff Swallow	*Hirundo pyrrhonota*	T	LM
Barn Swallow	*Hirundo rustica*	T	LMH
Wrens (Troglodytidae 2)			
Northern House Wren	*Troglodytes aedon*	W	L?
Marsh Wren	*Cistothorus palustris*	W	MH
Kinglets and gnatcatchers (Sylvidae 2)			
Ruby-crowned Kinglet	*Regulus calendula*	W	LMH
Blue-grey Gnatcatcher	*Polioptila caerulea*	W	LM
Thrushes and allies (Turdidae 4)			
Veery	*Catharus fuscescens*	T	L
Swainson's Thrush	*Catharus ustulatus*	t?	LM
Wood Thrush	*Catharus mustelinus*	W	LM
American Robin	*Turdus migratorius*	RW	MH
Mockingbirds, thrashers, and allies (Mimidae 2)			
Grey Catbird	*Dumetella carolinensis*	W	LM
Northern Mockingbird	*Mimus polyglottos*	RW	LMH?
Wagtails and Pipits (Motacillidae 1)			
American Pipit	*Anthus rubescens*	W	LMH
Waxwings (Bombycillidae 1)			
Cedar Waxwing	*Bombycilla cedrorum*	W	MH
Shrikes (Laniidae 1)			
Loggerhead Shrike	*Lanius ludovicianus*	W	LMH
Vireos (Vireonidae 9)			
White-eyed Vireo	*Vireo griseus*	W	LMH
Bell's Vireo	*Vireo belli*	T	LMH

Appendix 1. *continued.*

Species		Seasonal status	Elevation records
Vireos (Vireonidae 9) (*contd.*)			
Blue-headed Vireo	*Vireo solitarius*	W	LMH?
Cassin's Vireo	*Vireo cassini*	W	H
Plumbeous Vireo	*Vireo plumbeus*	RW	H
Yellow-throated Vireo	*Vireo flavifrons*	W	MH
Warbling Vireo	*Vireo gilvus*	t?	LM
Philadelphia Vireo	*Vireo philadelphicus*	T	LM
Red-eyed Vireo	*Vireo olivaceus*	T	LM
Emberizidae			
Wood warblers (Parulinae 39)			
Blue-winged Warbler	*Vermivora pinus*	W	MH
Golden-winged Warbler	*Vermivora chrysoptera*	T	LM
Tennessee Warbler	*Vermivora peregrina*	W	MH
Orange-crowned Warbler	*Vermivora celata*	W	LMH
Nashville Warbler	*Vermivora ruficapilla*	W	LMH
Northern Parula	*Parula americana*	W	LM
Yellow Warbler	*Dendroica petechia*	W	LM
Chestnut-sided Warbler	*Dendroica pennsylvanica*	T	LM
Magnolia Warbler	*Dendroica magnolia*	W	LM
Yellow-rumped Warbler	*Dendroica coronata*	W	LMH
Black-throated Blue Warbler	*Dendroica caerulescens*	WA	M
Black-throated Grey Warbler	*Dendroica nigrescens*	W	MH
Townsend's Warbler	*Dendroica townsendi*	W	MH
Hermit Warbler	*Dendroica occidentalis*	W	MH
Black-throated Green Warbler	*Dendroica virens*	W	LMH
Golden-cheeked Warbler	*Dendroica chrysoparia*	t	M
Blackburnian Warbler	*Dendroica fusca*	T	LM
Yellow-throated Warbler	*Dendroica dominica*	W	L
Grace's Warbler	*Dendroica graciae*	RW?	H
Palm Warbler	*Dendroica palmarum*	WA	M
Bay-breasted Warbler	*Dendroica castanea*	T	LM
Cerulean Warbler	*Dendroica cerulea*	T	LM
Black-and-white Warbler	*Mniotilta varia*	W	LMH
American Redstart	*Setophaga ruticilla*	W	LM
Prothonotary Warbler	*Protonotaria citrea*	T	LM
Worm-eating Warbler	*Helmitheros vermivorus*	t	LM
Swainson's Warbler	*Helmitheros swainsoni*	T	LM
Ovenbird	*Seiurus aurocapillus*	W	LM
Northern Waterthrush	*Seiurus noveboracensis*	W	LMH?
Louisiana Waterthrush	*Seiurus motacilla*	W	LM
Kentucky Warbler	*Oporornis formosus*	W	LM
Mourning Warbler	*Oporornis philadelphia*	T	LM
MacGillivray's Warbler	*Oporornis tolmiei*	W	MH
Common Yellowthroat	*Geothlypis trichas*	W	LMH
Hooded Warbler	*Wilsonia citrina*	t	LM
Wilson's Warbler	*Wilsonia pusilla*	W	LMH
Canada Warbler	*Wilsonia canadensis*	T	LM
Red-faced Warbler	*Cardellina rubrifrons*	W	H
Yellow-breasted Chat	*Icteria virens*	W	LM
Tanagers (Thraupinae 3)			
Summer Tanager	*Piranga rubra*	W	LMH
Scarlet Tanager	*Piranga olivacea*	T	LM
Western Tanager	*Piranga ludoviciana*	W	MH

Appendix 1. *continued.*

Species		Seasonal status	Elevation records
Grosbeaks and buntings (Cardinalinae 7)			
Rose-breasted Grosbeak	*Pheucticus ludovicianus*	W	LM
Black-headed Grosbeak	*Pheucticus melanocephalus*	W	MH
Blue Grosbeak	*Passerina caerulea*	W	LMH?
Indigo Bunting	*Passerina cyanea*	W	LM
Varied Bunting	*Passerina versicolor*	W	LM
Painted Bunting	*Passerina ciris*	W	LM
Dickcissel	*Spiza americana*	t	L
Brushfinches, seedeaters, sparrows, and allies (Emberizinae 7)			
Chipping Sparrow	*Spizella passerina*	RW	MH
Clay-colored Sparrow	*Spizella pallida*	W	H
Vesper Sparrow	*Poocetes gramineus*	W	H
Lark Sparrow	*Chondestes grammacus*	W	H
Grasshopper Sparrow	*Ammodramus savanarum*	W	LMH
Savannah Sparrow	*Ammodramus sandwichensis*	R?W	MH
Lincoln's Sparrow	*Melospiza lincolnii*	W	MH
Blackbirds and orioles (Icteridae 7)			
Red-winged Blackbird	*Agelaius phoeniceus*	RW	LMH
Yellow-headed Blackbird	*Xanthocephalus xanthocephalus*	WA	H
Brewer's Blackbird	*Euphagus cyanocephalus*	W	L
Great-tailed Grackle	*Quiscalus mexicanus*	RW	L
Orchard Oriole	*Icterus spurius*	W	LM
Hooded Oriole	*Icterus cucullatus*	RW	L
Baltimore Oriole	*Icterus galbula*	W	LM
Bullock's Oriole	*Icterus bullockii*	W	LMH?

Problems Associated with Pooling Mark-Recapture Data Prior to Estimating Stopover Length for Migratory Passerines[1]

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Abstract

One measure of the importance of a stopover site is the length of time that migrants spend at an area, however measuring the time birds spend at a stopover site has proven difficult. Most banding studies have presented only minimum length of stopover, based on the difference between initial capture and final recapture of birds that are captured more than once. Cormack-Jolly-Seber (CJS) models have used multiple recaptures to estimate stopover length by migrants, and recently a new model (Stopover Duration Analysis, SODA) incorporating recruitment estimates has been suggested. Using banding data from Red-eyed Vireos (*Vireo olivaceous*), American Redstarts (*Setophaga ruticilla*), and Northern Waterthrushes (*Seiurus noveboracensis*) captured during fall migration on Appledore Island, Maine, during 1999 and 2000, we evaluated stopover estimates from minimum stopover and SODA methods. In particular, we investigated the effects of pooling data for analysis on stopover estimates. Results from our banding data and model simulations suggest that pooling may result in biased stopover estimates, by increasing estimates with increased pooling interval sizes. Furthermore, pooling may also increase the variance in the estimate. Thus pooling should be used with caution and avoided when possible.

Key words: mark-recapture, migratory passerines, pooling, stopover length.

Introduction

Stopover sites may provide places for migrants to rest, avoid predators, and feed to build or rebuild fat stores that fuel migration. Adequate stopover sites may be critical for the successful completion of migration. The amount of time that individuals spend at a stopover site will impact the total time of migration. Furthermore, stopover length may provide a mechanism of evaluating the importance of stopover sites in conjunction with rates of mass change. Comparison of stopover lengths at different sites has been limited because of low recapture rates. Initially, minimum stopover length was calculated as the difference between date of capture and date of final recapture (Cherry 1982, Biebach et al. 1986, Moore and Kerlinger 1987). The use of Cormack-Jolly-Seber models on mark-recapture data has been recommended to provide a better estimate of stopover length (Lavee et al. 1991, Holmgren et al. 1993, Kaiser 1995, Pradel et al. 1997) because the models include all individuals, not simply those that are recaptured. Furthermore, using information about days on which birds were likely to be present, but not captured, these models also incorporate capture probabilities. However, like minimum stopover, these models do not evaluate the likelihood that a bird had been at the site prior to the date of capture. Schaub et al. (2001) incorporated recruitment analysis into models using mark-recapture data to develop a stopover duration analysis (SODA), which estimates total stopover length rather than only stopover after initial capture (referred to as stopover after).

Schaub et al. (2001) and Schaub and Jenni (2001) used SODA to estimate the length of stopover by several species of migrants using data pooled over 5-d intervals. Pooling involved reducing the number of "days" in a capture history by combining birds captured during particular time intervals. For example, data pooled over 3-day intervals would result in all birds captured or recaptured on days 1, 2, and 3 being combined into new interval 1, birds captured or recaptured on days 4, 5, and 6 being combined into new interval 2, and so on. Pooling decreases the number of parameters in time-dependent models, thus allowing comparison of models that include time-dependent as well as constant parameters. A similar method of subdividing long banding periods into smaller periods has been advocated in other long term banding studies involving population models (e.g., Tavecchia et al. 2001). Because many migrants stop for relatively short time periods, we were interested in the effects of pooling on stopover estimates. Specifically, we were interested in whether pooling data prior to fitting SODA models would affect the estimate obtained, and if so, what effect increasing the pooling interval would produce.

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California**.

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Methods

The Appledore Island Migration Banding Station was operated during fall migration (mid-August to the end of September) on Appledore Island, Maine, in 1999 and 2000. Appledore Island is the largest island in the Isles of Shoals, is dominated by shrubby vegetation, and is approximately 10 km southeast of Portsmouth, New Hampshire. A detailed description of the field site is available in Morris et al. (1994). We captured migrants in mist nets (12 m net, 30 mm mesh) that were opened around sunrise, closed around sunset, and checked at least once every thirty minutes throughout the day. We took all birds captured to a central location for banding. For each bird captured and recaptured, we recorded band number, species, age, sex, and a variety of morphometric measurements. For this study we used capture and recapture data for Red-eyed Vireos (*Vireo olivaceous*), American Redstarts (*Setophaga ruticilla*), and Northern Waterthrushes (*Seiurus noveboracensis*) captured during fall migration on Appledore Island, Maine, during 1999 and 2000.

Individuals that were captured at least one day after initial capture were used to calculate recapture percentages and minimum stopover length and all individuals captured were included in mark-recapture modeling of stopover length. Minimum stopover length was calculated by subtracting the initial capture date from the date of final recapture. This is a conservative estimate of the time a bird spent on Appledore because we could not assume that we captured an individual on its first day on the island nor could we assume that final recapture occurred on its last day on the island (Cherry 1982, Biebach et al. 1986, Moore and Kerlinger 1987).

Raw data were converted into capture history files for each species each year. A capture history is a matrix that indicates whether a bird was captured during a particular capture interval. Thus, in our initial capture history files, each capture interval corresponded to a single day of banding. To investigate the effects of pooling, data were pooled into intervals ranging between two and seven days, thus all captures and recaptures occurring within a single pooling interval were treated as a single capture event. The data file was truncated at the end of the last complete pooling interval. We created a new software program, Program FITMAN, in MATLAB (Anonymous 1992) that fit capture-recapture models by maximizing the log likelihood of the data, given the model, over the parameters using a Nelder-Mead simplex method. To validate FITMAN's performance, the parameter values produced by this program were then compared with those produced by Program MARK version 2.1, Program SURGE version 4.2 (Lebreton et al. 1992), and Program SODA (Schaub et al. 2001). We used AIC methods to choose the best model(s) for each data set. Once models were chosen, stopover length estimates were calculated following Schaub et al. (2001), and standard errors and 95 percent confidence intervals were determined using bootstrapping. In addition to estimating stopover length using banding data, we also estimated stopover length using simulated data sets, which used p (probability of capture), ϕ (probability of survival, in this case probability of a particular bird remaining at a stopover site), and γ (seniority estimate, in this case the probability that a particular bird was present on the previous day) values determined by modeling unpooled banding data using an appropriate model.

Results

Red-eyed Vireos, American Redstarts, and Northern Waterthrushes were regularly captured and recaptured on Appledore Island during fall migration during these two years (*table 1*). Minimum stopover lengths calculated from recaptured individuals were generally shorter than those estimated using SODA models, although several estimates were similar between the two methods and minimum stopover was longer than SODA estimates for American Redstarts during fall 1999 (*table 1*). The most frequently chosen SODA model across all species, both years, and three pooling intervals utilized constant p and ϕ and time-dependent γ (*table 1*).

For all three species studied, stopover length estimates based on mark-recapture banding data increased with increasing pooling interval (*fig. 1, table 1*). Additionally, results of simulations based on American Redstart banding data from fall 2000 showed increased stopover estimates with increased pooling interval (*fig. 2*). Estimates from data pooled over 7-d intervals were 33 to 100 percent higher than those obtained from unpooled data. The least amount of bias occurred in the p, ϕ, γ model, which was not chosen for any species in either year. Furthermore, the variance of the estimate also increased as pooling interval increased *(fig. 2*). The analytic approach used by Hargrove and Borland (1994) and extended here (*Appendix I*) also predicts an upward bias in stopover estimates caused by pooling (*fig. 3*). Thus, models using banding data, simulations based on banding data, and an analytic approach all suggest that pooling results in an upward bias in the estimate of stopover length.

Table 1—*Comparison of stopover estimates using 1, 3, and 5 day pooling intervals.*

			Recapture		1 d		3 d		5 d	
Species[1]	Year	*n*	rate (%)	Minimum stopover (d)	Model (AIC wt)	Stopover estimate mean ± S.E. (d)	Model (AIC wt)	Stopover estimate mean ± S.E.	Model (AIC wt)	Stopover estimate mean ± S.E.
REVI	1999	231	26.8	3.97 ± 3.01	p, ϕ, γ_t (1.0000)	5.93 ± 2.53	p, ϕ, γ_t (1.0000)	6.93 ± 0.84	p, ϕ, γ_t (0.9999)	8.85 ± 2.30
REVI	2000	354	16.9	2.70 ± 1.83	p, ϕ, γ_t (1.0000)	2.76 ± 0.71	p, ϕ, γ_t (1.0000)	5.01 ± 0.93	p, ϕ, γ_t (0.4659)	8.65 ± 4.40
									p, ϕ_t, γ (0.2600)	6.05 ± 1.55
									p, ϕ_t, γ_t (0.1757)	10.45 ± 4.95
									p_t, ϕ_t, γ_t (0.0817)	8.30 ± 7.80
AMRE	1999	99	12.1	3.08 ± 3.63	p, ϕ, γ_t (1.0000) p_t, ϕ_t, γ_t (NC)*	1.88 ± 0.74	p, ϕ, γ_t (1.0000)	5.31 ± 2.52	p, ϕ, γ_t (0.9998)	10.90 ± 6.70
AMRE	2000	210	21.4	3.11 ± 2.55	p, ϕ, γ_t (1.0000)	3.25 ± 0.51	p, ϕ, γ_t (1.0000)	4.74 ± 0.60	p, ϕ_t, γ (0.8887)	8.10 ± 3.90
									p_t, ϕ_t, γ (0.0549)	8.50 ± 5.90
									p_t, ϕ, γ_t (0.0349)	5.50 ± 2.25
									p, ϕ_t, γ_t (0.0188)	6.35 ± 1.60
NOWA	1999	153	22.2	4.15 ± 2.86	p, ϕ, γ_t (1.0000)	7.11 ± 11.76 C?*	p, ϕ, γ_t (1.0000)	6.06 ± 1.05	p, ϕ, γ_t (0.9899)	7.15 ± 1.25
NOWA	2000	251	17.9	4.64 ± 3.50	p, ϕ, γ_t (1.0000)	6.66 ± 7.08 C?*	p, ϕ, γ_t (1.0000)	5.94 ± 0.78	p, ϕ, γ_t (1.0000)	7.85 ± 1.50

*The notation NC means No Convergence, indicating that this model did not converge during the model choice procedure. The notation C? indicates a suspicion of convergence problems in the bootstrap procedure.

[1] REVI = Red-eyed Vireo; AMRE = American Redstart; NOWA = Northern Waterthrush

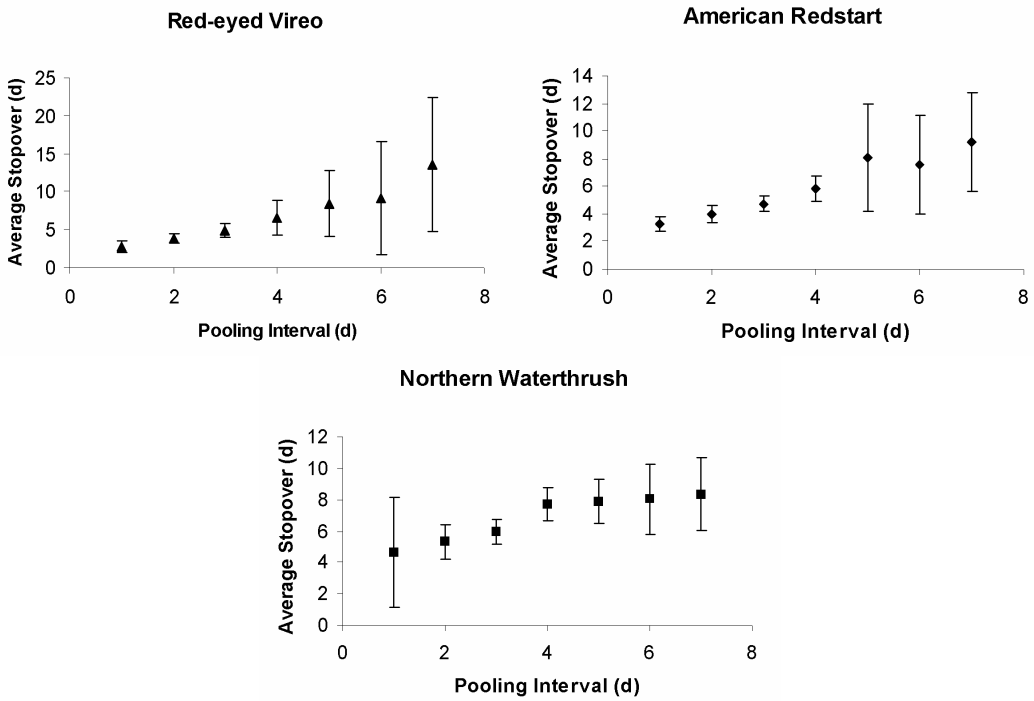

Figure 1—Comparison of stopover length estimates obtained from banding data that was pooled over different intervals and fitted to a p, ϕ, γ_t SODA model. Red-eyed Vireos, American Redstarts, and Northern Waterthrushes were captured and recaptured on Appledore Island, Maine, during fall 2000.

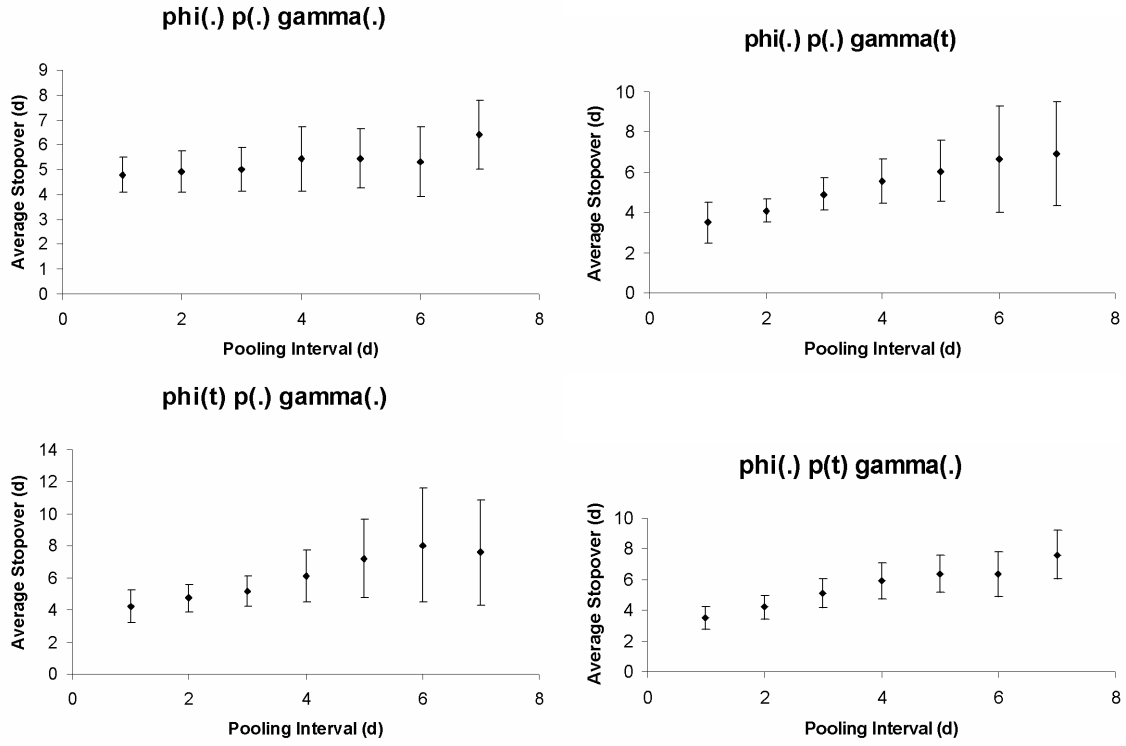

Figure 2—Results of simulations comparing stopover length estimates obtained from SODA models using different pooling intervals. Simulation data sets were created using parameter values obtained by fitting four different models to unpooled banding data of American Redstarts during fall 2000. By convention, constant parameters were designated as (.) and time-dependent parameters were designated at (t). The results presented represent the mean and S.E. of 250 simulations.

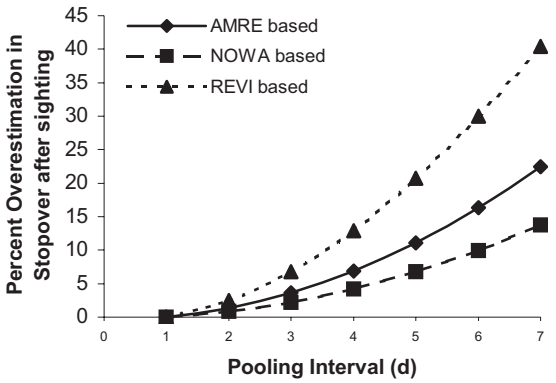

Figure 3—Dependence of the estimate of stopover after bias on pooling interval. The ϕ values were taken from fall 2000 Red-eyed Vireo (REVI), American Redstart (AMRE), and Northern Waterthrush (NOWA) banding data.

Discussion

Minimum stopover is a conservative estimate of stopover length (Cherry 1982, Biebach et al. 1986, Moore and Kerlinger 1987). SODA models generally estimated longer stopovers than those calculated by recaptured individuals. Because SODA models include all individuals captured, not only those that were recaptured, it has been suggested that these models are likely to provide a better overall estimate of the stopover length of migrants (Schaub et al. 2001). Thus these models are likely to improve understanding of how stopover sites are being used by migrants. It is, however, interesting to note both minimum stopover and SODA estimates provide similar patterns of variation in stopover across years and species, although the two methods provide different stopover length estimates for a given year and species.

Banding data are collected over many days, and thus time-dependent models require estimating numerous parameters. For example, a banding station open for 45d in the fall would require the estimation of 47 parameters to fit a p, ϕ, γ_t model, which may be difficult with the sample sizes of various species of migrants. To reduce the number of parameters estimated in SODA models, pooling data has been utilized (Schaub et al. 2001, Schaub and Jenni 2001). One disadvantage of this method is that recapture data is typically lost when capture and recapture occur during the same pooling interval. Longer pooling intervals result in greater loss of information about recapture. Furthermore, the choice of pooling interval is often haphazard, because direct comparison of models using different interval length is precluded.

In this study, SODA stopover estimates obtained from pooled banding data were higher than those from unpooled data, suggesting an upward bias in stopover estimates with pooling interval (*fig. 1, table 1*). Furthermore, simulations using population parameters derived from original banding data also predict this upward bias in stopover estimates with increasing pooling interval (*fig. 2*). Thus, SODA stopover length estimates obtained from fitting banding data and simulated data may be overestimates if the data were pooled prior to fitting the model. The extent of the bias is a result of numerous factors that include pooling interval, but also include p, ϕ, and γ. Smith and Anderson (1987) suggest that biases in survival rates using band recovery data are greatest when mortality during a long banding period is high. During stopover, departure of birds (analogous to mortality) is often dependent on weather conditions and thus may vary substantially across several days. If these days are within a single pooling interval, the differences in departure could result in substantial bias in the survival estimates.

The dependence of the stopover after bias on pooling interval can be seen given the ϕ values obtained from models fitted to the fall 2000 Red-eyed Vireo, American Redstart, and Northern Waterthrush banding data (*fig. 3*). The extent of the overestimation varied among the three species because of differences in the p, ϕ, and γ values for each species. The Hargrove and Borland (1994) results are based on an assumption of constant population size as well as constant capture and survival probabilities. Migration data do not meet these assumptions, particularly with regard to constant population size. Most migratory stopover sites have a highly variable population size during the migratory season, with very few birds present under certain conditions and large numbers of migrants present in others. Both the analytic and computer-numeric (simulation) results reveal the same predicted upward bias in stopover length when data are pooled prior to model fitting. Because the field data, the simulations, and the analytic approach to estimating stopover length all yield an increasing stopover estimate with increased pooling interval, our results suggest that this is a substantial problem that must be addressed. Furthermore, because all of our results suggest that pooling may result in overestimation of stopover length, it should be avoided whenever possible. When it is not possible to avoid pooling, the pooling interval should be minimized.

Acknowledgments

This research was funded in part by faculty research funding from Canisius College to SRM and HDS and

HHMI Research Assistantships to AML, DAL, and EMT. We are very grateful to the many people who assisted at the Appledore Island Migration Station during this study especially A. Breton, A. Chang, S. Cronenweth, C. Cushing, D. Fitch, D. Hayward, A. Hill, D. Holmes, R. Holt, C. Horrigan, M. McKenna, J. Munier, K. Palfy, S. Parkinson, M. Stauffer, B. Suomala, M. Suomala, J. Weldon, M. Wright and the Canisius College bird nerds. We would also like to thank the staff of the Shoals Marine Laboratory who facilitated many aspects of this study by providing logistic and moral support for the banding station volunteers. P. Doherty and D. L. Swanson provided valuable comments on an earlier version of this manuscript. This paper is contribution 9 of the Appledore Island Migration Banding Station and contribution 109 of the Shoals Marine Laboratory.

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Appendix 1— Estimation of the Bias in the Stopover After Sighting Estimate Due to Pooling

Hargrove and Borland (1994) presented derivations of the bias in the parameter estimates caused by pooling based on an open-population model where

a) the population size was assumed constant; and

b) the probability of survival (ϕ) and capture (p) were assumed constant throughout the study.

We have not attempted to extend Hargrove and Borland's results to derive an estimate of the bias in the seniority estimate (γ; Pradel 1996), but because the seniority may be calculated by "time-reversing" the data set and calculating the survival parameter for the time-reversed data set, we would expect similar biases in the estimate of seniority. Given estimates of the bias in the survival probability (ϕ) and the seniority, it would be possible to estimate the bias in the total stopover before and after sighting (Schaub et al. 2001). However, purely from the estimate of the bias in the survival probability, it is possible to estimate the bias in the stopover after sighting estimate, since the expected stopover after sighting for a model with constant survival probability is simply $-1/\ln(\phi)$ (Seber 1982).

Hargrove and Borland's derivation of the bias in the survival probability produced by pooling is:

$$\Phi_p = \Phi\lambda_4 \quad \text{(A1)}$$

where $\Phi = \phi^k$, which is the probability of surviving k days (where k is the pooling interval) based on the daily survival probability; Φ_p is the estimated survival over k days obtained from the pooled data; and λ_4 is a function defined by Hargrove and Borland (1994) and shown in equation A3. The bias in the estimate obtained from the pooled data is thus:

$$\Phi_p / \Phi = \lambda_4 \quad \text{(A2)}$$

Following the notation used by Hargrove and Borland (their equations A.12 and A.8):

$$\lambda_4 = \lambda_1/(\Phi(\lambda_1+k(1-\phi)/\phi) \quad \text{(A3)}$$

$$\lambda_1 = p/(1-(1-p)\phi) + k\Phi Q(1-\phi)/(\phi(1-\Phi Q)) \quad \text{(A4)}$$

where $Q=(1-p)^k$.

From these results we know that the stopover after sighting (SOA) estimate is

$$SOA= -1/\ln(\phi) = -1/\ln(\Phi^{1/k}) = -k/\ln(\Phi) \quad \text{(A5)}$$

So that the pooled estimate of the stopover after sighting is

$$\begin{aligned} SOA_p &= -k/\ln(\Phi_p) = -k/\ln(\lambda_4\Phi) = -k/(\ln(\lambda_4) + \ln(\Phi)) \\ &= -k/(\ln(\lambda_4)+(k)\ln(\phi)) \\ &= -1/((1/k)\ln(\lambda_4)+\ln(\phi)) \end{aligned} \quad \text{(A6)}$$

and the bias in the stopover after estimate is

$$\begin{aligned} SOA_p/SOA &= [-1/((1/k)\ln(\lambda_4)+\ln(\phi))]/[-1/\ln(\phi)] \\ &= \ln(\phi)/((1/k)\ln(\lambda_4) +\ln(\phi)) \\ &= 1/(\ln\lambda_4/(k \ln(\phi))+1) \end{aligned} \quad \text{(A7)}$$

Appendix 2— The Relationship of Population Size to the Seniority Parameter

Pradel's (1996) approach to the open-population models includes seniority (γ), which is the estimate of the probability that a bird sighted was present during the previous sighting interval. Under this model, the population on day i+1 (n_{i+1}) is related to the population on day i (n_i) by

$$n_i = \gamma_{i+1}n_{i+1} \quad \text{(A8)}$$

and

$$n_{i+1} = n_i/\gamma_{i+1} \quad \text{(A9)}$$

Knowing n_1 and the values of the γ_i (obtained from the model fitting procedure), we can calculate the expected population at all later times by iterative use of equation A9. This allows us to use a set of γ_i and ϕ_i values to produce a computer simulation that has the same expected population profile (set of relative n_i values) as the field data from which the p, ϕ, and γ values were obtained.

Implications of Different Shorebird Migration Strategies for Habitat Conservation[1]

Susan K. Skagen,[2] Stephen Brown,[3] and Rex Johnson[4]

Abstract

Shorebird migration strategies vary by species, migration distance and route, time of year, and resources at staging and stopover sites. The Western Hemisphere Shorebird Reserve Network has been highly successful in the identification, designation, and protection of important migration habitats for many species that stage in traditional areas. Recently, conservation efforts also focus on species and populations that disperse broadly on the landscape and that exhibit opportunistic use of available habitat in highly dynamic wetland systems. This unpredictability makes the conservation of wetland stopover habitats in the interior of North America highly challenging. We present an approach to identifying landscapes and wetlands critical to en route migrants in extensive ephemeral wetland systems.

Key words: ephemeral wetlands, migration stopover areas, shorebirds, wetland conservation.

Introduction

Shorebird migration strategies vary by species, migration distance and route, time of year, and resources at staging and stopover sites. There are several well-known examples of species or populations that stage in few key sites for long periods of time, lay on considerable fat stores, and 'jump' long distances (Myers et al. 1987, Piersma 1987). The Western Hemisphere Shorebird Reserve Network (WHSRN), a voluntary, non-regulatory coalition of more than 240 private and public organizations in seven countries, has been highly successful in the identification, designation, and protection of important migration habitats for many of these species groups (http://www.manomet.org/srn/; Harrington and Perry 1996). Currently, WHRSN has 54 designated sites totaling 20 million acres at the international, hemispheric, national, and regional levels.

Recently, conservation efforts also focus on species and populations that refuel only briefly at stopover sites, disperse broadly on the landscape, and 'hop' shorter distances between sites (Skagen 1997, Haig et al. 1998, Warnock et al. 1998). Many shorebirds crossing the North American interior exhibit opportunistic use of available habitat in highly dynamic wetland systems (Skagen and Knopf 1993, 1994; Warnock et al. 1998). In such systems, the use of specific wetlands within and between years is highly unpredictable.

The prairie wetlands of the glaciated regions of the northern U.S. Great Plains and into Canada, a region commonly referred to as the prairie pothole region (PPR), provides stopover resources for large populations of long- and intermediate-distance migrant during spring and fall (*fig. 1*; Skagen and Knopf 1993, Skagen et al. 1999). The PPR covers more than 700,000 km^2 and extends from north-central Iowa to central Alberta. During the Pleistocene Epoch, retreating glaciers carved a landscape dotted with millions of depressional wetlands or potholes. The climate of the PPR is highly dynamic with great interannual variation in rainfall, resulting in a complex association between prairie wetlands and groundwater tables (Euliss et al. 1999) and highly variable water levels in these extensive ephemeral wetland systems.

The unpredictability of shorebird habitat availability and the broad dispersion of migrating shorebirds in the PPR make conservation of critical wetland stopover habitats highly challenging. For example, wetlands that host large numbers of birds in one year may have no suitable shorebird habitat during many other years because conditions are too wet or too dry. In spring 1992, peak counts of all shorebird species at Dry Lake, Clark County, South Dakota, US, totaled more than 50,000 birds (Skagen 1997), yet waters were too deep for shorebird use from 1993 – 2002 (S. Skagen, unpubl. data). The extensive mudflats of Minnewaukan Flats, Devil's Lake, North Dakota, US, hosted more than 80,000 shorebirds during spring 1993 (Skagen 1997); this area has been inundated with water from fall 1993 to the present. When important sites are unsuitable, the

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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challenge is to determine whether shorebirds overfly the region, congregate in alternate sites, or disperse across the landscape.

An approach to identifying landscapes and wetlands critical to en route migrants is clearly needed for habitat management, conservation, and restoration efforts in extensive ephemeral wetland systems. Such an approach would differ substantially from successful approaches in landscapes with fewer wetlands and in which the presence of shorebird habitat is more predictable. We are developing an approach that incorporates habitat and landscape modeling at multiple scales and under various climate regimes and that will be useful in apportioning shorebird survey effort and interpreting shorebird distribution and abundance data in wet, dry, and transition years.

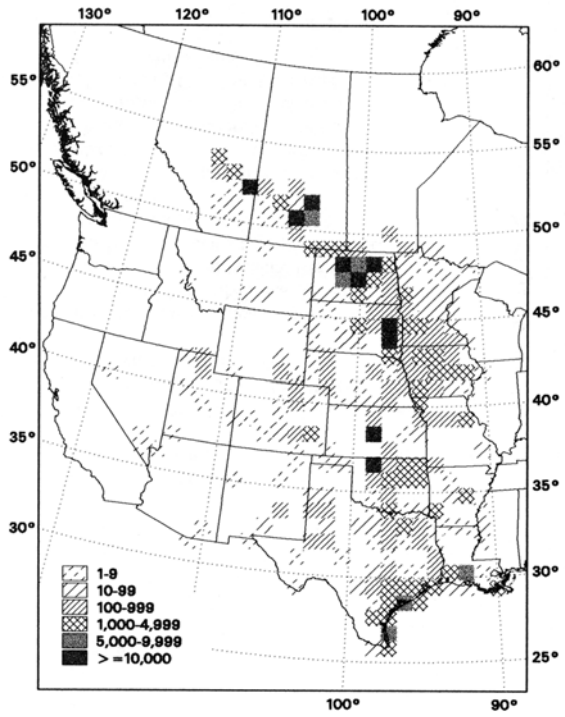

Figure 1— Distribution of long-distance migrating shorebirds in spring throughout midcontinental North America (reprinted with permission from Skagen et al. 1999).

Methods

We used a training dataset collected in eastern South Dakota during April and May of 1991, 1992, 1993, and 1995, during which we conducted shorebird surveys and recorded habitat conditions in 212 wetlands across 12 counties. Each wetland was buffered at various radii (1 km, 3 km and 5 km), and total area of wetlands of various types (temporary, seasonal, semipermanent, and permanent palustrine wetlands, and lacustrine systems), and total area of various land use types (grassland, cropland, and other) were determined using U.S. Fish and Wildlife Service National Wetland Inventory data and U.S. Fish and Wildlife Service land use database. Using AIC modeling techniques (Burnham and Anderson 1998) in an exploratory, not confirmatory, fashion, we constructed numerous habitat and landscape models and selected the most parsimonious models. This information was then used to define landscape types in an experimental design for a new field effort.

Our analyses included following predictor variables based on wetland attributes (wetland type [temporary, seasonal, semi-permanent, and permanent palustrine], wetland area and perimeter, area of habitat suitable [defined for each species of interest; for most Calidrid species, suitable habitat is the area of unvegetated wet mud and shallow water], and area of vegetated habitat), and landscape attributes within buffers of 1, 3, and 5 km radii (area of temporary and seasonal wetlands, area of semi-permanent palustrine wetlands and lakes, area of all wetland types combined, area of cropland [tilled annually], and area of grassland [including hayland, CRP, and pasture]). We ran logistic regression models based on shorebird presence during species-specific migration windows (the time period during which 90 percent of sightings occurred) and linear regression models using only wetlands with the species of interest present, again during species-specific migration windows (90 percent).

Results

Especially common in the PPR during spring are long-distance migrating shorebirds (*fig. 1*), species that travel an average of more than 14,000 km, including American Golden Plover (*Pluvialis dominica*), Hudsonian Godwit (*Limosa haemastica*), White-rumped Sandpiper (*Calidris fuscicollis*), Baird's Sandpiper (*C. bairdii*), Pectoral Sandpiper (*C. melanotos*), and Stilt Sandpiper (*C. himantopus*). Intermediate-distance migrants, species that traverse on average 6,000 - 12,000 km, that commonly stop over in the PPR include Lesser Yellowlegs (*Tringa flavipes*), Semipalmated Sandpiper (*C. pusilla*), Least Sandpiper (*C. minutilla*), and Long-billed Dowitcher (*Limnodromus scolopaceus*).

The most parsimonius logistic regression models to predict spring occurrence of four species common to the region (Semipalmated Sandpiper, White-rumped Sandpiper Pectoral Sandpiper, and Stilt Sandpiper) consistently included positive relationships with the area of suitable habitat within the wetland (*table 1*). Three of these species were more likely to occur in temporary and seasonal wetlands rather than semi-permanent wetlands and all four species showed an association with wetlands surrounded by cropland in one

Table 1— *Wetland and landscape attributes associated with the presence of four species of en route shorebirds during spring migration, 1992-1993, in eastern South Dakota.*

	Semipalmated Sandpiper		White-rumped Sandpiper		Pectoral Sandpiper		Stilt Sandpiper	
Year and general conditions	1992 dry	1993 wet	1992 dry	1993 wet	1992 dry	1993 wet	1992 dry	1993 wet
Number of wetlands	68	137	53	89	98	145	53	137
Area of suitable habitat in wetland	++	++	++	++	++	++	++	++
Area of vegetated habitat in wetland		----	++	----				
Wetland regime				--	----	----	----	----
Basin area				--				
Basin perimeter				--				
Number of wetlands within 1, 3, or 5 km			----		--			
Area of all wetlands within 1, 3, or 5 km			--			--		++
temporary/seasonal					++	++	----	
semipermanent/permanent	--					----		
Area of cropland within 1, 3, or 5 km	++	+	+	++	++			++
Area of grassland within 1, 3, or 5 km		----						

Note: ++ and ---- represent positive and negative associations in the most parsimonius models. + and -- represent positive and negative associations in closely approximating models (with a Δ AIC < 2.0).

or both years. The appearance of the other basin and landscape attributes in the models was inconsistent. The smaller species, the Semipalmated and White-rumped sandpipers, tended to use the larger semipermanent wetlands during the dry years, when mud/shallow water habitats occurred around the wetland edges, and increased their use of temporary and seasonal wetlands and sheetwater in wet years ($\chi^2 = 7.043$, df = 3, P = 0.071 and $\chi^2 = 10.78$, df = 3, P = 0.013 for Semipalmated and White-rumped Sandpipers, respectively).

Discussion

We offer three possible explanations for the positive association of these Calidrid sandpipers with the area of tilled cropland in the surrounding landscape in spring. First, small shorebirds prefer open habitats with little vegetation, and wetlands surrounded by tilled cropland may provide more open habitats in spring. We found, however, that even after the area of vegetated wetland habitat was included in models, the cropland factor remained important. Second, the topography of highly tilled areas may be flatter and wetlands that occur there may be more shallow-sided, thus more likely to provide the shallow (<5 cm) water habitats needed. This explanation warrants the inclusion of elevation change in future a priori models. And third, greater water fluctuations in wetlands embedded in cropland than those in grassland (Euliss and Mushet 1996) may result in more consistent exposure of invertebrates as foraging areas are depleted (Schneider and Harrington 1981).

The next step in the development of this approach is to refine the species-specific models that relate annual distribution and abundance of migrating shorebirds to habitat and landscape features and climate data. The results from the training set have defined landscape types of interest based on wetland regime/area and cropland area in a new study design. The resulting models ultimately will be used to allocate survey effort, to estimate shorebird abundance regionwide, to identify landscapes important for conservation and wetland restoration, and to provide management decision support at multiple spatial scales.

The dynamic nature of wetlands, whether due to natural or man-altered weather and ecosystem processes, has important implications for shorebird habitat conservation in ephemeral prairie wetlands systems. Site-based approaches are probably less effective in prairie wetland systems because of the difficulty in identifying wetland sites that predictably provide suitable shorebird stopover habitat. This problem may be reduced somewhat if wetland complexes were considered as single entities (Skagen and Knopf 1994, Haig et al. 1998). The geographically extent over which habitats vary and migrant distributions shift, however, would require that such complexes be extensive. Therefore, there is an urgent need for conservation programs that acknowledge and incorporate the shifting distributions of habitats and birds the landscape.

Acknowledgments

We thank T. Giles and A. Lueders for GIS support, data management, and data analyses. S. J. Dinsmore,

R. M. Corcoran, K. Castelein, and C. P. Melcher conducted the 1991-1995 field surveys. R. Reynolds provided the land cover data. Funding was provided by the Prairie Pothole Joint Venture and U.S. Geological Survey.

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Understanding the Stopover of Migratory Birds: A Scale Dependent Approach[1]

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Abstract

The development of comprehensive conservation strategies and management plans for migratory birds depends on understanding migrant-habitat relations throughout the annual cycle, including the time when migrants stopover *en route*. Yet, the complexity of migration makes the assessment of habitat requirements and development of a comprehensive conservation strategy a difficult task. We emphasize that development of a comprehensive conservation strategy depends on understanding that migrant-habitat relations during passage are scale dependent, and we outline a practical framework for the study of migrants during stopover that reflects spatial scale and allows us to draw stronger inferences about the behavior, ecology and conservation of migratory birds. This framework is organized into four components, each providing an increasing degree of resolution and information at different ecological scales from gross patterns of habitat availability and use by groups of migrants to finer-scale information on habitat suitability and consequences of *en-route* habitat use for individual birds. Combining information from these components with remote-sensing technology and Geographic Information Systems [GIS] places us in a position to develop conservation initiatives and management plans that are focused explicitly on migration and the stopover biology of migratory birds.

Key words: Migration, stopover ecology, scale, habitat selection

Introduction

Migration is a fundamental characteristic of the life history of many organisms from monarch butterflies to marine mammals and is surely one of the most fascinating of all behaviors. Over two-thirds of all the landbirds that breed in temperate North America, for example, migrate long distances to nonbreeding areas in Mexico, Central and South America and the islands of the Caribbean (Keast and Morton 1980, Rappole 1995). Some have argued that these long-distance, intercontinental migrants experience the better of two worlds by virtue of their migratory strategy: increased reproductive success by breeding in food rich, competitor poor temperate areas and increased survival by spending temperate winter in tropics (Greenberg 1980). Be that as it may, traveling long distances across areas that vary physiographically comes with considerable risks, and the mortality associated with intercontinental migration may be substantial, especially among young-of-the-year birds (Lack 1946, Greenberg 1980, Ketterson and Nolan 1983, 1985; Sillett and Holmes 2002). Hence, the migration period is likely to have an important role in limiting migratory landbird populations (see Sherry and Holmes 1995, Hutto 2000), and should factor into the development of conservation strategies aimed at protecting these populations (Moore et al. 1995).

Although many landbird migrants are capable of making spectacular, non-stop flights over ecological barriers, few migrants actually engage in nonstop flights between points of origin and destination. Instead, migration is divided into alternating phases of flight and stopover, with each stopover lasting a few hours to a few days. In fact, the cumulative amount of time spent at stopover sites far exceeds time spent in flight and largely determines the total duration of migration (Alerstam 1993). The place where a migratory bird pauses between migratory flights is called a stopover site.

When trying to understand how migrants "choose" stopover sites during passage, it is important to recognize that migration occurs over a broad geographic scale, but over a relatively short temporal scale, which necessarily limits time and information available to migrants to evaluate different sites. Moreover, migrants almost invariably finds themselves in unfamiliar surroundings (Moore et al. 1990, Petit 2000) at a time

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California**.

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when energy demands are likely to be high (e.g., Loria and Moore 1990), often faced with the need to acquire food in a short period of time, while balancing often conflicting demands between predator avoidance and food acquisition (e.g., Lindström 1990, Moore 1994, Cimprich and Moore 1999), competition with other migrants and resident birds for limited resources (e.g., Moore and Yong 1991, Carpenter 1993a,b), unfavorable weather (e.g., Gauthreaux and Belser 2000), not to mention the need to make accurate orientation decisions (e.g., Sandberg and Moore 1996a). How well migrants "offset" the costs of migration depends on how well they solve the problems that arise during passage. Solution of *en route* problems determines the success of a migration, while a successful migration is ultimately measured in terms of survival and reproductive success (Sandberg and Moore 1996b, Smith and Moore 2003).

The development of comprehensive conservation strategies and management plans for migratory birds depends on understanding migrant-habitat relations during stopover. This understanding is best gained by taking a hierarchical approach in which the mechanisms by which habitats are occupied as well as the costs and benefits of habitat use are studied at different ecological scales. Our objectives are two fold: (1) Emphasize that migrant-habitat relations during passage are scale dependent and (2) outline a practical framework for the study of migrants during stopover that reflects spatial scale and allows us to draw stronger inferences about the conservation of migratory birds.

Migrant-Habitat Relations

Although we might expect migrants to settle in habitats based on relative suitability, where suitability is tied to why the migrant stops over in the first place (Petit 2000), that outcome is not assured. Favorable *en route* habitat, where a fat-depleted migrant can rapidly meet nutritional needs, for example, is probably limited in an absolute sense, or effectively so because migrants have limited time to search for the "best" stopover site (Hutto 1985, Martin and Karr 1986). Intrinsic constraints on habitat use are those factors thought to determine habitat quality and upon which migrants make decisions about habitat use at a fine spatial scale – factors such as food and presence of predators (see Hutto 1985, Moore et al. 1995). As the spatial scale broadens, factors intrinsic to habitat give way to factors largely unrelated to habitat (see Gauthreaux 1980, Kelly et al. 1999). Indeed, at a broad spatial scale, habitat use is largely under control of factors extrinsic to habitat per se such as weather.

The study of landbirds during migration should reflect the hierarchical nature of a migrant's relationship to habitat (Moore et al. 1995), and should "focus" on the migrant-habitat relationship at different scales. Imagine an intercontinental songbird migrant traveling northward across the Gulf of Mexico. At this broad geographical scale, the hypothetical migrant might stop on East Ship Island off the Mississippi Gulf Coast rather than along the coast of Louisiana by virtue of prevailing winds alone (*fig. 1a*). That "decision," influenced as it is by extrinsic factors, is likely to have consequences for the migrant. For example, when stopover biology of migrants was studied simultaneously in spring at two sites along the northern coast of the Gulf of Mexico, White-eyed Vireos (*Vireo griseus*) were more likely to replenish depleted fat stores and stay for a shorter time if they stopover in a chenier in southwestern Louisiana (*fig. 2*), where food abundance was estimated to be greater, than on East Ship Island (Kuenzi et al. 1991).

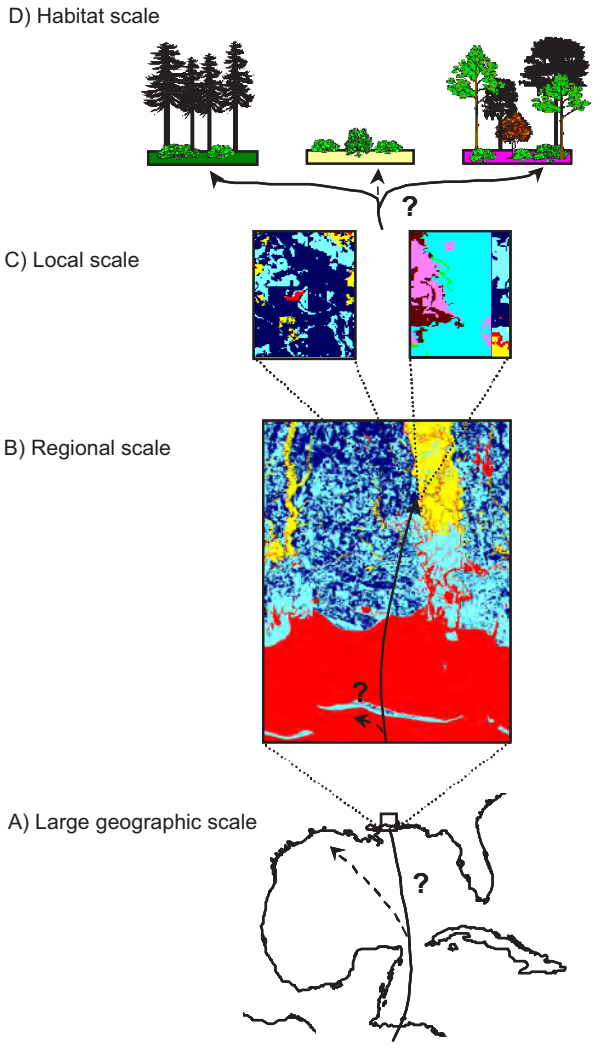

Figure 1— Conceptual hierarchy of en route habitat use by migratory landbirds making landfall after a trans-Gulf migratory flight in spring at various spatial scales.

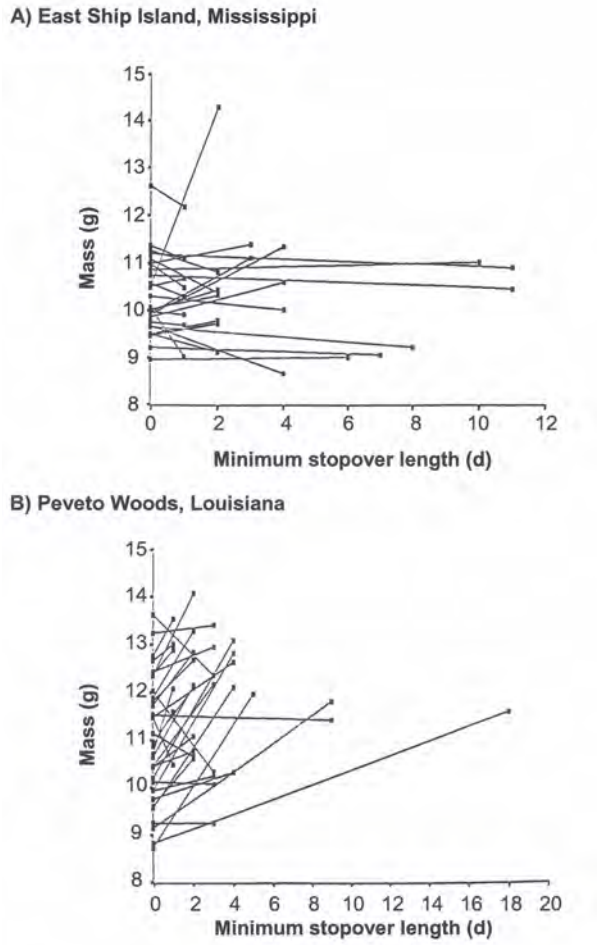

Figure 2— Mass change of White-eyed Vireos from first capture to last capture at A) East Ship Island, Mississippi (mean = 0.00 ± 0.08 g/d, N = 30), and B) Peveto Woods, Louisiana (mean = 0.33 ± 0.08 g/d, N = 33) in 1988.

Our hypothetical migrant may fly inland and make landfall in a patch of hardwood forest rather than land in coastal woodland or on barrier island, a decision that is probably influenced by the migrant's energetic condition as well as wind and other weather conditions (see Lowery 1945, Gauthreaux 1971, Moore and Kerlinger 1987, Gauthreaux and Belser 2000). The result of the "decisions" that migrants make at this broad geographic scale is reflected, for example, in data collected from surveys stratified into three latitudinal bands from the immediate coast up to 85 km from the coast in southern Mississippi[1] (*fig. 3a*). In general, more individual migratory birds were observed inland away from the coast during spring migration.

When our hypothetical bird makes landfall, she encounters a landscape of different habitats at a local scale (*fig. 1c*). Observations of migrants arriving along the northern coast of the Gulf of Mexico following a trans-Gulf crossing suggest that migrants assess alternative habitats (*fig. 1d*) during an initial exploratory phase shortly after arrival (Aborn and Moore 1997). An "exploratory phase" to habitat selection would be adaptive when migrants encounter a variety of habitat types and the availability of suitable habitat is unpredictable. Although migrants could arrive at a stopover site with prior information about the distribution of resources and habitats, migrating birds experience a variety of unfamiliar habitats and usually spend little time at one location, circumstances that reduce the value of prior information.

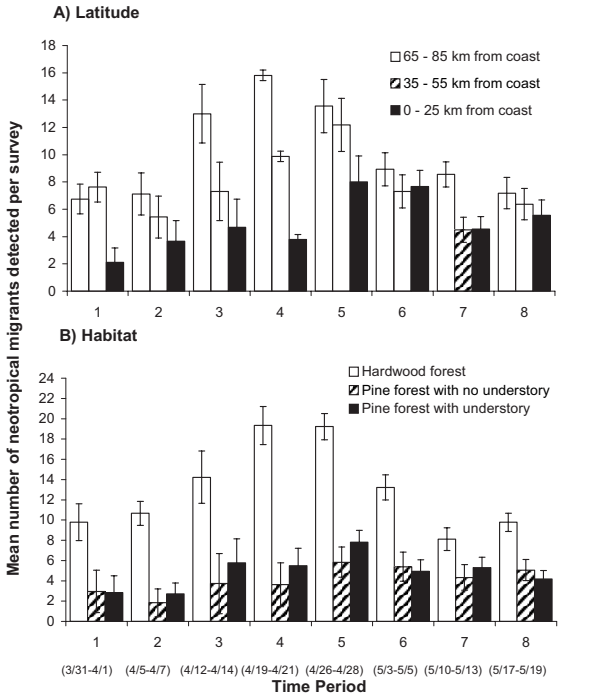

Figure 3— Mean number (±se) of neotropical migratory landbirds detected per survey at coastal sites (N = 6 sites per treatment) of A) different distances from the coast and B) various habitat types within Mississippi during spring 1993.

Nevertheless, several lines of evidence suggest that migratory species exhibit selective use of locally available habitats during stopover (Moore et al. 1995, Petit 2000): (1) Use of habitat out of proportion to its availability (*fig. 3b*; see also Moore et al. 1990, McCann et al. 1993); (2) Species-specific patterns of distribution among different habitats (e.g. Bairlein 1983); (3) Habitat use correlated with food availability (e.g., Hutto 1985, Martin 1985, Martin and Karr 1986, Yong et al. 1998); (4) Shifts in habitat use correlated with changes in dietary preferences (Moore et al. 1990, Moore and Woodrey 1993); (5) Habitat use in relation to energetic condition (Aborn and Moore 1997, Moore and Aborn 2000). What cues

[1]unpublished data, Moore and Simons.

migrants use to select among alternative habitats are poorly understood (Moore and Aborn 2000).

Scale-Dependent Framework

The study of migrants during stopover should reflect their scale dependent relationship with habitat. We begin with a regional habitat map of the landscape in question based on land cover classification of a multi-spectral remotely-sensed image. The abundance and spatial pattern of habitat types of the study landscape are derived using a geographic information system (GIS) (e.g. Simons et al. 2000). We use this map as a setting or geographic framework in which to develop our study design. We organize our study design into four components, each providing an increasing degree of resolution and information at different spatial scales of a migrant's relationship to habitat; from gross patterns of habitat availability and use by groups of migrants, to finer scale information on habitat suitability and consequences of *en-route* habitat use for individual birds.

Radar Component - Weather surveillance radar is a useful tool for the detection, monitoring and quantification of the movement of birds in the atmosphere (Gauthreaux and Belser 2000, 2003; Diehl et al. 2003). As such, radar is capable of addressing questions about broad geographic scale movements over various time scales. Over the course of a migration season, for example, radar provides an indication of where and how frequently migratory flights are made. Although weather surveillance radar can be used to determine areas where migrants stopover, it provides only a rough indication of density in relation to habitat type and little, if any, information on species, much less age, sex or energetic condition. Consequently, radar information is most valuable when integrated with data at the next level of analysis.

Census Component - At a finer resolution, field personnel quantify abundance and diversity of landbird migrants in different habitats and/or in relation to different spatial features by means of surveying protocols (e.g. point counts, line transects). These data can be used to address daily and within-season patterns of migration. For example this approach has been used to examine species-area relationships of migrants *en route* within a single habitat type (see Martin 1980, Blake 1986, Cox 1988).

Telemetry Component - At the local and habitat scale, one can use radio-telemetry to study the movement pattern of migrants in relation to landscape variables. For example, radio-telemetry can be used in conjunction with translocation experiments designed to test predictions about patch occupancy: How do migrants react to patch size, habitat boundaries, habitat type? Radiotelemetry also helps us to understand how migrants make decisions about habitat use during stopover (Aborn and Moore 1997, Moore and Aborn 2000). Radio-telemetry can provide insight into stopover duration, temporary home range size, and exploratory behavior of migrants, as well as whether the factors of habitat patch size and placement within the landscape also affect the availability and suitability of stopover habitat for birds.

Behavioral (Direct Observation) Component - At the habitat scale, the consequences of the migrant-habitat relationship are evaluated by (a) observing how individual migrants use habitat (e.g., Loria and Moore 1990) and (b) using capture-recapture methods in different habitats (e.g., Yong et al. 1998), which allows quantification of the migrant's performance (e.g., energetic status, rates of mass change and length of stopover).

Data derived from the Radar, Census, Telemetry and Behavioral Components are analyzed against the spatial context provided by the regional habitat map. Dynamic spatial models that combine information on migrant stopover ecology (e.g., habitat preferences, energetic condition and flight ranges) with habitat data can be used to simulate how patterns of habitat availability (patch size, shape and distribution) may affect migratory bird populations. For example, Simons et al. (2000) illustrated the application of spatial models to test predictions about how spatial features of the stopover landscape along the northern coast of the Gulf of Mexico might affect habitat suitability, create migratory corridors, or serve as ecological 'traps' for migrants.

Conservation Implications

The spatial scale over which migration occurs, coupled with the variety of habitats migrants encounter during passage make the challenge of conserving stopover habitat for migratory birds uniquely different from that of protecting breeding and wintering habitats (see McCann et al. 1993, Moore et al. 1993, Watts and Mabey 1994, Moore et al. 1995, Petit 2000). The spatial scale presents political and economic difficulties with respect to assigning responsibility for the protection of migratory bird populations, while habitat heterogeneity along migratory routes presents ecological difficulties for understanding what habitats are most important, where they occur, and how their distribution and abundance are changing as a result of development and land conversion (Moore and Simons 1992, Mabey and Watts 2000). However, if the persistence of migratory bird populations depends on birds' abilities to find favorable conditions for survival throughout the annual cycle, factors associated with *en route* ecology must figure in any analysis of population change and in the development of a comprehensive conservation "strategy" for landbird migrants.

A variety of management issues are involved in the conservation of migratory bird stopover habitats. Some conservation issues concerning the integrity and/or suitability of stopover habitat in the southeastern United States include global/climate change, conversion of natural habitats, coastal erosion, bird collisions with communications towers, the role of fire in managing landscapes, livestock grazing and white-tailed deer overbrowsing, the suitability of man-made habitats, invasive exotic plants, and forest management practices (Woodrey et al., in press). Over the past decade, we have gained a deeper understanding of the behavior, ecology and ecophysiology of migratory birds during passage. That understanding, in combination with the recent accessibility of remote-sensing and GIS technology and the scale-dependent approach outlined here, provide us a framework or perspective to identify those issues most-relevant to the development of successful conservation initiatives and management plans that are focused explicitly on migration and the stopover biology of migratory birds.

Acknowledgments

We thank D. Ewert, R. Smith, S. Mabey, C. Szell, Jeff Farrington, M. Guilfoyle, C. Hunter, R. Chandler, P. Kerlinger and S. Gauthreaux, Jr, for their contribution to the development of the scale-dependent framework developed here. Our research with migratory birds has been supported by the National Park Service, U.S. Fish & Wildlife Service, USDA Forest Service, National Science Foundation (BSR-9020530 and BSR-9100054 to FRM), and the National Geographic Society.

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Repeats, Returns, and Estimated Flight Ranges of Neotropical Migratory Birds in Utah Riparian Habitat[1]

Dan A. Roberts,[2] Jimmie R. Parrish,[2,3] and Frank P. Howe[2]

Abstract

We present data on capture and recapture of neotropical migrants at constant-effort mist net sampling locations in Utah between 1994 and 2002. Data were collected in accordance with MAPS (Monitoring Avian Productivity and Survivorship) protocols. Since 1994, a total of 23,789 birds have been captured (i.e., total captures include new captures, recaptures, and unbanded individuals) representing 149 species. Data collected thus far provide some measure of site fidelity and longevity for species breeding in and migrating through Utah. Of the 18,358 birds banded, 2,367 (12.9 percent) were subsequently recaptured at least once. The longest interval between initial capture and recapture was over eight years.

Assessments of subcutaneous fat carried by each bird captured were also made in accordance with MAPS protocols. Using Yellow Warbler (*Dendroica petechia*) as an example, we calculated an estimated maximum travel distance (EMTD) that migrants can fly from Utah on the energy derived from fat metabolism. Based on our calculations, juvenile Yellow Warblers could potentially outdistance adults and travel almost 1,000 km from Utah without refueling.

Key Words: captures, estimated maximum travel distance (EMTD), fall migration, fat metabolism, Mist netting, recaptures, spring migration, Yellow Warbler (*Dendroica petechia*).

Introduction

The extent to which neotropical migrants return annually to specific localities for breeding is poorly understood. The premise has been that successful breeding in a given locality one year will enhance the likelihood that individuals will return to that locality for breeding in subsequent years (Nolan 1966, Darley et al. 1977, Pinkowski 1979). Loftin (1977), Ely et al. (1977), and Rogers et al. (1982) have summarized fidelity to wintering grounds, although data are still lacking for many species of neotropical migrants for both wintering and breeding grounds. Our data provide some measure of site fidelity and longevity for species using Utah riparian areas during breeding and migration seasons.

Subcutaneous fat accumulates in birds, particularly before and during periods of migration. Fat weight as related to theoretical maximum flight ranges has been investigated at least since the 1950s (Odum and Perkinson 1951, Odum and Connell 1956, Odum 1958, Odum et al. 1961, Odum et al. 1965, Rogers 1965, Rogers and Odum 1966, Rogers et al. 1982). Most of these studies have dealt with existence energy requirements, flight energy needs, flight speed calculations, and the caloric value of total fat in determining the likelihood that passerines could complete long-distance migrations. Odum and Perkinson (1951), Odum and Connell (1956), Odum (1958), and Rogers (1965) extracted total fat from tower-killed migrants to determine caloric values of fat which were used to estimate maximum potential flight ranges. It has been estimated that birds could travel several hundred if not thousands of miles on the energy available from fat metabolism during flight, although comprehensive estimates for a number of species remains unavailable.

We present data for neotropical migrants captured at constant-effort mist net sampling locations in Utah between 1994 and 2002. While the study was initiated to investigate breeding season demographics in Utah riparian habitat, an assessment of subcutaneous fat was recorded as part of the overall data collection procedure for each bird captured. Fat data collected for Yellow Warblers (*Dendroica petechia*) was used to estimate potential travel distances to and from Utah that birds can fly without refueling.

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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Study Area and Methods

Study Area

The Utah Division of Wildlife Resources has been monitoring birds in riparian habitat for the past 10 years (see Howe 1992). Beginning in 1994, constant-effort mist net sampling has been conducted annually at a randomly selected number of these sites in accordance with MAPS (Monitoring Avian Productivity and Survivorship) protocols (DeSante and Burton 1994 and subsequent annual updates) (*fig. 1*).

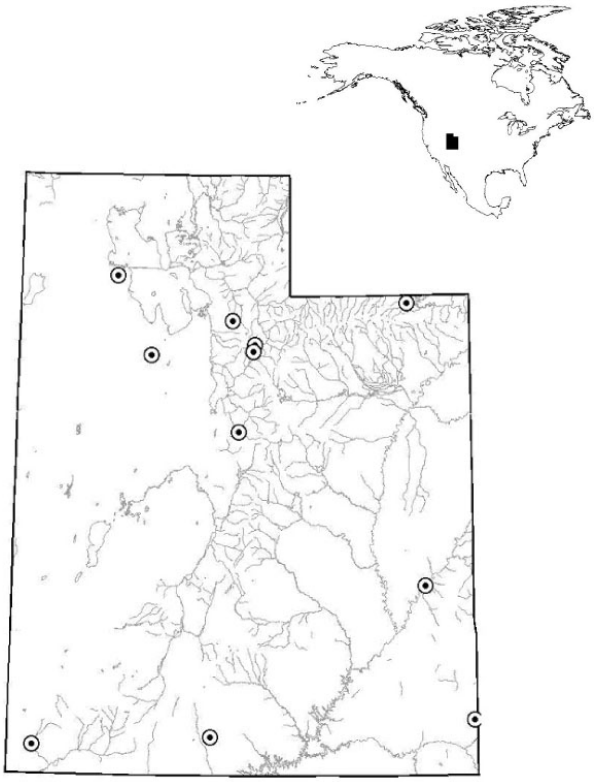

Figure 1— Location of 1994-2002 mist net sampling areas in riparian habitat in Utah.

Methods

Mist net sampling at each location was conducted once each 10-day period between 1 May and 28 August annually from 1994-2002 by field biologists trained in MAPS survey protocols and data collection techniques. A total of ten mist nets were operated continuously for 6 hours at each monitoring station beginning ca. one-half hour before official sunrise on each scheduled sampling day.

Data collected from captured birds included sex, age, weight, breeding condition, fat score, wing chord measurement, feather wear, molt condition, date and time of capture, and general observations (see Pyle 1997). The breeding condition of males (e.g., cloacal protuberance) and females (e.g., condition of brood patch) was also recorded. Captured birds were weighed to the nearest 0.1-g on a digital balance calibrated before each sampling event and banded with a U.S. Fish and Wildlife Service numbered leg band.

New, Repeat, and Return Captures

In order to estimate how many of the banded individuals returned to the same area to breed each year (i.e., site fidelity), we established criteria using several factors. Among these were 1) date of capture, 2) the number of recaptures, 3) the frequency of recapture, 4) the time interval between initial capture and subsequent recapture, and 5) rate of return to the same area in subsequent years. Birds were categorized as being either new captures, repeat captures, or return captures. New captures were those individual birds which were unbanded when captured. Repeat captures were designated as those individuals recaptured within <90 days after initial capture, and return captures were those individuals recaptured after at least 90 days or more (Rogers et al. 1982). Occasionally, individual new captures would escape before being banded and those individuals were designated as unbanded birds.

Fat Score

As assessment of the amount of subcutaneous fat present in captured Yellow Warblers was recorded as a numerical 'fat score' in accordance with MAPS protocols (DeSante and Burton 1994 and subsequent annual updates) (*table 1*). Fat weights for each observed fat score for adult male, adult female, and juvenile Yellow Warblers were then pooled for each respective age and sex category (*table 2*).

Breeding and Migration Season Chronology

We wanted to determine whether an individual bird captured was a resident or a migrant. We used Julian date vs. calendar date to maintain consistency in plotting capture results for multiple years. Breeding and migration season chronology estimates were calculated based on observed fat scores and breeding condition of individual birds captured (*fig. 2*). The assumption was that breeding birds carry less fat and are less likely, and indeed less capable, of traveling for extended periods or distances away from the area where they were captured.

Table 1— *Description of fat scores (see DeSante and Burton 1994) assigned to each individual bird captured which were used for calculating a fat free weight and the amount of subcutaneous fat available for conversion to flight energy.*

Fat Score	Description
0	No fat visible in the furculum or anywhere on the body.
1	A very small amount of fat in the furcular hollow (<5% filled) but not enough to cover the bottom of the furculum. None or just a trace of fat under the wing, on the abdomen, or anywhere else on the body.
2	The bottom of the furculum is completely covered but the furcular hollow is less than 1/3 filled. A small amount of fat may be present under the wing, or abdomen, or both.
3	The furcular hollow is about half full (actually anywhere from 1/3 to 2/3). A covering pad of fat is definitely present under the wing pit and usually on the abdomen.
4	The furcular hollow is full (actually anywhere from 2/3 full to level with the clavicles). A thick layer of fat also occurs under the wing and on the abdomen.
5	The furcular hollow is more than full; that is, the fat is bulging slightly above the furculum. The fat under the wing as well as that on the abdomen is also well mounded.
6	Fat is bulging greatly above the furculum. Large mounds of fat occur under the wings and on the abdomen.
7	The fat pads of the furculum, wing pit, and abdomen are bulging to such an extent that they join. Nearly the entire ventral surface of the body is thus covered with fat, and fat even extends onto the neck and head.

Table 2— *Fat scores, fat weight, energy estimates, and distance calculations for Yellow Warblers captured during mist net surveys in Utah during 1994-2002. Distance estimates are based on a flight energy of 0.79 Kcal/hr for adult males, 0.76 Kcal/hr for adult females, and 0.78 Kcal/hr for juveniles (see text for explanation).*

Age/Sex	Fat score	N	Weight[1] (g)	Fat weight[2] (g)	Fat energy (Kcal/hr)	Est. flight time (hrs)	EMTD[3] (km)
Adult males	0	155	8.79	0.00	0.00	0.00	0.00
	1	66	9.03	0.23	2.08	2.63	146.14
	2	30	9.26	0.46	4.16	5.26	292.28
	3	35	9.49	0.69	6.24	7.89	438.43
	4	29	9.72	0.92	8.32	10.51	584.57
	5	15	9.95	1.16	10.40	13.14	730.71
	6	2	10.18	1.39	12.48	15.77	876.85
Adult females	0	219	8.43	0.00	0.00	0.00	0.00
	1	102	8.68	0.25	2.26	2.98	165.64
	2	56	8.93	0.50	4.52	5.96	331.27
	3	37	9.18	0.75	6.78	8.94	496.91
	4	44	9.44	1.00	9.04	11.92	662.55
	5	11	9.69	1.26	11.30	14.90	828.18
	6	3	9.94	1.51	13.56	17.87	993.82
Juveniles	0	88	8.63	0.00	0.00	0.00	0.00
	1	37	8.86	0.24	2.03	2.75	152.84
	2	30	9.10	0.47	4.27	5.50	305.69
	3	37	9.34	0.71	6.40	8.25	458.53
	4	38	9.58	0.95	8.54	11.00	611.38
	5	8	9.81	1.19	10.67	13.74	764.22
	6	2	10.05	1.42	12.81	16.49	917.06
	7	1	10.29	1.66	14.94	19.24	1069.91

[1]Weights for fat score 0 represent the mean fat free weight (FFW) for each age/sex category.
[2]Weights for each fat score represent the difference between the total weight at the time of capture and FFW for each age/sex category.
[3]EMTD = Estimated Maximum Travel Distance.

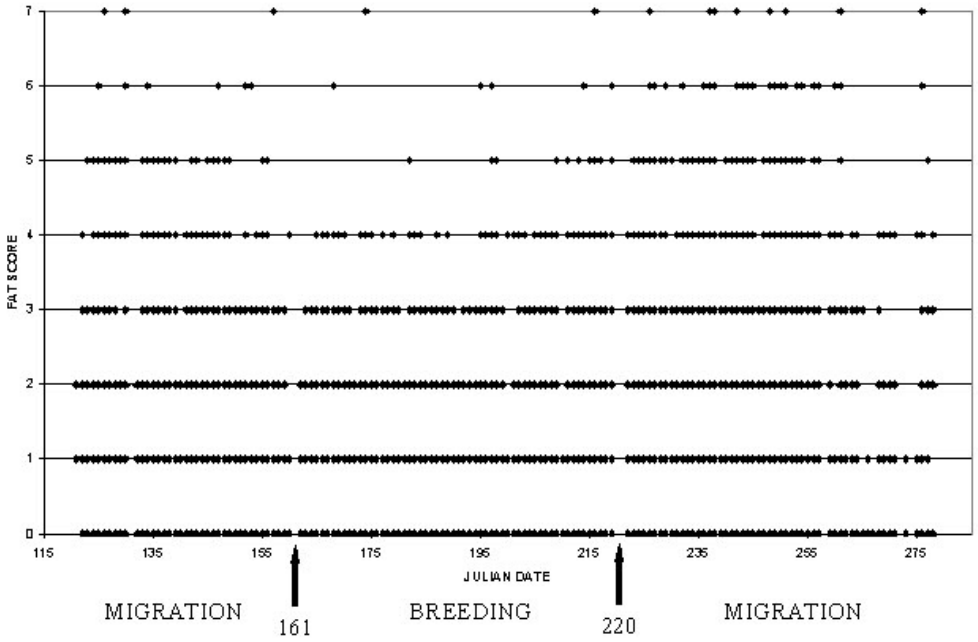

Figure 2— Fat scores recorded for each individual bird captured during mist net surveys conducted in Utah riparian habitat. Julian date versus calendar date was used to more accurately reflect seasonal variation in the fat scores recorded (see text for details).

Fat Score/Fat Weight Regression

Simple linear regression equations (e.g., $Y = \beta 0 + (\beta 1 \bullet X$, where $\beta 0$ = fat free weight (FFW), $\beta 1$ = increase in fat weight for each increase in fat score, and X = recorded fat score) were used to estimate the average increase in fat weight with an increase in fat score for each age and sex category. For example, the linear regression equation for adult male Yellow Warblers is $Y = 8.79 + 0.23X$, where the FFW is 8.79 g, and the increase in weight for a fat score of 1 (and each additional increase in fat score) is 0.23 g (*table 2*). Calculated linear regressions were then plotted for further evaluation using Program MINITAB (V. 12.23) (*fig.3* presents an example using data for adult male Yellow Warblers). It was assumed that if the resulting R^2 values obtained were reasonably high and the slope was positive, then the caloric values could be used to calculate the potential distance that birds could travel during spring and fall migration periods without refueling by metabolizing subcutaneous fat.

Flight Distance Estimates

The existence metabolic rate (EMR) for passerine birds has been estimated to be 0.04 – 0.05 Kcal/gram of FFW/hr (Rogers 1965). For data presented in this paper, we established an EMR of 0.045 Kcal/gram of FFW/hr (i.e., the median of values reported by Rogers 1965). In addition to our EMR value, our flight distance estimates are based on the following assumptions: 1) the flight metabolic rate (FMR) for passerines is estimated to be approximately twice that of the EMR (i.e., 0.09 Kcal/gram of FFW/hr) (see Rogers 1965), 2) the flight speed of passerines is approximately 30 knots (55.6 km/hr) (Nisbet et al. 1963), 3) the caloric value of fat is 9 Kcal/gram (Rogers 1965), 4) potential maximum hours of flight time is the total energy derived from fat divided by the FMR, and 5) maximum potential flight distance is the product of the potential hours of flight based on available flight energy from fat multiplied by flight speed.

Once the potential energy had been determined, we calculated the estimated maximum travel distance (EMTD) that male, female, and juvenile Yellow Warblers could travel from Utah without refueling. Variations in EMTD would be expected to increase with an increase in fat score. For example, individual Yellow Warblers with higher fat scores would be expected to have a higher EMTD capability to and from a given capture location.

Results and Discussion

New, Repeat, and Return Captures

Since 1994, a total of 23,789 captures have been recorded (i.e., total captures include new captures, repeat captures, return captures, and individual birds that were not banded) representing 149 species. Of the 18,358 (77 percent) birds banded, 2,367 (12.9 percent) birds representing 75 species were subsequently recaptured

at least once (*table 3*). In contrast, 15,991 (87.1 percent of new captures) individual banded birds have yet to be recaptured at least once since their initial banding.

The total number of new captures increased steadily from 1994 until 2000 and has ranged from a low of 810 to a high of 3,507 (*table 3*). The number of repeat captures ranged from 66 (7.9 percent of new captures within the year) to a high of 327. The highest yearly percentage of repeat captures was 12.3 percent which occurred in 1998. The total number of recaptures (including returns and birds recaptured more than once) ranged from 66 to 709 (*table 3*).

Of the total recaptures, 830 (35.1 percent) individual birds were recaptured at least 1 year after their original capture date, 367 (15.5 percent) were recaptured at least 2 years after initial capture, 137 (5.8 percent) were recaptured at least 3 years after initial capture, and 47 (2.0 percent) individuals were recaptured at least 4 years after initial capture. Only 13 (0.5 percent) recaptured birds have been recaptured at least 5 years from their original capture date.

Table 3— *Total new captures, recaptures, repeat captures, and return captures of neotropical migrants in Utah during 1994-2002 (see text for further explanation).*

Year	New captures[1]	Repeat captures[2]	Return captures[3]	Total recaptures[4]
1994	834	66	0	66
1995	810	67	42	109
1996	1,545	165	138	305
1997	2,377	205	197	401
1998	2,204	270	260	533
1999	2,258	214	280	496
2000	3,507	327	372	709
2001	2,388	224	359	591
2002	2,435	189	245	437

[1]Total banded for each year (i.e., birds unbanded at time of initial capture).
[2]Total recaptures within 90 days of initial capture.
[3]Total recaptures 90 days and greater from initial capture from previous year(s).
[4]Total of repeats + returns for each year (includes birds recaptured more than once)

The greatest single longevity record from this study belongs to a male Yellow Warbler recaptured during the 2002 field season at the same location where initial banding occurred in 1994. A total of 2,937 days (8.05 years) had elapsed between the time of initial capture and the 2002 recapture.

Breeding and Migration Season Chronology

We determined that birds captured between 10 June (Julian Date 161) and 8 August (Julian Date 220) were considered as residents (breeders) and that birds captured prior to 10 June and after 8 August were considered as migrants. Adult males captured prior to June 10 or after August 8 had little or no cloacal protuberance (MAPS score of 1 or 0), and females captured during the same period showed little or no evidence of a brood patch presence (MAPS score of 0), or the brood patch area was molting (MAPS score of 5). Nearly all (98.4 percent) of the fat scores recorded during the potential breeding season were at 4 or below. In fact, most fat scores were at 2 or below (87.2 percent), and nearly half (49.1 percent) had fat scores of 0 (*fig. 2*).

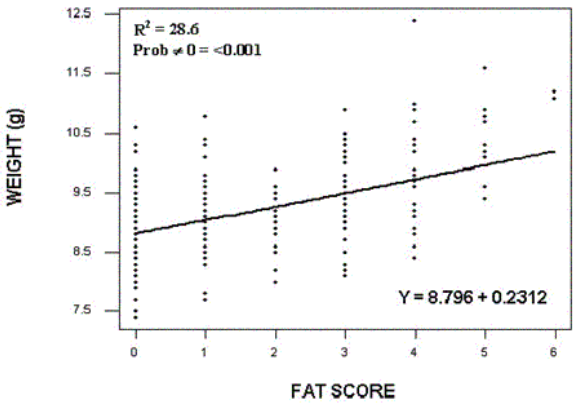

Figure 3— Regression of fat score and weight (in grams) of migrant adult Male Yellow Warblers captured in Utah riparian habitat. Regression calculated from field data collected during mist net surveys conducted in Utah riparian habitat.

Estimated Maximum Travel Distance (EMTD) Calculations

At least 7,894 birds (43 percent of birds banded) representing 125 species met the above criteria for consideration as migrants. After eliminating species known to be winter residents in Utah, only 10 migratory species had sufficient sample sizes (e.g., at least 100 individuals) to be considered for EMTD calculations. Of these, Yellow Warblers were selected for EMTD calculations for this paper based on fat scores recorded for captured individuals.

Typically, adult Yellow Warblers are sexually dichromic enough to distinguish between sexes when captured during migration periods. The highest fat score recorded for both adult males and females during field surveys was 6 and the highest fat score recorded for juveniles was 7. The fat score versus weight regression yielded an R^2 of 28.6 ($P < 0.001$) for adult male Yellow Warblers, an R^2 of 28.9 ($P < 0.001$) for

adult female Yellow Warblers, and an R^2 of 25.1 ($P < 0.001$) for juveniles.

Adult male Yellow Warblers with a fat score of 6 (e.g., 1.4 g of available fat, EMTD 877 km) could potentially travel less distance than adult female Yellow Warblers with a fat score of 6 (e.g., 1.5 g of available fat, EMTD 994 km) (*table 2*). EMTD for juveniles with a fat score of 6 (e.g., 1.7 g of available fat) was 917 km.

Using one of our northernmost mist net sampling stations as a potential starting point, we determined that adult male Yellow Warblers could potentially travel from northern Utah as far south as southern Arizona and southern New Mexico without refueling during fall migration (*fig 4*). Further, birds were capable of traveling as far north as the northern portions of the Idaho panhandle and northern Montana during spring migration without refueling. Adult female Yellow Warblers could potentially travel a bit farther south than males to the northern border of Mexico during fall migration and to the southern border of Canada during spring migration (*fig. 4*). Assuming birds began migration with a fat score of 6, individual females could be arriving in Utah from as far away as northern Montana in the fall and southern Arizona in the spring without refueling.

Juvenile Yellow Warblers could potentially travel farther than adults to as far south as the northern portions of Sonora and Chihuahua Mexico during fall migration without refueling and as far north as southern portions of Alberta and Saskatchewan during spring migration (*fig. 5*).

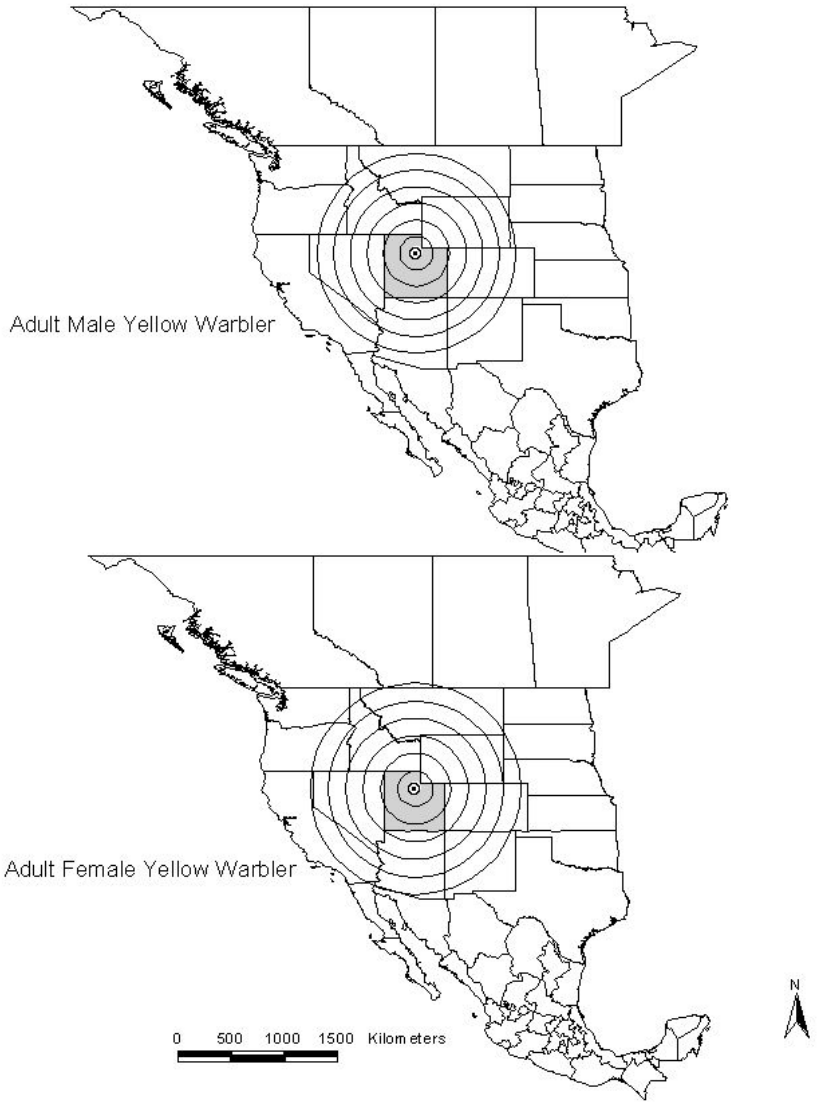

Figure 4— Potential distances traveled to and from north-central Utah by adult Yellow Warblers during spring and fall migration periods. Concentric circles represent potential maximum distances individuals could travel from north-central Utah with fat scores ranging from 1 (lowest potential distance/smallest circle) to 6 (highest potential distance/largest circle).

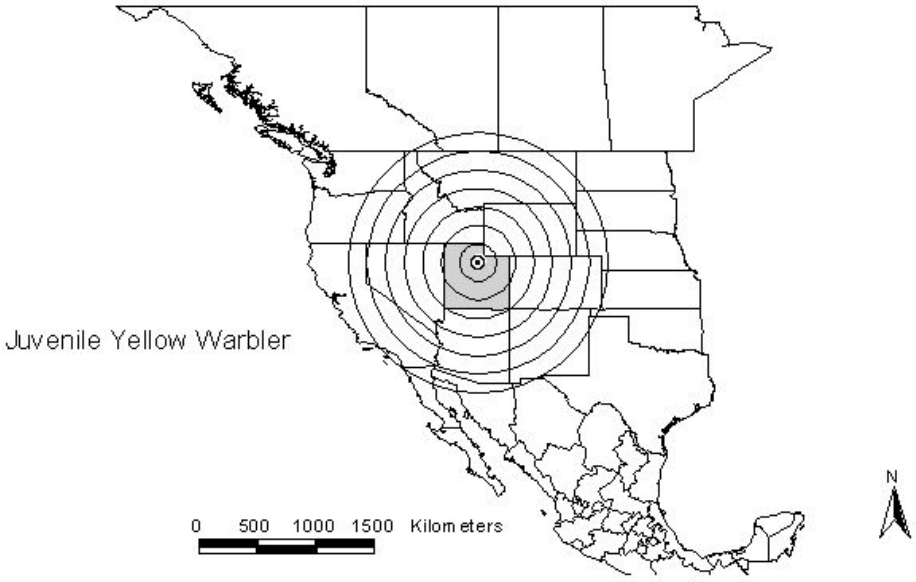

Figure 5— Potential distance traveled to and from north-central Utah by juvenile Yellow Warblers during spring and fall migration periods. Concentric circles represent potential maximum distances individuals could travel from north-central Utah with fat scores ranging from 1 (lowest potential distance/smallest circle) to 7 (highest potential distance/largest circle).

Summary

Of 23,789 total captures representing 149 species of neotropical migrants recorded in Utah riparian habitat during 1994-2002, only 2,367 (12.9 percent) birds representing 75 species were subsequently recaptured at least once. Recapture percentage ranged from a high of 35.1 percent within 1 year of initial capture to a low of 0.5 percent after 5 years. Over one-half (50.6 percent) of the recaptures occurred within 2 years of initial capture. Site fidelity may vary for a given species, and additional factors such as mortality rate (where known), sex, and age should also be considered in future studies of this kind. However, our results indicate that some individuals return to the same breeding grounds for much longer than 5 years.

Estimated maximum travel distance (EMTD) calculated for Yellow Warblers ranged from a low of 817 km for adult males to a high of 994 km for adult females, with juveniles potentially traveling further than adult males but less than adult females. We recognize that EMTD is dependent upon published values for the estimated flight speed of passerines and existence metabolic rate (EMR) or flight metabolic rate (FMR). Obviously, an increase in the estimated flight speed results in a proportional increase in flight distance, and an increase in EMR results in a proportional decrease in flight distance. It seems unlikely, that flight speeds or EMR values are identical for all neotropical migrants. Future studies should attempt to refine estimates of flight speed and EMR or FMR, which would allow for more accurate EMTD calculations. Studies are also needed for additional breeding as well as wintering locales. More comprehensive EMTD calculations could provide substantial benefit to wildlife managers in attempting to identify critical staging and foraging areas used during spring and fall migration periods.

Acknowledgments

Constant-effort mist net sampling in Utah has been made possible through the consistent support of the Utah Division of Wildlife Resources and numerous cooperators in the Utah Partners in Flight Program, including U. S. Forest Service, U. S. Bureau of Land Management, U. S. Fish and Wildlife Service, U. S. Bureau of Reclamation, Utah Reclamation, Mitigation, and Conservation Commission, and the Department of Defense. We also thank C. M. White, T. Rich, and R. Norvell for reviewing the manuscript and providing helpful comments.

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Towards the Establishment of Landbird Migration Monitoring Networks in the United States[1]

Jay D. Carlisle[2] and C. John Ralph[3]

Abstract

Migration monitoring of landbirds, in its various forms, is a well-established research endeavor across much of North America. While monitoring efforts at individual sites have contributed much to our knowledge of the biology of migrants, these studies have limited potential for population monitoring and for addressing certain broader questions about migrants. Meanwhile, there is still much to be learned about the habitat use, conservation needs, population trends, demographics, and general stopover ecology of migrants. As a model for migration monitoring networks, the establishment and operation of monitoring and research networks for other purposes in avian research has met with much success. We suggest that the involvement of many monitoring sites in a larger network can provide unique and necessary research, conservation, and monitoring opportunities for the study of birds during migration. While many are willing and eager to participate in such networks, the critical issue has been the ability of institutions to afford personnel to coordinate them. Here we review historical and present networks devoted to avian research and consider applications to the development of migration monitoring networks in the Americas.

Previous and Ongoing Work in Landbird Migration Monitoring

There are many historical and contemporary examples of migration research and monitoring, primarily including banding and counting efforts at bird observatories and research stations scattered across the United States and Canada. The first such station was probably Oliver Austin's at Cape Cod started about 1939. It and many others continued for varying periods and then blinked out. Notably among those were the stations of "Operation Recovery" (Baird et al. 1958), a program founded in the late 1950s whose goal was to band fall migrating birds at stations along the northeastern United States coast and recapture the individuals at stations to the south; recovery rates were very low, however.

The fall operation of the Allegheny Front Migration Observatory can be said to be the oldest continuous running landbird migration monitoring station in North America, beginning in 1957 by the Brooks Bird Club and George A. Hall. In 1960, the first of the more modern stations continuing today was Long Point Bird Observatory in Canada. This, and others since, were all modeled on the European tradition of bird observatories. That is, a central station with capture and banding being principal tools, a concentration on migration, and a substantial reliance upon volunteers. Long Point later expanded into Bird Studies Canada, and now into a model of a migration network, as it incorporates other stations. A year later, in 1961, Powdermill Nature Reserve began a bird observatory, in all but name, and established a still relatively rare tradition of year-round monitoring. In 1963 Point Reyes Bird Observatory was founded, and in 1968 it started its permanent offshore station on the Farallon Islands, the latter very much in the tradition of European observatories. Manomet Bird Observatory began in 1966. Point Reyes and Manomet have both felt it necessary to alter their names to reflect what they felt was their broader geographic or perhaps taxonomic mandates, but fortunately their bird monitoring operations continue to the present.

Early objectives of stations were banding recoveries, but by the late 1960s, investigators have found a multitude of data that can be derived from capture and release of birds (e.g., Ralph and Dunn 2004). Certainly, each individual monitoring site is invaluable for learning about the migratory patterns for a local area. The full potential of individual studies to contribute to population monitoring during migration, among other potential valuable contributions, is only reached when they are incorporated into a network (e.g., Dunn 1995). Successful examples of individual sites joining together for research and monitoring purposes in North America are many and include, for the breeding season, Monitoring Avian Productivity and Survivorship (DeSante et al. 2003), and several during migration, including HawkWatch International (http://www.hawkwatch.org), Hawk Migration Association of North

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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America (HMANA) (McCarty and Bildstein this volume), The Program for Regional and International Shorebird Monitoring (PRISM) (Bart et al. this volume), and Operation Recovery (Baird et al. 1958). Notable in Europe is the European-African Songbird Migration Network (Bairlein 1998), a large-scale collaborative effort aimed to work on many of the as-yet unanswered questions about migration.

Below, we consider the need for establishing a formal network for monitoring landbird migration in the United States.

Formation of Migration Monitoring Networks in North America

Momentum towards establishing one or more migration monitoring networks in North America has been present and building during the last several decades. In 1993, a workshop was hosted by the Canadian Wildlife Service and the United States Geological Survey-Biological Resources Division in order to consider the potential utility of migration monitoring as a population-monitoring tool (Blancher et al. 1994, Dunn 1995). Meeting participants made decisions and these resulted in documents, one of which (Hussell and Ralph 1998) has the recommendations for operation of migration monitoring stations. Following this lead, Bird Studies Canada developed the Canadian Migration Monitoring Network (CMMN), a network of approximately twenty individual migration monitoring stations now spread across southern Canada (Dunn 1995). The main goal of the CMMN is to monitor populations of bird species not well monitored during breeding or winter season surveys (Dunn 1995).

Since the formation of the CMMN, several formal discussions in the United States have occurred at national or regional meetings (e.g., at American Ornithologists' Union meetings in 1998 and 2001; at the Western Bird Banding Association meeting in 2001) in order to further formalize a network of U.S. stations similar to the CMMN.

Why Establish a Network in the United States?

There are several compelling reasons for establishing a formal network of migration monitoring stations in the United States. In this paper, we first consider why we need monitoring in the United States and then consider the need for a network. In detecting trends and demographic characteristics, no single method (e.g. Breeding Bird Survey, migration counts) is perfect for their detection (e.g., Dunn and Hussell 1995). It is wise to have two or more programs in place, both in the United States and Canada. A network in the United States could augment efforts by the CMMN, particularly by increasing sample size for less commonly observed migrants. Lastly, the CMMN is not monitoring these factors for all United States migrants, as many of 'our' species have breeding ranges that barely extend into Canada.

The cooperation of many stations in a network allows for increased sample size in population monitoring, particularly for regional and/or geographic comparisons. Participation in a network provides enhanced opportunities for collaborative research. One of the most attractive attributes of a network is the centralization of data storage and work involved in trend analysis, habitat relationships, and demography. A network also provides an opportunity for standardization of methods, as standardization among stations is critical. Lastly, a network can provide clear focus on particular questions (e.g., population trend monitoring or productivity), adding motivation for participants as well as enhancing funding opportunities.

As exemplified by the CMMN, monitoring regional and/or continental bird populations is most effective within a network. Forming an additional migration monitoring network in the United States will augment the CMMN in monitoring migrants that breed largely in Canada and Alaska (by increasing power of trend and other analyses). A United States network will also enable us to better monitor populations of migrants breeding predominantly in the continental United States.

We have become increasingly aware of the importance of stopover habitats (e.g., Moore et al. 1995), and how limiting the migratory period can be in the life history of migrants (Sillett and Holmes 2002). Thus, the opportunity exists for a migration monitoring network to contribute to identification and conservation of important stopover habitats in each region. In this light, broad-scale analyses of habitat use patterns, stopover ecology, and migratory connectivity (e.g., Hobson and Wassenaar 1997, Kelly et al. 2002) will all be much more feasible working within a network.

The goal of establishing a formal network of migration monitoring stations in the United States is well within our reach. Contemporary research networks, like the CMMN or the European-African Network, can serve as guides in our efforts. Bart and Ralph (this volume) discuss further statistical considerations in needs for network establishment. To this end, a joint effort involving the Klamath Bird Observatory, U.S. Forest Service, Cornell Laboratory of Ornithology, Idaho Bird Observatory, and many others is currently moving towards such a network. Over the past several years in

this effort, a continually updated register of migration monitoring stations in North America has been undertaken (http://www.fs.fed.us/psw/topics/wildlife/birdmon/pif/mnstalst.shtml) and expanded.

Acknowledgments

The authors thank all migration monitoring session participants for their contributions. Thanks also to E. Dunn for her valuable comments on an earlier version of this manuscript.

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Suggestions for Establishing a Network of Landbird Migration Monitoring Sites

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Abstract

Landbird migration monitoring stations, primarily using constant-effort mist netting and sometimes specialized censuses, are valuable because: (1) many of the species captured, especially northern-nesting ones, are not well surveyed by other methods; (2) demographic and other vital information for management and conservation can readily be collected; and (3) such stations provide excellent opportunities for education and outreach activities. Migration monitoring helps us describe and understand the causes of large-scale trends in population size or other parameters. In this paper, we suggest guidelines for choosing focal species for migration monitoring, accuracy targets for estimating trends in population size and fitness parameters, and present a simple model which clarifies the factors to consider in selecting migration monitoring sites and designing the monitoring programs at them.

Introduction

Many North American birds are not well surveyed by existing programs because they breed in the boreal or arctic region and winter south of the United States. Many other species are poorly covered because they breed in areas not covered by existing programs (e.g., high elevation areas), or because they are not easily detected or identified by existing surveys (e.g., parids, most woodpeckers). Monitoring programs for these species should involve regular surveys during migration, though specialized surveys on their breeding, and perhaps wintering, grounds should also be undertaken as often as is feasible. This report discusses design of long-term migration monitoring for landbirds using constant-effort mist netting and at times diurnal migrant counts, building on work by Hussell (1981), Ralph (1981), Fuller and Titus (1990), Blancher et al. (1994), Dunn and Hussell (1995), Hussell and Ralph (1998), and Ralph and Dunn (2004). The number of birds passing per unit time, or more commonly an index to this number, is usually collected, and other information such as demographic information on age- and sex-ratios, and "condition" information, such as weight, fat scores, stage of molt, and disease state, may also be collected. We discuss the goals, objectives, and methods for landbird migration monitoring and propose a strategy for statistically validating the establishment of a network of landbird monitoring sites that will be sustainable for the long term.

Goals

Migration monitoring mainly addresses problems at a large spatial scale, except for those involving local habitat use during stopover by migrants. Thus, many patterns observed at a given site are determined, in part, by events occurring hundreds or thousands of kilometers away. The management issues that a network of migration monitoring sites can help address are thus ones that occur at the regional to continental level. Five broad management issues of importance at this scale may be distinguished (*table 1*).

Table 1 also identifies the general information needed to address each issue using three categories: trend in population size, spatial patterns in abundance, and indicators of fitness, such as nutritional condition, parasite load, disease state, or contaminant burden. The first management issue, identifying species at risk, is a major concern for numerous agencies and other groups, and mainly requires information on trend in population size. Other information, such as an assessment of imminent threats, is also needed, but is not provided by migration monitoring stations. The next three management issues – understanding causes of undesirable trends, deciding how to reverse them, and evaluating impacts on birds of large scale projects – require information on fitness and, to a lesser extent, abundance. The final issue – identifying habitats important during migration – certainly has application on a site-specific scale, but its most important applications are on regional levels, such as defining critical habitat in a

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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bioregion. Other management issues could be identified, and they could be described in different ways. The scheme in *table 1*, however, is probably sufficient to identify the kinds of information, collectable at migration monitoring stations, which will be of greatest value in understanding and managing bird populations. In the sections below, we consider ways to estimate trend in population size and to measure indicators of fitness.

Objectives

Objectives are described in this section by identifying the focal species, defining the parameters to study, and then establishing an accuracy target for each, expressed in terms of needed statistical power to meet the accuracy target.

Estimating Trends in Population Size

Focal Species

While migration monitoring can be useful for all species, it is most important for northern species and populations, and for species breeding south of the boreal zone that are not well surveyed by the Breeding Bird Survey (BBS). Because many species breed in both northern and southern areas, a rule is needed to decide how much of a species' population can be outside the area covered by the monitoring program without causing serious bias in the trend estimate. An analysis of this issue (Bart et al. 2004), using range wide trends for well-surveyed, southern species, and then estimating the trends with partial data sets, led to the following guideline: if more than one-third of the species' range is not sampled by the BBS, or similar programs, then supplementary programs are needed. The shorebird initiative has investigated how to survey northern-nesting species (Skagen et al. 2004). They concluded that a combination of occasional surveys throughout the breeding range, along with annual surveys of migrating birds, provided the best chance for obtaining reliable trend estimates. Due to the similarly high cost of surveying landbirds in the boreal and arctic regions, and the comparatively low cost of migration surveys using mist-netting stations or census, we assume the same will be true of the species surveyed by landbird migration monitoring stations. An effort has been made by the Partners in Flight (PIF) Monitoring and Assessment Working Group to identify the species that: (1) have significant breeding populations (i.e., one-third or more of the population) in the boreal and arctic regions; (2) are not well covered by the BBS for other reasons; or (3) are well suited to study at migration monitoring stations. Their list includes 80 species, all but 8 with significant northern populations. This list will need review and revision by specialists in migration monitoring, but it provides an initial indication of the focal species for trend estimation.

Parameter Definition

For trend estimation, the best parameter is probably the rate of annual change, that is, the total change during a specified number of years, in total population size, defined as the total number of birds of a given species present in Canada or the United States during the breeding season in each year. This number includes non-territorial birds, which are often excluded in breeding studies for practical reasons, and excludes individuals that move north into the southern United States after breeding.

Accuracy Targets

For trend estimation, Bart et al. (2004) have suggested 80 percent power to detect a 50 percent decline over 20 years with a level of significance of 0.10, using a two-tailed test, and acknowledging effects of potential bias. They also recommend that this objective should be achieved in an area the size of the 11 western states, excluding California. These recommendations were based in part on study of Breeding Bird Survey data, and thus may not be fully applicable to migration studies, but the results were also based on consideration of how large a change is needed before conservation action occurs, relative costs of achieving higher or lower power, and estimates of feasible effort. We regard their recommended accuracy target as a default for the landbird migration monitoring program and suggest using it unless or until a better analysis appears, specifically focused on migration stations.

Table 1—*Management issues that migration monitoring can help address (XX-critical; X-important).*

	Information needed		
Management issue	**Trends**	**Abundance**	**Fitness**
1. Identifying species at risk	XX		
2. Understanding causes of declines or other trends of concern		X	XX
3. Deciding how to reverse undesirable population trends		X	XX
4. Estimating impacts on birds of proposed, large-scale projects		XX	XX
5. Identifying habitats important during migration		X	XX

Measuring Indicators of Fitness

Focal Species

Measuring fitness components by finding and tracking nests is expensive on the breeding grounds, but relatively inexpensive at migration monitoring stations, due to the large number of birds captured by mist nets. Thus, these measures can profitably be recorded for most species that are caught regularly – or that would be caught regularly with an improved network of stations. Thus all of the 80 species with northern populations, and most of the other roughly 350 landbirds in North America, should be considered potential focal species for the program to measure fitness indicators.

Parameter Definition

As noted above, several indicators of fitness can be assessed at migration monitoring stations, especially for birds that are captured (age ratios are obtainable for a few species even without capture). Five kinds of information that seem particularly worthwhile are (1) age ratios, (2) indicators of current nutritional status, (3) contaminant burden, (4) frequency of selected diseases, and (5) indicators of past habitat suitability (e.g., by ptilochronology or isotope analysis). A careful analysis is needed to decide which parameters would be most useful and most feasible to measure.

Accuracy Targets

Long-term information on fitness indicators is needed because management decisions must often be made too quickly to gather the needed long-term information, and because many processes affecting demographic rates are most easily understood by studying long-term datasets. Establishing an accuracy target is difficult because so many questions might be important to address. In the absence of a detailed analysis, we suggest 80 percent power to detect a 50 percent difference between two groups, or a 50 percent decline during 10 years, as reasonable initial targets.

Strategies

In this section, we discuss statistical factors to consider in selecting migration monitoring sites, and in designing the surveys at them for the purpose of understanding population trends. The other factors in survey design involved with the measures of fitness would require a far more complex analysis than we attempt here. As is usual in discussing error in statistical analysis we consider bias and precision separately.

Bias in trend estimates equals the long-term trend (if any) in the "index ratio." This ratio is the survey result (e.g., number of birds per unit effort), divided by the parameter of interest (total population size in our case) (Bart et al. 1998). To explain, suppose we define the survey result, in a given year, as the mean number, y, of birds recorded at one or more stations, and we define the entire species' population size as Y. The index ratio is thus y/Y, and we seek a design that minimizes the expected long-term trend in this quantity.

Now suppose that we multiply and divide the index ratio by a term, Y_1, arbitrarily defined (except that it cannot be 0). One useful way to define Y_1 is "the number of birds that pass through the surveyed area" where "surveyed area" may be defined in any convenient way, such as the borders of the monitoring stations or several stations in a bioregion. Adding this term, we obtain:

$$\frac{y}{Y} \quad \frac{Y_1}{Y}\frac{y}{Y_1} \qquad (1)$$

The term Y_1/Y may be thought of as the proportion of the birds of one species in the population that pass through at least one of the migration monitoring sites, say P. The term y/Y_1 may be thought of as the overall "capture" rate, C say, among all sites. We thus have

$$\frac{y}{Y} \quad PC \qquad (2)$$

so bias in the index, number of birds recorded, as an estimate of population trend, equals the long-term trend in PC.

Thus, in establishing a migration monitoring network, we seek a design such that the slope of $PC = 0$. That is, there is no change in the index ratio. It is possible that a long-term trend in P would just be balanced by an opposite trend in C, but the safest course is to design the program so that minimal long-term trends occur in both P and C. The "trend" in this case refers to the trend across all stations, so it is possible that trends at some sites (in either P or C) might be balanced by the opposite trends at other sites. The safest course, however, is probably to select each site, and design the program at it, to minimize trends in P and C at that site.

Trends in P can be minimized by selecting a site where either habitat is unlikely to change (a difficult condition to achieve), where habitat is maintained by management at a given stage of succession, or where habitat has little influence on the number (strictly, the proportion) of birds passing through the site. Strong trends in P are also made less likely by having lots of sites, well distributed across habitats, elevations, and other features that might be correlated with numbers of passage migrants. Then, if a change in migration routes occurs, numbers will decline at some monitoring sites,

but will increase at others, so the change in *P*, for the whole network, may be small. Long-term trends in *C* are also minimized by selecting sites where habitat is not likely to change or does not influence numbers of birds or behavior (such as residence time) that affects capture probabilities. If habitat change cannot be avoided, then, ideally, different successional stages should be present at each site and at different sites, or both, so that change in *C* through time, for the entire network, will be small.

The precision of the trend estimate depends mainly on how similar trends are at different sites (with trends weighted, approximately, by numbers of birds at each site). Such variation can be reduced by locating migration sites where they catch birds from as large an area as possible, and by reducing sampling error within sites, which is accomplished mainly by training, standardization, and having a good sampling plan.

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Suggestions for Planning a Migration-Monitoring Network Based on the Experience of Establishing and Operating the MAPS Program[1]

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Abstract

Based on the experience of creating and implementing the Monitoring Avian Productivity and Survivorship (MAPS) program, I suggest that, to be successful, a migration-monitoring network must: (1) provide strong justification for the data it proposes to collect; (2) provide direct links between those monitoring data and both research and management goals; (3) provide critical information useful at both small (local) and large (regional) spatial scales; (4) utilize standardized protocols for all aspects of data collection; (5) provide electronic data verification programs to be used by cooperators; (6) utilize state-of-the-art analytical models for making inferences; (7) have a central repository for all data and an organization responsible for timely analysis of data and publication of results; (8) provide frequent and substantive feedback and results to its cooperators; (9) undergo peer review after an appropriate pilot period; and (10) adequately budget for program development, data management and analysis, publication of results, and outreach. I discuss how MAPS has achieved, or attempted to achieve, each of these suggested requirements.

Discussion

Considerable discussion has occurred recently regarding the establishment of a continent-wide network of migration-monitoring stations. The purpose of this paper is to suggest and discuss ten requirements that I believe are crucial for the successful establishment of such a network. These suggestions are based upon 14 years of experience with the establishment and operation of the MAPS (Monitoring Avian Productivity and Survivorship) Program. For each of these requirements, I discuss how the MAPS Program fulfilled, or attempted to fulfill, the requirement.

Requirement 1: Provide a clear definition of the program and its monitoring goals, and a strong justification for the data the network proposes to collect. The MAPS (Monitoring Avian Productivity and Survivorship) Program is a cooperative effort among public agencies, private organizations, and individual bird banders to operate a continent-wide network of over 500 constant-effort mist netting and bird banding stations (DeSante 1992, DeSante and O'Grady 2000). At each station, the program utilizes a standardized netting and habitat-assessment protocol during the breeding season (May-August). The program also utilizes standardized analytical procedures, including modified Cormack-Jolly-Seber mark-recapture models. The specific monitoring objectives of MAPS are to provide, for a suite of target species at multiple spatial scales: (1) annual indices of adult population size and post-fledging productivity (from analyses of data on the numbers of adult and young birds captured), and (2) annual estimates of adult population size, apparent adult survival rate, proportion of residents in the adult population, recruitment into the adult population, and population growth rate (from modified Cormack-Jolly-Seber analyses of mark-recapture data) (DeSante et al. 1995). The justification for monitoring (and basing management on) vital rates (primary demographic parameters) is that: (1) environmental stressors and management actions affect vital rates directly and usually without time lags (Temple and Wiens 1989, DeSante and George 1994); and (2) monitoring vital rates provides crucial information about the stage(s) of the life cycle at which population change is effected, critical information about the health and viability of populations, a clear index of habitat quality, and useful information on source-sink dynamics (Van Horne 1983, Pulliam 1988, DeSante 1995, DeSante and Rosenberg 1998, DeSante et al. this volume).

An often-cited justification for a migration-monitoring network is that population trends of landbird species breeding across boreal Canada and Alaska and wintering south of the United States are not being monitored by either the North American Breeding Bird Survey (because there are too few roads and observers through the vast area of the boreal forests) or the Christmas Bird Count (because there are very few count circles south of the United States) (Blancher et al. 1994, Dunn and Hussell 1995, Francis and Hussell 1998). While this may be sufficient justification for the establishment of a network of migration-monitoring stations across southern Canada, it provides only weak justification for

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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stations throughout the United States. I suggest that additional justification is needed for a network of migration-monitoring stations in the United States, and that the appropriate justification should involve efforts to determine habitat characteristics that provide high quality stopover habitat for migratory landbirds, especially declining species. If the major goal of a continent-wide network of migration-monitoring stations becomes assessing the quality of stopover habitat rather than monitoring population trends, the character of the program would change with regard to both station location and station longevity. The most suitable station locations for long-term trend monitoring of migrating birds are locations from which birds are likely to move on as quickly as possible (i.e. locations that are not especially attractive for stopover such as an island or sparse, coastal habitat), because current methods for trend analysis assume that each day's count is an independent sample of the population (Dunn and Hussell 1995). By contrast, if the monitoring questions involve interest in stopover ecology and suitability of habitat for migrants, then stations that have overall large populations of birds would be preferable (Ralph et al. 2004).

Aspects of stopover ecology that could be useful for assessing habitat quality of a stopover site might include total numbers and species diversity of birds using the site, proportion of birds using the site that are adults, mean length of stopover at the site, and rate of mass gain or loss at the site. These could be coupled with site-specific and local landscape-level habitat characteristics in an effort to identify habitat characteristics associated with high quality stopover sites. Certainly each station in a network aimed at assessing the quality of stopover habitat would need to be operated for some minimum number of years, because stopover-habitat quality will likely vary somewhat as a function of weather conditions. However, in such a scenario, each station would not necessarily need to be maintained indefinitely into the future, as they would in a program aimed solely at the long-term monitoring of population trends.

Requirement 2: Provide direct links between the monitoring data and both research and management goals. The specific research objectives of MAPS are to identify and describe, for a suite of target species at multiple spatial scales: (1) temporal and spatial patterns in demographic indices and estimates (DeSante 2000); and (2) relationships between these temporal and spatial patterns and ecological characteristics of the target species (DeSante 2000), population trends of the target species (DeSante et al. 1999), station-specific and landscape-level habitat characteristics (Nott 2000, 2002), and spatially-explicit weather data (Nott 2002, Nott et al. 2002a). The specific management objectives of MAPS are, for the suite of target species at the appropriate spatial scales, to use these temporal and spatial patterns and relationships to: (1) determine the proximate demographic cause(s) of population change (DeSante et al. 2001); (2) formulate station-specific and landscape-level management strategies to reverse population declines and maintain stable or increasing populations (Nott 2000); and (3) evaluate the effectiveness of the management strategies implemented in an adaptive management context.

I suggest that it is critical that the data from a migration-monitoring network be suitable for addressing important research questions and be able to be linked directly to potential avian management efforts. This latter requirement may be especially difficult to achieve for data from a migration-monitoring network, because the origins and destinations of birds captured at such stations are generally unknown, thus creating formidable problems as to exactly where any management efforts should be implemented. Linkages between monitoring and management, however, would be easier to establish if the program were focused more on questions of stopover habitat quality. Indeed, it is possible that destruction or degradation of stopover habitat is a major cause of population decline in some migratory species. In such cases, programs aimed at monitoring population trends on either the breeding grounds (such as the BBS) or wintering grounds (such as the CBC) suffer from the analogous problem of determining where along the migration pathway management efforts should be implemented.

Requirement 3: Provide critical information useful at both small (local) and large (regional) spatial scales. MAPS provides useful information at each of the following five major spatial scales: (1) the range-wide scale, which can vary from the entire continent for widely distributed species (i.e., all of continental United States and Canada), through major portions of the continent (e.g., United States and southern Canada east of the Great Plains for many eastern species), to a small portion of the continent for species with restricted ranges (e.g., Wrentit, Golden-cheeked Warbler, etc.); (2) the regional scale, which also can vary from the size of a MAPS Region (e.g., the Northwestern or Southeastern regions), through large NABCI Bird Conservation Regions (e.g., the Great Basin), to small physiographic strata (e.g., the Sierra Nevada); (3) the local management unit scale, which can encompass an individual national forest, national park, or military installation, and which can also vary substantially in size; (4) the local landscape scale, which can, for example, be a 2- to 10-km-radius area surrounding an individual MAPS stations; and (5) the scale of the individual MAPS station, which is typically the 20-ha area within which nets are operated. MAPS provides information at each of these spatial scales by pooling data from stations over successively larger areas.

For monitoring population trends of migrating populations, it is generally agreed that sampling should be conducted daily, or near daily (at least 75 percent of the days during the period when the middle 95 percent of the individuals normally occur), in order to allow modeling of the effects of weather and date on numbers of migrants present (Hussell et al. 1992, Ralph et al. 2004). Daily or near-daily coverage will also improve the precision of trends, decrease the number of years to establish weather and date effects, and decrease the number of years before a trend can be detected (Dunn et al. 1997, Thomas et al. 2004). Because the effort necessary to obtain meaningful results from a migration-monitoring station will, therefore, be much greater than the effort needed to run a MAPS station (which is operated only once in each of 6-10 consecutive 10-day periods), a migration-monitoring network will likely contain many fewer stations than the existing MAPS network. Nevertheless, it will be important that a migration-monitoring program be organized in a manner that data from stations can be pooled to provide information at several spatial scales, and that sufficient data be available from each area of interest at each scale.

Requirement 4: Utilize standardized protocols for all aspects of data collection. A summary of the standardized MAPS protocol is as follows. About ten 4-tier, 12-m-long mist nets are erected at fixed locations within the central eight ha of the 20-ha study area (MAPS station). These nets are operated for six morning hours per day beginning at local sunrise, for one day per 10-day period, and for six to ten consecutive 10-day periods (depending on latitude) beginning between May 1-10 (at low latitudes) and June 10-19 (at high latitudes) and continuing through July 30-August 8 (at all stations). All birds captured are identified to species, age, and (if possible) sex, and all unmarked birds are marked with a uniquely numbered U.S. Geological Survey/Biological Resources Division (USGS/BRD) leg band. The net-opening and -closing times and net-run times are recorded to the nearest ten minutes. The breeding status for all species present at the station (including those that were never captured) is determined each year from data collected during each day of station operation (these data are similar to those collected by breeding bird atlas projects). A detailed habitat map of the station is prepared, and the structure and pattern of each habitat present is assessed during the first year or two of station operation and then once every five years (or sooner if major habitat changes occur). All of these data are recorded on standardized MAPS data forms which are available from the Institute of Bird Populations (IBP) website, using standardized codes. Detailed instructions for the establishment and operation of MAPS stations are provided by the *MAPS Manual* (DeSante et al. 2003) while detailed instructions for assessing the habitat are provided by the *MAPS Habitat Structure Assessment (HSA) Protocol* (Nott et al. 2002b), both of which are also available on the IBP website.

It should be noted that the present MAPS protocol and the exact layout of the data sheets and wording in the MAPS Manual is the result of improvements that were made during and after the first three years (1989-1991) of the program, which amounted to an IBP-sponsored feasibility study, and the four-year (1992-1995) pilot project and evaluation of the program which was concluded in 1996. For example, the MAPS season initially extended for 12 10-day periods through August 28. However, we found that substantial numbers of birds captured during the last two periods (August 9-28) carried moderate fat deposits indicating that they likely did not breed or were not produced within the landscape surrounding the station. Thus, we revised the program in 1997 to exclude operation after Period 10 (July 30-August 8).

Some analogous modifications to a developing migration-monitoring program should be expected, although it is likely that they will be fewer than what was experienced by MAPS, because the current state-of-the-art regarding migration monitoring is relatively much better developed than was the state-of-the-art regarding breeding season monitoring of productivity and survival when MAPS was first developed in 1989. While a number of different techniques, ranging from mist netting and diurnal visual counts to nocturnal call counts, will likely be employed in migration monitoring, and different stations might employ different suites of these techniques, it will still be important that each technique be standardized and fully described in standardized and readily accessible written manuals.

Requirement 5: Provide electronic data verification programs to be used by contributors. In order to assure the highest quality information, all MAPS data are subjected to rigorous within- and between-record computerized data verification procedures. Within-record procedures check the codes and ranges of all data entered, including banding, effort, breeding status, and HSA data; and compare species, age, and sex determinations to supplementary data on skull pneumatization, breeding condition, extent of molt and molt limits, feather wear, and wing chord. Between-record procedures compare date, time, station, and net of capture on banding data sheets with analogous information on summary of effort sheets; and compare all records for a given band number for discrepancies in species, age, and sex determinations. All discrepancies or suspect data are examined and, if necessary, corrected. These verification procedures are codified into MAPSPROG, an electronic data input/import, verification/editing computer program that allows MAPS co-

operators to verify and submit their MAPS banding, effort, breeding status, and habitat data. The MAPSPROG Program (currently Version 3.7.2; Ruhlen and Michel 2003) and the MAPSPROG User's Guide and Manual (Froehlich et al. 2003) are also available on the IBP website.

To be successful, I suggest that a migration-monitoring network will also need to provide electronic programs that will allow cooperators to enter, verify, and edit their own data before they submit those data to the coordinator. For trend monitoring, this might not be quite so important, but if age ratios are desired then internal consistency of each record must be checked to ascertain that the birds are appropriately aged. The appropriate state-of-the-art models for length of stay and stopover ecology now involve mark-recapture analysis (Kaiser 1995, 1999), for which between record verification is essential.

Requirement 6: Utilize state-of-the-art analytical models for making inferences. The MAPS Program employs a number of standardized analytical models and techniques for analyzing MAPS data. For example, MAPS utilizes logistic regression models to make inferences regarding spatial and temporal differences in productivity indices for a given species. In addition, we recently developed and tested a technique that corrects capture rates of both adult and young birds to account for missed effort (Nott and DeSante 2002a). This technique, which is a modification of work by Peach et al. (1998), obviates both the need for eliminating data to perform constant-effort between-year comparisons of indices of adult population size and productivity, and the need to use chain indices to make inferences regarding trends in adult population size and productivity. MAPS uses modified Cormack-Jolly-Seber mark-recapture models (Pollock et al. 1990, Lebreton et al. 1992) to estimate annual adult survival rates. These models are implemented through the computer programs SURVIV (White 1983) and MARK (White and Burnham 1999). We employ both a within- and between-year transient model to provide survival-rate estimates that are unbiased by the presence of transient individuals in the data and to estimate the proportion of residents among newly captured adults (Pradel et al. 1997, Nott and DeSante 2002b). Akaike's Information Criterion ($QAIC_C$, adjusted for small sample sizes and overdispersion of data) is used for model selection for both logistic regression models of productivity and mark-recapture models of survival (Burnham and Anderson 1998). The relative likelihood of each model in an *a priori* set of candidate models is estimated with $QAIC_C$ weights (w_i; Burnham and Anderson 1998). A model averaging procedure, that is based on the w_i values for each model and that includes model selection uncertainty, is used to provide the best estimates for parameters of interest (Burnham and Anderson 1998). This method of multi-model inference permits use of the entire set of candidate models to make inferences regarding the importance of a variable to a parameter estimate, rather than basing conclusions solely on the single best-fit model.

It will be important that analyses of data from a migration-monitoring network also be performed using standardized state-of-the-art analytical models and model selection methods. As mentioned above, state-of-the-art analyses of stopover ecology necessitate the use of modified Cormack-Jolly-Seber mark-recapture models (Kaiser 1995, 1999).

Requirement 7: Establish a central repository for all data and an organization responsible for timely analysis of data and publication of results. The Institute for Bird Populations serves as the coordinator and central data repository for MAPS data. At the beginning of each season, IBP provides copies of the standardized MAPS protocol and data forms to all new cooperators, and requests that established cooperators download copies of the current forms from IBP's web-site. MAPS cooperators are asked to provide computer entry, verification, and editing of their MAPS data prior to submitting them to IBP. IBP then provides management and archiving of all MAPS data and fills requests for these data from valid users. IBP also provides computer entry, verification, and editing of MAPS data from cooperators who are unable to submit data through MAPSPROG. Finally, IBP provides analyses of data and reports, appropriate collaboration with other researchers, and dissemination of results from the Program. Backup copies of all MAPS data, along with all appropriate metadata, have also been provided to the Biological Resources Division (BRD) of the U.S. Geological Survey.

It will be vitally important that a central repository be established for migration-monitoring data and that some agency or organization be responsible for 1) filling requests for the use of the data, 2) providing timely analyses of the data, and 3) publishing and disseminating the results.

Requirement 8: Provide frequent and substantive feedback and results to its cooperators. Peer-reviewed annual reports from the MAPS Program are published biennially in *Bird Populations*, a journal of global avian demography and biogeography. IBP has also recently become a partner with USGS/BRD in the National Biological Information Infrastructure (NBII) and has made the annual reports of the MAPS Program available on-line through the NBII/MAPS web-based query interface for MAPS data (IBP 2003). This avian demographics query interface provides regional, between-year changes in adult population size and productivity indices and regional annual estimates of adult

apparent survival rates from mark-recapture analyses of MAPS data. For each of the 718 MAPS stations operated for at least one year through 2000, the query interface provides the geographic location, history of operation, a brief habitat description, USGS-NPS National Vegetation Classification Standard (NVCS; http://biology.usgs.gov/npsveg/nvcs.html) classifications of the dominant and subdominant habitat types to formation level, and the composite breeding status of all species captured, seen, or heard at the station. IBP also provides an annual newsletter, *MAPS Chat*, to all MAPS cooperators and other interested parties. Finally, during the 12 years between 1991 and 2002, IBP produced 27 peer-reviewed papers; 22 manuals, handbooks, and non-peer-reviewed position papers; and 109 technical (mostly annual) reports to federal and state agencies and non-governmental organizations dealing with results of the MAPS Program.

A successful migration-monitoring program must also strive to produce frequent and substantive feedback to its cooperators and timely publications of its results.

Requirement 9: Undergo peer review after an appropriate pilot period. The MAPS Program underwent a peer-reviewed evaluation after completing a four-year (1992-1995) pilot project. The evaluation was undertaken in three parts. First, a general evaluation of the MAPS Program was conducted by DeSante (1997), who (1) examined growth and continuity of the program, distribution of stations, and verification and accuracy of age determinations; (2) compared MAPS and BBS data for between-year changes in indices of adult population size; (3) compared patterns of reproductive success from MAPS productivity indices for various nest-location and migration-strategy classes with analogous patterns from nest-monitoring data and life history theory (DeSante 2000); and (4) compared predicted population changes modeled from MAPS productivity indices and adult survival-rate estimates against observed population changes from BBS and MAPS data at two spatial scales (DeSante et al. 1999, 2001). Second, an evaluation of the statistical properties of the MAPS Program was conducted by Rosenberg (1997), who (1) evaluated the ability to detect spatial differences in productivity at various spatial scales; (2) evaluated the statistical power to detect spatially heterogeneous survival rates and exponentially declining survival rates among various spatial scales (Rosenberg et al. 1999, 2000); and (3) examined the relative bias in survival rate estimates caused by pooling simulated populations with heterogeneous survival rates (Rosenberg et al. 2000). Finally, a peer-review of the MAPS Program and its evaluations (DeSante 1997, Rosenberg 1997) was completed by a panel convened by USGS/BRD at the Patuxent Wildlife Research Center (Geissler 1997).

I suggest that a similar four-year pilot program be established for a migration-monitoring network and that a similar evaluation and peer review be conducted at the end of the pilot period. Such a length of time will allow mark-recapture models to be employed to estimate stopover times and make inferences regarding the stopover ecology of various stations.

Requirement 10: Adequately budget for data management and analysis, publication of results, program development, and outreach. Perhaps the most difficult aspect of creating a migration-monitoring network will be securing funding to keep the network operating over the long term. I suggest that the key to success lies in achieving the ability to provide timely results and frequent and substantive feedback to its cooperators. I further suggest that this ability can only be achieved by budgeting and securing sufficient funding, beginning with the very first year of operation or even earlier, to provide for adequate program development, for data management and analysis, and for the production, publication, and dissemination of results. A rule of thumb might be that 1/3 of the total cost of a monitoring program should be dedicated to these critical data analysis and publication efforts. Moreover, all of the actual field costs of all of the cooperating stations must be included in the total cost of the program. Thus, for example, if the annual cost of operating a single station in the migration-monitoring network would average $5,000 (this assumes that much of the field work is provided by volunteers) and the network would consist of 80 stations (total field cost of $400,000), efforts should be made to secure $200,000 per year for program maintenance and development, data verification, management, and analysis, publication of results, and outreach. Some of these latter funds would be secured and expended by the individual stations (for data entry and verification, for example), but much of these funds would need to be secured and expended by the organization responsible for coordinating the program.

It may be tempting to try to establish and operate a long-term, large-scale monitoring program with less funding, but experience with MAPS suggests that long-term success will be greatly aided if these more aggressive funding goals are articulated up-front and are rigorously pursued. Let me also add that the continued long-term generation of such levels of funding is a very difficult task that cannot be taken lightly.

Acknowledgments

I thank J. D. Carlisle for suggesting the subject matter of this paper. I thank the many federal agencies and state and private sources that have provided funding to the MAPS Program, especially, the USDA Forest Ser-

vice, the USDI National Park Service, Fish and Wildlife Service, National Fish and Wildlife Foundation, and USGS Biological Resources Division, and the USDoD Legacy Resources Management Program, Department of the Navy, and Department of the Army. I especially thank all of the over 500 MAPS cooperators and their volunteers for their generous contributions of data to the MAPS Program. I also thank J. D. Carlisle, R. B. Siegel, and P. Pyle for many comments on an earlier draft of this manuscript. This is Contribution No. 206 of The Institute for Bird Populations.

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Counting Migrants to Monitor Bird Populations: State of the Art[1]

Erica H. Dunn[2]

Introduction

The aim of this paper is to summarize background information on what migration monitoring is, what biases are present and how they can be addressed, evidence that resulting trends are biologically meaningful, and what the benefits and limitations of the method are. Some topics have been covered elsewhere in greater detail (Dunn and Hussell 1995, Dunn et al. 1997, Francis and Hussell 1998). However, an overview provides a useful introduction to this session, and here I discuss potential biases more fully than elsewhere.

For the purposes of this presentation, 'migration monitoring' refers to intensive (near daily) counting of migrants at specific sites, with the aim of tracking population change over time. Each daily count is a sample of the birds resting in, or passing through or over the specified count area within a 24-hr period. Counts can consist of many sample types, such as number of birds crossing the face of the moon, registrations on a radar screen, number of migrants recorded giving flight calls as they pass overhead, number of birds counted in diurnal migration or stopover, or number of resting birds captured in mist nets, to name a few. Here I concentrate on the latter two types; specifically, hawk watches and counts of nocturnal songbird migrants during stopover.

In total, there are more than 150 North American landbird species for which migration counts are potentially as good as, or better than, other sources of data currently available for trend analysis (Hussell 1997, Dunn unpubl. data). These include raptors (which are often too sparsely distributed and secretive to be well sampled by the Breeding Bird Survey), long-distance migrants which breed in the boreal forest and winter in the neotropics (escaping coverage both by Breeding Bird Surveys [BBS] and Christmas Bird Counts), and short-distance migrants that breed in arctic and boreal zones and winter in the US.

Sources of Variation in Migration Counts

Migration counts have been criticized as reflecting variation resulting from weather and other factors unrelated to population change, which could render trends unreliable. In order to answer this criticism, it is necessary to review the sources of variation in migration counts, and the ways in which they can be addressed.

The schematic in *figure 1* indicates the sources of variation in daily counts. The 'monitored population' is the portion of the population contributing migrants to the flow of birds potentially countable at the monitoring site. Birds do not all pass in one day, of course, but rather come in pulses. The 'migrating population' (large chevron) represents the number of birds passing through or over the count site in a 24-hr period. The size and seasonal distribution of these pulses will vary with weather factors and lag effects (such as depletion in numbers due to high proportions of birds already having passed). Nonetheless, the total of all birds in all migrating populations over a given season should add up to the 'monitored population.' As long as migrating populations are well-sampled, seasonal variation in the frequency of migration pulses should not cause variation in annual indices derived from migration counts.

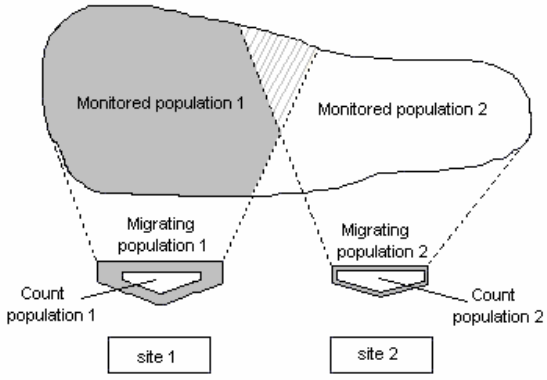

Figure 1— Schematic diagram of migration, indicating stages at which variability can affect daily bird counts (see text). (Redrawn from Dunn and Hussell 1995).

Of course, not all birds in a migrating population can be counted. Most observers counting diurnal migrants observe during a limited time period each day, and many birds will pass through before or after that

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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period. In the case of nocturnal migrants, not all of the birds passing over during the night will actually stop to spend the day at the monitoring site. The 'count population' in *figure 1* (inner chevron) represents the number of birds in the migrating population that are present during the count period and therefore 'available' to be included in the count. At some sites the count population may represent a very high proportion of the migrating population (as illustrated for site 2 in *figure 1*); for example, when diurnal migrants must pass through a narrow funnel due to local geography. Under average conditions, however, the count population may often represent a relatively small proportion of the migrating population.

Ideally, the count population would always represent a constant proportion of the migrating population. This is certain *not* to be true, however, due primarily to variable weather conditions, but also to other factors. For example, migrants running into poor weather may land *en masse* at a site, when they might otherwise have continued migrating. These 'fall-outs' represent a count population that is a much higher proportion of a given night's migrating population than would normally be the case. Weather will also affect the proportionate size of the count population in more subtle ways. If winds are blowing in a particular direction, for example, a higher proportion of diurnally-migrating birds may be moved towards the observation post, where a greater number can be seen and identified than usual. Analyses can model the effects of weather and to some degree adjust for them (see next section).

Finally, not every bird in the count population will be detected and included in the daily migration sample. If the daily tally consists of netting totals, for example, many individuals that are present (i.e., part of the count population) will nonetheless escape becoming part of the actual sample. If visibility is poor at a hawk watch, a smaller proportion of the count population will be detected than when it is clear; and if leaves have emerged, fewer nocturnal migrants may be recorded in visual counts during their stopover than on days prior to leaf-out. Again, inclusion of weather and date factors in analyses can help reduce the effects of such variation.

Variation in daily effort will also cause variation in the proportion of the count population that is tallied, and it is for this reason that it is important to standardize daily count protocol to the extent possible. Visual counts should be taken over a standardized count period (taking place at the same time each day), mist-netting should be done with standardized effort, nets should be of the same type and be put in the same location from day-to-day and year-to-year, etc. (See Hussell and Ralph 1998 for detailed recommendations on operating procedures).

Habitat type and structure affects the numbers and kinds of birds present at a stopover site, and using standardized count locations is important for ensuring that sampling is the same each day. However, change in habitat over time will alter the proportions of birds present that are tallied in daily counts. For example, fewer birds may be visible, or captured in mist nets, as vegetation grows taller. *Habitat change is the most serious potential bias for trend monitoring using migration counts.* Whenever possible, sites should be selected where vegetation is unlikely to change over time (e.g., riparian shrub that is maintained by regular flooding). Habitat management plans should be developed and strictly adhered to (Hussell and Ralph 1998). Pooling data from several nearby stations (close enough to certainly be sampling the same 'monitored population,' as defined for *figure 1*) may help modulate effects of habitat change at individual sites.

Landscape-level habitat change could also alter the number of birds tallied at a stopover site, independently of population change. For example, birds in a landscape full of suitable stopover habitat will spread throughout the area, but if the landscape is cleared of all but a single grove of trees, then the number of birds in the isolated habitat patch will increase even if population size has not changed. Trends based on data from coastal sites, islands or oases, where birds tend to land regardless of habitat, should be less affected by changing landscapes. At other sites, landscape-scale changes can only be taken into account when interpreting the meaning of trends on a site-by-site basis. If there are multiple sites sampling the same population but experiencing different degrees of landscape change, these effects could potentially be modeled in pooled analysis. Detecting changes in migrants' use of a particular stopover site because of habitat change (separate from changes in population size) is, of course, a valid study objective in itself, but will require careful survey design in order to allow teasing apart of the causal factors.

Habitat change has much less effect on counts of diurnal migrants such as hawks. Numbers seen should be little affected by condition of habitat on the ground, as long as vegetation growth does not alter the observers' field of view over time.

Detecting the Population Size Signal

Migration count data are highly skewed (a few high daily counts in a season, and many low ones). *Figure 2* illustrates the kind of patterns that can typically occur. In year 1, daily counts were close to the long-term average, but several days were missed at the peak of the season when counts would normally be high. Counts in year 2 were more variable, and there was a

fall-out early in the season that led to one extremely high count. Despite the high daily variation in counts, and the very high count during year 2, it is obvious from the figure that *in general*, the daily counts in year 1 were higher than in year 2.

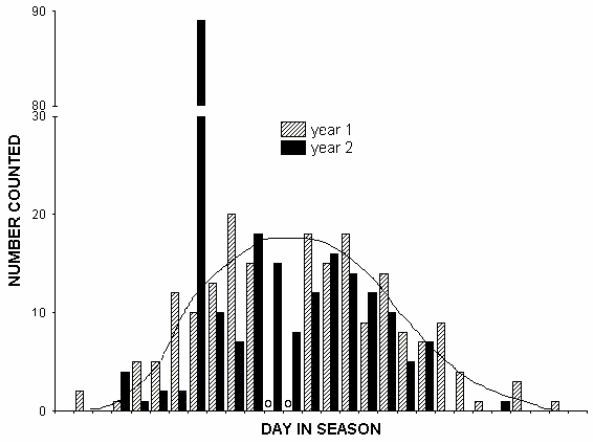

Figure 2— Hypothetical daily migration counts in each of two years, adapted from real data. Curved line shows long-term average count; "0" indicates days in year 1 when no data were collected.

The trend analysis method commonly used for migration counts (Dunn et al. 1997, Francis and Hussell 1998) is based on the assumption that each day's count is an independent sample of the monitored population, and that the difference in mean log daily counts among years is the best signal that population size has changed between years. Weather effects may obscure the population size signal on some days (e.g., the fall-out day in year 2; *fig. 2*), but is unlikely to do so across the entire season. Because each day's count is given equal weight for the season, it does not matter if a few days are missed, even at the height of migration. However, if daily counts contain many residents and lingering birds counted on previous days, the assumption that each day's count is an independent sample of the population is violated. (See Hussell and Ralph [1998] for further discussion and ways to minimize repeat counts. The analysis method described below is not suited to species such as shorebirds which typically remain at a given stopover site for several days or weeks.)

Because the analysis method assumes independence of daily samples, good migration monitoring sites for nocturnal migrants are, somewhat paradoxically, the sites where birds least want to be, such as sites with poor stopover habitat where birds stop only because there are few alternatives (e.g., islands, coastlines). Birds leave as soon as possible, such that daily turnover is essentially complete. Many people assume that such sites are unsuited to migration counting, because daily number of birds present is often highly variable as a result of weather conditions. However, the assumptions of the analysis are most likely to be met at such a site, and weather-related variability can be reduced through analysis.

Analyses can model the variation in daily counts that is caused by environmental variables unrelated to population size (see details in Dunn et al. (1997) and Francis and Hussell 1998). In brief, a multivariate analysis is run in which the dependent variable is the log-transformed daily count (log transformed to reduce skew and to allow use of parametric statistics). Independent variables (including higher-order terms where necessary to model non-linear effects) describe date, moon phase (in analyses for nocturnal migrants, since moon phase has been shown to influence their numbers on stopover), and weather conditions (wind speed and direction, temperature, visibility, etc.). Finally, a dummy variable is entered for each year. In effect, the analysis determines whether a particular day's count is higher or lower than expected for the date of the count, given the weather and moon phase conditions under which the count was taken (e.g., higher or lower than expected for that date given temperatures above normal and winds from the southeast). The coefficient estimated by the analysis for a given year variable represents the mean daily count of birds expected in that year, under average conditions of weather, date and moon phase. Note that, for the model to work well, there must be a large collection of daily samples of the number of birds expected under different conditions (near daily samples over 5-10 years) before appropriate adjustments can first be estimated. (Thereafter, however, additional years can be immediately compared with earlier years.) Results of analyses have been shown to reduce the variance of annual indices by as much as 5-fold over unadjusted annual indices (Hussell 1985).

Analyses that model date effects (omitting weather) are easy to do, and will give results that are more accurate and precise than simply summing all daily counts for use as an annual index. Step-by-step instructions for conducting such analyses using standard statistical software can be obtained from the author, either for nocturnal passerines (daily counts) or for diurnal raptors (hourly counts).

If sites are close enough together that it is certain they are sampling the same 'monitored population' (see text describing *figure 1*), then data can be pooled for common analysis as in Francis and Hussell (1998), who effectively weighted each site according to magnitude of daily counts. The population signal is assumed to be the same at each site, so the weighting method should not affect the result. However, if stations are far enough apart that they may be sampling different populations, which could be changing in different ways, then data should only be combined if the relative

size of the sampled populations is known, so that each site can be given appropriate weighting. Unfortunately, precise population origin of migrating birds is almost never known. The magnitude of counts at each site is no guide to the size of the population being sampled (see text describing *figure 1*, in which site 2 has the higher count population but a smaller monitored population), so should not be used as a weighting factor when sampled populations are not identical. Currently, therefore, we can only detect regional patterns of population change from migration counts by looking for regional similarities in the separate results from each station. An important corollary is that each migration station is free to choose count methods best suited to conditions at the site, because magnitude of counts (which is affected by count method) will not be a factor in comparing trends among locations.

Evaluation of Migration Count Trends

Comparisons of ground counts and birds flying over (as assessed by radar, infrared and other detection methods) indicates weak to moderate correspondence between numbers of birds migrating and those on the ground on a night-to-night basis, but a more general correspondence over the course of a season (Williams et al. 2001, Zehnder et al. 2001), as suggested by discussion of *figure 1*. No such comparison has been made using ground counts adjusted for weather.

There is accumulating evidence that weather-adjusted migration counts produce population trends which correlate significantly with independent trends from the Breeding Bird Survey, although with maximum r^2 values of about 0.65, and correspond well in range of trend magnitudes (Hussell and Brown 1992, Hussell et al. 1992, Pyle et al. 1994, Dunn and Hussell 1995, Dunn et al. 1997, Francis and Hussell 1998). Strength of the relationships has been shown to depend on the degree to which the BBS trends represent the same population being sampled by the migration count (Hussell 1997, Francis and Hussell 1998). Migration counts sample birds from a broad geographic range (e.g., southern Ontario stations may sample birds from Alaska as well as from northern Ontario and western Quebec; Brewer et al. 2000), so migration count trends at certain sites may integrate data from portions of the range where populations could well be following separate trajectories. More comparative evaluation of migration count trends is needed, particularly for stations known to sample migrants *only* from a well-defined region that is also well-covered by BBS. Good candidates include sites in the southeastern United States which sample Neotropical migrants that breed only within the eastern United States.

Strengths and Limitations of Migration Counts for Population Monitoring

Overall, intensive, site-specific migration counts have the following strengths:

- For many North American species, migration counts offer the best (sometimes the only) source of information on population change, and for other species, migration counts can help confirm trends from independent monitoring programs.
- Migration counts sample birds from broad areas of breeding (e.g., Wassenaar and Hobson 2001), such that a trend from a single site represents conditions on a large portion of the breeding range.
- All individuals are sampled (juveniles and non-breeders as well as breeders), avoiding certain biases in surveys that primarily record singing birds.
- For certain migration counts (particularly diurnally-migrating raptors), habitat change at the count site should have little effect on results.

Limitations of migration counts for population monitoring purposes include the following:

- Daily counts are affected by weather, which requires sophisticated analysis to address. This is beyond the capabilities of many station operators, so analysis capabilities probably have to be developed on their behalf (e.g., centrally, as in the Canadian Migration Monitoring Network; see http://www.bsc-eoc.org/national/cmmn.html). Multivariate analysis methods have only recently been developed, and more work should be done to ensure that the most appropriate adjustments are being made.
- In most cases, the breeding and wintering locations of migrants counted at a particular site are unknown, such that further research or conservation action cannot be directed at the most appropriate breeding or wintering location, although advances are being made in defining linkages to breeding and wintering sites (e.g., Rubenstein et al. 2002).
- Trends from different sites cannot be pooled into regional or range-wide trends (see discussion above). Analysis of data from many more sites is needed, in order to determine how variable trends may be among nearby sites and across regions.
- Habitat change is potentially a serious cause of bias in migration count trends for species counted during stopover (see discussion above).

- Counting migrants for the purpose of detecting population trends requires sustained effort over many years, often requiring paid staff to ensure long-term continuity.

Other Types of Migration Counts

This paper has concentrated on intensive counts at specific sites, but much of the discussion is relevant as well to other types of migration counts. For example, analysis of daily bird lists contributed to a long-running checklist program in Quebec showed that trends in numbers of birds counted during migration corresponded poorly to BBS trends (Dunn et al. 1996, 2001). This result should not be surprising, given the needs described above for standardized effort and near-daily counts, and given the known biases of generalized birding (e.g., tendency for observers to go out on dates when many birds can be expected, and to cease visiting sites that become unproductive).

If migration counts are taken from radar images of nocturnal passage, the entire daily migrating population (*fig. 1*) can, in theory, be counted. This would circumvent the potential biases in ground counts that are caused by daily variation in the proportion of the migrating population that forms the count population, and the proportion of the count population that is actually detected by observers. However, radar images do not reliably distinguish between individual targets and flocks of small birds, detection rates vary with height of flight, and sensitivity of radar equipment is likely to improve over time. While all these issues can be addressed to some extent (e.g., through analysis or equipment calibration), there is one crucial limitation to radar counts: species-specific population trends cannot be derived, because species are indistinguishable on radar. (This is also a problem with counts of birds passing the disk of the moon; but that method has the added disadvantage that counts can only be made on nights – and at the hours of the night – when the moon is fully visible.)

Recording of migration flight calls is another means of taking a migration count. Not all species have distinctive calls, and for those that do, there is little known about the factors that might affect calling rate. If call rate varies—for example with conditions of visibility, motivation of the bird or its physical condition, elapsed time of flight, or number of conspecifics within hearing—then call counts will be subject to many biases, just as ground counts are. In addition, calls are likely to differ in detectability over the full range of altitudes at which birds migrate. If call counts are taken in combination with radar, then correction could be made for altitude, but only if it is assumed that all species are equally distributed among altitudinal levels.

Some combination of ground counts, radar and call recording may provide more accurate and precise estimates of population trend than ground counts alone. However, given the effort and expense of using all methods in combination, few stations are likely to try this, and most studies that combine methods will likely be focused on research rather than on population monitoring *per se*. This kind of research may not lead to development of new methods for population monitoring, but should help in evaluating the best methods for running traditional migration monitoring stations, and in improving our understanding of the sources of variation in daily counts.

Conclusions

Partners in Flight has recommended improvement of migration monitoring as a means of addressing important information gaps on the status of North American landbird species (Rich et al. 2004). Money should go first into developing centralized data analysis and liaison with existing stations in order to promote adoption of standardized protocols. Most existing stations were started for reasons other than population monitoring, and often, relatively little would be needed to convince operators to upgrade their efforts so that results will be suitable for trend analysis. Establishment of new stations by enthusiasts should also be encouraged (especially in areas with little coverage, such as the southeastern US). However, until we learn more about the number and distribution of stations required to generate trends for particular breeding populations, large amounts of money should probably not be directed towards establishing a lot of new, professionally-run monitoring stations, unless they are justified by collection of data that will be useful as well for other purposes (e.g., collection of data on age ratios, stopover ecology, habitat use, etc.).

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Using Autumn Hawk Watch to Track Raptor Migration and to Monitor Populations of North American Birds of Prey[1]

Kyle McCarty[2] and Keith L. Bildstein[2]

Abstract

Raptors are secretive, area-sensitive predators whose populations can be logistically difficult and financially prohibitive to monitor. Many North American populations of raptors are migratory however, and on migration raptors are frequently counted at traditional migration watchsites. Experiences at Hawk Mountain Sanctuary (HMS) and elsewhere suggest that long-term migration counts can be used to monitor regional populations of raptors. Hawkwatchers have collected count data on standardized Hawk Migration of North America (HMANA) Daily Report Forms since the mid-1970s. In 1998 HMS, HMANA, the National Audubon Society, and the Lab of Ornithology at Cornell University began Internet-based data entry of migration watchsite counts at the BirdSource website. By autumn 2002, the *Autumn Hawk Watch* web page was collecting and displaying daily count reports from 66 watchsites in three Canadian provinces, 26 United States, and in Mexico, Costa Rica, and Bolivia. *Autumn Hawk Watch* provides participants and interested parties with near real-time maps and tables that document the movements of raptor migration across the Americas each autumn. The web page also captures count data for later use in monitoring raptor populations, and provides HMANA with timely summaries of each count, which are published in the HMANA *Journal of Hawk Migration Studies*.

Key Words: Autumn Hawk Watch; Hawk Migration Association of North America; Hawk Mountain Sanctuary; Internet; migration monitoring; raptors.

Introduction

Raptors are wide-ranging and often secretive predatory birds, many of whose populations are logistically difficult and financially prohibitive to survey and monitor (Bildstein 1998). One particularly cost-effective method for monitoring populations of these birds is to sample regional and even continental populations at traditional migratory bottlenecks and concentration points (Zalles and Bildstein 2000). An incipient network of raptor migration watchsites (i.e., lookout points typically situated on mountain-tops, coastal plains, river valleys, and lakesides and other migration "leading lines") exists in North America, and during the past 70 years migrants have been counted on a regular or irregular basis at more than 1,800 short-term or permanent watchsites (McCarty et al. 2000).

Although most raptor migration watchsites are in the northeastern United States, the recent addition of season-long migration counts at sites in Gulf Coast Texas (Smith et al 2001) and Mexico (Zalles and Bildstein 2000), and in Caribbean slope Costa Rica (Bildstein, pers. obs.), together with the establishment of an array of watchsites in the western United States in the 1980s (Smith and Hoffman 2000), has created a potentially effective network for assessing regional and continental populations of migratory birds of prey. Since the mid 1970s, most migration data have been collected using Hawk Migration Association of North America (HMANA) Daily Report Forms, or "green sheets." As such, much of the information collected at these sites is compatible and regional and continental assessments of population change are possible. Unfortunately, most of this information is not available in electronic format in a single database, making broad-scale, multi-site analyses difficult. However, monitoring numbers of migrating hawks at single migration watchsites has been used to great effect (e.g., Carson 1962, Newton 1979, Kerlinger 1989, Bednarz et al 1990, Zalles and Bildstein 2000, Mueller et al. 2001), and the use of data from networks of sites holds great promise. The establishment of several North American-style, season-long count efforts in Mesoamerica and the Caribbean Basin in the past 10 years, for example, increases the potential for tracking world populations of three species, Mississippi Kite (*Ictinia mississippiensis*), Broad-winged Hawk (*Buteo platypterus*), and Swainson's Hawk (*B. swainsoni*), as well as continental populations of a fourth species, Swallow-tailed Kite (*Elanoides forficatus*) (Zalles and Bildstein 2000, Bildstein and Zalles 2001).

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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Here we (1) report several examples of how a single-site, long-term migration watchsite database has been used to track changes in raptor populations and migration behavior, and (2) describe a new webpage that uses the power of the Internet to capture, analyze, and display the results of counts at a network of migration watchsites across North and Central America.

The Conservation Potential of Migration Watchsite Count Data

Hawk Mountain Sanctuary (HMS) was founded in 1934 by conservationist Rosalie Edge to stop the shooting of thousands of migrating raptors along the Kittatinny Ridge in the central Appalachian Mountains of eastern Pennsylvania, 120 km northwest of Philadelphia, Pennsylvania. In late September 1934, Hawk Mountain's Maurice Broun began counting migrating raptors from what was then called Observation Rocks. Although Broun's counts were initiated primarily to document the numbers of raptors being "saved" at the Sanctuary, so as to enlist financial support for the conservation effort, it quickly became apparent that a series of annual counts would enable conservationists to monitor regional populations of birds of prey. Today, Hawk Mountain maintains the longest and most complete record of raptor migration in the world (Bildstein and Compton 2000).

One of the first conservation uses of the Hawk Mountain long-term database was an analysis of annual ratios of juvenile and adult Bald Eagles (*Haliaeetus leucocephalus*) seen at Hawk Mountain before and after the widespread use of DDT in mid-20th Century North America. A bimodal pattern in the seasonal timing of the flight of Bald Eagles at Hawk Mountain, with a major movement in late August-early September, and a second smaller movement peaking in mid-November, suggested that although both "southern" and "northern" birds migrated at the site, most of the birds were southern Bald Eagles nesting in Florida. In 1952, a concerned Maurice Broun began commenting on a substantial decline in the ratio of juvenile-to-adult Bald Eagles at the site, which began in the late 1940s and, thereafter, remained low through the 1950s, 1960s, and mid-1970s (Bildstein 1998). A decade after Broun reported the shift, Rachel Carson used the same database in *Silent Spring* to support her arguments for the impact of organochlorine pesticides on populations of Bald Eagles and other species of predatory birds (Carson 1962).

Particularly notable is that the same database, which now extends into the 21st Century, was also used to track the eventual recovery of Bald Eagle populations following bans on DDT in Canada and the United States in the early 1970s. Even more remarkable is that shifts in overall numbers of Bald Eagles seen at the site lagged declines and subsequent increases in the ratios of juvenile-to-adult birds by 5 to 10 years, exactly as expected if the shifts in ratios of age classes reflected shifts in reproductive success in the monitored population (Bildstein 1998).

A more recent example of the utility of the HMS database involves its use, together with counts from other migration watchsites and information from additional geographically explicit databases. Beginning in the 1980s and extending into the early 1990s, many migration watchsites in the northeastern United States began reporting substantial declines in numbers of Sharp-shinned Hawks (*Accipiter striatus*). The declines were especially notable at coastal watchsites, where flights consisted largely of juvenile individuals. Although initial reports of the decline were accompanied by suggestions of natural population cycling or shifts in wintering range, by the early 1990s additional reports became more ominous, and included suggested links to widespread habitat or prey-base loss induced by acid precipitation or declines in populations of Neotropical songbird migrants (Viverette et al. 1996).

To test the hypothesis that the declines resulted from northward shifts in wintering areas of the regional population, researchers at Hawk Mountain compared migration count data from the Sanctuary and Cape May Point, New Jersey with those from National Audubon Society Christmas Bird Counts (CBCs) north and south of the two migration watchsites. The analysis of CBCs conducted from 1979 through 1989 revealed that numbers of Sharp-shinned Hawks seen on CBCs north of the two migration count sites increased substantially whereas numbers seen on CBCs south of the two watchsites had not. The results support the shift-in-migration behavior hypothesis (i.e., migratory short-stopping). That Cape May Point counts declined more abruptly than those at Hawk Mountain may reflect the fact that the Sharp-shinned Hawk flight at the former site consists almost entirely of juvenile individuals, whereas that at the latter includes many more adults. Juveniles are more likely to modify their migration patterns in light of changed environmental conditions than are adults (Berthold 1993).

Although the reason for the shift in behavior remains uncertain, the change coincided with a series of particularly mild winters, as well as with increases in the numbers of backyard birdfeeders in northeastern North America. Sharp-shinned Hawks rank above domestic cats (*Felis catus*) as the number one predator of birds at backyard birdfeeders (Dunn and Tessaglia 1994), and the growing number of bird feeders in the northeastern United States together with milder winters may have combined to produce the shift (Viverette et al. 1996).

This latter example suggests the utility of migration counts in documenting shifts in migratory behavior, as well as in documenting changes in overall population, and also highlights the importance of using count data in conjunction with other geographically explicit databases such as the Christmas Bird Count.

Realizing the Conservation Potential of Migration Watchsite Count Data Using *Autumn Hawk Watch*

HMANA was founded in 1974 when it became clear (1) that large numbers of individuals were starting to count raptors on migration, (2) that it was important to organize the wealth of information derived from those counts, and (3) that there was a need to develop a standard field sheet to collect these data. The plan was to distribute count data to the public and the scientific community, and to improve techniques to monitor populations of birds of prey (Roberts 2001). Today, cooperators at several hundred watchsites across the continent report their results to HMANA each year, contributing this information to a growing archive of more than 80,000 standardized daily report forms (DRFs). Most of the counts are reported in the HMANA journal every year (*fig. 1*).

In 1996, HMS partnered with HMANA and began cataloging and archiving the DRFs. In an effort to make the data more available to potential users, as well as to speed the summarization and analyses of the data, in 1998 HMANA, HMS, the National Audubon Society (NAS), and the Laboratory of Ornithology at Cornell University (CLO) created the *International Broad-winged Hawk Survey*. The *Survey* enabled hawkwatchers from North to South America to enter counts of migrating Broad-winged Hawks into a web-based data set and to view their collective results in near real-time animated maps of "waves" of these raptors migrating across North America. In 1999 the web page (now called *Autumn Hawk Watch*) was expanded to include all species of diurnal raptors migrating in North America, as well as information on weather conditions.

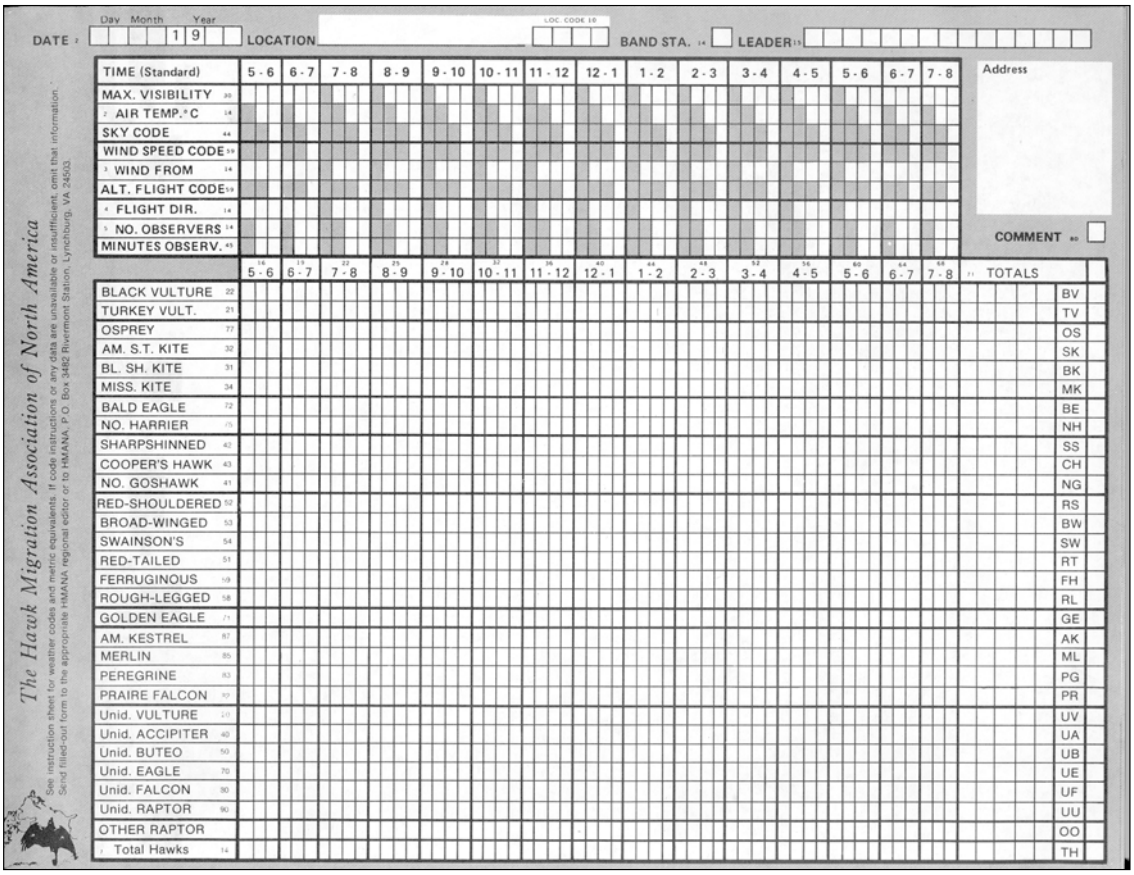

Figure 1—The Hawk Migration Association of North America daily report form, a "green sheet."

In order to simplify the transition for hawkwatchers from a paper to an electronic archive, the *Autumn Hawk Watch* data entry web page was designed after the DRF and uses the same codes for weather variables already familiar to hawkwatchers. After data entry, watchsite coordinators can print summaries of daily counts for their site, and users of *Autumn Hawk Watch* can view and print counts from all watchsites, making the timely entry of count data by each watchsite coordinator essential to the value of the web page to other users.

To enhance the educational impact of the raw count data, and to track the migration as it happens, *Autumn Hawk Watch* generates a series of animated maps for 29 raptor species showing the abundance of migrants recorded at each watchsite over 1-day, 5-day, or 10-day intervals throughout the entire count period, generally running from August to December, and also creates cumulative, static maps and tables by species over 5-day or 10-day periods, or for the entire count period (*fig. 2*). Users also can view counts from a single watchsite, shown in tabular format for a specific date or over 5-day periods (*fig. 3*).

The effectiveness of the *Autumn Hawk Watch* database toward realizing the potential to track raptor populations is tied to ensuring accuracy of data entry and helping project coordinators to control data quality for their watchsite. To reduce errors made during data entry, CLO and HMS fulfill administrative functions within *Autumn Hawk Watch*, such as maintaining regional checklists of migratory raptors, placing count limits on each species based on geographic regions and time of year, and alerting users if they report unusual sightings of a species or enter counts exceeding the limits. Another important feature of *Autumn Hawk Watch* is its ability to accept sporadic or even anecdotal data. Thus, single days of observation at an individual site, or even partial days of observation, can be accepted and archived in the geographically explicit database for future use. Since many watchsites are operated strictly on a part-time or volunteer basis, this type of information is important because it builds a base on which to expand further monitoring efforts.

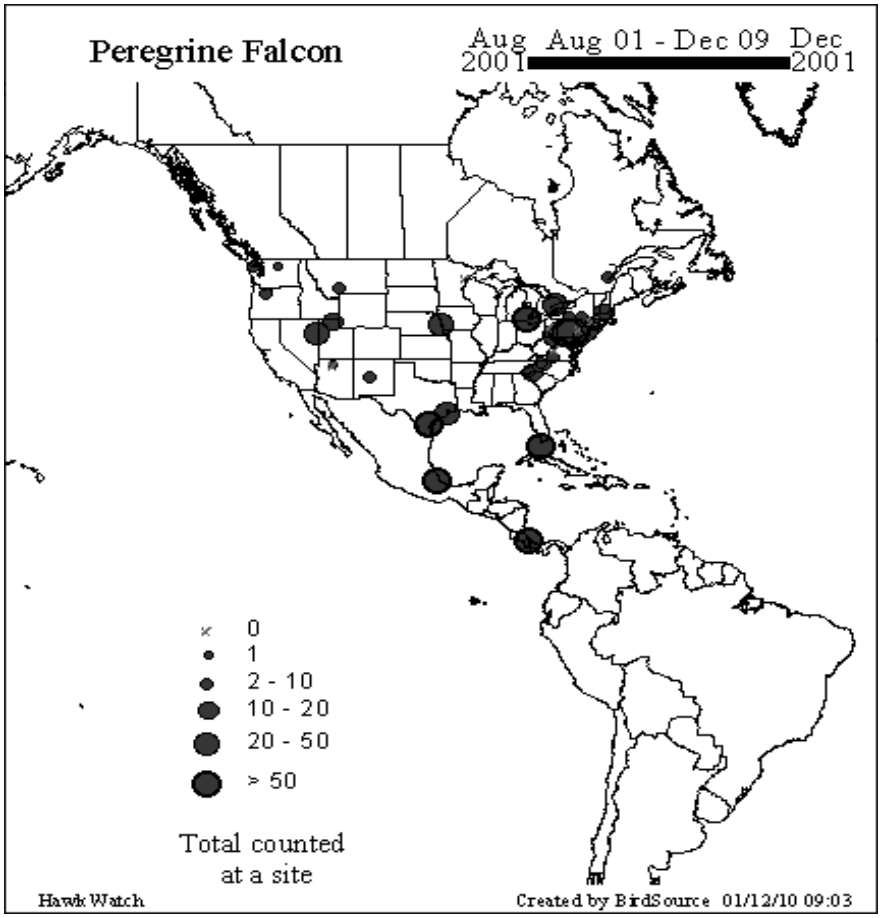

Figure 2—Autumn Hawk Watch map showing counts of Peregrine Falcons (*Falco peregrinus*) from 1 August to 9 December 2001 at all watchsites.

Species	for 10-26	for 10-27	for 10-28	for 10-29	for 10-30	for 10-31	10-26 to 10-31	Total count up to 10-31
Black Vulture *Coragyps atratus*	0	0	2	0	2	0	4	28
Turkey Vulture *Cathartes aura*	6	20	10	3	32	0	71	240
Osprey *Pandion haliaetus*	2	1	0	0	0	0	3	573
Bald Eagle *Haliaeetus leucocephalus*	0	3	1	0	1	0	5	112
Northern Harrier *Circus cyaneus*	5	18	6	1	2	1	33	194
Sharp-shinned Hawk *Accipiter striatus*	40	201	25	7	10	2	285	4664
Cooper's Hawk *Accipiter cooperii*	12	50	17	0	10	1	90	820
Northern Goshawk *Accipiter gentilis*	0	4	13	0	4	1	22	30
Red-shouldered Hawk *Buteo lineatus*	1	17	49	16	12	1	96	180
Broad-winged Hawk *Buteo platypterus*	0	0	0	0	0	0	0	3842
Red-tailed Hawk *Buteo jamaicensis*	52	579	521	68	123	3	1346	2158
Golden Eagle *Aquila chrysaetos*	3	5	8	2	1	0	19	35
American Kestrel *Falco sparverius*	3	0	1	0	0	0	4	580
Merlin *Falco columbarius*	3	2	0	0	0	0	5	170
Peregrine Falcon *Falco peregrinus*	0	0	0	0	0	0	0	34
raptor sp. *Falconiformes*	2	9	0	2	0	0	13	121
Total	**129**	**909**	**653**	**99**	**197**	**9**	**1996**	**13781**

Figure 3—Table generated by the Autumn Hawk Watch web page showing counts of migrant raptors over a 5-day period (26 to 31 October 2001) and total count for the season for Hawk Mountain Sanctuary.

Results from the first four years of the *Autumn Hawk Watch* project indicate that the long-range plans to organize hawk migration data, to make the data more accessible, and to improve techniques to monitor raptor populations are being accomplished. Overall, 99 different watchsites in five countries in North, Central, and South America entered data into the *Autumn Hawk Watch* database in at least one year from 1999 to 2002. Fifty-one watchsites participated in 1999, 53 in 2000, 58 in 2001, and 66 in 2002. In 2001, 53 watchsites were in North America and five were in Central America (*fig. 4; tables 1, 2*). The watchsites averaged 57 days of observation (3333 total days) in 2001, mostly between 26 August and 1 November. (Although impressive, these numbers represent but a fraction of the vast amount of effort expended each year by hawkwatchers in North and Central America.) *Autumn Hawk Watch* tracked the movements of 28 species of raptors in 2001. Most data entry was performed by cooperators at each site; however 16 watchsites provided electronic copies or field sheets of counts to HMS, which then entered the data into the *Autumn Hawk Watch* database. Data entry by watchsite cooperators increases both the accuracy and timely entry of data, and the website works best when participants directly enter their own data. All count data appearing on the website also are published in the HMANA *Journal of Hawk Migration Studies*.

By 2002, count data were reported from three Canadian Provinces, 26 United States, Mexico, Costa Rica, and Bolivia. Fifty-two percent of the sites were in northeastern North America, and more than one-quarter of all sites were in either Pennsylvania or Connecticut. Geographic distribution reflects the numbers of watchsites available. Currently, more participation is needed from the western and, particularly, the central flyways of North America, including the entire Mississippi River corridor.

Conclusions

The long-term goal of *Autumn Hawk Watch* is to advance the ability of ornithologists and amateur hawkwatchers to monitor continental populations of raptors efficiently and to allow rapid information transfer. The *Autumn Hawk Watch* website is designed to accommodate data for 200 known watchsites in North, Central, and South America, with the potential to add any number of new watchsites. Currently, data can be entered from 1998 to the present, and planned entry of historical DRFs from the archive will enhance the expanding database. In addition to the benefits to the hawkwatching and scientific communities, *Autumn Hawk Watch* has the potential for broadening the general public's knowledge of and exposure to the timing, geography, and extensiveness of hawk migration in the Americas.

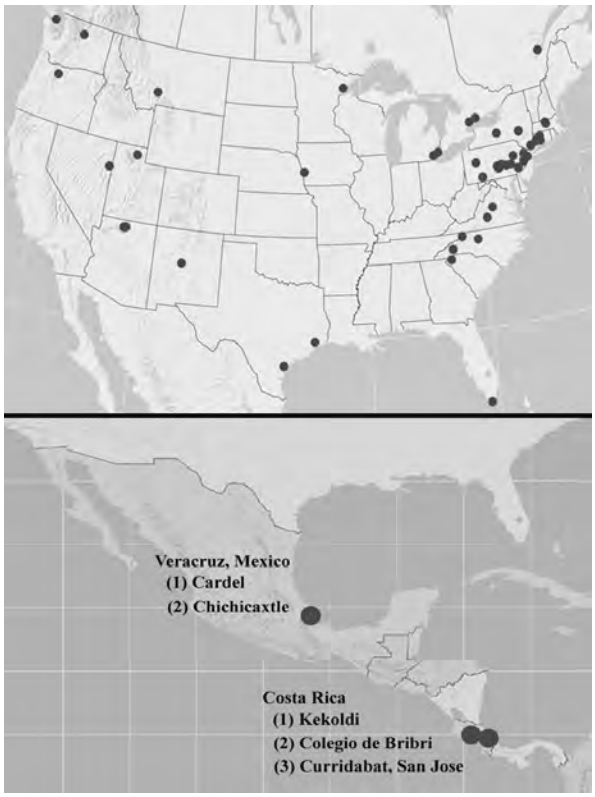

Figure 4—Watchsite locations

Acknowledgments

Autumn Hawk Watch would not be possible without the continued support of coordinators at each watchsite and their associated staff and volunteers, as well as the efforts of S. Kelling and his co-workers at the Cornell Lab of Ornithology who oversee the *Autumn Hawk Watch* web page. We thank them all. This is conservation science contribution number 95 from Hawk Mountain Sanctuary.

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Table 1—*Number of watchsites participating in* Autumn Hawk Watch *per year.*

Year	United States	Canada	Mexico	Costa Rica	Bolivia	Total
1999	38	4	2	7	-	51
2000	43	5	2	1	2	53
2001	48	5	2	3	-	58
2002	57	6	1	2	-	66

Table 2—Autumn Hawk Watch *participants, 1999-2002.*

Continent State, country, or province	Watch site	Continent State, country, or province	Watch site
North America: United States			
Arizona	Lipan Point, Grand Canyon	Massachusetts	Blueberry Hill
	Yaki Point, Grand Canyon		Bolton Flats
			Mount Watatic
Connecticut	Bent-of-the-River Sanctuary		Wachusett Mountain State Reservation
	Briggs Hill		
	Chestnut Hill		Mohonk Preserve
	Flat Hill		
	Flirt Hill	Michigan	Southeastern Michigan Raptor Research
	Good Hill		
	Heritage Village		
	Huntington State Park	Minnesota	Hawk Ridge Nature Reserve
	Johnnycake Mountain Farm		
	Lighthouse Point	Montana	Bridgers Mountains
	Maltby Lakes		
	Osborne Hill	Nevada	Goshute Mountains
	Quaker Ridge		
	Torrington Middle School	New Hampshire	Little Round Top
Florida	Curry Hammocks	New Jersey	Cape May Point
			Kittatinny Mountain Raptor Banding Station
Idaho	Lucky Peak		
			Montclair Hawk Lookout
Illinois	Illinois Beach State Park		Picatinny Peak
			Picatinny Peak – The Domes
Iowa	Hitchcock Nature Area		Raccoon Ridge
	MacBride Nature Recreation Area		Scotts Mountain
Louisiana	Northern Shore of Lake Calcasieu		Sunrise Mountain, Stokes State Forest
Maine	Acadia National Park		Wildcat Ridge Hawkwatch
	Harpswell Peninsula/Casco Bay		
		New Mexico	Manzano Mountains

Table 2 *(continued).*

Continent State, country, or province	Watch site	Continent State, country, or province	Watch site
North America: United States (contd.)			
New York	Central Park	Pennsylvania (contd.)	Waggoner's Gap
	Chestnut Ridge Hawk Watch		Jacks Mountain
North Carolina	Chambers Mountain	South Carolina	Caesar's Head
	Mahogany Rock Mountain		Tibwin Plantation
	Mount Pisgah		
	Pilot Mountain State Park	Texas	Hazel Bazemore Hawk Watch
			Smith Point
Oregon	Bonney Butte		
		Utah	Wellsville Mountains
Pennsylvania	Allegheny Front-Central City		
	Bake Oven Knob	Vermont	Putney Mountain
	Brady's Bend		
	Hawk Mountain Sanctuary	Virginia	Candler Mountain
	Little Gap		Kiptopeke State Park
	Militia Hill		Rockfish Gap
	Rocky Ridge County Park		Snickers Gap
	Rose Tree Park		
	Second Mountain	Washington	Chelan Ridge
	Stone Mountain		
North America: Canada			
British Columbia	Rocky Point Bird Observatory	Ontario (contd.)	Holiday Beach Migration Observatory
			Iroquois Shoreline Raptor Watch
Ontario	Cranberry Marsh		St.-Anne-de-Beaupré
	Hawk Cliff		
	High Park	Quebec	St.-Anne-de-Beaupré
Central and South America			
Bolivia	Concepción	Costa Rica (contd.)	Matina
	Viru-Viru		Puerto Viejo Sarapiqui
			Sixaola
Costa Rica	Bordon		Valle La Estrella
	Colegio de Bribri		
	Curridabat, San Jose	Mexico	Cardel
	E.A.R.T.H.		Chichicaxtle
	Kéköldi		

Migration Monitoring in Shorebirds and Landbirds: Commonalities and Differences[1]

Susan K. Skagen[2] and Jonathan Bart[3]

Abstract

Several aspects of a developing program to monitor shorebirds in the western hemisphere are pertinent to migration monitoring of landbirds. Goals of the Program for Regional and International Shorebird Monitoring (PRISM) include estimating population size and population trends of 74 species, sub-species and distinct populations of North American shorebirds, monitoring shorebird use at stopover locations, and assisting local managers in meeting management goals. Migration monitoring, one of three components of PRISM, works in concert with breeding and wintering surveys to achieve these goals. Existing and emerging migration surveys across several regions are now being integrated with a major focus on reducing potential sources of bias (frame, selection, and measurement). Experience with shorebirds suggests that migration monitoring might also be achievable with landbirds, though different and innovative approaches would have to be developed. We discuss an approach to the selection of monitoring sites in an extensive dynamic ecosystem where birds are broadly and unpredictably dispersed during migration.

Key Words: dynamics, ecosystem, landbirds, migration, monitoring, shorebirds.

Introduction

Several aspects of a developing program to monitor shorebirds in the western hemisphere are pertinent to current discussions of migration monitoring of landbirds. Although there is considerable debate over whether surveys during migration can provide useful information about population trends, there is general agreement that migration surveys can monitor use at stopover locations, elucidate habitat relationships during this period, help local managers meet management goals, and supplement trend information from breeding surveys. For these reasons, and because some people believe that migration surveys do have potential value in trend estimation, a bi-national committee is designing and implementing a comprehensive shorebird survey with the intent that potential problems will be identified and minimized, and that the reliability of the resulting program will be carefully assessed. Components of this program may prove useful in the development of landbird migration monitoring programs.

Program for Regional and International Shorebird Monitoring

The Program for Regional and International Shorebird Monitoring (PRISM) has the overall goals of estimating population size and population trends of North American shorebirds, monitoring shorebird use at stopover locations, and assisting local managers in meeting their shorebird management goals. Ultimately PRISM will address 74 taxa including 49 species, 17 of which have 2-3 subspecies or distinct populations (Bart et al. 2002).

Migration monitoring, one of three components of PRISM, works in concert with arctic, boreal, and temperate breeding surveys and wintering neotropical surveys to achieve these goals. An important role of migration monitoring is to provide an early warning of population declines; independent data from breeding ground surveys may then support or refute such declines. For more complete descriptions of PRISM, see Bart et al. (2002) at http://wss.wr.usgs.gov and Bart et al. (this volume).

Integration of existing and emerging temperate nonbreeding surveys across several regions is now underway. These programs include the International Shorebird Survey (ISS), Maritimes Shorebird Survey (MSS), Western Shorebird Survey (WSS), the South Atlantic Migratory Bird Initiative, and surveys of Prairie Canada, the Great Salt Lake, Delaware Bay, the Lower Mississippi Alluvial Valley, and the northern Great Plains. The challenges in using nonbreeding surveys to

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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estimate trends in population size are to provide a good index of the number of birds in the study area during the study period and to reduce the likelihood of a long-term trend in the ratio of this index, or survey result, to population size (the "index ratio").

Potential for bias is the major problem to be solved in designing the nonbreeding surveys. Here we focus on three sources of bias: frame bias, selection bias, and measurement bias. Frame bias is a long-term trend in the proportion of birds in the population that are in the study area during the study period, as discussed above. Frame bias occurs at the largest spatial scale (the entire study area) if there is incomplete coverage of migration areas or periods. It can be avoided if the study area is large and inclusive (such as southern Canada and all of the United States, extending southward) and if the study period is long. Selection bias is a long-term trend in the proportion of the birds in the study area during the study period that are in inaccessible or uncounted areas.

Selection bias occurs at the regional scale when portions of the study area have a 0.0 probability of entering the sample. It can be minimized if most sites with potential shorebird habitat have a chance at entering the sample so that there is little chance of a long-term net movement between surveyed and non-surveyed sites. Measurement bias is a long-term trend in the ratio of birds recorded to birds present during surveys. Measurement bias occurs at the local or site scale when there is a change in detection of birds present during surveys. It can be avoided if survey methods (ground counts, counts from boats, aerial counts/photography) that count all birds present are used or if detection rates can be estimated and applied.

The general approach of the migration monitoring component of PRISM is to define the outer bounds of the study area, to delineate shorebird survey regions within that area, and to conduct surveys to estimate shorebird-days within each region. This permits combination across survey sites and rigorous (though not completely bias-free) estimation of population trends. Regional assessments define or refine sampling plans, evaluate and undertake site selection procedures, and define and evaluate standardized field and analytical approaches. To minimize selection bias, each region is subdivided into (a) "Type 1" habitat that is regularly used by shorebirds and will be surveyed (usually by sampling) 3-6 times annually, (b) "Type 2" habitat that contains few, but some, shorebirds and will be surveyed every several years to document continued low use, and (c) "Type 3" habitat which is assumed to have virtually no shorebirds and will not be surveyed regularly (but will be occasionally viewed by local biologists and bird watchers). Survey sites and survey period will be identified based on all existing information on shorebird distribution and timing of use in the region. Finally, site maps and survey protocols will be developed and the potential for bias evaluated.

Similarities and Differences with Landbird Systems

Conceptualizing a migration monitoring program may be initially easier for shorebirds than for landbirds. PRISM is feasible because there are relatively few shorebird species/taxa to address, and most of these species are habitat specialists, primarily wetland associates. Furthermore, coastal shorebirds generally concentrate year after year in the same sites. Experience with shorebirds suggests that migration monitoring might also be achievable with landbirds though different and innovative approaches would have to be developed.

An early step in landbird migration monitoring would be to identify a set of northerly breeding species for which migration surveys would serve as an early warning for declines. Syntheses of existing data on en route distribution and chronology of these targeted species (e.g., as for shorebirds in Skagen et al. 1999) would be extremely useful in delineating regions and methodologies.Information on the dispersion of individuals (whether broadly dispersed or concentrated in a few sites) and habitat relationships would help determine if random or non-random approaches to site selection would be desirable.

Site selection is of paramount importance for migration monitoring of en route migrant landbirds that disperse broadly and whose distributions shift continually through the season and probably between years. These characteristics are exhibited by shorebirds migrating across extensive ephemeral wetland systems of northern Great Plains (Skagen et al., this volume). Monitoring, therefore, would have similar challenges. The feasibility of monitoring shorebirds under these dynamic conditions using a combination of methods is currently being tested. With this approach, one stratum of sites (high probability of use, similar to "Type 1" above) is selected using all existing information, including expert opinion and past survey history. Stratum 1 sites are then surveyed three times during each survey season, spring or fall. A second stratum of sites (lower or unknown probability of use, similar to "Type 2" above) is chosen using habitat and landscape models to subdivide the landscape into 'types' based on important attributes (such as wetland area and cropland area), followed by random selection of survey sites (townships) within the landscape types.

Total shorebird-days across the landscapes are then determined by extrapolation of the survey results to the

landscape types based on models generated under different weather/climate scenarios, using adjustments for species chronology and assumptions of length-of-stay. Shorebird-days for Strata 1 and 2 are summed to yield total shorebird-days in the region. The feasibility of the approach is highly dependent upon a base of volunteers to adequately carry out the surveys. Because the task is large relative to the volunteer pool in this region of the country, surveys may be undertaken at only 5-yr intervals.

The dynamic nature of habitats has important implications for long-term monitoring programs, whether change occurs over a short time scale as days, months, or years or over longer time scales of decades and centuries. As mentioned above, distributions of en route shorebirds that inhabit wetlands in the US interior shift as wetland conditions and habitat availability vary (Skagen and Knopf 1993, 1994). Similarly, distributions of grassland birds respond to changes grassland structure tied to variability in precipitation, fire regimes, and land management practices (Vickery and Herkert 1999, Winter 1999). Composition of forest bird communities shifts as forest structure responds to the interplay of forest succession, fire, and other disturbances. At longer time scales, even riparian forests in arid landscapes of the western US change through time in response to geomorphic processes, anthropogenic disturbance, land use practices, and vegetation succession (Scott et al. 2003).

Migration monitoring of landbirds will be challenging because of the need to incorporate methods that can continue to track populations as they shift to new sites in future years. Initial studies on habitat and landscape relationships of en route migrants may utilize GIS and remote-sensing (with ground-truthing to confirm habitat types), delineation of strata by habitat types of interest, and random sampling of sites within the strata (if birds are broadly dispersed). We see the need for new and innovative approaches to site selection for long-term monitoring of systems in which temporal heterogeneity plays a dominant role.

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Monitoring Bird Migration in the Caribbean Basin: Multi-national Cooperation Can Close the Loop[1]

Paul B. Hamel,[2] Cecilia M. Riley,[3] W. C. Hunter,[4] and Mark S. Woodrey[5]

Abstract

The Gulf Coast Bird Observatory (GCBO) and the Southeastern Working Group of Partners in Flight have developed a protocol to monitor landbirds with volunteer observers performing avian censuses in the field. Field observations are compiled within a powerful internet database, and recording and summary capability is maintained by the GCBO. More than 100 observers have supplied data from sites primarily in the southeastern United States. Results of three case studies are presented, illustrating the application of migration monitoring data to land conservation, community education, and research hypothesis generation, not only in southeastern United States, but across the Caribbean Basin as well. Such results will allow us to make appropriate decisions for habitat conservation of migratory songbirds during their passage through the southeastern United States. Because the protocol is easy to perform and widely applicable, we suggest this protocol be used as a means to monitor migration throughout the Caribbean Basin.

Key words: citizen science, conservation planning, internet-based data management, monitoring migration, Neotropical Migratory Birds, stopover habitats, volunteer observers.

Introduction

The essence of the Partners in Flight (PIF) process is the voluntary cooperation among a variety of groups with distinct agendas (Pashley et al. 2000). This cooperation is largely based on the implementation of conservation activities directed to sustain migratory bird populations in the western hemisphere (Baxter, this volume). Practical considerations govern such cooperation and can produce both substantial and tangible benefits to secure the future of migratory birds in the western hemisphere (Fitzpatrick, this volume; Riley, this volume). Interest in the conservation of birds in the Caribbean islands is also great. In over 11,000 papers listed by Wiley's (2000) comprehensive bibliography of Caribbean ornithology, more than 2,400 refer to species status, over 1,100 address species' conservation, nearly 500 relate to migration, and almost 500 pertain to endangered species. Caribbean islands are the primary wintering grounds of a number of species, some of which are extremely rare, such as the Bachman's Warbler (*Vermivora bachmanii*) (Hamel 1986). Studies of species wintering primarily in Caribbean habitats contribute to our understanding of the role of the nonbreeding season in the life cycle of these migrants (Latta 2001, Rubenstein et al. 2002).

Monitoring migratory birds during their passage is a key to identifying preferred landscapes, habitats and migration routes of these species (Gauthreaux and Belser, this volume). Despite sincere efforts, the Partners in Flight process has been unable to integrate the efforts of independent nations and islands of the Caribbean Basin into a functional partnership to preserve the fauna. These efforts have been hindered by differences in language, distances and barriers posed by water, and high endemism on individual islands. While acknowledging the challenges to such cooperation, we present one approach that would integrate workers of differing capabilities, interests, and time into a single mechanism to monitor movements of birds across the Gulf of Mexico and Caribbean.

The Migration Monitoring Program of the Gulf Coast Bird Observatory (GCBO 2002b) is a flexible yet comprehensive, citizen-science protocol that observers in the Caribbean Basin may use to observe, record, and share information about the geographical and temporal distribution of Neotropical migratory birds. The

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[1] A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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Migration Monitoring Program permits interested people to conduct projects of short duration or within a limited area. Individually, these projects may not constitute sufficient scope so as to be "publishable," but in aggregate, they become a powerful window from which we can learn about the behavior of the migratory birds. Some of these efforts have produced sufficient information to identify and justify the acquisition of conservation properties, as well as to document the seasonal movements of landbird migrants in distinct, often high-volume areas in the southeastern United States. The Migration Monitoring Program, through its internet-based data entry and retrieval focus, enables one to record and explore extensive details of avian migration.

The Gulf Coast Bird Observatory and the Southeastern Working Group of Partners in Flight have developed a protocol to monitor landbird migration (Riley et al. 2001). There are multiple objectives of this citizen-science program: to obtain data on spring arrival and fall departure, to identify staging and dispersal areas, to determine species-specific migratory pathways, to compare movements spatially and temporally, to identify 'hot-spots' and their variability from year to year, to assess weather effects on flight pathways, to identify key stopover habitats, and to identify primary corridors between coastal areas and interior breeding sites.

Methods

The protocol for the Migration Monitoring Program is simple. Volunteers select a site (of any size/shape) that may be of interest to them, with the single restriction that it must be surveyed in four or fewer hours. All migratory birds seen or heard during the survey period are recorded. Basic weather variables (wind speed and direction, sky conditions, start and ending temperatures) taken from the Breeding Bird Survey methodology are collected each sample date. In addition, volunteers provide general information about the habitat surveyed by selecting from a menu of habitat types, and surrounding landscape categories. Volunteers survey their sites a minimum of once per week during the appropriate migratory season; in spring: 20 March - 1 June; and in fall: 15 July - 1 November. The GCBO distributes data sheets, compiles inputted data, and maintains the database (GCBO 2002a). One of the greatest strengths of the approach is the ease of automated data entry via the GCBO website (GCBO 2002b).

Results

The Migration Monitoring Program is now in its sixth year. As of March 2002, 104 volunteer participants have submitted data on spring and fall observations from more than 93 locations, primarily in the southeastern United States (13 different states) and one site in Belize (*table 1*, *fig. 1*). Migration monitoring can be used to accomplish a variety of conservation activities. Here, we focus on three examples, including land protection activity, community education, and research hypothesis generation facilitated by the program.

Table 1– *Five of the 93 sites with the largest species richness that are included in the GCBO-Southeastern Partners in Flight Migration monitoring database.*

Number of species	Location
132	Sabine Woods, Texas
119	Paradise Pond, Texas
117	Kennesaw Mountain, Georgia
109	Bayou Sauvage National Wildlife Refuge, Louisiana
98	River Legacy Park, Texas

MIGRATION MONITORING LOCATIONS

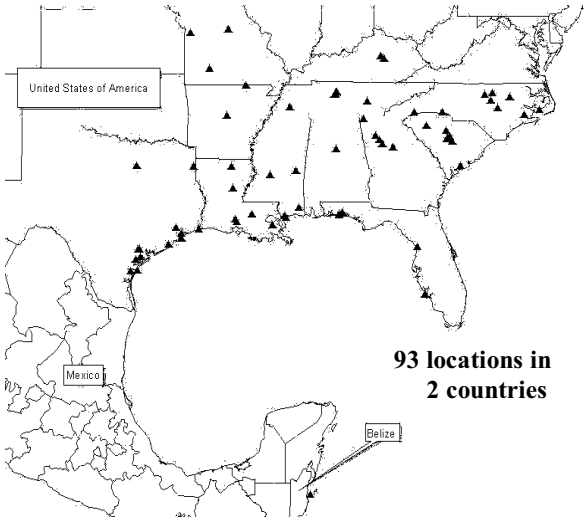

Figure 1– Distribution of the initial 93 sites in the Migration Monitoring network.

Land Protection Activity

One of the sites, Paradise Pond, near Port Aransas, Texas, is an example of how the Migration Monitoring Program was used to support a land protection effort at important stopover habitat for neotropical migratory

birds in areas near the Gulf of Mexico shore and Caribbean Sea. One volunteer observer, Joe Frandolig, selected the site as his post for the Migration Monitoring Program. In four years of work, (1998-2001), Mr. Frandolig contributed 270 hours of field observations, during which he observed 5,436 individuals of 119 migratory species at Paradise Pond. More than a dozen species with high PIF priority scores have been recorded from Paradise Pond, including Prothonotary Warbler (*Protonotaria citrea*), Bay-breasted Warbler, (*Dendroica castanea*), Painted Bunting (*Passerina ciris*), Kentucky Warbler (*Oporornis formosus*), Dickcissel (*Spiza americana*), Blue-winged Warbler (*Vermivora pinus*), Cerulean Warbler (*D. cerulea*), Wood Thrush (*Hylocichla mustelina*), Golden-winged Warbler (*V. chrysoptera*), Worm-eating Warbler (*Helmitheros vermivorus*), Black-throated Blue Warbler (*D. caerulescens*), Prairie Warbler (*D. discolor*), and Bobolink (*Dolichonyx oryzivorus*). The data gathered in Mr. Frandolig's efforts were used to secure support for land acquisition and infrastructure enhancements for the new Paradise Pond Bird Sanctuary.

Community Education

The gathering, recording, and disseminating of information on migratory bird activity have direct applicability to community education and planning in addition to site-specific conservation. These efforts are also a great eye-opener for people who conduct the work because they provide direct, current information that participants can offer to their local communities as education. From participants' observations, we can learn about the effects of land conversion activities on bird migration in communities surrounding the monitoring site. Jim Sipriola of Arlington, Texas, another volunteer participant in the Migration Monitoring Program, noticed a decline in migrant populations while monitoring his site over a four-year period. He proposed that this decline might be related to land use changes in the vicinity of his monitoring site and formed an advisory group to monitor site management activity. Such information, gathered locally and presented in community forums by a resident citizen, is a powerful and credible stimulus for community education and local conservation activity.

Research Hypothesis Generation

Opportunities to use data in the Migration Monitoring database extend beyond identifying valuable sites for conservation purposes. Because the land area of the Caribbean is small but widely spread, neither a single observer nor a small group of observers could ever hope to survey it. However, the Migration Monitoring protocol accommodates a widely scattered sampling by allowing multiple observers to record information obtained at multiple sites in an all-inclusive database. Such extensive data can reveal insights into the timing and pathways of migration by individual species. Such has been the case for a neotropical migrant of great concern, the Cerulean Warbler (*Dendroica cerulea*). Numerous observations of Cerulean Warblers in spring and fall migration have been made and recorded from Kennesaw Mountain, Georgia by a group of dedicated observers led by Giff Beaton. Observations of the Cerulean Warbler at this location are far more numerous than at other localities in this program. Parker (1994) and Garrido and García Montaña (1975) have documented the movement of Cerulean Warblers across the Gulf of Mexico. Parker (1994) provides a wealth of details on the spring migration of Cerulean Warblers, based on a short period of observations in the highlands of Belize. Garrido and García Montaña (1975) report a very small number of Cerulean Warblers observed in Cuba, but noted that all incidence of the warbler occurred in fall, and almost always in the Peninsula de Guanahacabibes, the very western part of the country. It has been suggested that the birds seldom occur in Cuba, even in the fall (Garrido, pers. comm.). Though scarce, the information presented by Parker (1994) and Garrido and García Montaña (1975) is sufficient to frame a hypothesis that the axis of Cerulean Warbler migration across the Gulf of Mexico is from the mainland of Central America to the central Gulf Coast, in both fall and spring. Without more information, this hypothesis is just idle speculation. Data accumulated in Migration Monitoring such as Cerulean Warbler records from Kennesaw Mountain, will make possible the refinement and subsequent testing of this hypothesis and many others like it. Such hypothesis testing will be a further stimulus to conservation action in the Caribbean Basin.

Discussion

Analyses of data from the Migration Monitoring Program will allow us to make appropriate decisions for conservation of migratory songbird habitats during their passage through the southeastern United States. The example of Paradise Pond Bird Sanctuary illustrates how data gathered as part of this program can support the implementation of conservation actions that protect habitat for migratory birds. Opportunities for conservation actions similar to the Paradise Pond Bird Sanctuary exist throughout the Caribbean Basin. The Migration Monitoring protocol is an effective tool because it allows multiple volunteer observers to visit localities and gather and record observations that would otherwise be too costly if performed as a detailed research project. The database, armed with query capabilities, permits interested parties to identify migratory pathways and to use these identifications to pose and model hypotheses of migratory movements of

individual species at specific times. The community of volunteer observers who submit observations to the database will undoubtedly feel a sense of ownership and responsibility towards their site, and are likely to become more active towards the conservation of migratory bird habitat in their communities.

The Migration Monitoring protocol is easy to perform and is widely applicable. Thus, we suggest the Migration Monitoring protocol as a means to monitor migration throughout the Caribbean Basin. However, no data has yet been submitted from any Caribbean site. Several obstacles may contribute to the failure of attracting cooperation among colleagues who live or who work in the Caribbean.

Some discussion of the potential barriers to cooperation may prove useful. We identify island geography, distance, language, the labor pool of observers, endemism, and political constraints of international treaties as obstacles to cooperation among Caribbean partners. The geography of the Caribbean is an obvious and most vexing contributor. Distances among potential sites are great, and the practical difficulties of travel make overcoming these distances difficult. In addition, four languages are spoken on the Caribbean islands: French, Dutch, English, and Spanish. Human populations on these island nations are typically small, reflecting limited labor pools of knowledgeable local citizens to conduct the myriad of activities involved in scientific, ornithological, and conservation activities (Carey, pers. comm.). The high level of endemism characteristic of the islands leads to difficult choices for local conservation action. The greatest contribution that a Caribbean nation can offer to conservation of biodiversity is the maintenance of healthy populations of its endemic taxa, creatures that are especially valued and proudly recognized by citizens of that nation. This heightened attention to endemic birds may require leaving the monitoring of migratory birds as a desirable secondary goal. Still, the Migratory Bird Treaty, an umbrella for international conservation of migratory birds, only applies to Canada, Mexico, and the United States of America. Avenues for cooperation to sustain and protect migratory birds offered by that treaty do not include nations of the Caribbean Basin, Central or South America.

In spite of the growing interest in the study of patterns of migratory bird movement in the Caribbean (Wiley 2000), detailed data on location, timing, effects of local weather events, and volumes of movement by migratory birds are scarce. A migration monitoring project has operated in Florida since 1993 (Riley et al. 2001; Wallace, pers. comm.) and has been useful in identifying conservation sites, monitoring the movements of species, and clarifying the status of migratory birds during passage. The opportunity to follow this model and to employ the voluntary observations of local residents and visitors to Caribbean islands exists throughout regions of the Gulf of Mexico.

Central to this protocol's success is the internet-based data entry and retrieval capability supported by the Gulf Coast Bird Observatory. A critical addition to the existing database will be the translation of instructions and web-based data entry interface into French, Spanish, Dutch, and ultimately Portuguese, so that the utility of the system will be increased by the full range of potential users, including participants from the Caribbean islands. Similarly, a need exists to develop a composite list of species where all the names of potentially-occurring birds are readily accepted by the error-checking routines of the data-entry software. Provisions regarding local names for all birds in the American Ornithologists' Union Checklist (American Ornithologists' Union 1998) will facilitate this task. We look forward to its accomplishment.

Finally, observations from the Migration Monitoring database will be available in the future for consolidation with other, wide-ranging efforts that are currently in the planning stages such as the eBird internet website (eBird 2002).

Acknowledgments

For their help with database development, management, data entry, and funding for this work, we acknowledge M. Parrinello, Dr. V. Raghavan and J. Buys, the University of Louisiana at Lafayette - Energy and Environmental Information Resources Center, U.S. Geological Survey, The Great Texas Birding Classic, and Team Audubon. The manuscript has been reviewed by N. Schiff, S. Prasad, T. Dell, and J. Carlisle, who offered important improvements to the style and content of this descriptive paper.

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Advances in Statistics

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Abstract

The papers included in the Advances in Statistics section of the Partners in Flight (PIF) 2002 Proceedings represent a small sample of statistical topics of current importance to Partners In Flight research scientists: hierarchical modeling, estimation of detection probabilities, and Bayesian applications.

Sauer et al. (this volume) examines a hierarchical model describing attributes and change of aggregates of bird populations using a Bayesian statistical inference approach with WinBUGS. They point out that WinBUGS provides a user-friendly software environment for hierarchical modeling that more realistically describes many biological contexts.

The authors of two papers focus on the issue of detection. Farnsworth et al. (this volume) presents a summary of detection probability estimation procedures, including distance sampling, double observer methods, time-depletion (removal) methods, and hybrid methods that combine these approaches. They conclude by presenting a method that combines distance and removal sampling methods, along with results. Earnst and Heltzel (this volume) describe estimates of detection ratios based upon songbird surveys as a function of species, forest type, and season. They report that detection ratios reflecting detectability differed with species (not surprising), but also with timing of surveys (even a couple of weeks makes a difference) and habitat.

Stauffer et al. (this volume) describes a Bayesian interpretation of Akaike weights, useful for assessing the competitiveness of a collection of models with a series of datasets. They illustrate these ideas with habitat selection models for Northern Spotted Owl in California.

Statistical Guidelines

We conclude this summary by recommending that the following statistical components be included in future PIF proposals for sample surveys and experiments:

1) Any project proposing an "experiment" with a comparison of "treatments" should include results of a power analysis in the methodology section of the proposal, indicating

   a) the effect sizes of interest (i.e., what differences of biological significance are being examined in the experiment?),

   b) the confidence level, and

   c) the number of replicates required to attain a specified level of power in the experiment. We emphasize that the level of power may differ, depending on the nature of the "experiment." 80 percent power is a generally accepted standard, but there are circumstances where desired power might be higher or lower.

2) Any project proposing to estimate a trend (e.g., in abundance, productivity, nesting success, survival, fitness, occupancy) should indicate

   a) the amount of decline or increase that is of biological interest, and

   b) the number of replicates required with a specified confidence level and power to detect this trend in the project, based upon a power analysis.

3) Projects proposing to estimate parameters (e.g. abundance, occupancy, productivity, nesting success, survival, fitness) should indicate the amount of precision anticipated for the specified confidence level and sample size.

4) Projects examining demographic parameters such as survival and breeding propensity, should use up-to-date software available for these estimates, such as MARK or an equivalent alternative (e.g., SURGE).

5) Confidence levels lower than 95, such as 90 percent, may sometimes be more appropriate for sample surveys and experiments, given the statistical difficulties inherent in the analysis of

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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these datasets that are sometimes sparse and often noisy. A 90 percent two-sided confidence interval can be useful, for example, because it can be split into an upper one-sided 95 percent confidence interval and a lower one-sided 95 percent confidence interval, if one is interested in the minimum value that a parameter may take (use the upper one-sided 95 percent CI) or the maximum value that a parameter may take (use the lower one-sided 95 percent CI). Standards lower than 95 percent may also be useful when other sources of error in the decision-making process are appreciably larger than the significance level of 5 percent.

Readers are referred to Nur et al. (1999) for further discussion and recommendations for those designing monitoring programs and analyzing these data.

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Farnsworth, G. L., J. D. Nichols, J. R. Sauer, S. G. Fancy, K. H. Pollock, S. A. Shriner, and T. R. Simons. This volume. **Statistical approaches to the analysis of point count data: a little extra information can go a long way.**

Earnst, S. L. and J. Heltzel. This volume. **Detection ratios of riparian songbirds.**

Stauffer, H. B., C. J. Zabel, and J. R. Dunk. This volume. **Application of Bayesian methods to habitat selection modeling of the Northern Spotted Owl in California: new statistical methods for wildlife research.**

Statistical Approaches to the Analysis of Point Count Data: A Little Extra Information Can Go a Long Way[1]

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Abstract

Point counts are a standard sampling procedure for many bird species, but lingering concerns still exist about the quality of information produced from the method. It is well known that variation in observer ability and environmental conditions can influence the detection probability of birds in point counts, but many biologists have been reluctant to abandon point counts in favor of more intensive approaches to counting. However, over the past few years a variety of statistical and methodological developments have begun to provide practical ways of overcoming some of the problems with point counts. We describe some of these approaches, and show how they can be integrated into standard point count protocols to greatly enhance the quality of the information. Several tools now exist for estimation of detection probability of birds during counts, including distance sampling, double observer methods, time-depletion (removal) methods, and hybrid methods that combine these approaches. Many counts are conducted in habitats that make auditory detection of birds much more likely than visual detection. As a framework for understanding detection probability during such counts, we propose separating two components of the probability a bird is detected during a count into (1) the probability a bird vocalizes during the count and (2) the probability this vocalization is detected by an observer. In addition, we propose that some measure of the area sampled during a count is necessary for valid inferences about bird populations. This can be done by employing fixed-radius counts or more sophisticated distance-sampling models. We recommend any studies employing point counts be designed to estimate detection probability and to include a measure of the area sampled.

Key words: Detectability, distance sampling, double-observer, point counts, removal sampling.

Introduction

Point count surveys are a popular method for sampling bird populations. Point counts can be conducted over a large area for very little cost compared with more intensive survey methods such as spot mapping or nest searching. In their basic design of timed bird counts they are also simple to conduct, requiring only knowledge of birds and their songs. However, analyses relying on data from point count surveys have been strongly criticized (e.g. Burnham 1981) because most implementations of point counts have a shortcoming: they are conducted without attempting to estimate or adjust for detection probability. Even though point counts are coming under increasing scrutiny (e.g. see Rosenstock et al. 2002, Thompson 2002), they are still used in many surveys (e.g., the North American Breeding Bird Survey [BBS], see Robbins et al. 1986). In a review of published reports in ornithological journals from 1989 to 1998, Rosenstock et al. (2002) found the most frequently employed technique to draw inferences about landbird abundance was unadjusted point counts. Most of the users of point counts are apparently unaware of the limitations on the inferences that may be appropriately drawn from such unadjusted counts (Barker and Sauer 1994).

Using unadjusted point counts to evaluate populations of landbirds requires a major assumption: that changes in the counts (e.g. between years or habitat types) reflect a difference in the true population of birds being sampled. However, counts are not censuses: the expected number of birds counted at a point is a product of the population size (N) and the detection probability (p), where the detection probability is the probability that a bird drawn randomly from the population within

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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the sampled area will be detected by the observer. Thus differences between counts may reflect differences in the detection probability, differences in population size, or both.

Because the deficiencies in point counts have been well documented, a substantial amount of effort has been devoted to development of statistical methods to permit estimation of detection rates from point counts. Generally, these methods require collection of ancillary data during the count, and these additional data are used in the context of statistical models to estimate detection probabilities. Examples of these ancillary data include collection of distance information from the point to the bird, allowing for distance estimation of density (Buckland et al. 1993, 2001; Rosenstock et al. 2002), collection of counts by two observers at the same point and time allowing estimation of detection rates using capture-recapture methods (Nichols et al. 2000), and collection of counts divided into time intervals allowing application of removal methods (Farnsworth et al. 2002). These methods provide a variety of alternative approaches for estimating detectability, and incorporating these methods in logistically-efficient ways is a crucial challenge for investigators.

Another method recently proposed is a double-sampling approach (Bart and Earnst 2002). This method attempts to calibrate a quick survey method (e.g. point counts) by performing a census on a subsample of plots. Having a known population size on some plots allows for the estimation of detection probability. This probability can then be used to adjust counts from all the plots upon which the quick method was used. We feel the double-sampling approach is extremely effort intensive, and hence is not a comparable alternative method for counting birds in most habitats in which point counts are conducted. Performing a reliable census of a subsample of point counts would not be practical in most habitats such as forested areas where intensive nest-searching or territory mapping is very difficult and unlikely to provide a reliable census.

In this paper, we will discuss the methods available to deal with issues of detection probability and density from point count surveys. First, we define two of the important conceptual issues that often complicate estimation and analysis of point count data: (1) components of detection probability and (2) area sampled during point counts. For each method we will briefly address its strengths and weaknesses. Finally, we will explore the potential to combine methods and describe an example of combining distance and removal sampling to estimate density. We restrict the discussion to point count surveys designed to count breeding landbirds.

Components of Detectability

In many point count surveys, most birds are detected by hearing songs or calls. In point count surveys of this type it may be useful to separate the overall detection probability into different components. In order for a bird to be recorded by an observer, the bird must vocalize audibly and this noise must be heard and recognized by the observer. We thus separate the components of detection probability into the probability a bird vocalizes (P_a) and the probability it will be detected by the observer given that it vocalized (P_b) such that the overall detection probability $P = P_a \times P_b$. We assume these two probabilities are independent.

Density Estimation

In addition to separating these components of detection probability, area sampled during point count surveys is often an important complication in analysis of point counts. Often, the effective area sampled during point counts is vague, and observers tend to hear birds with varying efficiency. Although some estimation procedures explicitly estimate density of birds (e.g. distance sampling), other methods only estimate abundance. For all abundance estimation methods, differences in adjusted counts may reflect a difference in population size due to different amount of area sampled. For example, if point counts are conducted one year and repeated in a subsequent year and more birds are detected in the later year, it may reflect a greater detection radius in the later year and not a biologically meaningful increase in population size. In addition, many studies employing point counts are more interested in density of birds than abundance, and an important initial motivation of distance methods was to explicitly address this area surveyed issue by modeling detection as a function of distance from the point. Methods that do not include measures of distances to each bird should incorporate some measure of the area sampled as well as an estimate of detection probability.

Existing Methods

Distance Sampling

Distance sampling is a well-established framework for estimating detection probability and density from count data (Buckland et al. 1993, 2001). As applied to point counts, distance sampling theory models the detection probability as a monotonically declining function of distance. The probability a bird is detected when located at distance r from the point is described by the detection function $g(r)$. Distance sampling requires a number of assumptions. For example it assumes that birds are not affected by the presence of the observer. This method also normally requires the assumption that

all birds at the center of the point are detected [i.e. that $g(0) = 1$].

The observer records the distance to all birds detected during a limited-interval count (e.g. 5 min). All observations are then pooled across many count locations to identify the specific shape of the detection function $g(r)$ that is most appropriate. Akaike's Information Criterion (Burnham and Anderson 1998) may be used to choose the most parsimonious model for $g(r)$ from several potential curves. Combining the total number of birds detected with the detection function leads to an estimate of density and an estimate of the variance. The theoretical underpinning of this method is well understood and will not be explored in detail here (for details on curve-fitting see Buckland et al. 1993, 2001).

Although distance sampling has been around for quite some time, many investigators have not adopted it as a field technique (Rosenstock et al. 2002). One obstacle preventing its widespread use appears to be the perception that measuring distances to birds is too difficult in many field situations. This can be overcome to some degree by assigning birds detected to distance categories instead of measuring actual distances (for recommendations see Buckland et al. 1993, 2001; Rosenstock et al. 2002).

However, a more serious problem with using distance sampling for point count surveys occurs when $g(0) \neq 1$. In many habitats where the majority of birds are detected by sound such as high-canopy forests the probability of detecting a bird at the center of the count circle may be substantially less than one. A bird directly over the head of an observer still must vocalize and be heard (and identified) to be recorded during a point count. Using the components of detection probability discussed above, distance sampling should work well for modeling the probability a bird is detected given that it sings (P_b) as a function of distance from the observer, but distance sampling does not directly address the first component of detection probability, the probability a bird vocalizes audibly (P_a).

Double-Observer Method

Based on the work done by Cook and Jacobson (1979) with aerial surveys, Nichols et al. (2000) designed a procedure to estimate detection probability during point counts by using two observers. One observer is designated the primary and the other the secondary. The primary conducts a point count normally. The secondary is aware of the birds detected by the primary and records any additional birds that were missed by the primary. The two observers alternate roles during successive point counts. Every bird that is detected by the secondary provides information about the detection probability of the primary observer, and by switching roles, the technique allows for estimation of the detection probability of each observer. These observer-specific detection probability estimates can then be used to estimate the combined detection probability for both observers during a point count and the associated variance (for details see Nichols et al. 2000).

A similar approach using mark-recapture framework with two (or more) independent observers is also possible (discussed in Pollock et al. 2002). These double-observer approaches (independent and dependent) to estimation of detection probability only deal with the second component of detection probability discussed above (probability bird is detected given that it sings, P_b). Using two observers allows estimation of how many birds of those available to be counted (vocalizing audibly) are missed but does not directly address the birds that are missed because they did not vocalize during the count.

The double-observer method estimates detection probability, but this should still be combined with a measure of the area sampled. The double-observer method estimates bird abundance by adjusting counts based on detection probability. If the area sampled is different between counts, these adjusted counts may obscure a real change in bird density. For example if a disturbance such as forest clearing had the combined effects of decreased bird density and increased detection radius (by removing barriers to sound travel), point counts before and after the disturbance may show no difference. This can be overcome by using fixed-radius point counts where a change in bird density will be reflected in estimates of bird abundance within the count circle (see Nichols et al. 2000).

Removal Sampling

The removal sampling framework is based on the idea that as the population of animals being sampled is depleted by removing individuals, the decrease in new animals being caught provides an estimate of the total number of animals originally present (Moran 1951). In its simplest form, the detection probability is assumed to be equal for all animals and constant throughout a series of trapping episodes. As originally conceived, animals were caught and killed, reducing the population available to be caught. The next trapping episode thus is expected to catch fewer animals because the population is smaller but the probability of capture is the same.

As applied to point counts, this method treats birds detected as removed from the population of birds available for initial detection (for details see Farnsworth et al. 2002). In this method, the count period is divided into several time intervals. As birds are detected in one time interval, they are considered "removed" from the

population of birds being sampled in subsequent intervals. One advantage of this approach is that, under an assumption that every bird has some *a priori* probability >0 of vocalizing during the sample period, it can estimate the number of birds missed during the count including those that did not vocalize. In this way, the estimate of detection probability derived from the removal method is the product of the two components of detection probability ($P = P_a \times P_b$).

Without some measure of the area sampled during a point count, this method will be vulnerable to the same confounding effects of detection radius and density discussed above. However, this can be overcome by using fixed-radius counts to estimate density (for details see Farnsworth et al. 2002). Another way to estimate density is by combining the ideas of removal sampling and distance sampling into one unified procedure (see below).

Emerging Syntheses

With the increased awareness of the shortcomings of unadjusted point counts, improved counting techniques are required that permit estimation of detection probability. Though available for some time, distance sampling is becoming more widely used. In addition, double-observer and removal sampling have recently been adapted to point counts. There is considerable work to be done to combine several of these methods into a unified approach to estimation of bird density. Here we present a method that combines distance and removal sampling. Combining removal and distance sampling allows a detection function to be used that does not require $g(0) = 1$.

We consider only the simplest possible case: a count divided into two time-intervals of equal length and every bird detected identified as within a fixed radius or beyond a fixed radius from the observer. In theory a combined method may include any number of time intervals and distance categories and fit any of a number of curves for the detection function, but here we provide only a simple example and will use the half-normal function to model the decline in detection probability with increasing distance.

The rationale for this method is as follows. A bird may only be detected if it vocalizes, but the probability it will be detected given that it vocalizes decreases with increasing distance from the observer. The probability a bird vocalizes within a time-interval is P_a, and the probability a bird is detected given that it vocalizes is P_b. The overall detection probability is the product of these two independent probabilities: $P = P_a \times P_b$. The probability a bird is detected given that it sings (P_b) is a function of distance from the observer (r). In the simple case discussed here we define

$$P_b \quad \exp\left(\frac{-r^2}{2\sigma^2}\right)$$

where σ is a parameter with units of distance (e.g. meters) describing how quickly P_b declines from 1 with increasing distance from the observer. Thus the overall detection probability is:

$$P \quad P_a \exp\left(\frac{-r^2}{2\sigma^2}\right)=$$

With two time-intervals and two distance categories, there are four sufficient statistics, defined as X_{ij} = number of birds first recorded in the ith distance category during the jth time interval. For example X_{11} is the number of birds detected within the radius $r1$ of the observer during the first time-interval. Having a count divided into at least two time intervals allows for the estimation of P_a, and classifying birds detected into at least two distance categories allows for estimation of the decline in P_b with increasing distance. *Appendix 1* derives the equations necessary for these estimators as well as an estimator for density from these parameters.

The assumptions of this particular model are as follows:

1. Birds are not moving during the count period.
2. The probability a bird vocalizes is the same for all birds and constant throughout the count period.
3. Birds are assigned to the proper distance category.
4. Birds are counted without mistakes (properly identified and no double-counting).

Example

In 2000, we conducted 824 point counts along established BBS routes. For each count we recorded all birds detected during three minutes, separated into those initially detected in the first 1½ min and those first detected in the final 1½ min. Each bird detected was identified as being within 50 m of the observer or beyond 50 m. In addition each bird recorded was noted as being detected by sight or by sound. For this example, we consider the three most frequently recorded bird species detected by ear, Red-eyed Vireos (*Vireo olivaceus*), American Robins (*Turdus migratorius*), and American Crows (*Corvus brachyrhynchos*).

Among the three species analyzed, Red-eyed Vireo was the most frequently recorded (X.. = 676) and had the highest estimated density ($\hat{D}$ = 0.35 birds per ha; *table 1*). American Crow was the next most frequently

Table 1-- *Counts and estimates of model parameters and density (*D*) for three most frequently detected species during 824 point counts separated into two time intervals and two distance categories. Parameter* P_a *represents the probability a bird vocalizes during one time interval and* σ *reflects the decline in detection probability with increasing distance from the observer. Larger* σ *corresponds to slower decline in detectability (i.e. louder vocalization).*

Species	X_{11}	X_{12}	X_{21}	X_{22}	$\hat{P}_a \pm \hat{SE}$	$\hat{\sigma} \pm \hat{SE}$ (m)	$\hat{D}$ (Ha^{-1})
Red-eyed Vireo	183	38	321	134	1.00 ± 0.04	71 ± 3	0.35
American Robin	134	34	186	86	0.97 ± 0.05	65 ± 3	0.28
American Crow	23	8	392	136	0.92 ± 0.06	183 ± 17	0.18

detected species (X.. = 559), but its estimated density ($\hat{D}$ = 0.18 birds per Ha) was lower than the less frequently-recorded American Robin (X.. = 440; $\hat{D}$ = 0.28 birds per Ha). This was due to the greater estimate of the parameter σ for American Crow (σ_{crow} = 183m and σ_{robin} = 65m). Vocalizations of American Crows can be heard at a greater distance than vocalizations of American Robins.

This example demonstrates one potential way removal sampling and distance sampling may be combined. The model described here was necessarily simple due to the limitations of having only four sufficient statistics. Future efforts should include more time intervals and distance categories and attempt to relax some model assumptions. For example the assumption that the probability an undetected bird will vocalize is constant throughout the count period is probably not valid because if there is heterogeneity within the population of birds being sampled with regard to singing frequency, the birds singing most consistently will be more likely to be detected in the first time interval. More time intervals and distance categories will improve the precision of estimates.

Discussion and Recommendations

Point counts will undoubtedly remain a standard method for sampling many bird species because they are easy to implement. A small number of trained observers can record birds over a large area at a very low cost. If inferences are to be drawn about populations of these bird species beyond mere presence/absence information, auxiliary information should be collected. A little extra information recorded about the birds detected during counts can go a long way to improving the inferences one can make about bird populations. When designing a study using point counts, the investigator(s) should incorporate ways to estimate detection probability and measure the area sampled.

Point counts can estimate detection probability by having two observers or by separating the count period into intervals and recording in which interval a bird is first detected. Having more than one observer conducting counts at the same time may have the additional advantage of minimizing errors in species identification because each observer may provide a check on the other's identification of species. Similarly, having two observers each estimating distances to birds detected will provide a measure of the precision of these estimates. If counts are divided into intervals, we recommend having at least three intervals of equal length. Having three or more intervals allows the model to incorporate heterogeneity in the probability of vocalizing (P_a) as demonstrated by Farnsworth et al. (2002). To avoid violating assumption 1 (that birds are not moving during the count), investigators may want to use counts of short duration (e.g. 3 min). The model framework can be applied to counts divided into intervals of different length (Farnsworth et al. 2002), but the mathematical formulations are simpler with equal time intervals.

In addition, counts should be designed to include a measure of the area sampled or the distance to each bird detected. If fixed-radius counts are used, the size of the radius must be chosen such that a bird that vocalizes within the radius can be detected by the observer. Too large a radius will mean that birds near the edge (farthest from the point, but within the radius) will have very low, perhaps zero probability of detection even if they vocalize. Too small a radius will unnecessarily reduce the number of birds used in analyses. Most point count surveys are designed to count many different species at the same time. Some of the species recorded will have loud vocalizations and some faint vocalizations. In such situations, it may be useful to assign birds detected into several distance categories. This would allow data to be analyzed as fixed-radius counts of different size for different species. Of course assigning birds detected into many distance categories also allows for analyses that model the decline in detection probability with increasing distance from the point such as distance sampling and the hybrid model described here.

Overall we recommend future point count surveys to record the additional information necessary to apply these existing and emerging statistical models. The best way to apply these principles will depend on the needs and goals of specific projects, but we offer the following rules of thumb to help design new count protocols. (1) Separate the count period into three or more time-intervals of equal length. (2) Record the distance to each bird detected. This may be done by assigning each bird detected into one of several (e.g. four) distance categories. For example, we recommend a ten-minute count separated into five intervals of two min each with birds identified as first detected in one of these distance categories: 0 – 25 m, 25 – 50 m, 50 – 100 m, and >100 m from the point. Such counts could be performed with one observer or could employ the double observer frame-work by having the primary observer conduct the count as above and the secondary observer record additional birds not detected by the primary observer. The above distance categories are provided as a suggestion designed to provide easily conducted counts that are appropriate for a variety of species (with loud and faint vocalizations). Focused studies targeting particular species may benefit from different distance categories.

We agree with the many recent recommendations to stop using unadjusted point counts for drawing inferences about landbird populations. There are now several methodological approaches to estimation of detection probability that should provide estimates of avian abundance and density superior to those based on unadjusted counts. These model-based approaches include distance sampling, multiple observers and temporal removal modeling. Unlike distance sampling and multiple observers, the temporal removal approach permits estimation of detection probability in a manner that includes the probability that a bird in the sampled area vocalizes. Combination methods that include two or more of the above approaches are currently under development and should provide additional modeling flexibility and estimator robustness as demonstrated here. We believe that avian ecologists should avoid using unadjusted point counts in favor of model-based methods such as those described here. We look forward to the next several years, as avian ecologists gain experience with these methods and biometricians develop a suite of methods and associated inference procedures. We expect such efforts to yield increased knowledge of avian population dynamics and increased ability to make wise management and conservation decisions.

Acknowledgments

We thank J. Hines for his expert help with the code necessary to run SURVIV. An explanation of the removal model with examples of SURVIV code may be found at the website: http://www.mbr-pwrc.usgs.gov/software/CountRemoval.html.

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Appendix 1

The expected number of birds counted during the jth time interval ($X_{.j}$) within a ring defined as the area between the distance r and $r + dr$ from the observer may be expressed as:

$$E(X_{.j}) \quad N_r p(1-p)^{j-1} \quad DA_r p(1-p)^{j-1}$$

$$D\pi\left[(r+dr)^2 - r^2\right] P_a \exp\left(\frac{-r^2}{\sigma^2}\right)\left[1 - P_a \exp\left(\frac{-r^2}{\sigma^2}\right)\right]^{j-1}$$

where N_r is the population of birds within the ring, A_r is the area of the ring, and D is the density of birds. The probability a bird is detected in the time interval is p, which is a function of the probability a bird vocalizes (P_a) that declines with increasing distance from the observer according to the parameter σ. If dr is very small relative to r, then dr^2 can be ignored yielding:

$$E(X_{.j}) = D\pi 2rP_a \exp\left(\frac{-r^2}{\sigma^2}\right)\left[1 - P_a \exp\left(\frac{-r^2}{\sigma^2}\right)\right]^{j-1} dr$$

The ith distance category is defined as the ring formed between the distances r_{i-1} and r_i (with $r_0 = 0$) from the observer. Thus the expected number of birds counted within the ith distance category during the jth time interval is:

$$E(X_{ij}) \quad \int_{r_{i-1}}^{r_i} D\pi 2rP_a \exp\left(\frac{-r^2}{\sigma^2}\right)\left[1 - P_a \exp\left(\frac{-r^2}{\sigma^2}\right)\right]^{j-1} dr$$

This model will work for any number of time intervals and distance categories. In the following example, we consider only the simple case with two time intervals and two distance categories: (1) from the observer to r_1 and (2) from r_1 to ∞. The expected value of the number of birds counted in the first time interval within r_1 of the observer (X_{11}) is:

$$E(X_{11}) \quad \int_0^{r_1} D\pi 2rP_a \exp\left(\frac{-r^2}{\sigma^2}\right) dr \quad D\pi P_a \sigma^2 \left[1 - \exp\left(\frac{-r_1^2}{\sigma^2}\right)\right]$$

and the expected value for the number of birds counted in the first time interval beyond r_1 of the observer (X_{21}) is:

$$E(X_{21}) \quad D\pi P_a \sigma^2 \left[\exp\left(\frac{-r_1^2}{\sigma^2}\right)\right]$$

The expected values of the number of birds counted in the second time interval (X_{12} and X_{22}) are:

$$E(X_{12}) \quad D\pi P_a \sigma^2 \left[1 - \exp\left(\frac{-r_1^2}{\sigma^2}\right) + P_a \frac{\exp\left(\frac{-2r_1^2}{\sigma^2}\right)}{2} - \frac{P_a}{2}\right]$$

$$E(X_{22}) \quad D\pi P_a \sigma^2 \left[\exp\left(\frac{-r_1^2}{\sigma^2}\right) - P_a \frac{\exp\left(\frac{-2r_1^2}{\sigma^2}\right)}{2}\right]$$

The expected total number of birds detected during the entire count (X..) is the sum of the four expected values above:

$$E(X..) \quad D\pi P_a \sigma^2 \left[2 - \frac{P_a}{2}\right]$$

In order to estimate the parameters P_a and σ, we must find the conditional probabilities of each of the four sufficient statistics. We do this by finding the probability a bird is a member of X_{ij} given that it is a member of X.. The advantage of this is that the unknown parameter D can be removed from the equations (to be calculated later). The result is:

$$\pi_{11} \quad P(y \in X_{11} \mid y \in X..) \quad \frac{1 - \exp\left(\frac{-r_1^2}{\sigma^2}\right)}{2 - \frac{P_a}{2}}$$

$$\pi_{12} \quad P(y \in X_{12} \mid y \in X..) \quad \frac{1 - \exp\left(\frac{-r_1^2}{\sigma^2}\right) + \frac{P_a}{2}\exp\left(\frac{-2r_1^2}{\sigma^2}\right) - \frac{P_a}{2}}{2 - \frac{P_a}{2}}$$

$$\pi_{21} \quad P(y \in X_{21} \mid y \in X..) \quad \frac{\exp\left(\frac{-r_1^2}{\sigma^2}\right)}{2 - \frac{P_a}{2}}$$

$$\pi_{22} \quad P(y \in X_{22} \mid y \in X..) \quad \frac{\exp\left(\frac{-r_1^2}{\sigma^2}\right) - \frac{P_a}{2}\exp\left(\frac{-2r_1^2}{\sigma^2}\right)}{2 - \frac{P_a}{2}}$$

The conditional multinomial probability density function is:

$$f(X_{11},X_{12},X_{21},X_{22}) = \frac{X..!}{X_{11}!X_{12}!X_{21}!X_{22}!}(\pi_{11})^{X_{11}}(\pi_{12})^{X_{12}}(\pi_{21})^{X_{21}}(\pi_{22})^{X_{22}}$$

The values for P_a and σ that maximize the following likelihood function

$$L(P_a, \sigma \mid X_{11}, X_{12}, X_{21}, X_{22}) \propto (\pi_{11})^{X_{11}}(\pi_{12})^{X_{12}}(\pi_{21})^{X_{21}}(\pi_{22})^{X_{22}}$$

represents the maximum likelihood estimates for these two parameters. Program SURVIV may be used to find these maximum likelihood estimates with associated estimates of their variances. These estimates of P_a and σ may then be combined with X.. and the total number of counts conducted (n) to estimate density (D):

$$\hat{D} \quad \frac{\text{X..}}{\text{n}\pi\hat{\sigma}^2\left(2\hat{P}_a - \frac{\hat{P}_a^2}{2}\right)}$$

If $\hat{\sigma}$ is represented in meters, then $\hat{D}$ above will have units birds per m^2. Converting this estimate of density to birds per Ha is thus:

$$\hat{D} \quad \frac{\text{X..}}{\text{n}\pi\hat{\sigma}^2\left(2\hat{P}_a - \frac{\hat{P}_a^2}{2}\right)} \times 10{,}000$$

Generalized Linear Models and Point Count Data: Statistical Considerations for the Design and Analysis of Monitoring Studies

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Abstract

The success of avian monitoring programs to effectively guide management decisions requires that studies be efficiently designed and data be properly analyzed. A complicating factor is that point count surveys often generate data with non-normal distributional properties. In this paper we review methods of dealing with deviations from normal assumptions, and we focus on the application of generalized linear models (GLMs). We also discuss problems associated with overdispersion (more variation than expected). In order to evaluate the statistical power of these models to detect differences in bird abundance, it is necessary for biologists to identify the effect size they believe is biologically significant in their system. We illustrate one solution to this challenge by discussing the design of a monitoring program intended to detect changes in bird abundance as a result of Western juniper (*Juniperus occidentalis*) reduction projects in central Oregon. We estimate biologically significant effect sizes by using GLMs to describe variation in bird abundance relative to natural variation in juniper cover. These analyses suggest that for species typically positively associated with juniper cover, a 60-80 percent decrease in abundance may be expected as a result of juniper reduction projects. With these estimates of expected effect size and preliminary data on bird abundance, we use computer simulations to investigate the power of GLMs. Our simulations demonstrate that when data are not overdispersed and sample sizes are relatively large, the statistical power of GLMs is approximated well by formulas that are currently available in the bird literature for other statistical techniques. When data are overdispersed, as may be the case with most point count data, power is reduced.

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Key words: Generalized linear models, juniper removal, monitoring, overdispersion, point count, Poisson.

Introduction

Measuring changes in bird abundance over time and in response to habitat management is widely recognized as an important aspect of ecological monitoring (Greenwood et al. 1993). The use of long-term avian monitoring programs (e.g., the Breeding Bird Survey) to identify population trends is a powerful tool for bird conservation (Sauer and Droege 1990, Sauer and Link 2002). Short-term studies comparing bird abundance in treated and untreated areas are also important because they can identify changes in bird responses to specific management actions (Nichols 1999). However, the ability of avian monitoring programs to effectively guide management decisions requires that studies be designed to detect differences that are biologically meaningful.

The statistical ability to detect differences in abundance between two treatments (e.g., habitats or management practices) is described by statistical power. To evaluate power one must answer two questions. (1) What statistical models are appropriate for the distributional properties of the data? Probably the most widely used method for monitoring bird abundance is point count surveys (Ralph et al. 1995). However, the properties of data produced from point counts may violate assumptions of commonly used statistical techniques. Count data often show non-normal distributions, especially when abundances are low and there are many zeros in the data. One approach to analyzing these data is to use generalized linear models. With such models, one may specify non-normal distributions and results can be interpreted in a manner similar to the familiar analysis of variance framework. (2) What is a biologically meaningful effect size? That is, what difference in abundance can be considered biologically, not just statistically, significant? Once these two questions have been answered, power analyses can be carried out to identify the appropriate sampling effort needed for a rigorous study design (Nur et al. 1999, Foster 2001).

In this paper we discuss some properties of count data with an emphasis on how they can be analyzed with generalized linear models. We then use these models to analyze point count data from central Oregon and evaluate variation in bird abundance as a function of natural variation in Western juniper (*Juniperus occidentalis*) cover. We use the results to define a biologically significant effect of juniper removal and conduct computer simulations to investigate the power of generalized linear models to detect changes in bird abundance resulting from reduction of juniper cover. Our objective is to illustrate how the design of monitoring projects based on point count data can be improved by the definition of *a priori* effect sizes, the application of generalized linear models, and attention to the distributional properties of the data.

Distributional Properties of Count Data

The fixed-radius point count method of measuring bird abundance generates count data (i.e., the number of birds at a station). The distribution of such data is bounded by zero because one cannot detect a negative number of birds. If stations are visited once, the number of individuals detected per station will always be either zero or a positive integer. When bird abundances are low, the frequency distribution of detections is likely to be highly non-normal (right-skewed, with a majority of observations at or near zero). If this is the case, then the use of statistical tests that assume normal distributions (e.g., t-tests, least-squares regressions) may be inappropriate. Perhaps the simplest approach to comparing patterns of abundance measured by point counts is to use tests that are more flexible about the distributional properties of the data. Such approaches include non-parametric tests (Sokal and Rohlf 1995, Zar 1999) or resampling tests that use permutations of the data to make statistical inferences (Manly 1991, Crowley 1992).

Another approach is to transform the data such that they meet assumptions of statistical methods based on the normal distribution. Such transformations must fulfill two objectives: they must standardize the shape of the distribution to the normal curve and decouple any relationship between the mean and variance. Often, square-root or log transformations are suggested for Poisson distributed count data, in which the variance increases with the mean (Sokal and Rohlf 1995, Kleinbaum et al. 1998, Zar 1999). When counts contain zeros, a constant must be added prior to log transformation, and is often suggested for square root transformation. Values of 0.5 or 3/8 for this constant are suggested (Sokal and Rohlf 1995, Zar 1999), but should be used with the recognition that the choice of constants may have implications for statistical estimation (Thomas and Martin 1996).

An alternative to nonparametric statistics or data transformations is the use of statistical techniques in which non-normal distributions can be specified. Generalized linear models (GLMs) are a flexible and widely used class of such models that can accommodate continuous, count, proportion, and presence/absence response variables (McCullagh and Nelder 1989, Agresti 1996, Crawley 1997, Dobson 2002). Many statistical packages (e.g., SAS, SPSS) implement these models for logistic, Poisson, and negative binomial regression. Although the application of GLMs to point count data is not new (Link and Sauer 1998, Brand and George 2001, Robinson et al. 2001), we review these models here to provide the context for our estimates of effect size and power.

Generalized Linear Models

The models with which biologists are most familiar are linear models of the form

$$y = b_0 + b_1x_1 \ldots + b_jx_j + e$$

where the first part of the right-hand side of the equation ($b_0 + b_1x_1 \ldots + b_jx_j$) specifies the expected value of y given $x_1 \ldots x_j$. This is called the 'mean' or 'systematic' part of the equation and contains a linear combination of x variables. The random component of the model (denoted by e), describes the deviation of the observed y values from the expected, and is assumed to be drawn from a normal distribution with constant variance. Generalized linear models (GLMs) extend simple linear models by allowing transformations to linearity in the mean part of the model, as well as non-normal random components (Agresti 1996). If *mu* is the expected value of y, then we can model not *mu* itself, but some function $f(mu)$ of the expected value

$$f(mu) = b_0 + b_1x_1 \ldots + b_jx_j$$

The function $f(mu)$ is called the link function. For the simple linear model above, the link function is $f(mu) = mu$. An alternative for loglinear models is to use a log link function, $f(mu) = \log(mu)$. Our model now becomes

$$\log(mu) = b_0 + b_1x_1 \ldots + b_jx_j$$

What about the random component of such a model? For count data, the random component is often likely to follow a Poisson distribution (Zar 1999), a distribution of integers between zero and infinity. The best-fit model is found by maximum likelihood techniques rather than minimizing the sums-of-squares. For a GLM with Poisson error, the usual link function is

log(*mu*) as above. Note that when the parameter estimates b_0 ... b_j are used to calculate a predicted value for *y*, the formula is

$$mu = \exp(b_0 + b_1x_1 ... + b_jx_j)$$

A key property of the Poisson distribution is that the variance equals the mean. This means that, for any given value of *mu*, the distribution of observed *y* should have a variance of *mu*. That is, Variance(*y*) = *mu*. If, instead, we observe that Variance(*y*) > *mu*, the data are overdispersed. Conversely, if Variance(*y*) < *mu*, the data are underdispersed.

Overdispersion is often caused by differences among data not accounted for by the model. Suppose the number of individuals of a particular species at a count site depended on both the treatment (burned vs. unburned) and the topography (slope) of the site. Unaware of this, we simply model the dependence of the count on the treatment alone. The remaining variation among sites accounted for by slope is thus ignored, and leads to greater variance in the data than expected in our Poisson GLM. The major problem associated with overdispersion is an inflated risk of Type I error (see below). When faced with such a problem, one solution is to calculate an overdispersion parameter, and multiply it with the estimated standard errors - thus increasing the 95 percent confidence intervals around the estimated parameters, b_0 - b_j, describing the treatment effects (Agresti 1996). Alternatively, one may specify a distribution that can incorporate the extra variance that cannot be accommodated by a Poisson distribution. One of the most common distributions for this application is the negative binomial (Crawley 1997). The negative binomial distribution has an extra parameter (*k*) that describes dispersion. As *k* approaches 0, there is less overdispersion and the negative binomial distribution approaches a Poisson distribution.

Apart from affecting Type I error, the distributional properties of count data have important implications for understanding our statistical ability (i.e., power) to detect differences in bird abundance of two areas that are compared.

Statistical Power: A Brief Review

Although the topic of statistical power as it applies to wildlife ecology has been addressed by others (e.g., Steidl et al. 1997 and Nur et al. 1999), we briefly review the concept to provide the reader with definitions of terms that we use throughout this paper. The backbone of conventional (i.e., frequentist) hypothesis testing is the evaluation of null hypotheses. If the null is rejected, then we conclude, for example, that there is a true difference between groups. Conversely, while failure to reject the null means that there is insufficient evidence of a true difference, it does not imply that the treatments are the same (Johnson 1999). Statistical tests based on frequentist theory provide a tool to estimate the probability, if the null hypothesis was true, of obtaining data as or more extreme than that observed (this probability is called the P-value). Such tests are concerned with two possible errors: Type I error and Type II error.

Type I error is the probability of rejecting the null when the null is true. This probability is usually represented by alpha (α), and for most tests the criteria for statistical significance is, by convention, $\alpha = 0.05$. Traditionally, there has been a strong emphasis on statistical hypothesis testing and the 0.05 critical value, but the arbitrary nature of critical values has been criticized (Johnson 1999, Anderson et al. 2000). Type II error represents the probability of failing to reject the null when the null is truly false, and is represented by beta (β). Beta is usually discussed in the context of power, defined as $1-\beta$, the probability of detecting a difference when one in fact exists. For most studies, power of >80 percent is considered acceptable (Nur et al. 1999), but like the 0.05 value for alpha, this threshold is arbitrary (Di Stefano 2003). Ideally, one should minimize both α and β, but because these are inversely related, a compromise must be reached. Alpha and beta are determined by distributional characteristics of the data, including the dispersion of the data, magnitude of difference we want to detect (i.e., effect size), and sample size.

A fundamental question that must be asked when calculating power concerns the magnitude of effect to be detected (Nur et al. 1999, Lenth 2001). In the context of point counts and management, an effect size would be the difference in bird abundance between managed and unmanaged habitats. If the hypothesized effect is large, then high power can be achieved with a relatively low sample size; alternatively, if the effect is small, then a larger sample size will be needed to achieve the same power. The difficulty comes in establishing *a priori* what effect size is important (Cohen 1988, Lenth 2001). Although a number of authors have addressed the issues of statistical power for detecting differences among treatments surveyed by point counts (Dawson 1981, Barker and Sauer 1995, Aigner et al. 1997, Nur et al. 1999), there has been little discussion of what should constitute a biologically significant change in abundance. Unfortunately, there is no simple rule of thumb that can be applied to all studies or all species. When population changes are of concern, modeling may be useful for generating estimates of change that would threaten the ability to meet management objectives. For example, population viability analyses may identify a threshold density below which the probability of extirpation increases. When

such a threshold is available, then a biologically significant effect could be defined as one that would drop the population density below this threshold. In other cases, the goal of monitoring may be to evaluate whether or not a management treatment has achieved the desired ecological conditions. In such cases a pilot study describing the response variable as a function of natural variation in the habitat component of management interest may provide valuable information on the expected effect of biological interest. In the sections below we have illustrated such an approach.

To design an effective monitoring study, then, one must first determine the magnitude of the effect we consider important, and then find the sample size necessary to detect such an effect size at a given level of statistical power.

GLMs and the Design of Monitoring Studies

To illustrate the application of generalized linear models to the design of bird monitoring, we present an analysis of data collected at point count stations in the Upper Klamath basin of Oregon. In this area, the Oregon Bureau of Land Management (BLM) is concerned with Western juniper encroachment into sagebrush habitat and has implemented juniper control through mechanical removal of juniper trees. The goal is to restore pre-encroachment conditions. In conjunction with BLM, the Klamath Bird Observatory is designing monitoring programs to evaluate ecological effects of juniper removal treatments based on changes in abundance of bird species that serve as indicators of desired habitat conditions. Here we illustrate the use of generalized linear models to (1) identify which species show patterns of abundance that are associated with natural variation in juniper cover, (2) generate an estimate of the expected effect of juniper removal based on this response, and (3) estimate the required sample size to detect this difference between treated and untreated stations.

Methods and Results

Estimating Expected Effect Size

Data Collection and Analysis

In May and June 2002, bird abundance was measured using standardized point count survey methodologies (Ralph et al. 1993) at 78 stations that had not received juniper reduction treatments. Five-minute counts were conducted between sunrise and 1000 PDT at each station; all landbirds seen or heard within 50 m of the station were recorded. Vegetation data were collected at each station using a relevé method (Ralph et al. 1993). These stations had no tree cover other than *Juniperus occidentalis*. Juniper cover was classified into two categories: high (>25 percent cover) and low (0-25 percent cover). Previous studies have shown changes in bird community composition occur when juniper cover is >30 percent (Holmes and Barton 2002), thus we considered this a biologically relevant classification. We restricted our analyses to the five most abundant bird species which had detections at >5 stations in both high and low juniper areas.

To evaluate the ability of juniper cover (our variable of biological interest) to explain variation in bird abundance, we fit GLMs with Poisson distributions and log links with juniper cover (high and low) as a categorical predictor variable. Such an analysis is often referred to as "Poisson regression" and is discussed at length in both GLM texts (McCullagh and Nelder 1989, Dobson 2002) and more general texts on regression (Kleinbaum et al. 1998). We used the Pearson chi-squared statistic to evaluate overdispersion (Agresti 1996). When we found evidence of overdispersion, we refit the models with a negative binomial distribution and log link. All statistical tests were conducted with SAS (PROC GENMOD).

GLM Results

Model results for the five species are presented in *table 1*. The first step in interpreting GLM results is to review the output for evidence of overdispersion. In the absence of overdispersion the Pearson chi-square statistic should be approximately equal to the residual degrees of freedom (number of observations minus number of model parameters; Agresti 1996). Statistical evidence of overdispersion can be evaluated by computing the probability of obtaining the observed Pearson chi-square statistic from a chi-square distribution with an expected mean equal to the residual degrees of freedom; small P-values provide evidence of poor model fit (Agresti 1996). For our data, most models using juniper cover as an explanatory variable were overdispersed; the only species for which the P-value of the Pearson chi-square statistic was >0.05 was the American Robin (*for scientific names see table 1*). Therefore, caution is warranted when interpreting the significance of parameter estimates.

Because counts of American Robins were not significantly overdispersed, the effect of habitat can be interpreted from the Poisson model. For this species, the habitat parameter was significantly different from zero (P = 0.002), evidence of a difference between the mean number of individuals detected at station of low and high juniper cover. For the remaining four species, we refit the models using a negative binomial distribution. Three fit the negative binomial model well (*table 1*). Only the Mountain Chickadee still showed a

Pearson statistic with a low P-value (P = 0.055) suggesting a lack of fit. The mean parameter estimates for the Poisson and negative binomial models are the same, but the confidence intervals are re-scaled to account for the additional variance. Using the negative binomial model, only one of these four species that all showed a significant effect of juniper cover with the Poisson model still showed a significant effect at the alpha = 0.05 level (*table 1*). The only species that retained a significant effect of juniper cover was the Chipping Sparrow (*table 1*), although the estimates for Mountain Chickadees and Gray Flycatcher approached the 0.05 criterion (*table 1*).

The parameter estimates of the model can be used to calculate the expected (mean) number of birds per station in high and low juniper cover (*table 2*). For example, the predictive equation for the number of American Robins detected per point is:

$$mu = \exp(-2.30 + 1.61x)$$

where x is 0 when juniper cover is ≤25 percent and 1 when juniper cover is >25 percent. Thus, there was an average of 0.10 individuals per station in areas with low juniper cover, and five times that number (0.5 individuals per station) at stations with high juniper cover.

Table 1– *Generalized linear model (specifying Poisson or negative binomial distributions and log link) results for the five most commonly detected bird species at 78 stations surveyed in 2002 in the Lakeview District of the Oregon Bureau of Land Management. The variable "Habitat" is coded 0 for stations with low (0-25%) juniper cover and 1 for stations with high (>25%) juniper cover. Thus exp(Intercept) is the mean abundance at low cover and exp(Intercept+Habitat) is mean abundance at high cover.*

		Poisson			Negative binomial		
Species	**Parameter**	**Estimate**	**SE**	**P-value**	**Estimate**	**SE**	**P-value**
Gray Flycatcher	Intercept	-1.61	0.29	<0.001	-1.61	0.42	<0.001
(*Empidonax wrightii*)	Habitat	1.12	0.42	0.008	1.12	0.61	0.094
	Dispersion (*k*)	na	na	na	3.76	2.13	
	Pearson chi-square	161.18		<0.001	83.09		0.270
	Df	76			76		
Mourning Dove	Intercept	-2.02	0.35	<0.001	-2.02	0.52	<0.001
(*Zenaida macroura*)	Habitat	1.20	0.50	0.016	1.20	0.94	0.200
	Dispersion (*k*)	na	na	na	8.67	5.28	
	Pearson chi-square	188.00		0.000	75.34		0.500
	DF	76			76.00		
Mountain Chickadee	Intercept	-2.30	0.41	<0.001	-2.30	0.69	<0.001
(*Poecile gamboli*)	Habitat	1.61	0.53	0.002	1.61	0.89	0.069
	Dispersion (*k*)	na	na	na	9.43	6.11	
	Pearson chi-square	215.00		0.000	96.71		0.055
	DF	76			76		
American Robin	Intercept	-2.30	0.41	<0.001	Not needed		
(*Turdus migratorius*)	Habitat	1.61	0.53	0.002			
	Dispersion (*k*)	na	na	na			
	Pearson chi-square	95.00		0.069			
	DF	76					
Chipping Sparrow	Intercept	-2.15	0.38	<0.001	-2.15	0.44	<0.001
(*Spizella passerina*)	Habitat	1.34	0.52	0.010	1.34	0.60	0.030
	Dispersion (*k*)	na	na	na	2.89	2.32	
	Pearson chi-square	102.64		0.023	66.65		0.770
	DF	76			76		

Table 2—*Distributional properties and effect sizes used in the power analyses for the four species with a significant (P < 0.10) difference in abundance between areas of low and high juniper cover. Mean abundance was predicted from GLM results (table 1). Standard deviations were calculated from raw data in each cover class. Percent difference is calculated as:* $[(\mu_{high\ juniper}-\mu_{low\ juniper})/\mu_{high\ juniper}] \times 100$. *Dispersion parameters were estimated with a generalized linear model specifying a log-link and negative binomial error distribution.*

Species	Predicted mean abundance (SD)		Percent difference	Dispersion parameter (*k*)
	Low juniper	High juniper		
Gray Flycatcher	0.20 (0.66)	0.61 (1.10)	67%	3.76
Mountain Chickadee	0.10 (0.54)	0.50 (1.10)	80%	9.43
American Robin	0.10 (0.35)	0.50 (0.78)	80%	na
Chipping Sparrow	0.12 (0.37)	0.44 (0.92)	74%	2.89

Estimating Required Sample Size: Power Analysis

Given our estimates of the magnitude of the effect that juniper removal might have on bird populations, what sampling intensity must be used to detect whether these effects actually occur? Power analysis software is now widely available, but nearly all are based on statistical designs that assume normality (e.g., ANOVA, t-test, linear regression). We were not aware of a widely available software package that could be used to perform power analysis for Poisson regression. Thus, given the distributional properties of the pilot data, we used a simple Monte Carlo simulation to investigate how the statistical power to detect our expected effects varied with sample size.

Power Analysis Methods

For our power analysis, we assumed that the difference between bird abundance in areas of high and low juniper cover reflects the magnitude of change we would expect to see if juniper removal treatments across a similar range of cover classes were indeed having the desired ecological effects on bird abundance. We defined this effect size as:

$$\text{Effect size} = (\mu_{\text{high juniper}} - \mu_{\text{low juniper}})/\mu_{\text{high juniper}}$$

This effect size can be expressed as a percent difference by multiplying it by 100. Calculated effect sizes for the four species with significant habitat parameters are presented in *table 2*. For example, American Robin abundance is predicted to be 80 percent lower in areas of low juniper cover compared to where juniper cover is high. Thus, we might consider this an estimate of the predicted effect on American Robins if management activities generate a similar change in juniper cover.

We compare three methods of calculating power. First, we used an analytical equation for calculating the power for detecting a difference between means of point count data from two treatments presented by Dawson (1981):

$$\textit{number of stations} > (b \times 20000)/(d^2 \times m)$$

where b is a value that corresponds to the desired power (3.84 for 50 percent, 6.15 for 70 percent, 7.84 for 80 percent, and 10.50 for 90 percent; Nur et al. 1999), and d is the percent difference between the groups, defined as:

$$d = 100 \times [(m_1 - m_2)/m]$$

where m_1 and m_2 are the means in each treatment category and m is the overall mean for both areas. This formula assumes that the variance equals the mean (as in a Poisson distribution), but generates the estimate of power based on Z scores.

We compared this estimate with two Monte Carlo simulations. The first assumed that bird detections were normally distributed and compared populations with a t-test. Although this approach ignores the distributional properties of count data, it offers an approximation of power calculations that would be available in most power analysis software that are based on statistical designs that assume normality. In these simulations, "control" data were generated by drawing values from a normal distribution with the estimated mean and standard deviation of bird detections at stations with high juniper cover (*table 2*). "Treatment" data were generated from a normal distribution with a mean and standard deviation that were reduced by the effect size generated by our earlier analysis (*table 2*; we assume the standard deviation scales linearly with the mean). To statistically test for differences between our simulated control and treatment data, we used a two-tailed t-test. We rejected the null hypothesis of no difference in means between high and low juniper areas when $P < 0.05$ for the habitat parameter.

Our second Monte Carlo procedure provided a more realistic simulation of the generation and analysis of count data. Data were generated by drawing from

either a Poisson distribution (American Robin) with a single parameter representing the mean, lambda (λ), or a negative binomial distribution (Chipping Sparrow, Mountain Chickadee, and Gray Flycatcher) with mean parameter (*p*) and a scale parameter (*k*) to simulate overdispersion. In both cases, the distributional parameters (λ or *p* and *k*) were estimated from the generalized linear model analysis (*table 1*) and are presented in *table 2*. To statistically test for differences between our simulated control and treatment data, we used a generalized linear model specifying a log link and Poisson or negative binomial distribution. Again, we rejected the null hypothesis of no difference in means between high and low juniper areas when $P < 0.05$ for the habitat parameter.

In both cases these simulations were repeated 100 times for each sample size (varied in increments of 1) across the range of necessary sample sizes suggested by the Dawson (1981) equation. Power was calculated as the percent of trials in which the null hypothesis was rejected. All simulations were performed in R (R Development Core Team 2003) and code is available upon request from the authors.

Power Analysis Results

For the American Robin, we investigated the sample size required to detect an 80 percent reduction in abundance from the estimated mean of 0.5 individuals per station at high juniper cover sites. The estimates of the Dawson equation and the approximation based on an assumption of normality provided similar results (*Fig. 1*). When the sample sizes were large and power >80 percent, our Poisson GLM simulations gave similar estimates to the other two methods. However, when sample sizes were small, the Dawson equation and the assumption of normality both overestimated power compared with our simulated trials with the Poisson GLM (*fig. 1*). When data were overdispersed, the Dawson equation consistently overestimated power at small sample sizes, but usually converged with the GLM estimations as sample size increased. In contrast, simulations based on an assumption of normality typically produced estimates of power that were similar to the GLM estimates when sample sizes were small, but consistently underestimated power at larger sample sizes (*fig. 1*).

We found that in order to achieve 60-80 percent power to detect a change in the bird species we examined one would require surveys of 30 to 50 stations each in control and treatment areas. Overdispersion reduced power. A comparison is provided by American Robins and Mountain Chickadees, which shared the same abundance in treated and untreated areas, but Mountain Chickadees were overdispersed (*table 2*). Accordingly, the power to detect a difference for Mountain Chickadee was consistently lower than for American Robin (*fig. 1*). This difference was not accommodated by the Dawson equation (*fig. 1*).

Discussion

Fixed-radius point counts generate count data that, even after transformation, are often non-normally distributed. As a result, using statistical tests that assume normality may be inappropriate. Here, we have illustrated the application of generalized linear models to designing monitoring studies and analyzing point count data. These models are an effective alternative to nonparametric statistics because they generate estimates of means with Poisson or negative binomial distributions. These distributions can be used as the basis of simulations for modeling or power analysis. However, overdispersion is common and its statistical consequences are important to consider. If ignored within the context of Poisson regression, overdispersion inflates the risk of Type I error. Using Poisson regression results without considering overdispersion, we would have concluded that all six species showed a significant effect of juniper cover at the $\alpha = 0.05$ level (*table 1*). After correcting for overdispersion, only two showed an effect of juniper cover at the $\alpha = 0.05$ level.

Overdispersion will also affect power. Failing to account for overdispersion leads to artificially high estimates of power. As recognized in the original presentation (Dawson 1981) and reiterated more recently (Nur et al. 1999), the Dawson equation assumes that data are Poisson distributed. Our approach differs from previous estimates of power for treatment comparisons using point counts (e.g., Dawson 1981, Aigner et al. 1997) because we used computer simulations to generate data sets from Poisson or negative binomial distributions that more closely mimicked actual data generated by single-visit point counts. Using this approach, we have shown that the equation of Dawson (1981) tends to overestimate power relative to our simulated estimates of power for Poisson or negative binomial data analyzed with GLMs. This problem is most extreme when sample sizes are small; we conclude that the Dawson equation should not be used to estimate power of GLMs when the sample size will be small. The Dawson equation does not account for overdispersion, thus it will always overestimate power when data are overdispersed. Similarly, using power analyses that assume normal distributions may also produce erroneous results. One of the advantages of GLMs is that they provide a means of describing the dispersion of data and evaluating power with distributions that are appropriate for count data.

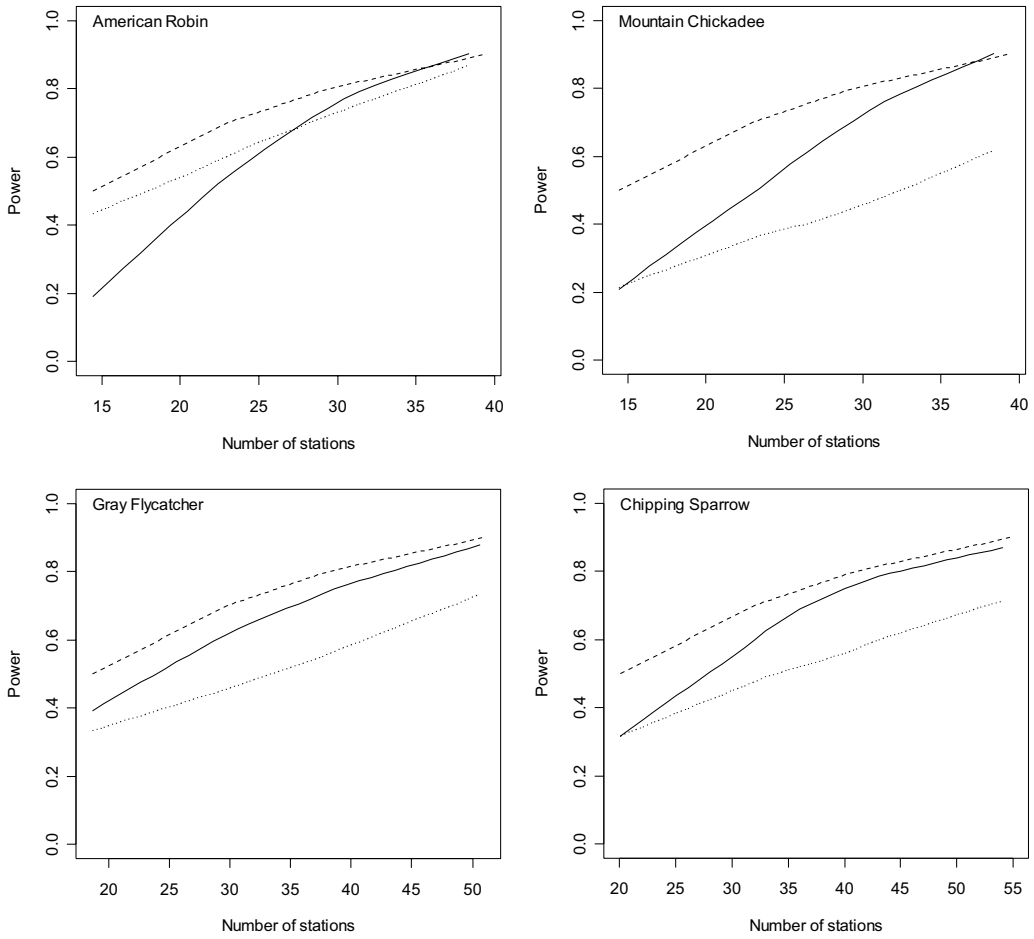

Figure 1—The effect of sample size (number of stations per treatment) on the estimated power to detect the difference in bird abundance between areas with and without juniper removal. Simulations increased sample size in increments of 1. Lines represent smoothed curves; simulations were run 100 times for each sample size. Dashed lines are estimates generated by the Dawson (1981) equation, dotted lines are based on simulations assuming normal distributions, and solid lines are based on simulations using Poisson or negative binomial distributions. Differences between treated and untreated areas and the normal, Poisson, and negative binomial parameters used to generate the simulations are presented in *table 2*.

When monitoring programs are designed with hypothesis testing as one of the goals, statistical power must be considered. Without consideration of power, monitoring programs risk inconclusive results that are unable to guide management decisions. To calculate statistical power for a given sample size, one must have a hypothesized or expected effect size in mind. We encourage ornithologists and managers to devote more effort to carefully considering the magnitude of effects that may have important biological implications. As one approach to estimating a biologically significant effect size, we have analyzed patterns of bird abundance relative to natural variation in juniper cover. This analysis suggests that the most common species in these habitats may exhibit relatively large changes in abundance (60-80 percent). Such information is valuable because it can be used to evaluate the statistical efficacy of monitoring designs to meet their objectives. Indeed, this information should be used to design monitoring projects before they begin.

Even with the modest sample size of our pilot data, we detected significant variation in the abundance of American Robins and Chipping Sparrows associated with natural variation in juniper cover. This difference suggests that these species will serve as useful indicators of the ability of juniper removal management activities to achieve the desired habitat conditions in these ecosystems. By generating an understanding of the strength with which these species are associated with natural variation in habitat conditions, these studies provide valuable information that can be used to generate and test hypotheses about the effect of habitat management activities.

Avian monitoring has the potential to be a useful tool for land managers throughout the world. However, for

this potential to be realized in an efficient manner, monitoring programs that aim to compare avian abundance in different habitats or treatments must be designed in such a way that they achieve high power for statistical inference. When used and interpreted correctly, generalized linear models provide a powerful tool for detecting changes in avian abundance.

Acknowledgments

This project was funded by the Joint Fire Sciences Project and the Lakeview District of the Oregon Bureau of Land Management. Support and assistance for the project from P. Buetner was critical to its success. Field work was conducted by R. P. Chapman, D. P. Haupt, K. P. Gluckert, and D. Van den Broek. Comments from J. Bart, M. Chase, N. Nur, T. Okuyama and K. Sieving's lab group greatly improved the paper.

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A Conceptual Guide to Detection Probability for Point Counts and Other Count-based Survey Methods[1]

D. Archibald McCallum[2]

Abstract

Accurate and precise estimates of numbers of animals are vitally needed both to assess population status and to evaluate management decisions. Various methods exist for counting birds, but most of those used with territorial landbirds yield only indices, not true estimates of population size. The need for valid density estimates has spawned a number of models for estimating *p*, the ratio of birds detected to those present. Wildlife biologists can be assisted in evaluating these methods by appreciating several subtleties of *p*: (1) *p* depends upon the duration of the count, (2) *p* has two independent components, *availability* of cues and *detectability* of cues, (3) detectability is a function of both the *conspicuousness* of cues (e.g., vocalizations, conspicuous movements) and the *abundance* of cues, and (4) discontinuous production of cues lowers availability, which has a direct and sometimes profound effect on *p*. Two recently-updated methods of estimating *p*, double-observer sampling and distance-sampling, are better suited to estimating detectability, while two others, double sampling and removal sampling, are better suited to estimating availability. While none of the four offers a complete solution at present, hybrids are under development, and a technique that can yield estimates of availability and detectability from survey data may be available in the near future.

Key words: abundance of cues, availability, bird survey, census, conspicuousness, detectability, detection probability, distance sampling, double sampling, double-observer sampling, index ratio, point count, removal sampling.

Introduction

Unlike most fish, insects, and nocturnal mammals, birds are typically surveyed without capturing or marking individuals. A number of passive sampling techniques, e.g., spot-mapping, line transects, and point counts, are commonly used for estimating numbers of birds. A complete taxonomy of sampling and analytical methods is given by Thompson (2002). The accuracy and precision of most techniques currently used to count birds has been questioned, because of their failure to provide estimates of detection probability (Nichols et al. 2000, Bart and Earnst 2002, Farnsworth et al. 2002, Rosenstock et al. 2002, Thompson 2002).

Detection probabilities are used to account for "birds present but not detected" on surveys (Thompson 2002: 19). The importance of estimating detection probabilities for bird counts has long been recognized (Burnham 1981), but 95 percent of recent avian population studies surveyed by Rosenstock et al. (2002) relied on unadjusted counts (called "indices") for analysis and comparison. This practice assumes, tacitly or otherwise, that detection probability is constant across the entire sample (Thompson 2002). It is now widely suspected that this assumption is violated in a number of ways (Thompson 2002). If so, comparisons of index data obtained at different times and places may lead to erroneous conclusions. Adoption of new survey methods that accurately estimate detection probabilities would alleviate this concern.

The recent flurry of publications on detection probability (Nichols et al. 2000, Buckland et al. 2001, Bart and Earnst 2002, Rosenstock et al. 2002, Farnsworth et al. 2002, and especially Thompson 2002) suggests that changes in sampling techniques may be imminent. These authors advance four largely independent methods for estimating detection probabilities, but an independent comparison of them is not available.

The purpose of this paper is to assist biologists and managers in understanding the concepts underlying detection probability and to help them select from among these new methods for estimating detection probability for vocalization-based counts. Unlike the quite proper development of estimation techniques in the statistically focused publications that introduce these techniques, this survey will define a small set of heuristic parameters that will be used to describe and distinguish the methods, leading to recommendations based on logical and empirical considerations.

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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The Meaning of P

If the goal of a sampling technique is to estimate the number, *N*, of individuals present in an area from a sample count, *C*, of that area, (See Appendix for table of parameters and symbols.), the expected value of the count is given by $E(C) = Np$, where p is the "detection probability" (Nichols et al. 2000, Farnsworth et al. 2002) or "index ratio" (Bart and Earnst 2002). Use of *C* (raw count data) to estimate the change in *N* over time (i.e., trend), requires the "proportionality assumption" (Thompson 2002) that a trend in p does not exist (J. Bart, pers. com). Populations in different areas and populations counted with different methods cannot be compared quantitatively with indices (i.e., *C* values) (Bart and Earnst 2002). In order to make inferences from count data without "discomfort with the knowledge that such inferences depend upon untested assumptions" (Nichols et al. 2000: 394), it is necessary to estimate *N*, preferably with methods that are grounded in statistical theory (Thompson 2002).

The standard form of such an estimate is given by

$$\hat{N} \quad \frac{C}{\hat{p}} \qquad (1)$$

(Nichols et al. 2002, equation 4). These parameters apply to the birds of a sex, species, area, or indeed any group that has a common value of p (Nichols et al. 2000). *P* is the probability of detecting a typical individual. It can be thought of as the average detection probability of all the individuals that reside in the area being surveyed, although is it never estimated in this way. Instead, it is estimated from population parameters. $\hat{D}$, the estimated population density, can be calculated as $\hat{N}/A$, where A is the area in which counts were made.

All of the above is uncontroversial mathematically. The real issue is how to obtain the estimate $\hat{P}$ of the parametric detection probability p, so the estimate $\hat{N}$ can be calculated. The four methods reviewed here estimate p in different ways. The following points are helpful in understanding p, and thereby recognizing the differences in estimation methods.

1. p is specific to the duration of the count

The single holistic parameter p incorporates a variety of causes of non-detection, including the bird's being silent during the count, attenuation of signal(s), masking of a song by ambient physical noise, the sounds of non-target animals (e.g., insects), noise made by the observer(s), and ascribing the sound to the wrong species. Regardless of the sources of p, its expected value is C/N (Nichols et al. 2000), where C is the count obtained in a count of duration m. It follows that p varies with C, and therefore any value of p is specific to the duration m of the count period used to obtain C. *Figure 1* is a standard accumulation curve that shows the cumulative number of individuals, *C*, detected for any amount of effort, e.g., minutes (m) spent counting. According to this uncontroversial relationship, C is expected to be slightly higher in a 5-min point count than it is in a 3-min point count, and considerably higher in 2 hr of observation. The practice of sampling until the cumulative count of individuals in an area levels off is merely an empirical way to maximize detection of all birds present (but the longer the count period, the greater the likelihood of over counting, see below).

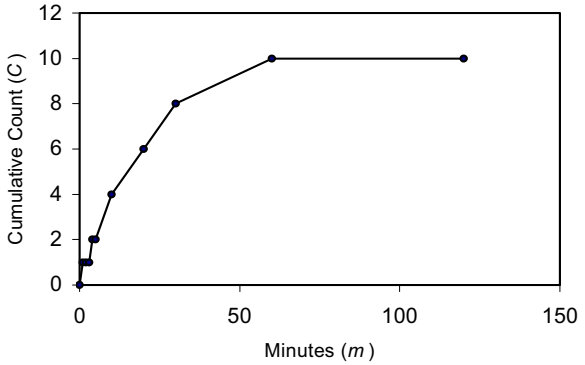

Figure 1—Hypothetical cumulative count (C) of individuals as a function of effort, e.g., minutes (m), in any kind of monitoring program. Detection probability, p = C/N, increases with effort (e.g., total person-minutes) until all individuals are counted.

The curve in *Figure 1* has the general form $p_m = 1-(1-p_{1m})^m$, where m is the duration of the count, p_m is estimated by C/N for counts of that duration, and p_{1m} is the detection probability for a 1-min count. For example, if C/N = 0.5 for 3-min counts, p_{1m} is 0.207. Once p_{1m} has been found, p_m for count periods of any duration, m, can be calculated, and applied as a correction factor to counts of that duration. This approach requires independent knowledge of N in the count areas in which p_m is estimated, as obtained with double sampling methods (Bart and Earnst 2002).

2. For aural surveys, p must estimate both "availability" and "detectability"

Although detectability of birds is a potentially a function of a number of factors, it is useful for aural surveys to subdivide p into two main components (Farnsworth et al. 2002):

$$p = p_s\, p_{d|s} \qquad (2)$$

where p_s is the probability that an average bird sings (or produces some other detectable cue) and $p_{d|s}$ is the probability it is detected, given that it sings. Recogniz-

ing the distinction between these two component probabilities, "availability" and "detectability," plays a central role in evaluating the four methods (see below). The next two sections explain each of these probabilities.

3. Detectability: Only one detection is required to count an individual

Unlike intensive survey methods, (e.g., territory-mapping, nest-finding protocols), "rapid survey" methods (e.g., point counts, line transects) define a single detection of an individual as sufficient to count that individual. Further detections of that individual do not change *C*. Indeed, count periods are intentionally made brief to minimize the possibility of double-counting of an individual (e.g., Buckland et al. 2001). So, detectability ($p_{d|s}$) is actually the probability that a bird will be detected *at least once* during its active periods. Therefore

$$p_{d|s} = 1-(1- p_{1d})^s \quad (3)$$

where p_{1d} is the probability of detecting an average cue; and *s* is the number of cues, i.e., songs or other detectable acts, it actually produces during the count period.

Conspicuousness. **P_{1d} is a measure of conspicuousness, i.e., it captures reductions in detectability due to the following four factors:**

Amplitude of the vocalizations of the average individual. Amplitude diminishes as the square of the distance between the source and the detector, so detectability is strongly influenced by distance and correlated factors, such as sound blocking structures.

Auditory acuity of the observer. Acuity is frequency-dependent in all humans, and is greatest at 1-2 kHz, below the frequencies of most bird sounds. One reason that *p* differs among species is the varying degree to which the birds' sounds fall outside this 1-2 kHz band. Moreover, individual humans vary in both general acuity and frequency response (Emlen and DeJong 1981). Obviously, *p* is observer-specific for these reasons, even if not for others.

Attentiveness of the observer. Because point counts are typically conducted in real time, i.e., the observer cannot rewind and hear or see any cues a second time, it is standard practice for an observer to attempt to focus on a single singer, identify it, and then move on to another. This means that the listening time of the observer is divided among all the singers, some of which will be missed if they cease vocalizing before the observer has a chance to attend to them.

Masking of focal sounds by other sounds, including ambient noise, speech of the observer and any assistants present, vocalizations of other species, and vocalizations of non-focal individuals of the focal species.

High amplitude mitigates the other three causes. If a sound is loud, it is more likely to be noticed and more likely to mask other sounds then to be masked. Amplitude is directly related to distance, while the other three factors come into play because of the low amplitude of sounds from distant sources.

Abundance of Cues. **Parameter *s* is the number of cues produced during a count period, independent of their intensity. High singing rates (*s/m*) mitigate all four causes of non-detection, by giving the observer multiple opportunities to make the single detection that is needed to count an individual.**

Equation (3) quantifies the intuitive relationship between singing rate and the likelihood of detecting an individual. The good news from this equation is that even inconspicuous cues (low p_{1d}) can result in detection when they are numerous (high *s*). For example, p_{1d} = 0.2, as one might find during an intense dawn chorus, translates to $p_{d|s}$ = 0.996, with a realistic *s* of 25, or five songs per min in a 5-min count period. Equation 3 also shows why the dawn chorus may not be the optimal time to conduct a survey. Singing rates (*s/m)* tend to be highest at this time, and owing to correlation of *s* among individuals, masking by other individuals may reduce p_{1d}, offsetting the advantage of high *s*. *Figure 2* shows these trade-offs graphically.

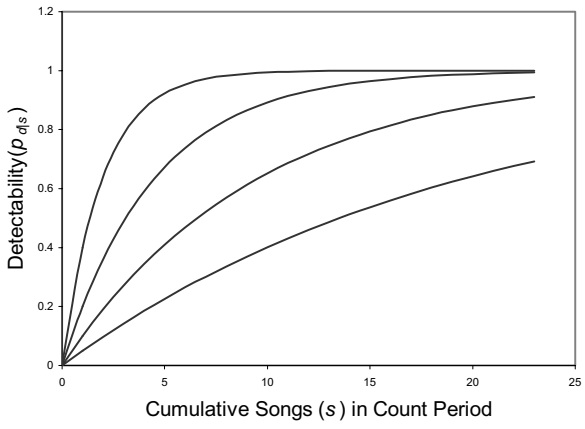

Figure 2—Probability of detecting an individual at least once during a count period as a function of the abundance of cues (e.g., the cumulative number of songs it sings, s), and the conspicuousness of a cue (i.e., the probability of detecting it once, p_{1d}). Each curve represents a different level of conspicuousness. A horizontal line anywhere on this graph crosses combinations of conspicuousness and cue abundance (i.e., p_{1d} and *s*) that yield identical detectability (pd|s).

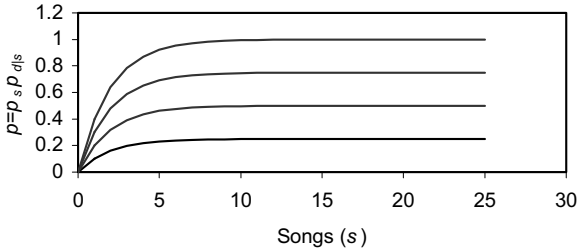

Figure 3—The joint effects of availability and detectability on detection probability (*p*). Conspicuousness (p_{1d}) is 0.40 in all cases. The top curve is identical to the top curve in *Figure 2.* The other curves show the effects of lower availability on overall detection, as singing males acquire mates and sing less often.

4. Availability: The overlooked component of detection probability.

Availability, the probability that a bird produces any cue at all during a count period, is often <1, and low availability may be the most serious cause of non-detection. Surveyors use scheduling to mitigate the low incidence of singing in the middle of the day, or late in the breeding season, but optimal timing is not possible for every sample. A correction for low availability due to time of day, season, or pairing status would greatly improve the accuracy of count data. Nonetheless, *p* has been estimated as though it were a single parameter until recently. Buckland et al. (2001) briefly referred to availability, but did not include it as an independent parameter in their model. Farnsworth et al. (2002) were the first to do this.

Equation 3 and *Figure 2* show that the probability of detecting an individual bird increases as its song production, *s*, increases. This is, however, not the whole story. If songs are evenly distributed across the time period in which a survey may be taken, *s* should be a good predictor of detection. But, if songs are clumped in time, i.e., delivered in bouts, silent intervals between bouts may be long enough to completely overlap a standard count period. The resulting reduction in p_s has a serious impact on overall detection, *p* (*fig. 3*). Substituting equation 3 in equation 2, we have

$$p = p_s\,(1-(1-p_{1d})^s) \qquad (4)$$

Because p_s is independent of $p_{d|s}$ (Farnsworth et al. 2002) and is free to vary from 0 to 1, there is no necessary correlation between singing rate *s/m* and the overall value of *p*. There may, however, be an empirical correlation between singing rate and $p_{s,}$ (e.g., Scott et al., in prep.), and this deserves further study.

Comparison and Evaluation of Models

The double-observer (Nichols et al. 2000), double-sampling (Bart and Earnst 2002), distance sampling (Buckland et al. 2001), and removal (Farnsworth et al. 2002) models have been proposed as methods for estimating *p*. Consumers (e.g., wildlife biologists) need criteria for choosing among these methods. The heuristic decomposition of detection probability, *p*, into several independent components makes it easier to compare and evaluate these methods. To be sufficient for estimating *p*, a method must explicitly or implicitly estimate the parameters of equations 2-4.

Double-Observer Method

The double-observer method obtains an estimate of *p* by comparing the numbers of birds detected by two observers, who count the birds in the same area at the same time. The second observer records the data for the primary observer, and at the same time is expected to detect additional birds that are missed by the primary observer. The method proposed for point counts is an adaptation of a technique originally designed for visual surveys from an aerial platform (Cook and Jacobson 1979). It is a member of a family of "multiple-platform" techniques (Buckland et al. 2001).

In actuality, the double-observer method (Nichols et al. 2000) produces an estimate of $p_{d|s}$ that incorporates the effects of observer skill, inattention, and noise of all kinds. The method offers no means of estimating p_s, and so tacitly assumes that $p_s = 1$. The authors who applied it to point count data have subsequently endorsed this interpretation (Farnsworth et al. 2002). It therefore should be used only in situations in which this assumption can be met.

Distance Sampling

Distance sampling uses the fall-off in detections with distance to model a distance-detection function for plots with preset dimensions. The plot may be sampled from fixed points or a transect line. This function is estimated from the estimated distances to the first detection of each individual per species. The distance-detection function is used to estimate a detection probability, which is construed (Buckland et al. 2001:37, equation 2.2) to be *p*, as defined here. Density, *D*, is estimated directly from *p* and *A*. $\hat{N}$ is calculated as $\hat{D} * A$.

Distance sampling was developed to deal with the effect of distance on *visibility* during ship-borne and airborne line-transect surveys of cetaceans. The line-transect theory has been extended, with appropriate

modification for differences in geometry, to "point transects," which are sets of variable circular plot surveys (Ramsey and Scott 1979, Reynolds et al. 1980), with updated estimation methods (Buckland et al. 2001).

Although distance sampling has been proposed for surveying territorial songbird populations (Buckland et al. 2001, Rosenstock et al. 2002), this recommendation comes with a number of caveats and disclaimers. A very clear assumption of the method is that all animals present at distance = 0 are detected. Leaving aside the very real possibility that the observer's presence may bias detection or even the presence of animals at close distances, this assumption tacitly requires that $p_s = 1$, i.e., that all animals present perform detectable acts during the survey period. The detection probability estimated by the distance method is therefore $p_{d|s}$, not p.

When cues are discrete, e.g., bird song, the assumption of perfect detectability at distance = 0 may be difficult to meet. This can be mitigated by increasing the time at the point. But, "the objects around a point should be located at an instant in time" (Buckland et al. 2001:147). These authors recommend a "snapshot" preceded by a few minutes of locating individuals and followed by a few minutes to confirm their presence at the time of the snapshot. If birds are counted throughout the period, as is typical in point counts, an upward bias in the estimate of numbers results.

Incidentally, if the recommended snapshot is essentially instantaneous, does it estimate $p_{d|s}$ or p_{1d}, in the terminology of this paper (see equation 3)? Actually, the two are equal when $s = 1$, as is the case in an instantaneous sample. Moreover, because the estimate of C is also instantaneous, the constant ratio of C and p discussed above is not violated.

Bout structure also poses problems. When "periods of detectability [are] interspersed with periods of unavailability" the distance method produces an estimate that is the product of density and the proportion of birds available for detection [i.e., p_s] at any given time (Buckland et al. 2001:189). This is a second way of saying that the distance method estimates $p_{d|s}$, not p. In such circumstances, e.g., whales that dive for long periods or songbirds that are silent for periods longer than the standard counting period, an independent estimate of p_s is required.

An alternative to conventional distance sampling is "cue counting," in which distance is estimated to every cue (song or other detectable event) rather than every animal. In this case, movement of the bird is not a problem, as long as all cues are counted. The detection function is estimated as with distance sampling, and the estimate of D requires an independent estimate of cue rate, which is s/m in the terminology of this paper. This is a possible area of research (Buckland et al. 2001). Potential difficulties are detecting and measuring distances to all the cues in a chorus of songbirds, and high variance in the cue rate owing to bout structure (see above).

Despite these difficulties, distance sampling does offer a potential solution to a major problem of point counts. The probability of detecting a single song, $p_{1d,}$ is a function of the amplitude of the song and related factors (see above). Because amplitude decreases as the square of distance increases, each bird would have a different p_{1d}. A method is needed to account for p_{1d} for the entire population, and the distance method would appear to meet this need.

Double Sampling

The double-sampling model was developed for waterfowl monitoring and has been adapted to the monitoring of breeding populations of upland birds (Bart and Earnst 2002). Unlike the other three models, double-sampling does not attempt to estimate p from the data to which it will be applied as a correction factor. A set of "rapid surveys," such as line-transects or variable circular plot counts, is taken as usual. In a random subset of the rapid survey plots, other workers conduct "intensive surveys," i.e., true censuses of all N individuals present. The estimate of p obtained from the ratio C/N in the intensive plots may then be used as the estimate of p for the rapid surveys.

To date, the main empirical shortcoming of this method is that it has not yet been applied to point-centered rapid surveys. The rapid surveys performed by Bart and Earnst (2002) involved area search, rather than aural sampling, in tundra (i.e., treeless) study plots, where the attenuation of a bird's signal with distance was a negligible problem. These relatively long "rapid" surveys in areas with relatively low bird density and high visibility made masking and inattention insignificant issues. But, application of double-sampling to aurally based point counts in areas with more complex vegetation will require an estimate of $p_{d|s}$. It may be that an adequate estimate of $p_{d|s}$ can be obtained with the distance method.

Intensive surveys of birds typically include nest searches and territory mapping. Territory mapping is essential to determine whether the territory centroid is on or off the measured intensive plot, and must be done just outside as well as inside the plot for this reason (Bart and Earnst 2002). Although highly desirable, intensive study plots can be expensive to census. Bart and Earnst (2002) provided estimators of cost, and a

routine for optimizing allocation of effort to intensive and rapid plots.

Removal Sampling

In developing their removal model, Farnsworth et al. (2002) explicitly set out to overcome the shortcomings of the double-observer and distance methods by accounting for p_s as well as $p_{d|s}$. This is a large step in the right direction. Their approach relies on the logic of removal sampling, in which the probability of trapping another individual declines as individuals are removed from a closed, finite population. The method of Farnsworth et al. (2002) relies on "virtual" removal. They divide a point count period into sequential segments, and record the number of birds first detected in each segment. The decline in new detections over the duration of the count is used to estimate p_s. The computational gambit that permits an estimate of p_s without knowing N is division of the N birds into one *ad hoc* subgroup in which all birds are detected and another in which some are detected. This assumption is relaxed in some reduced models.

Despite providing the first explicit decomposition of detection probability into availability and detectability, the model of Farnsworth et al. (2002) estimates only availability. Nevertheless, this model makes it possible to reanalyze old data sets that are subdivided temporally and produce an estimate of detection probability.

More recently, Farnsworth et al. (this volume) have added a distance component to their removal model, as suggested by Farnsworth et al. (2002). They estimate detectability ($p_{d|s}$) by dividing the count circle into two or more concentric rings, and assigning the first detection of each individual that is counted to one of these rings. This practice yields an estimate of detectability for the entire circle that is corrected for the falloff in detectability with distance. This "binning" of the data into concentric rings is an acceptable alternative to estimating the distance to each bird as long as birds are accurately assigned to rings (Buckland et al. 2002, Farnsworth et al. 2002).

Farnsworth and colleagues are seeking a method that can be applied retrospectively to point count data that were binned into time intervals and distance rings. For example, Ralph et al. (1995) recommended recording data separately for sequential 3-, 2-, and 5-min segments of a 10-min point count, so the results can be compared to BBS results, which are based on 3-min point counts, and other data sets. Similarly, the recently adopted protocol in the U. S. Pacific Northwest (Huff et al. 2000) recommends subdividing detections into at least two distance rings. Many data sets may therefore yield estimates of availability and detectability if this removal-distance method proves reliable.

Because this method is intended to estimate both availability and detectability from actual count data, without the expense of double-sampling, managers will follow its development with great interest. A few cautions are therefore in order.

The cues produced by territorial birds are often delivered in bouts of intense singing separated by intervals of total silence. This bout structure is a challenge for the removal method. Availability is estimated from changes in activity during count periods. In the most likely case, a 5-min count divided into 3-min and 2-min segments, some segment of the population must stop or start producing cues during that short interval. Availability will be overestimated as 1.0 if all individuals present are either silent or active throughout the 5-min count period. The longer are the bouts and interbout intervals, the greater this problem becomes. The proportion of the N individuals that must start or stop producing cues in order to yield an accurate estimate of availability is therefore a question that must be addressed.

Adding the distance method to the removal method is exactly what is needed to estimate detectability. But the requirement that the count be taken at an instant in time (see above) poses a problem for the method of Farnsworth et al. (this volume), which relies on changes in activity during a count period to estimate availability. Buckland et al. (2001, see discussion above) recommend sandwiching a "snapshot" between brief periods, in which active birds are accounted for, to obtain the instantaneous count. Perhaps such a "snapshot" can be taken during each of the time segments, thereby yielding the estimate of availability without compromising the estimate of detectability. This issue illustrates well the heuristic value of distinguishing between availability and detectability.

In summary, concern about this method does not center on the use of concentric distance rings, which is a well-understood alternative to estimating distance to each bird, but instead on the applicability of the distance method, in any form, to point counts that rely on aural cues. Nevertheless, because the removal-distance method is conceptually adequate (i.e., it recognizes the independence of availability and detectability) and mathematically rigorous, it deserves thorough study, with the hope that it proves robust to the caveats expressed above.

Conclusions

In conclusion, all four methods reviewed appear logically valid, when their stated and unstated assumptions are met. The currently predominant method for surveying songbirds, rapid aural point counts, will seldom meet all the assumptions or requirements of any of these methods. In their current forms, the double-observer and distance-sampling methods are better suited to estimating detectability, while the double-sampling and removal methods are better suited to estimating availability. Although incomplete at the time of this writing, all four of the new methods probably yield less-biased indices than raw point counts (Bart and Earnst 2002). A hybrid of two, three, or all four of these methods is the likely outcome of further development in this fast-moving field.

Acknowledgments

Discussions with B. Peterjohn and K. Pardieck about estimating detection probabilities from tape recordings inspired this paper. I thank the authors listed below for advancing the field with their penetrating insights. G. Johnson, J. Bart, B. Walker, and C. J. Ralph kindly reviewed the manuscript and provided much needed feedback

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Appendix 1. Detection Probability Cheat Sheet

Parameters discussed in this paper, and their algebraic symbols, if used.

Symbol	Parameter
A	Area. The measured area of a survey area.
C	Count. The number of individuals detected by some survey method in a single count area, or group of such areas.
D	Density. The number of resident individuals per unit area. $\hat{D}$ is often estimated as $\hat{N}$ / A, but it is the primary output of the distance method.
M	Time. As used here, the number of minutes in a single point count or other sample.
N	Population size. The number of individuals, or males, or other category of interest, that reside in a survey area. If the area is small, e.g., a point count circle, care must be taken to account for home ranges that are not wholly included in the area. One approach to this problem is to consider an individual a resident of a survey area if the centroid of its territory or home range lies inside the boundaries of the area (Bart and Earnst 2002). $\hat{N}$ is an estimate of N that is calculated from estimates of other parameters. It is the primary output of the double observer and double sample methods.
p	Detection Probability. The likelihood that a typical (average) individual residing in a survey area will be detected at least once during a survey period. Synonym of Index Ratio. $\hat{P}$ is an estimate of p that is produced by all four methods described in this paper.
$p_{d\|s}$	Detectability. The likelihood that at least one cue (a behavior that is physically detectable by the means employed in the survey) is detected during the count period of m minutes.
p_s	Availability. The likelihood that an individual residing in a survey area produces a cue during the survey period.
p_{1d}	Conspicuousness. The absolute energy content of a cue, at the survey point, discounted by the conspicuousness of competing cues. The probability that an average cue is detected.
S	Cue Abundance. The number of cues available for detection during a survey period. High cue abundance mitigates the effect of low conspicuousness.
s/m	Cue Rate. The number of cues occurring per unit time.
s/m	Song Rate. The number of songs occurring per unit time. A special case of Cue Rate.
	Cue. Any discrete behavior (e.g., a song, a display flight) that can be used, with appropriate equipment, to detect a bird. When evidence of the presence of a bird comes in packets, rather than continuously, each packet is a Cue.

Hierarchical Models and Bayesian Analysis of Bird Survey Information[1]

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Abstract

Summary of bird survey information is a critical component of conservation activities, but often our summaries rely on statistical methods that do not accommodate the limitations of the information. Prioritization of species requires ranking and analysis of species by magnitude of population trend, but often magnitude of trend is a misleading measure of actual decline when trend is poorly estimated. Aggregation of population information among regions is also complicated by varying quality of estimates among regions. Hierarchical models provide a reasonable means of accommodating concerns about aggregation and ranking of quantities of varying precision. In these models the need to consider multiple scales is accommodated by placing distributional assumptions on collections of parameters. For collections of species trends, this allows probability statements to be made about the collections of species-specific parameters, rather than about the estimates. We define and illustrate hierarchical models for two commonly encountered situations in bird conservation: (1) Estimating attributes of collections of species estimates, including ranking of trends, estimating number of species with increasing populations, and assessing population stability with regard to predefined trend magnitudes; and (2) estimation of regional population change, aggregating information from bird surveys over strata. User-friendly computer software makes hierarchical models readily accessible to scientists.

Key words: Bayesian methods, bird surveys, hierarchical models, Markov chain Monte Carlo, North American Breeding Bird Survey, ranking, trends.

Introduction

Bird survey results provide basic information for most of our conservation activities. We use surveys to (1) identify declining species; (2) rank species to assign priority for management; (3) model bird habitat associations; and (4) assess results of management activities. Unfortunately, bird survey data are often difficult to interpret and use. In particular, there are no definitive surveys for most species. Often, information is provided by several surveys such as the North American Breeding Bird Survey (BBS; Robbins 1986), the Christmas Bird Count (Dunn and Sauer 1997), or one of several waterfowl surveys (such as the Spring Breeding Ground Survey; Smith 1990). These sources provide information of varying quality, and large differences in quality of estimates can occur among species within any of the multispecies surveys.

For most surveys, there are also underlying concerns related to flaws in the survey designs. With few exceptions, bird surveys tend to provide incomplete coverage, missing portions of populations both locally (e.g. off roads) and rangewide (e.g., northern portions of species ranges), and unmodeled detectability of birds in most surveys is a large potential source of bias in estimation (Barker and Sauer 1995). To produce a credible analysis of these count data, it is necessary to use covariates to model factors associated with known differences in detectability (such as observer differences; Sauer et al. 1994), adding a great deal of complexity to the analysis. A variety of competing analyses have been proposed, based on distinct model assumptions and using alternative statistical models (e.g., generalized linear models, Link and Sauer 1997; generalized additive methods, Fewster et al. 2000). Naturally, their results are not entirely consistent. Our experience, however, is that given similar sets of explanatory variables the discrepancies tend to be relatively small; when they are not, the inconsistency is often attributable to differences in methods of combining estimates of varying quality.

Conservation activities often require summaries of these rather equivocal sources of information over space (e.g., for mapping abundances), time (e.g., for estimation of population change for individual species), and over species (e.g., for estimation of change for species groups). All of these problems can be reasonably and profitably evaluated as hierarchical models: data, the highest level of the hierarchy, provide an

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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imperfect view of parameters, which comprise an intermediate level of the hierarchy. The parameters are stochastically related (that is, weakly, rather than deterministically). Characteristics of this stochastic relation are the object of summary analyses; these are described as "hyperparameters," the lowest level of the hierarchy. In the past, relatively inefficient approaches such as route regression (Geissler and Sauer 1990) have used weightings to combine information over space in population change estimation. However, hierarchical models (Spiegelhalter et al. 1995) provide a convenient structure for the analysis of data that contain several levels of interest. Analytical tools such as Markov chain Monte Carlo (Gilks et al. 1996) are available for fitting hierarchical models. In this paper, we introduce the idea of hierarchical models for use in avian conservation, and discuss two general topics in which we have successfully applied these models: (1) Estimation of population change for individual species; (2) Summaries of estimates of population change for groups of species. We also provide a brief summary of hierarchical approaches to analysis of spatial pattern of abundance.

Hierarchical Models

It is not uncommon to find considerable variation in precision in collections of parameter estimates; some parameters are very poorly estimated, but some are very well estimated. All summaries of attributes of these collections are limited by precision of the estimates. Simple averages of trend estimates may be wildly imprecise due to the inclusion of a few poorly estimated values; estimated rankings of parameters are corrupted by the tendency for poorly estimated quantities to appear extreme relative to the group (Link and Sauer 1996). The proportion of positive trend *estimates*, a natural estimate of the proportion of positive trend *parameters*, is biased towards 0.50, and the precision of the estimate cannot be assessed without hierarchical structure.

It is useful to consider how we conceptualize the analysis of collections of estimates. Often, we view data (Y) as though they are governed by a fixed, unknown parameter (θ), and our statistics $F(Y|\theta)$ are based on distribution of data, given the unknown parameter. This view of parameters of species is limiting in most survey analyses, as our interest is actually in the attributes of collections of the parameters, not in the collections of the estimates. New analytical opportunities arise if parameters are viewed as random variables, themselves sampled from unknown distributions. This conceptualization, in which data and parameters are both random variables, is a hierarchical model.

Hierarchical models, like conventional fixed effects models, begin with the specification of sampling distributions for data; these distributions are determined by fixed values of parameters. The richer structure of hierarchical models arises from the assumption that the parameters themselves can be thought of as sampled from probability distributions. Although frequentist approaches exist to analysis of hierarchical models, they are often difficult to implement for complex situations. Analysis of hierarchical models is conveniently and rigorously accomplished through Bayesian methods. The goal of hierarchical analysis is to make probability statements about the distribution of θ, given the data and our assumptions about how the parameters are distributed. This indicates that a Bayesian analysis of a hierarchical model must specify the distributions:

(1) $f(Y|\theta)$, the sampling distribution of the data given the unknown parameter,

(2) $\pi(\theta|\Psi)$, the distribution of the parameters, in which Ψ is a hyperparameter (the parameter governing the distribution of the parameters).

From (1) and (2), an additional distribution is implied:

(3) $f(\theta|Y)$, the distribution of the parameters, conditional on the observed data.

In a Bayesian analysis, $\pi(\theta|\Psi)$ is referred to as the prior distribution, and $f(\theta|Y)$ is called the posterior distribution; inference about θ is based on the posterior distribution. Historically, Bayesian analyses have been of limited use for many practical applications. The posterior distributions are very difficult to calculate unless quite simple models are specified, and in part this complexity has led to concerns about the need to make assumptions about the prior distributions of the parameters (Gelman et al. 1994).

Another issue for Bayesian analysis is the necessity of specifying a prior distribution reflecting knowledge (or lack of knowledge) of likely values of the hyperparameters. This requirement is the focus of what we regard as much unreasonable and even hysterical criticism of Bayesian methodology as lacking in scientific objectivity. The choice of reasonable noninformative prior distributions for hyperparameters and the evaluation of alternative choices of prior specifications should lay to rest all such concerns. Unless either the inferential value of the data is very low or the prior specification for hyperparameters expresses a great deal of prior knowledge, the choice of prior is likely to have limited consequences for a Bayesian analysis.

Markov chain Monte Carlo (MCMC) procedures allow investigators to avoid the difficulties of calculating posterior distributions by using simulation-based approximations. Monte Carlo simulations are a widely-

used, stochastic approach to solving complex problems in mathematical modeling, in which independent values are randomly drawn from distributions of interest and the outcomes are summarized to characterize the model system. The only difference between MCMC, in its various formulations, and conventional Monte Carlo simulation methods is that the analyst draws correlated sequences, or first order Markov chains, in MCMC. In Bayesian applications, the distributions sampled are the posterior distributions of the parameters and hyperparameters; all Bayesian inference is based on these distributions. Features of the posterior distributions (means, medians, modes, quantiles, etc.) are approximated by the corresponding features of sampled values, just as in conventional Monte Carlo simulations.

Hierarchical models have great potential for application in bird conservation because so many of the problems are naturally hierarchical. Our research on hierarchical models began when we studied methods for summary of estimates of population change for groups of bird species (Link and Sauer 1998, Sauer and Link 2002). We recognized that standard procedures such as route regression estimation of population change were ad-hoc approaches to a hierarchical modeling situation (Link and Sauer 2002), and that many spatial problems were hierarchical in nature (e.g., Royle et al. 2002). Here we provide brief summaries of these hierarchical models.

Example I: Summary of Attributes of Groups of Species

Groups of species are often of interest in conservation biology. Conservation activities are often motivated by comparative analyses of population change and abundance for taxa such as Neotropical migrants (Robbins et al. 1989) or grassland birds. Taxa-level management is also traditional for groups such as waterfowl, and has led to development of coordinated conservation activities such as the North American Waterfowl Management Plan.

Common summaries of group attributes include average population trend, number of “declining” species, ranks of species by population trend, and identification of species with extreme changes. Any summary requires that the collection of species is meaningful, that some common characteristic of the species permits summary of population attributes among species. Complications associated with the summary are both practical (quality of information may vary greatly among species, making simple averages and summaries of estimates misleading) and conceptual (all groups are composites of many characteristics that are not necessary critical). Imprecise information creates a variety of problems. For example, it is unwise to develop criteria based on estimated magnitude of population trend, because an imprecise trend estimate may be quite large while still having a confidence interval large enough to include zero. Statistical significance is also a flawed measure, as a very small rate of change may be identified as "statistically significant" but be of little practical significance. Separating notions of statistical significance from magnitude of trend is a difficult conceptual issue, and most investigators adopt ad-hoc approaches that constrain analyses of magnitude to significant trends.

For example, for the 167 bird species in the Appalachians (Bird Conservation Region [BCR] 28; Commission for Environmental Cooperation 1997) for which population change data could be estimated from North American Breeding Bird Survey, 46 percent have trends >0, 33 percent of species have significant ($P < 0.05$) negative trend estimates, and 26 percent of species have significant positive trend estimates (*fig. 1*). Species with large estimated declines include Bewick’s Wren (*Thryomanes bewickii*, 26.67 percent/yr), Henslow's Sparrow (*Ammodramus henslowii*, 12.13 percent/yr), and Horned Lark (*Eremophila alpestris*, 10.53 percent/yr).

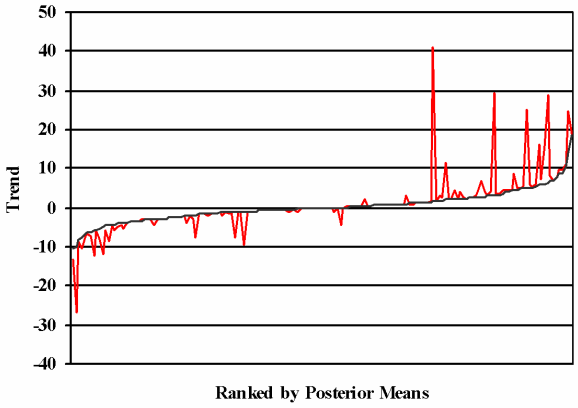

Figure 1— Graph of unadjusted trend estimates for 168 species of birds in the Appalachians (jagged curve) plotted against ranked posterior means (smooth line).

Hierarchical analyses of these data begins by supposing that the trend estimate $\hat{\beta}_s$ for species s is normally distributed with mean β_s (the true value) and variance σ_s^2. The actual variance is unknown, but an estimate $\hat{\sigma}_s^2$ is available; it is assumed that $(v_s / \sigma_s^2)\hat{\sigma}_s^2$ has a chi-squared distribution with v_s degrees of freedom, independent of the distribution of $\hat{\beta}_s$. Further, it is assumed that the sampling distributions are independent among species. Additional structure is added by assum-

ing that the (unobserved) values β_s are themselves a sample from a normal distribution, with mean μ and variance τ^2. To complete the specification of the model, we placed standard noninformative priors on μ, τ^2, and the variances σ_s^2: for μ, we used a normal distribution with mean of zero and variance 1000^2; for the variances τ^2 and σ_s^2, we used gamma priors with mean of 1 and variance of 1000. See Sauer and Link (2002) and Link and Sauer (2002) for discussion regarding choice of priors and noninformative priors.

We fit this model using program BUGS (Spiegelhalter et al. 1995). We ran the simulation, discarding the first 10,000 iterations to allow the results to converge on the posterior distributions. We then took means and variances from the simulation results to get estimates of parameters and hyperparameters. Posterior means of interest include the Bayes trend estimate for species *s*. These estimates represent the estimate for the species in the context of the group, and differ from the $\hat{\beta}_s$ in that they are "shrunken" toward the prior mean μ, with the amount of shrinkage relative to the amount of information associated with the original estimate. They are similar to empirical Bayes results (Link and Sauer 1987), but also take into account uncertainty in estimates of precision. One important feature of the MCMC procedure is the ease with which composite results can be constructed based on the posterior means. For example, at each step of the MCMC sampling, we may count the number of species for which the latest value sampled from the posterior distribution of β_s is positive, and call this quantity N_{inc}. The resulting chain of values $\{N_{inc}\}$ is then a sample from the posterior distribution of this composite parameter, allowing legitimate inference to be made about the number of increasing trends in the population. Similarly, we may keep track of the rank of sampled values from the posterior distribution of trend for a particular species, relative to those for other species. The result once again is a sample from the posterior distribution of a composite parameter. Inference based on this posterior distribution properly accounts for all sources of variation in the estimates, removing essentially insurmountable difficulties inherent to conventional (non-Bayesian) analyses.

Defining Population Stability

We also use the MCMC replicates to estimate a measure of population stability. The natural approach to determine whether populations are stable is to define a range of values in which the population is considered "stable," then to determine the probability that the species' estimate is in the region. We say that a population is stable if $\beta_s \in (-\delta,\delta)$, where δ is a maximum acceptable deviation of trend from 0. Since β_s is unknown, we cannot state with certainty whether $\beta_s \in (-\delta,\delta)$; however, we can compute the posterior probability of stability using the MCMC sample, as

$$\Pr(\beta_s \in (-\delta,\delta)|\mathrm{Y}).$$

This probability can be enumerated directly from the MCMC replicates.

Results for the Appalachians

For the 167 species, the posterior mean number of species with positive trend estimates was 78.54 (95 percent confidence interval: [71,86]). The estimate based on the observed trend estimates was 77. We present results for selected species (*table 1*). For species with extreme estimates of change, the analysis suggests that the actual estimated trends have little value in predicting the actual rank of the species. Bewick's Wren has the most extreme estimated trend of –26.7, but the posterior mean trend was –10.1, and the analysis estimates an average rank of 6 (i.e., it is the 6th most extreme declining trend). Dickcissel (*Spiza americana*), with an estimated trend of –13.3, has an average rank of 3.3. Often, large differences in point estimates of trends have little meaning, and the MCMC analysis reorders these estimates to accommodate differences in precision. We also present a list of unstable (probability of stability to be less than p = 0.05) with regard to the interval of [-2, 2]) increasing and declining species for the stratum (*Appendix 1*). This information provides a reasonable way of defining species with unstable populations, and allows managers to more confidently describe priority species based on scientific information. We note that some of the estimates of number of declining species from the MCMC

Table 1-- *Estimated trends, posterior mean trends, N of survey routes, estimated ranking, and probability of stability for four species in the Appalachian BCR.*

Species	Trend %/yr	N	Posterior mean (CI)	Rank	Stability Pr($\beta_s \in (-2,2) \mid Y$)
Henslow's Sparrow	-12.1	34	-5.0 (-11.5, 1.7)	26.0	0.17
Bewick's Wren	-26.7	23	-10.1 (-18.3, -2)	6.0	0.02
Horned Lark	-10.5	105	-7.9 (-12.1, -3.6)	22.0	0.00
Dickcissel	-13.3	8	-10.4 (-14.4, -4.5)	3.3	0.01

Note: CI refers to a 95% credible interval

analysis (78.5) are not greatly different from the number estimated from the unadjusted trend estimates (77). Consistency in numbers based on "naïve" analyses and more sophisticated analyses is comforting, and often indicates that many of the species have trends that are quite precisely estimated. However, the MCMC estimate is based on appropriate models, and in other situations the estimates can be very different.

Example II: Estimation of Population Change

Estimation of population change from survey data is sometimes controversial due to the need to aggregate information over space. The BBS is a good example of a difficult-to-analyze survey. The BBS is a roadside survey, based on data from survey routes composed of 50, 3-min point counts conducted once each year. The sum of counts of individuals of each species over the 50 stops is generally used as the dependent variable in analyses (Robbins et al. 1986). Started in 1966, the BBS covers almost all of the 37 BCRs North of Mexico, but some provide very poor information and some provide huge amounts of information. Combining information from these regions has always been problematic, and often ad-hoc weightings are used to accommodate regional differences in population abundance and precision of estimates (e.g., ter Braak et al. 1984; Geissler and Sauer 1990; Link and Sauer 1998, 2002). Modeling of regional population change is also complicated by the need to accommodate differences in detectability among the observers conducting the survey. Often, it is possible to construct year effects models at the scale of BCRs that accommodate differences in observer quality and survey information with regions, but combining information among regions to obtain overall estimates requires additional modeling (Link and Sauer 1998). However, hierarchical models provide a reasonable way of accommodating the constraints of the survey in a regional summary (Link and Sauer 2002).

The model:

$$\log(\lambda_{i,j,t}) = S_i + \beta_i (t - t^*) + \omega_j + \eta\, \mathrm{I(j,t)} + \gamma_{\mathrm{i,t}} + \varepsilon_{\mathrm{i,j,t}}$$

provides an approach for modeling regional population change from the BBS. In this description, $\lambda_{i,j,t}$ is the expected value of $Y_{i,j,t}$ (the count for year t for stratum i and observer-route j, this structuring is needed because segments of routes surveyed by an individual observer are the "comparable" units). Stratum-specific intercept (S_i), slope β_i, and year effects ($\gamma_{i,t}$), observer/route effects (ω_j), and overdispersion effects ($\varepsilon_{i,j,t}$) all can influence counts, as can a start-up effect (η) that allows an initiation effect for new observers to have lower counts the first year they conduct a survey on a route (I(j,t) is a dummy variable to index the first year of counting by an observer). Finally, t^* is a baseline year for change estimation. The model is hierarchical in that the effects are themselves treated as variables governed by hyperparameters. Here, observer/route effects, year effects, and overdispersion effects are treated as mean zero normal random variables. Each set of effects were identically distributed, with common variances σ^2_{ω} for observer effects and σ^2_{e} for overdispersion, and with stratum-specific variances $\sigma^2_{r,i}$ for year effects. The variance hyperparameters all were given flat inverse gamma distributions (Link and Sauer 2002). It has been noted that, after controlling for various covariate effects, counts are more variable than indicated by Poisson distribution, hence the overdispersion parameter is needed (Link and Sauer 1998). Note that year effects are constrained to show variation around a slope parameter, allowing accommodation of yearly differences in precision. For the complete model description and a discussion of alternative model formulations, see Link and Sauer (2002).

Within this model, we define annual indexes as the year effects, scaled by the baseline regional intercept and slope, and exponentiated, then multiplied by an additional factor to accommodate the proportion of routes on which the species was encountered (z_i), or:

$$n_{i,t} = z_i \exp\left(S_i + \beta_i (t - t^*) + \gamma_{i,t}\right)$$

Trend (B_i) for any interval t_a to t_b can be defined as the ratio of the annual indices, to the appropriate power:

$$B_i = \left\{ \frac{n_{i,t_b}}{n_{i,t_a}} \right\}^{\frac{1}{t_b - t_a}}$$

Regional indexes are sums of regional totals, or the indexes multiplied by the regional areas (A_i):

$$N_t = \sum_i A_i n_{i,t}$$

and composite trend (B) is calculated as:

$$\overline{B} = \left\{ \frac{N_{t_b}}{N_{t_a}} \right\}^{\frac{1}{t_b - t_a}}$$

Means and credible intervals (percentiles of posterior distributions) are estimated for all of these quantities from the MCMC replicates.

Sample Application: Northern Bobwhite in Appalachians

We used the hierarchical model to estimate trends for Northern Bobwhites (*Colinus virginianus*) in the Appa-

lachians. We divided the Appalachians into three strata (Northern [NY, PA, NJ], central [MD, WVA, VA], and southern [AL, GA, NC, TN, KY]), estimated trend and indexes separately for each strata, then estimated composite trend for the Appalachians. We also conducted an estimating equation route regression (Link and Sauer 1994) and residual indices (Sauer and Geissler 1990) for comparison. Route regression results indicated a trend of -5.77 percent/year, $p < 0.001$, n routes = 195, while the posterior mean trend estimate from the MCMC result was -5.86 percent/year, (95 percent CI: -6.69,-5.02). General similarities also exist in patterns of population change over time from residual indices and annual indices from the hierarchical models (*fig. 2*). Primary differences exist in scaling of the results, possibly due to the naïve scaling of residual indices to a mean abundance in the midyear of the time series (Sauer and Geissler 1990, Link and Sauer 2002).

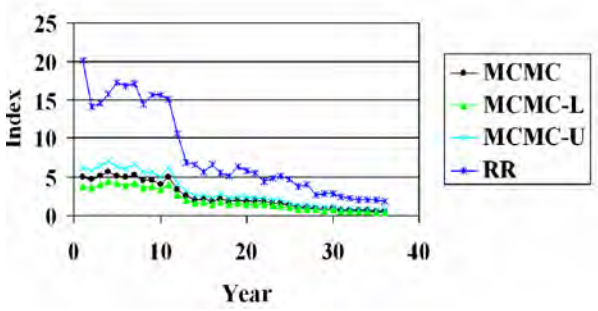

Figure 2— Population year effects for Northern Bobwhite in the Appalachian BCR from BBS data. RR indicates route regression residual indices, while MCMC represents the annual indices from the hierarchical models with 95 percent credible intervals.

Hierarchical Spatial Modeling

Spatial dependence often arises in ecological data due to spatial structure in underlying habitat and landscape structure. In some instances, it is possible to model these sources of spatial dependence explicitly, for example within a regression framework. However, it is not always possible to define or characterize the appropriate suite of dependent variables which explain spatial patterns in data. Consequently, in problems dealing with spatially indexed data it may be desirable to model residual spatial variation which leads to dependence among observations. While one goal in developing spatial models may simply be to account for unexplained spatial dependence (yielding more appropriate inferences about model parameters), spatial dependence is often of direct interest in problems which involve mapping or spatial prediction.

Whatever the motivation, there are many approaches for developing models for spatial data, depending on the type of data at hand and the goals of the analysis. A fairly general and concise description can be developed for most problems simply by considering the addition of a spatially indexed random effect within a hierarchical modeling framework. For normal data models, this approach yields the classical linear mixed model (e.g., Laird and Ware 1972) for which analysis may proceed using classical methods, but which we feel is more conveniently analyzed using Bayesian methods, especially when there is direct interest in estimating specific random effects (i.e., spatial prediction). In addition, the Bayesian hierarchical formulation often facilitates the analysis of non-normal data models, such as for count data, which are commonly collected in many ecological studies.

Spatial models arise by specification of a spatial dependence prior distribution on a collection of spatially indexed parameters. As an example, Royle et al. (2002) recently suggested a simple spatial association model for mapping relative abundance from BBS data. The BBS yields spatially indexed counts, say $y(s)$, which are naturally conceived of as realizations of a Poisson random variable with mean $\lambda(s)$. As in traditional log-linear models, it is natural to consider models for the logarithm of the Poisson mean. Thus, a simple spatial model for BBS counts is:

$$\log(\lambda(s)) = \mu + \alpha(s)$$

where μ is a constant mean and $\alpha(s)$ is the spatial effect (or route effect in the case of BBS data) for location s. Now, the spatial modeling task is to specify a model (a prior distribution) for these spatial effects which accommodates potential dependence among them and satisfies the goal of mapping and prediction.

To this end, there are dozens of possibilities for choice of spatial prior distributions. For example, in discrete space (such as if the sample region were composed of discrete spatial units), Markov random fields, or spatial autoregression models are appealing. This is the approach taken in applications to image analysis, and also in applications where data are indexed by discrete geopolitical units such as counties or physiographic strata such as BCRs (He and Sun 2000). This idea underlies the common autologistic model for mapping occurrence of a species, or range mapping (Wu and Huffer 1987, Hoeting et al. 2000). The method commonly known as "kriging" presents an alternative approach for spatial parameterizations of the random effects that is more natural for continuous spatial domains. The essence of most kriging models is to assume a multivariate normal distribution on the vector of random effects $\alpha = (\alpha(s_1), \alpha(s_2),\ldots,\alpha(s_n))$ with an n x n variance-covariance matrix of the random effects, $\Sigma(\theta)$. The variance-covariance matrix is assumed to be completely specified by a covariance function which dictates the distance-associated covariance between any two locations, s and s', and which depends on the parameter θ,

say k(s,s′;θ). There are many common spatial covariance models in widespread use (see Cressie 1991, p. 61). Royle et al. (2002) made use of the exponential model given by:

$$k(s,s'; \theta) = \exp(-d(s,s')/\theta)$$

where $d(s,s')$ is the distance between locations s and s'. The parameters μ and θ, as well as the random effects, may be estimated using standard MCMC methods. In addition, prediction of random effects at locations where no data are available is possible because of the relationship implied by the spatial correlation model. A collection of predictions, such as on a regular grid over the study area, yields the desired map.

The importance of observer effects in BBS data is widely known and it is necessary to accommodate observer variation within this spatial model. This may be done by the addition of random observer effects which are assumed to be spatially *independent*. That is, the model for the Poisson mean becomes

$$\log(\lambda(s)) = \mu + \alpha(s) + \eta(s)$$

where $\eta(s) = \text{Normal}(0,\sigma^2)$. The observer effects play the role of measurement error (the "nugget" effect) in the classical kriging model and they are not of direct interest in the analysis but instead serve to soak up residual overdispersion. This model may also be expanded to accommodate spatial covariates such as habitat and temporal variation such as trends.

Benefits of Hierarchical Models

Unfortunately, many of the questions that must be addressed in conservation biology cannot be easily answered using conventional statistical approaches. Even questions such as ranking species for magnitude of decline, which superficially appears to be a simple procedure, are complicated by the need to simultaneously address magnitude of change and significance of change. Hierarchical models are a natural way to approach these questions (e.g., Link and Sauer 1998, Sauer and Link 2002). Bayesian models provide an appropriate conceptual framework for dealing with collections of estimates, whether they arise from comparison of trends for a variety of species or from the need to summarize geographic patterns of population change from a single species. Earlier analyses of populations, such as the route regression method, provide ad-hoc approaches for accommodating error in summaries of estimates, but hierarchical models make the assumptions associated with those methods explicit, and provide the first reasonable means for appropriate aggregation of population change estimates over space or species. Hierarchical models also allow for estimation of derived attributes, such as the population stability metric and rankings of population change. Finally, Bayesian approaches to analysis of hierarchical models are relatively easy to implement in programs such as BUGS. BUGS programs to implement the examples presented in the paper are available from the authors.

Acknowledgments

We thank N. Nur, H. Stauffer, and an anonymous reviewer for helpful comments. We also thank the BBS participants and coordinators who collect and maintain this useful and interesting database.

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Appendix 1

List of posterior mean trends, estimated ranking, and probability that the population trend is within the range [-2,2 percent/yr] for species with unstable populations in the Appalachian BCR.

Species	Posterior mean	Estimated ranking	$Pr(\beta_s \in (-2,2) \mid Y)$
Unstable increasing species			
Great Blue Heron (*Ardea herodias*)	6.7	156.3	0.00
Canada Goose (*Branta canadensis*)	13.9	165.3	0.00
Mute Swan (*Cygnus olor*)	18.7	166.9	0.00
Wood Duck (*Aix sponsa*)	5.2	148.9	0.01
Red-tailed Hawk (*Buteo jamaicensis*)	4.2	143.8	0.01
Wild Turkey (*Meleagris gallopavo*)	6.7	154.9	0.01
Ring-billed Gull (*Larus delawarensis*)	10.6	164.1	0.00
Red-bellied Woodpecker (*Melanerpes carolinus*)	4.2	144.2	0.00
Yellow-bellied Sapsucker (*Sphyrapicus varius*)	8.8	161.3	0.00
Blue-headed Vireo (*Vireo solitarius*)	4.3	144.4	0.01
Common Raven (*Corvus corax*)	5.1	147.9	0.02
Tree Swallow (*Tachycineta bicolor*)	5.5	151.6	0.00
Red-breasted Nuthatch (*Sitta canadensis*)	4.9	147.4	0.02
Hermit Thrush (*Catharus guttatus*)	4.6	146.6	0.00
Magnolia Warbler (*Dendroica magnolia*)	4.8	147.6	0.00
Yellow-rumped Warbler (*Dendroica coronata*)	5.9	151.1	0.03
House Finch (*Carpodacus mexicanus*)	7.6	158.9	0.00
Unstable declining species			
Northern Bobwhite (*Colinus virginianus*)	-5.7	10.9	0.00
Whip-poor-will (*Caprimulgus vociferus*)	-6.0	11.6	0.01
Northern Flicker (*Colaptes auratus*)	-3.5	24.1	0.00
Eastern Wood-Pewee (*Contopus virens*)	-3.2	27.4	0.00
Horned Lark (*Eremophila alpestris*)	-7.9	6.6	0.00
Bewick's Wren (*Thryomanes bewickii*)	-10.1	6.5	0.02
Golden-winged Warbler (*Vermivora chrysoptera*)	-8.1	4.7	0.00
Prairie Warbler (*Dendroica discolor*)	-4.3	17.4	0.00
Cerulean Warbler (*Dendroica cerulea*)	-2.9	32.4	0.03
Yellow-breasted Chat (*Icteria virens*)	-3.6	23.4	0.00
Field Sparrow (*Spizella pusilla*)	-3.8	20.9	0.00
Vesper Sparrow (*Pooecetes gramineus*)	-6.9	7.5	0.00
Grasshopper Sparrow (*Ammodramus savannarum*)	-6.3	9.3	0.00
Dickcissel (*Spiza americana*)	-10.4	3.3	0.01
Red-winged Blackbird (*Agelaius phoeniceus*)	-2.7	33.8	0.00
Eastern Meadowlark (*Sturnella magna*)	-3.6	22.9	0.00
Brown-headed Cowbird (*Molothrus ater*)	-3.5	24.2	0.00
House Sparrow (*Passer domesticus*)	-2.9	31.7	0.00

Improving the Breeding Bird Survey[1]

Jonathan Bart,[2] Joseph B. Buchanan,[3] and Bob Altman[4]

Abstract

We investigated increasing the number of Breeding Bird Survey (BBS) routes and reducing potential bias as ways to increase the number of species adequately monitored by the BBS in the Pacific Northwest. Estimates of place-to-place variance in trends were used to assess the effects of increasing the number of additional BBS routes. Increasing the number of BBS routes from the current number (149) to 210 would increase the number of adequately covered species, using a recently proposed standard, from 42 at present to 60. If potential bias was reduced from its estimated current value (0.008) to 0.003, then the number of adequately monitored species at present would be 75 and would increase to 84 with 210 BBS routes. Implementing effective waterbird, raptor and nocturnal species surveys would cover up to 45 more species resulting in adequate coverage for 121 (74 percent) of the 164 species that warrant monitoring. We recommend that all three approaches–increasing the number of BBS routes, reducing potential bias, and implementing new surveys–be considered in efforts to improve bird monitoring programs.

Key words: Breeding Bird Survey, optimization, sample size, birds, surveys, trend estimation, bias

Introduction

Bart et al. (2004) suggested an accuracy target for landbird monitoring programs and that expansion of the Breeding Bird Survey (BBS), or other similar surveys, would be an effective way to achieve the target for more species. They estimated how many BBS routes would be needed to achieve the accuracy target for 80 percent of the species suited to monitoring using the BBS. Their estimate was based on a single rangewide estimate of route-to-route variation in trend for each species that warrants monitoring, and they did not present any information about how many species would be adequately monitored with numbers of routes other than the number they recommended. In this paper, we explore optimal allocation of new BBS routes at the scale of a Bird Conservation Region using more detailed information on spatial variation in trend, and we estimate how many more species would be adequately monitored with different numbers of new routes. We also discuss the relative merits of adding BBS routes and other ways to increase the number of adequately monitored species.

Methods

The study area covered 254,240 km^2 and included portions of California, Oregon, Washington and British Columbia within the Northern Pacific Rainforest Bird Conservation Region (BCR 5) (*fig. 1*). Most of the study area is coniferous forest with small amounts of other habitats such as riparian, oak/prairie, agricultural, and residential/urban. The Alaskan portion of this BCR (southeast and south-coastal Alaska) was not included because the road network is extremely limited; this prevented us from evaluating the efficiency of additional routes in this area.

We defined species that warrant monitoring as those for which management action would be considered if it were known that their populations were seriously declining. To produce the list, we identified all species whose breeding range (as depicted in National Geographic Society [1999]) covered >10 percent of the study area. This list was then scrutinized to determine whether it excluded or included any species that clearly did or did not meet our general criteria. This process produced 164 species that warrant monitoring in the established. We used a guideline from Bart et al. (2003) that a species should be recorded ≥5 times, during a 20-year period, to calculate within-route trends. Trends cannot be reliably calculated from just a few routes. We used a guideline from Link and Sauer (1994) that trends should only be calculated for species

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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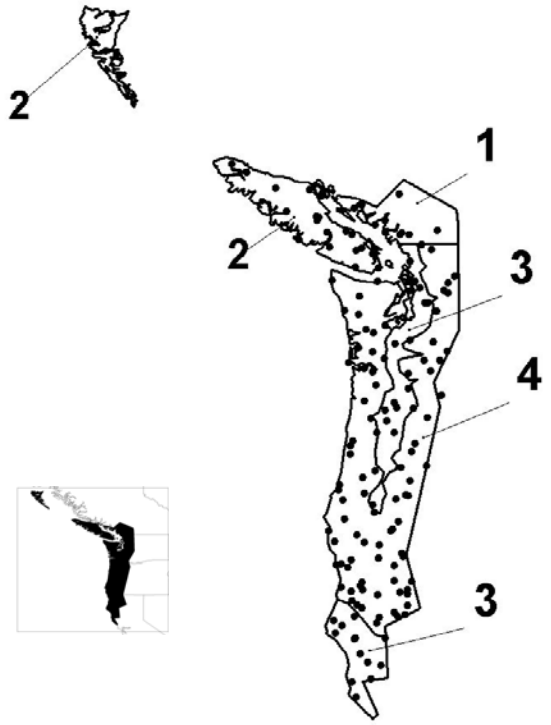

Figure 1— Study area, strata (numbers 1-4), and current BBS routes (dots).

recorded on ≥14 routes. Thus, we only considered species recorded ≥5 times on ≥14 routes as being suitable for coverage by the BBS. Under this rule, 103 species within our study were possibly suitable for monitoring with the BBS if the number of routes was increased.

The study area was stratified according to the distribution of BBS routes, major habitat features, and political boundaries. Four strata were delineated: mainland British Columbia, Vancouver and the Queen Charlotte islands, interior valleys and lowlands in the United States, and forested areas in the United States (*fig. 1*). The two strata in the United States were delineated using a USGS land use/land cover map.

The study area at present contains 149 official BBS routes. We added routes beyond this value in groups of 10 (except the first group which was 11) and determined how many species were adequately monitored (see below) with each new increment of routes.

We used procedures described by Bart et al. (2004) for determining whether species were adequately covered for monitoring purposes by the BBS. Specifically, Bart et al. (2004) recommended that species should be considered adequately monitored if a 20-year data set had 80 percent power to detect a 50 percent decline using a two-tailed test, a significance level of 0.10, and incorporating effects of potential bias in the analysis. They suggested that at present a reasonable value for potential bias with BBS data is 0.008, and they showed that under this assumption, the power objective is met if the standard error of the trend is <0.0073. They recommended various measures to reduce bias and suggested that implementing these measures would reduce potential bias to 0.003, in which case the standard error needed to meet the accuracy target is 0.0113. They also indicated that meeting the accuracy target in areas as small as our study area was probably not realistic. It can be shown that the accuracy target within one portion of an area, across which inferences will be made, is (target standard error for the entire area)/$\sqrt{p}$, where p is the proportion of the entire area covered by the study area. We illustrate the procedure for investigating whether to establish additional BBS routes by assuming that trends will be estimated across an area three times larger than our study area. Under this assumption, p is 0.33, and the target standard errors are $0.0073/0.33^{0.5} = 0.013$, under current conditions, and $0.0113/0.33^{0.5} = 0.020$ if potential bias is reduced to 0.003. We used these two values, 0.013 and 0.020, as the target standard errors for the trend estimate within our study region.

Trends were estimated using a simple form of route regression (Bart et al. 2003) in which the linear trend is calculated for each route and the mean of these trends is divided by the mean number of birds recorded on the routes. The result is an essentially unbiased estimate of the trend, defined as the rate of change of an exponential curve fit to the true population sizes using the method of least squares. With stratified sampling, the estimated variance of the trend estimate may be expressed as:

$$v(r) \quad \sum_{h}^{L} \frac{W_h^2 s_h^2}{f_h n_h}, \qquad (1)$$

where W_h is the proportion of the study area in stratum h, s^2_h is a function of the variance of the trends among routes in stratum h and does not depend on number of routes surveyed, f_h is the fraction of routes in stratum h on which the species is recorded frequently enough to estimate trends (i.e., ≥5 times) and n_h is the number of routes in stratum h. The f_h and s^2_h were calculated for each species with sufficient BBS data (species recorded ≥5 times on ≥14 routes). The $v(r)$, and from this the se(r), were then calculated for each sample size. In adding routes, we maintained proportional allocation (i.e., at each sample size, the fraction of routes in each stratum was approximately equal to the fraction of the study area in the stratum).

Results and Discussion

At present, the accuracy target is met for 42 species, or 41 percent of the 103 species suitable for coverage with the BBS. As the number of routes is increased, the number of adequately covered species rises (*fig. 2*; see *Appendix 1*). With 210 routes, it is 60, (58 percent of the 103 species suitable for coverage with the BBS) and at 300 routes it is 71 species (69 percent). The number of species added to the list increased very slowly beyond 300 routes. Adding routes beyond about 210 would not be very productive given the effort that would be required (see *fig. 2*). Of the 18 species that would be added by increasing the number of routes to 210, several are of conservation concern in the region including forest species, Black-throated Gray Warbler (see *Appendix 1* for scientific names, 160 routes) and Rufous Hummingbird (*Selasphorus rufus*, 190 routes); lowland riparian species, Yellow Warbler (160 routes) and Yellow-breasted Chat (190 routes); and a grassland associate, the Western Meadowlark (180 routes).

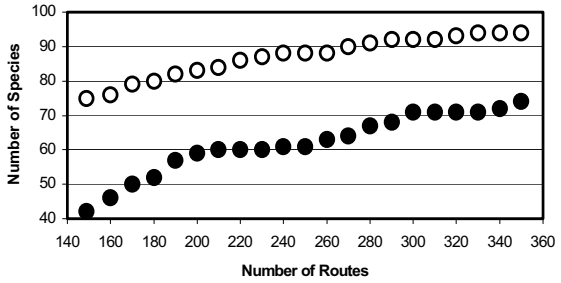

Figure 2— Number of adequately monitored species (out of 103 that are potentially suitable for monitoring with the BBS) as a function of number of BBS routes and potential bias (closed circles = bias of 0.008; open circles = bias of 0.003).

In contrast to the option of adding more BBS routes, our results showed the value of reducing potential bias. With a bias of 0.003, the current number of adequately monitored species would be 75, or 73 percent of the 103 species suitable for coverage with the BBS (*fig. 2*; see *Appendix 1*). With 210 routes, the number would be 84 (82 percent), and with 300 it would be 92 (89 percent). Of the 9 species that would be added by increasing the number of routes to 210, only 2 could be considered of conservation concern–Vaux's Swift (200 routes) with its association for large old-growth snags for nesting, and Chipping Sparrow (170 routes), a species associated with declining oak savannah and woodland habitats. Even with 350 routes, the number of adequately monitored species, with bias = 0.008, was less than the number that would be adequately monitored with the current sample size (149 routes) if potential bias could be reduced to 0.003 (*fig. 2*). At the species level, reducing potential bias to 0.003 without adding any routes would add 33 species to the adequately monitored list, including species of some conservation concern such as Rufous Hummingbird, Brown Creeper, Black-throated Gray Warbler, Yellow Warbler, Yellow-breasted Chat, and Western Meadowlark. Thus, measures discussed in Bart et al. (2004), such as training and evaluation, overlap in consecutive surveyors on a route (to identify inconsistencies between observers), off-road surveys, habitat-based models, and double sampling, might produce a greater increase in number of adequately monitored species than even doubling the current number of routes. Thus, reducing potential bias is an effective way to increase the number of species that are adequately monitored by the BBS.

Adding new BBS routes appears to be a reasonable strategy in most of the study area because of the significant and increasing human population to conduct the surveys, and a sufficiently developed road network in most of the area. Annual coverage of existing BBS routes is >90 percent, but it is unknown how successful recruitment might be for enlisting volunteers to conduct the additional routes indicated by our analysis. However, we recently learned that about 60 routes in British Columbia are being surveyed but are not included in the BBS data set. Adding 60 routes would increase the number of species adequately covered by the BBS to 60 (58 percent) under current conditions and to 84 (82 percent) if potential bias were reduced to 0.003.

A combination of bias reduction, increased BBS coverage, and supplemental monitoring may be most effective. For example, if potential bias were reduced to 0.003 and the number of routes increased to 170, then 95 species would be adequately monitored. We believe that 61 of the 164 species that warrant monitoring in our study area were not well suited to coverage using the BBS. Among these, 37 are aquatic species, 10 are raptors, 7 are nocturnal species, and the rest are other terrestrial species. Thus, if special surveys were instituted that covered most (e.g., 45) of the 54 aquatic species, raptors, and nocturnal species, then the number of adequately covered species would be 121 or 74 percent of the 164 target species (*Table 1*). Thus, adding routes, reducing potential bias, and implementing surveys for aquatic birds, raptors, and nocturnal species would result in adequate coverage for about three-quarters of the species that warrant monitoring. Some of the other species are more common in surrounding areas and thus might be covered adequately if similar strategies were used in surrounding areas. Others would require specialized surveys.

Table 1— *Strategies for improving the number of adequately monitored species.*

N of BBS routes[1]	Potential bias	Other surveys	N (%) of adequately monitored species
149	0.008	None	42 (26%)
200	0.008	None	51 (31%)
200	0.003	None	70 (48%)
250	0.003	None	86 (52%)
250	0.003	Aquatic species, raptors, and nocturnal species	121 (74%)

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Appendix 1— *Species currently covered by BBS effort (149 routes; bias = 0.008), or that would be adequately covered by reducing bias to 0.003 or by adding new routes with either level of bias. Adequate levels of coverage >350 total routes are not shown.*

	Species covered and associated levels of bias		Total number of routes needed to adequately cover species at each level of bias	
Species	**0.008**	**0.003**	**0.008**	**0.003**
Great Blue Heron, *Ardea herodias*		•	260	
Common Merganser, *Mergus merganser*		•	190	
Turkey Vulture, *Cathartes aura*		•		
Osprey, *Pandion haliaetus*		•		
Red-tailed Hawk, *Buteo jamaicensis*	•	•		
American Kestrel, *Falco sparverius*		•	290	
Ring-necked Pheasant, *Phasianus colchicus*				190
Blue Grouse, *Dendragapus obscurus*				270
California Quail, *Callipepla californica*	•	•		
Mountain Quail, *Oreortyx pictus*		•		
Killdeer, *Charadrius vociferus*		•	260	
Spotted Sandpiper, *Actitis macularia*		•	190	
Band-tailed Pigeon, *Columba fasciata*		•		
Rock Dove, *Columba livia*				270
Mourning Dove, *Zenaida macroura*		•	280	
Common Nighthawk, *Chordeiles minor*		•	350	
Vaux's Swift, *Chaetura vauxi*				200
Belted Kingfisher, *Ceryle alcyon*				280
Acorn Woodpecker, *Melanerpes formicivorus*		•	200	
Northern Flicker, *Colaptes auratus*	•	•		
Red-breasted Sapsucker, *Sphyrapicus ruber*	•	•		
Downy Woodpecker, *Picoides pubescens*		•	190	
Hairy Woodpecker, *Picoides villosus*		•	160	
Pileated Woodpecker, *Dryocopus pileatus*		•	170	
Olive-sided Flycatcher, *Contopus cooperi*	•	•		
Western Wood-Pewee, *Contopus sordidulus*	•	•		
Willow Flycatcher, *Empidonax traillii*	•	•		
Dusky Flycatcher, *Empidonax oberholseri*	•	•		

Appendix 1 (continued)

Species	Species covered and associated levels of bias		Total number of routes needed to adequately cover species at each level of bias	
	0.008	0.003	0.008	0.003
Pacific-slope Flycatcher, *Empidonax difficilis*	•	•		
Western Kingbird, *Tyrannus verticalis*				330
Hutton's Vireo, *Vireo huttoni*				190
Cassin's Vireo, *Vireo cassinii*	•	•		
Red-eyed Vireo, *Vireo olivaceus*		•	280	
Warbling Vireo, *Vireo gilvus*	•	•		
Steller's Jay, *Cyanocitta stelleri*	•	•		
Gray Jay, *Perisoreus canadensis*				240
Western Scrub-Jay, *Aphelocoma californica*		•	180	
American Crow, *Corvus brachyrhynchos*	•	•		
Northwestern Crow, *Corvus caurinus*	•	•		
Common Raven, *Corvus corax*	•	•		
Tree Swallow, *Tachycineta bicolor*			350	160
Violet-green Swallow, *Tachycineta thalassina*	•	•		
Cliff Swallow, *Petrochelidon pyrrhonota*	•	•		
Northern Rough-winged Swallow, *Stelgidopteryx serripennis*		•	300	
Barn Swallow, *Hirundo rustica*	•	•		
Black-capped Chickadee, *Poecile atricapilla*		•	300	
Chestnut-backed Chickadee, *Poecile rufescens*	•	•		
Bushtit, *Psaltriparus minimus*		•	340	
Brown Creeper, *Psaltriparus minimus*		•	240	
White-breasted Nuthatch, *Sitta carolinensis*				230
Red-breasted Nuthatch, *Sitta canadensis*	•	•		
House Wren, *Troglodytes aedon*		•	210	
Winter Wren, *Troglodytes troglodytes*	•	•		
Bewick's Wren, *Thryomanes bewickii*		•	270	
Marsh Wren, *Cistothorus palustris*				320
Golden-crowned Kinglet, *Regulus satrapa*		•	170	
Swainson's Thrush, *Catharus ustulatus*	•	•		
Hermit Thrush, *Catharus guttatus*	•	•		
Varied Thrush, *Ixoreus naevius*		•	280	
American Robin, *Turdus migratorius*	•	•		
European Starling, *Sturnus vulgaris*		•	200	
Cedar Waxwing, *Bombycilla cedrorum*	•	•		
Orange-crowned Warbler, *Vermivora celata*	•	•		
Yellow-rumped Warbler, *Dendroica coronata*	•	•		
Black-throated Gray Warbler, *Dendroica nigrescens*		•	160	
Townsend's Warbler, *Dendroica townsendi*				170
Hermit Warbler, *Dendroica occidentalis*	•	•		
Yellow Warbler, *Dendroica petechia*		•	160	
MacGillivray's Warbler, *Oporornis tolmiei*	•	•		
Wilson's Warbler, *Wilsonia pusilla*	•	•		
Common Yellowthroat, *Geothlypis trichas*	•	•		
Yellow-breasted Chat, *Icteria virens*		•	190	
Western Tanager, *Piranga ludoviciana*	•	•		
Spotted Towhee, *Pipilo maculatus*	•	•		
Chipping Sparrow, *Spizella passerina*				170

Appendix 1 (continued)

Species	Species covered and associated levels of bias		Total number of routes needed to adequately cover species at each level of bias	
	0.008	**0.003**	**0.008**	**0.003**
Savannah Sparrow, *Passerculus sandwichensis*				180
Song Sparrow, *Melospiza melodia*	•	•		
White-crowned Sparrow, *Zonotrichia leucophrys*	•	•		
Dark-eyed Junco, *Junco hyemalis*	•	•		
Black-headed Grosbeak, *Pheucticus melanocephalus*	•	•		
Lazuli Bunting, *Passerina amoena*		•	170	
Western Meadowlark, *Sturnella neglecta*		•	180	
Red-winged Blackbird, *Agelaius phoeniceus*				220
Brewer's Blackbird, *Euphagus cyanocephalus*	•	•		
Brown-headed Cowbird, *Molothrus ater*	•	•		
Bullock's Oriole, *Icterus bullockii*				220
Purple Finch, *Carpodacus purpureus*		•	160	
House Finch, *Carpodacus mexicanus*	•	•		
Red Crossbill, *Loxia curvirostra*		•		
Pine Siskin, *Carduelis pinus*		•	170	
American Goldfinch, *Carduelis tristis*	•	•		
Lesser Goldfinch, *Carduelis psaltria*	•	•		
Evening Grosbeak, *Coccothraustes vespertinus*				210
House Sparrow, *Passer domesticus*		•	300	

Estimating Total Population Size for Songbirds[1]

Jonathan Bart[2]

Introduction

A conviction has developed during the past few years within the avian conservation community that estimates of total population size are needed for many species, especially ones that warrant conservation action. For example, the recently completed monitoring plans for North American shorebirds and landbirds establish estimating population size as a major objective. Obtaining these estimates rigorously, however, is difficult. Rosenberg and Blancher (this volume) describe one approach that generates point estimates based on several assumptions. Here, I describe an alternate approach which incorporates uncertainty about the assumptions and establishes a range for the true population size. It is illustrated by estimating population size for four shrubsteppe species across a large portion of their range using Breeding Bird Survey (BBS) data.

The BBS consists of roadside routes randomly selected within one-degree blocks throughout the United States (except Hawaii) and southern Canada. Each route has 50 stations regularly spaced at 0.5-mile intervals, and is surveyed once during the breeding season (mainly in June) starting 30 minutes before dawn. Observers record all birds detected for 3 minutes at each station. The Survey has been widely hailed as one of the best wildlife monitoring programs in the world (e.g. Ralph et al. 1995). Its results are used each year in dozens of publications for both applied and theoretical purposes (Sauer et al. 1999).

An estimate of population size, based on BBS data, may be made by writing down an algebraic expression that describes the relationship between mean birds/BBS route and total population size, and then estimating the terms in this relationship. This approach is followed below.

Parameter Definition

The goal is to estimate population size, defined as the average number of birds present during the breeding season in the study area. "Average" means average across the breeding season and across whatever years of data are used in the analysis. The approach is to estimate the number of males and then to divide this estimated by the estimated proportion of birds that are males, usually 0.5.

Relationship between Mean Birds/BBS Route and Population Size

A single equation could be used to describe this relationship, but for simplicity it is first presented below in four steps. The study area is partitioned into regions (i.e., strata) within which possibly different methods will be used to estimate the number of males present. We may then write (1)

$$\textit{Number of males} = \Sigma\,(\textit{Size of region})\,(\textit{Regionwide density}) \quad (1)$$

where the sum extends across all the delineated regions. Define "habitat" in such a way that all occurrences of the species are in the habitat. In the limiting case, a single habitat is defined which includes the entire study area. Many species, however, have fairly narrow and well-known habitat associations and in these cases it may be useful to incorporate habitat into the analysis. Also define "roads" as the roads used to select BBS routes and include in their definition a strip centered on the roads and extending out to the farthest distance at which the species is detected. We may then express regionwide density of males as (2)

$$\left(\begin{array}{c}\textit{Regionwide}\\ \textit{density}\end{array}\right) = \left(\begin{array}{c}\textit{Roadside}\\ \textit{density}\end{array}\right) \frac{\left(\begin{array}{c}\textit{Prop. of region}\\ \textit{that is habitat}\end{array}\right)\left(\begin{array}{c}\textit{Regionwide density}\\ \textit{in habitat}\end{array}\right)}{\left(\begin{array}{c}\textit{Prop. of roads}\\ \textit{that are habitat}\end{array}\right)\left(\begin{array}{c}\textit{Density along roads}\\ \textit{in habitat}\end{array}\right)} \quad (2)$$

This expression may be described by saying that regionwide density of males equals roadside density with two "corrections", the first for any difference between the amount of the species' habitat along roads and regionwide, and the second for any difference between the species' density in its habitat regionwide and along roads. For example, a woodland species might generally occur at higher densities in woods along roads than throughout the region. The second correction term in expression (2) would adjust for this difference. One advantage of expression (2) is that it describes a true

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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relationship but as an initial approximation the two correction terms might be ignored (i.e., assumed to be 1.0) and then subsequent work might be undertaken to determine whether this causes significant bias in the estimate of population size.

Roadside density of males may be expressed as

$$\left(\begin{matrix}\text{Roadside}\\ \text{density}\end{matrix}\right) = \frac{\left(\begin{matrix}\text{Number}\\ \text{present}\end{matrix}\right)}{\left(\begin{matrix}\text{Area}\\ \text{surveyed}\end{matrix}\right)} \qquad (3)$$

and the number of males present may be expressed as

$$\left(\begin{matrix}\text{Number}\\ \text{present}\end{matrix}\right) = \frac{\left(\begin{matrix}\text{Number birds}\\ \text{recorded}\end{matrix}\right)\left(\begin{matrix}\text{Proportion of birds}\\ \text{recorded that are males}\end{matrix}\right)}{\left(\begin{matrix}\text{Prop. of males}\\ \text{that sing} \geq 1 \text{ time}\end{matrix}\right)\left(\begin{matrix}\text{Prop. of singing}\\ \text{males detected}\end{matrix}\right)} \qquad (4)$$

Expression (4) equates the number of males present with the number of birds recorded adjusted for the proportion of birds recorded that are males, the birds that are present but do not sing during the 3-min listening period, and by the proportion of the birds that do sing but are not recorded by the surveyor.

The four expressions above can be combined and written more compactly as

$$\text{Number of males} \quad \sum_i A_i \left(\frac{y_i}{x_i}\right)\left(\frac{m_i r_{1i} r_{2i}}{f_i g_i}\right) \qquad (5)$$

where the sum extends across all of the regions and

A_i = area of region i,

y_i = number of individuals recorded in region i,

x_i = area surveyed in region i which in turn depends on the average area within which birds are audible at the BBS stations,

m_i = proportion of the birds recorded that are males,

$r_{1i} = h_{Reg}/h_{Road}$ where h_{Reg} and h_{Road} are the proportions of region i, and of the surveyed (roadside) portion of region i, covered by the species' "habitat",

$r_{2i} = d_{Reg}/d_{Road}$ where d_{Reg} and d_{Road} are the densities of the species in its habitat throughout region i and in the surveyed portion of region i,

f_i = proportion of the territorial males in the surveyed area, in region i, that sang 1^+ times while the surveyor is present, and

g_i = proportion of audible birds that were recorded in region i on the BBS.

The first two terms in expression (5) are the regionwide area and the recorded density of birds along roads. Their product may be viewed as an initial estimate of the regionwide density of males. The third term is an adjustment to this estimate to account for the proportion of birds recorded that are males, are from non-representative habitat along roads, and detection rates that are less than 1.0. In the simplest case, the five quantities in this term - m_i, r_{1i}, r_{2i}, f_i, and g_i - all equal 1.0 and the adjustment term drops out.

Interval Estimates

Expression (5) is exact; it simply provides a convenient way to express population size. All of the quantities on the right side except A_i would vary to some extent from sample to sample. With large numbers of routes surveyed and birds recorded we may assume that population size is approximately equal to expression (5) with the variables replaced by their expected values. Thus,

$$\text{Number of males} \cong \sum_i A_i \left(\frac{Y_i}{X_i}\right)\left(\frac{M_i R_{1i} R_{2i}}{F_i G_i}\right) \qquad (6)$$

where the terms in expression (6) are the expected values of the corresponding variables in expression (5), with expectation being calculated across the set of possible samples that might have been obtained in region i during the years of the study. Thus, population size may be estimated using estimates of the parameters, calculated from the survey or obtained in other ways, and upper and lower confidence bounds may be obtained using statistical methods or, more crudely, by using the upper and lower bounds for each parameter if formal error estimation is not warranted.

Example

The approach is illustrated using BBS data for four shrubsteppe-obligate birds in Region 4 of the U.S. Forest Service which covers Nevada, Utah, western Wyoming, and southern Idaho. A recent GAP map has been produced for this area (*fig.1*) and an extensive accuracy assessment has been carried out (Edwards et al. 1998). Estimates of population size within this region are obtained for Brewer's Sparrow (*Spizella breweri*), Black-throated Sparrow (*Amphispiza bilineata*), Gray Flycatcher (*Empidonax wrightii*), and Sage Thrasher (*Oreoscoptes montanus*). Estimates are obtained only for the Forest Service region; rangewide estimates would require additional analyses. For convenience, the subscript is omitted below. I assumed

that 50 percent of the birds are males and thus doubled the estimated number of males to obtain estimated population sizes.

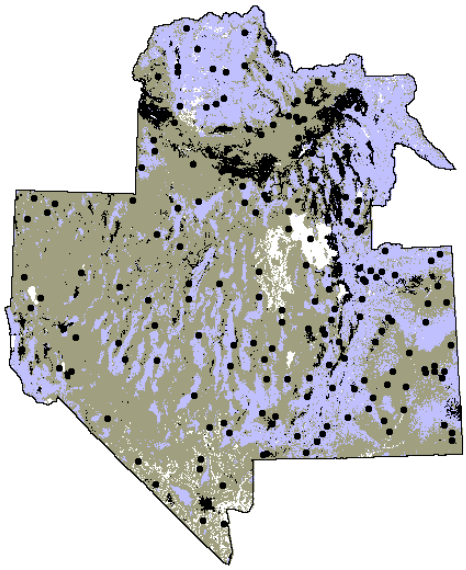

Figure 1— U.S. Forest Service Region 4. Dots indicate BBS routes; habitats are: light gray = montane; dark gray = shrubsteppe; black = agricultural, residential; white = water, missing data. Light areas southwest of Great Salt Lake and in southern Nevada are missing data.

The area, A, is 718,000 km^2. The mean number/route, y, and 95 percent confidence intervals are reported in *table 1*. The surveyed area, x, depends on the average distance at which birds are just audible. This distance could be estimated through field trials but these have not been done. Experience with the species and terrain suggests that the average is probably between 150m and 200m which corresponds to x = 3.53 and x = 6.28 km^2 per 50-stop BBS route.

The habitat term, r_1, was estimated by computing the proportions of various habitat types, as depicted by the GAP map, along roads and throughout the region. Each BBS route was buffered using a 100-m width, and the resulting polygons were intersected with the GAP map. The results showed that most shrubsteppe habitats are equally abundant along roads and regionwide (*table 2*). For example, all of the shrub steppe habitats covered 49 percent of the region and 46 percent of the roadside strips. Thus, r_1 appears to be close to 1.0. I used 0.9 and 1.1 as the lower and upper bounds.

Rotenberry and Knick (1995) studied the density of breeding passerines <25m and >400m from roads in southern Idaho. Densities were equal for Brewer's Sparrows and Sage Sparrows (*Amphispiza belli*) and slightly but non-significantly higher for Sage Thrashers away from roads. Many of the BBS routes in shrub-steppe regions are on seldom-used "two-tracks" that probably have less influence on the surrounding terrain than heavily used, paved roads. This fact and the results from Rotenberry and Knick's (1995) study strongly suggest that densities along BBS routes are similar to regionwide densities. I therefore used a range of 0.9-1.1 for r_2.

Best and Peterson (1985) and Wiens et al. (1987) studied song frequency in Brewer's Sparrows. Song frequency varied between and within years and between habitats but the average probability of singing one or more times in a 3-min period was approximately 0.4-0.6, and I therefore used this as the range for f for Brewer's Sparrows. I am not aware of similar data for the other three species, and therefore used a somewhat wider range, 0.3-0.7, for f for them.

In a simulation of singing bird surveys using tape recorded songs Bart (1985) estimated the mean fraction of audible birds recorded by 20 BBS surveyors. The mean varied from 0.63 to 0.81 among eight species, all of which were fairly common. The trials had a mean of 20 birds present which is probably higher than most BBS stations in the Great Basin, and it seems reasonable that detection rates are probably higher with fewer birds present. I therefore used 0.7 and 0.8 as the lower and upper bounds for g.

Estimated population sizes for the four species varied from <1 to about 22 million birds (*table 3*). The confidence intervals are fairly wide, but it would be relatively easy to undertake field or analytic work to narrow the ranges for y, x, m, and f, the variables known most poorly at present. Thus, this approach provides a means for meeting the recently established goal of estimating population size for many species breeding within the area covered by the BBS. Other methods, however, will be needed for northern-nesting species and species recorded only rarely on the BBS.

Table 1— *Mean birds per route and 95 percent confidence interval for four shrubsteppe species.*

Species	Mean number recorded/route	Standard error	95 percent confidence interval	
			Lower	Upper
Brewer's Sparrow	19.8	2.00	15.8	23.8
Black-throated Sparrow	9.5	1.52	6.5	12.5
Gray Flycatcher	1.5	0.50	0.5	2.5
Sage Thrasher	11.8	1.65	8.5	15.1

Table 2— *Proportion of the region and of the roadside strip covered by different habitats.*

General habitat	Specific habitat	Region	Roadsides
Montane	Forest	0.22	0.16
	Mountain scrub meadow	0.09	0.08
	Bitterbrush	0.00	0.00
	Sub-total	0.31	0.24
Shrubsteppe	Blackbrush	0.03	0.04
	Creosote-Greasewood	0.04	0.03
	Mixed scrub	0.02	0.01
	Sagebrush	0.12	0.10
	Sagebrush steppe	0.14	0.13
	Salt desert scrub	0.14	0.15
	Sub-total	0.49	0.46
Grassland/agriculture	Grassland	0.05	0.06
	Agriculture	0.06	0.12
	Sub-total	0.11	0.18
Other	Dune/lava flow	0.03	0.01
	Water	0.02	0.01
	Wetlands/riparian	0.01	0.03
	Residential	0.01	0.01
	Sub-total	0.07	0.06

Table 3— *Estimated population sizes of four shrub-steppe passerines in Region 4 of the U.S. Forest Service.*

Species	Lower bound	Upper bound
Brewer's Sparrow	3,700,000	22,200,000
Black-throated Sparrow	1,300,000	12,200,000
Gray Flycatcher	99,000	900,000
Sage Thrasher	1,700,000	15,900,000

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Detection Ratios of Riparian Songbirds[1]

Susan L. Earnst[2] and Jeannie Heltzel[3]

Abstract

This paper presents preliminary results from the first year of a two-year study designed to evaluate bias in a typical songbird survey by examining differences in detection ratios among species, cover types, and time of the season. Detection ratios, calculated as number of individuals detected during a 15-25 minute fixed-width transect survey divided by the number of individuals shown to be present through intensive nest searching and territory mapping, were obtained for riparian songbirds on 22, 1.5-ha plots in southeastern Oregon. During intensive territory mapping and nest finding, overall, 80 percent of territories were identified after 3 hours of effort per plot, the estimated number of territories stabilized after about 9 hours, and nests or probable nests were located on 204 (78 percent) of the 261 identified territories. The pooled detection ratio for all species was 0.46 (±0.03 se). Species-specific detection ratios ranged from 0.59 in Song Sparrows to 0.20 in MacGillivray's Warbler. The detection ratio was higher in willow/meadow cover type than in aspen, possibly due to the more frequent nest loss in willow/meadow and presumably higher detectability of re-nesting pairs, the higher density of individuals and species in aspen, and the greater structural complexity of aspen. Total detections were higher earlier in the season (17-22 May) than later (31 May-19 June), suggesting a decline in detectability with nesting phenology. Further study to understand the visual and auditory detectability of individual territory-holders as a function of distance from the observer, stage of nesting, paired status, date, time of day, and various other factors, will help evaluate potential sources of bias and aid in identifying rapid survey methods that are likely to be most efficient.

Key words: avian, density, detection ratios, double sampling, index, riparian

Introduction

Point counts and other methods that use singing birds to monitor and assess avian abundance across time or habitats provide an index to abundance. Indices may lead to biased results if detectability varies systematically among subgroups being compared (e.g., among species, habitats, or years). Although a balanced and standardized design can reduce the effects of some sources of bias, other sources cannot be accounted for by design or specialized analyses (Bart and Schoultz 1984; Johnson 1995). As a result, doubling sampling (Bart and Earnst 2002) and other methods that estimate density are becoming more widely used (e.g., distance sampling, Buckland et al. 2001; double observer, Nichols et al. 2000; removal method, Farnsworth et al. 2002). In double sampling, a large number of plots is surveyed using a rapid survey method (point counts, distance methods, double observer), and the true 'number present' is determined on a subsample of these plots (Bart and Earnst 2002). We define 'number present' as those individuals whose first nest of the season or territory centroid (for those whose nest was not found) is within the plot. Other definitions can be used as long as each bird in the population of interest is assigned a single place by the definition. The number of individuals recorded on rapid surveys, averaged across observers, is used as the numerator in the detection ratio and the 'number present' is the denominator. This ratio is best conceptualized as an index ratio, or correction term, between the numbers recorded during rapid surveys and the parameter of biological interest (number of birds on territories). The correction term reflects errors caused by territory holders being absent, behaving in a non-detectable manner, or missed by the observer during rapid surveys.

Double sampling is being used to assess the density of riparian songbirds on Sheldon and Hart Mountain National Wildlife Refuges as part of a larger study (Earnst et al., this volume). Here we describe preliminary detection ratios obtained as part of that ongoing work. Understanding factors that affect detectability will help to evaluate potential sources of bias in songbird surveys and aid in identifying survey methods that are likely to be most efficient. Specifically, the aim of this paper is to describe the a) average or pooled detection ratio across all species; b) variation in detection ratios among species and habitats; and c) seasonal trend in overall detections on rapid surveys.

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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Methods

As part of the larger study, 106 riparian plots were placed systematically across perennial streams and cover types on Hart Mountain National Wildlife Refuge. Of those 106 plots, 22 were intensive plots in the 2001 field season and form the basis for all analyses in this paper. Another 11 of the 106 plots will be intensive plots in 2002, resulting in 33 percent of all plots being sampled with the intensive method. We chose intensive plots in representative patches of aspen, willow, and meadow cover types along five different drainages, but did not choose a true random sample of the 106 plots due to time constraints of traveling among plots. Each plot was 150 m long by 100 m wide, the center-line was marked at 50 m increments and ran near and parallel to the stream, and the width of the riparian vegetation was typically less than the width of the plot.

In this application of double sampling, we used a fixed-width transect method as the rapid survey method and we used nest searching and territory mapping to obtain the actual number present. Each of 4 observers conducted one rapid survey on each plot, with each plot surveyed once during 17-22 May, twice during 31 May - 9 June, and once during 15-19 June. During a rapid survey, the observer walked slowly along the center-line recording all birds seen or heard within the plot. Time spent on a rapid survey depended on cover type—25 minutes in aspen, 20 in willow, and 15 in meadow. We used the time constraints of Dobkin et al. (1988a,b) because one goal of the larger study was to compare avian abundance in 2000-2002 to that in 1991-1993 (Earnst et al., this volume). The time constraints were originally designed to allow more time in habitats with higher avian abundance (Dobkin et al. 1988b).

Nest searching and territory mapping were conducted by the 2 authors on 11 intensive plots each (11 aspen, 8 willow, and 3 meadow) from 17 May through 19 July. After each visit to a plot, we recorded number of hours on plot and number of nests and territories of each species. Territory mapping was a season-long iterative process; maps from previous visits were modified upon each subsequent visit. In addition to nests, we recorded 'probable nests' on known territories when a) a female repeatedly flushed from a single location in a species-specific manner characteristic of a nest; b) an adult of a ground-nesting species was observed feeding immobile young; or c) an adult of a shrub/tree nesting species was repeatedly observed taking food to one location during the nestling phase (see also Vickery et al. 1992, and Martin and Geupel 1993). These operational definitions represent cases in which the observer was confident of the location of the nest to within a few meters and thus confident that the nest was within the plot.

The detection ratio for a species was calculated as the average number of individuals recorded per rapid survey divided by the average number of nests or territory centroids discovered during intensive surveys. Standard formulas for ratio estimators were used (Cochran, 1977, Ch. 6), with plot as the sampling unit (N = 22). Pooled detection ratios for more than one species were calculated by first summing the numerator and denominator across species. The coefficient of variation (CV = standard error/$\bar{x}$) was used as a measure of precision. Standard errors (se) are given with means throughout and scientific names of species mentioned in text and figures are given in *table 1*. T-tests were used to compare detection ratios. The distribution of the test statistic (i.e., mean difference between ratios) is symmetrical and thus close to a t-distribution, under the null hypothesis of no difference, thus t-tests are valid.

Results

We monitored a total of 261 territories of 32 species (*table 1*). Cumulative hours spent per plot averaged 12.5 hours for meadow and willow plots, which had an average of 6.5 territories per plot, and 23.1 hours for aspen plots, which had a mean of 17.3 territories per plot (*table 2*). When data from all plots were pooled, it indicated that approximately 80 percent of territories were identified after only 3 hours of monitoring, and the estimated number of territories stabilized after about 9 hours (*fig.1*). Approximately 60 percent of nests or probable nests were found after an average of 18 hours per plot and 80 percent were found on those plots visited for 42 hours. Overall, nests were located on 70 percent of territories (183/261), and nests or probable nests were located on 78 percent of territories (204/261).

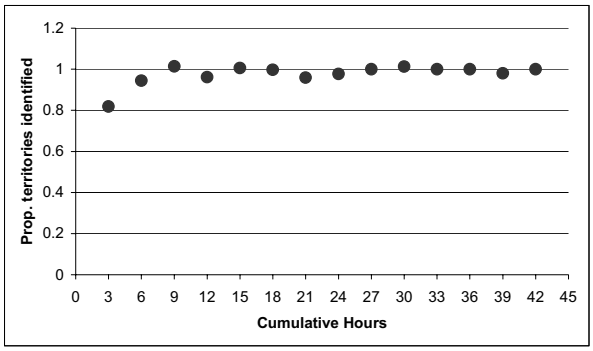

Figure 1— Proportion of territories identified within 3-45 cumulative hours of effort on plots. Cumulative effort and results were recorded at the end of each plot-day (effort per day varied from 1-8+ hrs per plot), thus each plot does not necessarily enter each cumulative category.

Table 1— *Number of territories and nests of species holding >5 territories within the 22 intensive plots on Hart Mountain, 2001. The 204 total nests include the 21 probable nests given in parentheses.*

Species	Scientific name[a]	AOU code	Territories	Total nests
Yellow Warbler	*Dendroica petechia*	YWAR	39	33 (2)
House Wren	*Troglodytes aedon*	HOWR	30	28 (2)
Dusky Flycatcher	*Empidonax oberholseri*	DUFL	27	23
American Robin	*Turdus migratorius*	AMRO	26	23 (1)
White-crowned Sparrow	*Zonotrichia leucophrys*	WCSP	14	13 (3)
Savannah Sparrow	*Passerculus sandwichensis*	SAVS	13	8 (1)
Song Sparrow	*Melospiza melodia*	SOSP	12	10 (3)
Tree Swallow	*Tachycineta bicolor*	TRES	12	10
Warbling Vireo	*Vireo gilvus*	WAVI	11	8
Northern Flicker	*Colaptes auratus*	NOFL	9	9 (2)
MacGillivray's Warbler	*Oporornis tolmiei*	MACW	8	4 (2)
Cassin's Finch	*Carpodacus cassinii*	CAFI	7	6 (1)
European Starling	*Sturnus vulgaris*	EUST	7	6 (1)
Green-tailed Towhee	*Pipilo chlorurus*	GTTO	7	1 (1)
Dark-eyed Junco	*Junco hyemalis*	DEJU	6	2
Yellow-rumped Warbler	*Dendroica coronata*	YRWA	5	2
Other species			28	18 (2)
Grand Total			261	204 (21)

[a]Scientific names of species mentioned in the text but not in *table 1* are as follows: Barn Swallow (*Hirundo rustica*), Black-headed Grosbeak (*Pheucticus melanocephalus*), Brewer's Blackbird (*Euphagus cyanocephalus*), Brewer's Sparrow (*Spizella breweri*), Bullock's Oriole (*Icterus bullockii*), Cliff Swallow (*Petrochelidon pyrrhonota*), Swainson's Thrush (*Catharus ustulatus),* Western Tanager (*Piranga ludoviciana*), Western Wood-Peewee (*Contopus sordidulus*), and Wilson's Warbler (*Wilsonia pusilla*).

Table 2— *Mean observer effort and mean number of territories, nests, and species holding territories by cover type on intensive plots on Hart Mountain, 2001 (N = 11 plots in aspen and 11 plots in willow/meadow).*

Cover type	Visits	Hours	Species	Territories	Nests	Probable Nests
Aspen	12.0 ± 1.0	23.1 ± 2.9	10.9 ± 1.1	17.3 ± 2.2	12.5 ± 1.9	1.4 ± 0.4
Willow/Meadow	8.4 ± 1.1	12.5 ± 2.2	4.5 ± 0.7	6.5 ± 0.9	4.0 ± 0.7	0.7 ± 0.2

The pooled detection ratio for all species was 0.46 (±0.03 se). Species-specific detection ratios, which were calculated for the 16 species having >5 territories present, ranged from 0.59 in Song Sparrows to 0.20 in MacGillivray's Warbler (closed bars, *fig.2*). A reasonably precise detection ratio was obtained for 11 of these species (CV < 0.25, see $\bar{x}$'s and se's in *figure 2*, closed bars) and the coefficient of variation was <0.40 for the other 5 species (Cassin's Finch, Dark-eyed Junco, Green-tailed Towhee, MacGillivray's Warbler, and Yellow-rumped Warbler). The precision of the species-specific detection ratios will increase with the addition of more plots (and thus more territories for each species) in the 2002 field season, and differences among species will be investigated more thoroughly then. In the final calculation of density, a pooled detection ratio will be used for groups of species having similar detection ratios.

A second detection ratio, which can be thought of as a maximum or 'potential' detection ratio, was based on 3-4 rapid surveys that each intensive surveyor performed on each of the plots on which she also mapped territories and found nests. We used the same rapid survey method (same time-constraints, stayed on the survey line), but we were familiar with the individuals on each plot, referred to our territory maps during the rapid survey, and specifically looked and listened for individuals on each known territory. This method of obtaining 'potential' detection ratios minimized the chance that an observer would overlook a territory owner that was present and behaving in a detectable manner. Thus, we interpret 'potential' detection ratios

<1 as being due primarily to territory owners being absent or undetectable (i.e., not singing and not visible) during the survey, rather than the observers failing to detect them. As expected, the 'potential' detection ratio tended to be higher than the regular detection ratio (i.e., that obtained by observers inexperienced with the plot) for all species combined ($\bar{x}$ = 0.56 ± 0.04 vs. $\bar{x}$ = 0.46 ± 0.03, t = 1.89, P = 0.07), and was significantly higher for Yellow Warbler, Dusky Flycatcher, and MacGillivray's Warbler (*fig.2*). More importantly, all 'potential' detection ratios were substantially less than 1.0 (open bars, *fig.2*), indicating for example that up to 20 percent of Warbling Vireos and 80 percent of Yellow-rumped Warblers were not detectable during transect surveys even when observers looked and listened for specific territory holders.

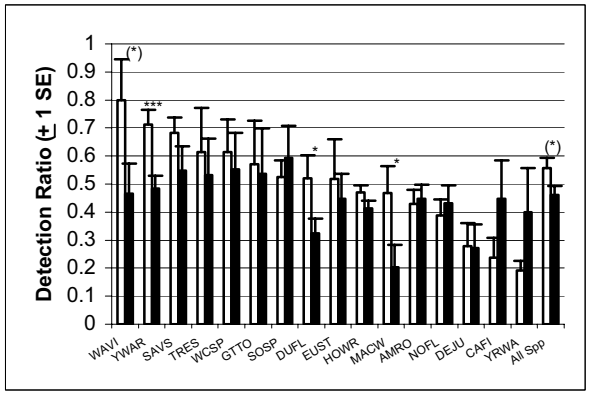

Figure 2— 'Potential' detection ratio (open bars) and observed detection ratio (dark bars) for 16 species with at least five territories present and for all species pooled. Potential detection ratio is the detection ratio by observers familiar with the territories and specifically trying to detect known territory holders. The observed detection ratio is the average of the detection ratio of four observers who had no previous experience with the plots (N = 22 plots). Statistical significance based on independent t-tests with asterisks indicating significance levels as follows: (*) P < 0.10, * P < 0.05, ** P < 0.01, *** P < 0.001. See *table 2* for four-letter species codes and number of territories present.

Detection ratios in the willow/meadow cover type were 28 percent higher than those in aspen for all species combined ($\bar{x}$ = 0.58 ± 0.05 vs. $\bar{x}$ = 0.42 ± 0.03, t = 2.49, P = 0.02, *fig.3*). Five species had at least three territories in each cover type (MacGillivray's Warbler, Yellow Warbler, Dusky Flycatcher, White-crowned Sparrow, and American Robin) and the pooled detection ratio for these five common species was also significantly higher in willow/meadow than in aspen ($\bar{x}$ = 0.52 ± 0.05 vs. $\bar{x}$ = 0.38 ± 0.03, t = 2.25, P = 0.03; *fig.3*).

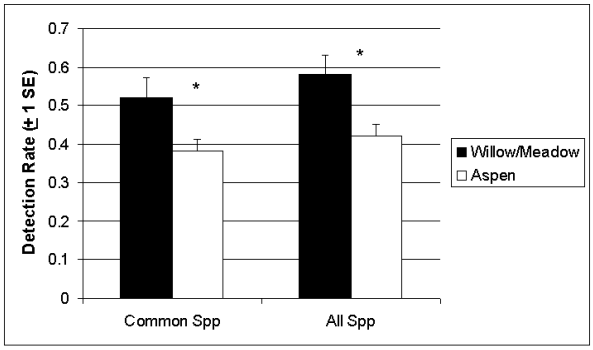

Figure 3— Pooled detection ratio on willow/meadow (N = 11) and aspen plots (N = 11) for 5 species that had at least three territories within each cover type and for all species pooled. Statistical significance based on independent t-tests, with asterisks indicating significance levels as follows: * P < 0.05; ** P < 0.01; *** P < 0.001.

To investigate whether detections varied over the course of the season, we calculated number of individuals detections per plot-survey in three calendar periods (17-22 May, 31 May-9 June, and 15-19 June). Detections per plot were higher in the first period (15.6 ± 1.5) than during the second (10.8 ± 0.9, paired t = 4.90, P < 0.001) or third (11.9 ± 1.0, paired t = 2.92, P = 0.008) for all species combined, excluding Brewer's Blackbirds. Brewer's Blackbirds were unusual in showing a 5-fold increase from the first to the third period (0.27, 0.63, and 1.35 individuals per plot) when flocks of parents and young moved into some plots. Similarly, a few relatively uncommon species that arrived later than others (Black-headed Grosbeak, Western Wood-Pewee, Swainson's Thrush) also had somewhat more detections in the last period than in earlier periods.

Discussion

The finding that 80 percent of territories were identified after only 3 hours of monitoring, and the estimated number of territories stabilized after about 9 hours, suggests that our territory-mapping method is a reliable and efficient method for determining total number of territories per plot. Nest finding also was useful in determining the number of territorial pairs present, especially for rare or secretive species, plots with high density, and edge territories. In addition, nest finding allowed a valuable ancillary study of nest success. It is possible that territory mapping alone would provide a reliable count of true number present for most territorial songbird species and thus be an appropriate intensive method, but this needs further study. The intensive method of repeated territory mapping and nest finding used here minimized the potential for problems inherent in less intensive methods such as spot mapping (e.g., Eagles 1981, and

method, is an attractive sampling plan because it makes fewer assumptions than distance sampling, double-observer, or removal methods (see Bart and Earnst 2002).

Numerous authors during the past two decades have highlighted the pitfalls of interpreting indices of abundance (Burnham 1981, Bart and Earnst 2002, Farnsworth et al. 2002, Nichols et al. 2000, Rosenstock et al. 2002, Thompson 2002). Likewise, three findings from the current study demonstrate the value of estimating detection ratios and suggest caution in interpreting indices. First, the low 'potential' detection ratio ($\bar{x}$ = 0.56 ± 0.04), obtained by observers who knew the territories well and specifically listened for known territorial birds, is strong evidence that many breeding birds will not be detected by survey methods that rely primarily on auditory cues, such as point counts. This suggests the need for a rapid method, such as an area search, that would increase visual detections. The strip transect method used here resulted in almost identical detections per plot compared to fixed-radius point counts that sampled an equivalent area and time, and it resulted in somewhat fewer detections per plot than a single visit, medium-intensity, area-search/spot-map technique that required 45 minutes per meadow plot and 270 minutes per willow or aspen plot (Dobkin et al. 1998b).

Although a low detection ratio is not itself a problem, the lower the average ratio, the more potential for variation among subgroups of interest, such as species, habitats, or years. For example, in this study, the detection ratio was three times higher for Song Sparrows than MacGillivray's Warblers. Not surprisingly, two of the species with the lowest detection rates included one that sings sporadically (MacGillivray's Warbler) on our study site and one with a quiet, easily missed song (Dusky Flycatcher). Other field studies have also reported a low overall detectability and high variability among species (e.g., DeSante 1981), and tape-recording studies have shown that even experienced surveyors missed up to 35 percent of audible birds (Bart and Schoultz 1984) and were significantly less successful in detecting some species than others (Kepler and Scott 1981; Bart 1985).

Second, an important source of variation and potential bias, is the change in singing rate and visibility across stages of the nesting cycle (Wilson and Bart 1985). In our study, detections per plot dropped 24 percent from 17-22 May to 15 -19 June. This illustrates the need for plots to be surveyed at the same time each year relative to arrival and nesting phenology and for surveys to be completed within the window of relatively high detectability. This task is complicated by the likelihood that nesting phenology—timing of pair bond formation, nest initiation, incubation, nestling care, re-nesting after nest loss, or initiating a second clutch—varies by species and year and may not always be related to phenology of male arrival (B. Walker, pers. comm.) or other easily detected cues.

Third, detection ratios varied between cover types, thus complicating the use of indices to make inferences about the relative value of a cover type. The higher detection ratio in willow/meadow habitat compared to aspen habitat was expected based on the less complex vegetative structure and the fewer number of individuals and species present. Other studies have shown that observers are more efficient when density of species (Scott and Ramsey 1981) and conspecifics (Bart and Schoultz 1984) is lower. It is also possible that the higher detection ratio resulted from a higher detectability of pairs that were re-nesting after nest failure (in particular, a higher singing rate by re-nesting males), since nest failure was more common in willow /meadow than aspen habitat in 2001 (Heltzel and Earnst 2002). The difference in detectability in willow /meadow compared to aspen habitat was probably even higher than estimated here since our rapid survey method allowed 15 or 20 minutes in willow/meadow habitat and 25 minutes in aspen.

Our study was designed to allow comparison to a 1991-1993 study on the same areas, but not all aspects of the design are optimal for double sampling. For example, the small size of plots (1.5 ha) and their high edge-area ratio meant that several territories were on plot edges. Because edge birds were not always present on the plot, they added noise to the rapid estimate, and during intensive searches, required substantial effort to determine whether the nest or territory centroid was inside the plot. Plot size should be large relative to the territory size of species of interest. Our plot size was sufficient for many songbirds (Yellow Warblers, Warbling Vireos, Dusky Flycatchers) but larger plots would have been better for Bullock's Orioles, Black-headed Grosbeaks, and Western Tanagers, which have large territories and move widely among areas.

Our definition of number present worked well for most songbirds but not for those that used riparian areas during some periods or activities but rarely nested there. For example, some species nested in the uplands near plots and moved fledglings to riparian areas later in the summer (Brewer's Sparrows and Brewer's Blackbirds); others foraged widely away from nests (Cliff Swallows and Barn Swallows); and some migrants used plots for a week or more but did not nest there (Wilson's Warblers and Swainson's Thrushes). If these species are of particular interest, a definition of 'number present' other than location of nest or territory centroid is needed for them.

Further study to understand the visual and aural detectability of individual territory-holders as a function of distance from the observer, stage of nesting, paired status, date, time of day, and various other factors will help to evaluate potential sources of bias and aid in identifying rapid survey methods that are likely to be most efficient. Also, double sampling can be used to empirically evaluate the potential bias of the various rapid methods, including methods that estimate density (e.g., distance sampling, or double observer), and can be used to evaluate their efficiency (i.e., the standard error of the density estimate obtained from double sampling). The optimal intensive method should also be evaluated empirically, perhaps by conducting territory mapping and/or nest finding on a color-marked population.

Acknowledgments

This project was funded by the Nongame Bird Program, U.S. Fish and Wildlife Service, Region 1; thanks to T. Zimmerman and M. Green for their support of this component of the study. Thanks to the staff of the Sheldon-Hart Refuge Complex for logistical support and to J. Bart and A. Holmes who provided many useful suggestions throughout the study. N. Nur, B. Walker, H. Stauffer, and an anonymous reviewer provided constructive comments on an earlier version of the manuscript.

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Application of Bayesian Methods to Habitat Selection Modeling of the Northern Spotted Owl in California: New Statistical Methods for Wildlife Research[1]

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Abstract

We compared a set of competing logistic regression habitat selection models for Northern Spotted Owls (*Strix occidentalis caurina*) in California. The habitat selection models were estimated, compared, evaluated, and tested using multiple sample datasets collected on federal forestlands in northern California. We used Bayesian methods in interpreting Akaike weights calculated for the estimated models. This approach combines Akaike weights with prior probabilities to provide posterior probabilities for the set of competing models for each dataset. This process can be iterated with multiple sample datasets to calculate a succession of posterior probabilities that provide revised assessments of the relative credibility of the models. The posterior probabilities also provide weights for model averaging. They can be used to measure the importance of the covariates in the models, and they provide the weights for model averaging of the predictive values and estimates of the coefficients of the covariates, along with error. This approach offers a robust solution to modeling habitat associations, providing a more realistic assessment of error and uncertainty in the results. We illustrate these methods with sample datasets for the Northern Spotted Owl in California.

Key words: AIC, Akaike weights, Bayesian methods, habitat selection modeling, model averaging, Northern Spotted Owls, posterior probabilities, prior probabilities.

Introduction

It is now widely accepted practice among wildlife researchers and managers to use the parsimonious a priori model selection and inference strategy advocated by Burnham and Anderson (1998). With this approach to model selection, a relatively small collection of biologically plausible candidate models is selected for analysis prior to data collection. The models are then fitted using a sample dataset, and Akaike's Information Criterion (AIC) is used to compare the models (Akaike 1973). AIC "measures" the error, or Kullback-Liebler "distance," between the estimated model and the dataset. The model with the lowest AIC is the best fitting among the collection of candidate models. Since AIC = deviance + 2K where K is the number of parameters estimated in the model, AIC "penalizes" a model for the number of parameters and discourages a model from having too many parameters and over-fitting a sample dataset. For application, it is best to use a corrected Akaike's Information Criterion, AICc, particularly for small datasets, because it is more accurate (Burnham and Anderson 1998).

Burnham and Anderson (1998) also recommend the use of Akaike weights, that can be calculated from the AIC (or AIC_c) values. The Akaike weights A_i of all candidate models

$$A_i = e^{-\{(AIC_i - \text{minimum}(AIC_j))/2\}} / \Sigma_k e^{-\{(AIC_k - \text{minimum}(AIC_j))/2\}}$$

sum to 1 ($\Sigma_i A_i = 1$) and can be interpreted as estimates of the relative likelihoods of the models being the best fitting, among the collection of candidate models. Burnham and Anderson (1998) demonstrate convincingly, using bootstrapping techniques with multiple examples, that this interpretation of Akaike weights is reliable in most instances. Akaike weights therefore estimate the relative credibility of the models and can be interpreted as the probability of models being the best fitting, among the collection of candidate models.

Herein we report on the observation that Akaike weights also have a very interesting Bayesian statistical interpretation useful to the wildlife managers. Akaike weights can be interpreted as the relative likelihoods of the "parameter space" of models and used to calculate a probability distribution that is the posterior distribution (Hilborn and Mangel 1997). Wildlife managers

[1] A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California**.

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could therefore begin with a prior distribution providing a measure of the relative credibility of a collection of candidate models. The initial prior could be "non-informative," giving equal probability to each model, if prior information is unavailable or unreliable. Managers could then revise this assessment, calculating the posterior distribution for the models, based upon the prior distribution and the Akaike weights calculated from a dataset. Using a second dataset, this process could be repeated, using prior probabilities that are the posteriors from the first dataset analysis, to obtain new posterior probabilities. If multiple datasets are available, this process could continue sequentially, providing posteriors that represent updated estimates of the probabilities of the models best fitting the population, among the collection of models. This process allows for the continual refinement and evaluation of a suite of candidate models as new data become available. This "strength of evidence" approach (Burnham and Anderson 1998) to model selection and refinement incorporates new "information" which is weighed by the evidence up to that point. Wildlife managers may have traditionally been inclined to stop using a model when it performed poorly on a new dataset, and replace it with a new model that performs well on the new dataset, a "continual reinvention," as opposed to the approach we are advocating, continual refinement or adaptation. We do, however, recognize that if all models continually perform poorly, reinvention may be necessary. Nonetheless, the approach we present is consistent with the application of adaptive resource management. We will begin by reviewing the ideas of Bayesian statistical analysis.

Bayesian Statistical Analysis

Bayesian statistical analysis begins by assuming a prior distribution representing the current understanding, or a measure of the relative credibility, about a parameter (Iversen 1984, Hilborn and Mangel 1997, Congdon 2001, Gill 2002). A sample dataset is then analyzed, assuming a model such as a normal, Poisson, or binomial distribution. A likelihood function for the parameter is calculated from the data and the model. The posterior distribution is the product of the likelihood and the prior, scaled to sum to 1. The idea is the following

$$\text{prior} \rightarrow \text{likelihood} \rightarrow \text{posterior}$$

where posterior = prior•likelihood / Σ prior•likelihood for a discrete parameter. In the case of a continuous parameter, summation "Σ" should be replaced with integration "∫". This process is based upon Bayes Theorem that states, for parameter value B and data D, in the discrete case,

$$\Pr(B|D) = \Pr(D|B)\bullet\Pr(B) / \Sigma \Pr(D|B)\bullet\Pr(B)$$

Here Pr(B|D) = conditional probability of *B, given D*, is the posterior probability of B. Pr(D|B) = conditional probability of D, given B, is the likelihood of D. Pr(B) = probability of D is the prior probability of B. Therefore Bayes Theorem can be interpreted as

$$\text{posterior}(B) = \text{likelihood}(D|B)\bullet\text{prior}(B) / \Sigma\ \text{likelihood}(D|B)\bullet\text{prior}(B)$$

The denominator is a scaling factor ensuring that the posterior probabilities sum to 1. So posterior probabilities are scaled products of prior probabilities and likelihood values, obtained from the data and model.

A collection of models can be interpreted as a categorical "parameter space" with discrete values equal to each of the models. The models themselves are estimated using frequentist estimates for the parameters. The Akaike weights, the relative likelihoods of the models being the best fitting to the dataset, therefore, can be interpreted as likelihoods for the models. They can hence be multiplied times prior probabilities, and scaled, to provide posterior probabilities for the parameter space of models.

An Example with Binary Data

As an example, consider the binary dataset {1,0,1} of three measurements, representing the presence or absence of a wildlife species at sample sites. We will use a simple binomial model to describe this dataset for purposes of illustration

$$B(x;p,n) = k\bullet p^{x}\bullet(1-p)^{(n-x)}$$

where x = the number of 1's (= 2 for this dataset), n = the number of samples (= 3 for this dataset), and k = the binomial coefficient = $\binom{n}{x} = \frac{n!}{x!(n-x)!}$ is a constant (=3 for this dataset). The likelihood function for the parameter p, based upon this dataset D = {1,0,1} and the model, is proportional to $p\bullet(1-p)\bullet p = p^2 - p^3$ (*fig.1a*). The classical frequentist maximum likelihood estimator for the parameter p, based upon this dataset, calculates the maximum value estimate at $\hat{p} = 2/3 = 0.33$ (=x/n) for this model likelihood function. Alternatively, Bayesian statistical analysis begins with a prior for *p*, such as a non-informative prior based upon a flat conjugate beta distribution (*fig.1b*)

$$BE(p;\alpha,\beta) = BE(p;1,1)$$
with parameters $\alpha = 1$ and $\beta = 1$,

and calculates a posterior also given by a beta distribution, but with different parameters (*fig.1c*)

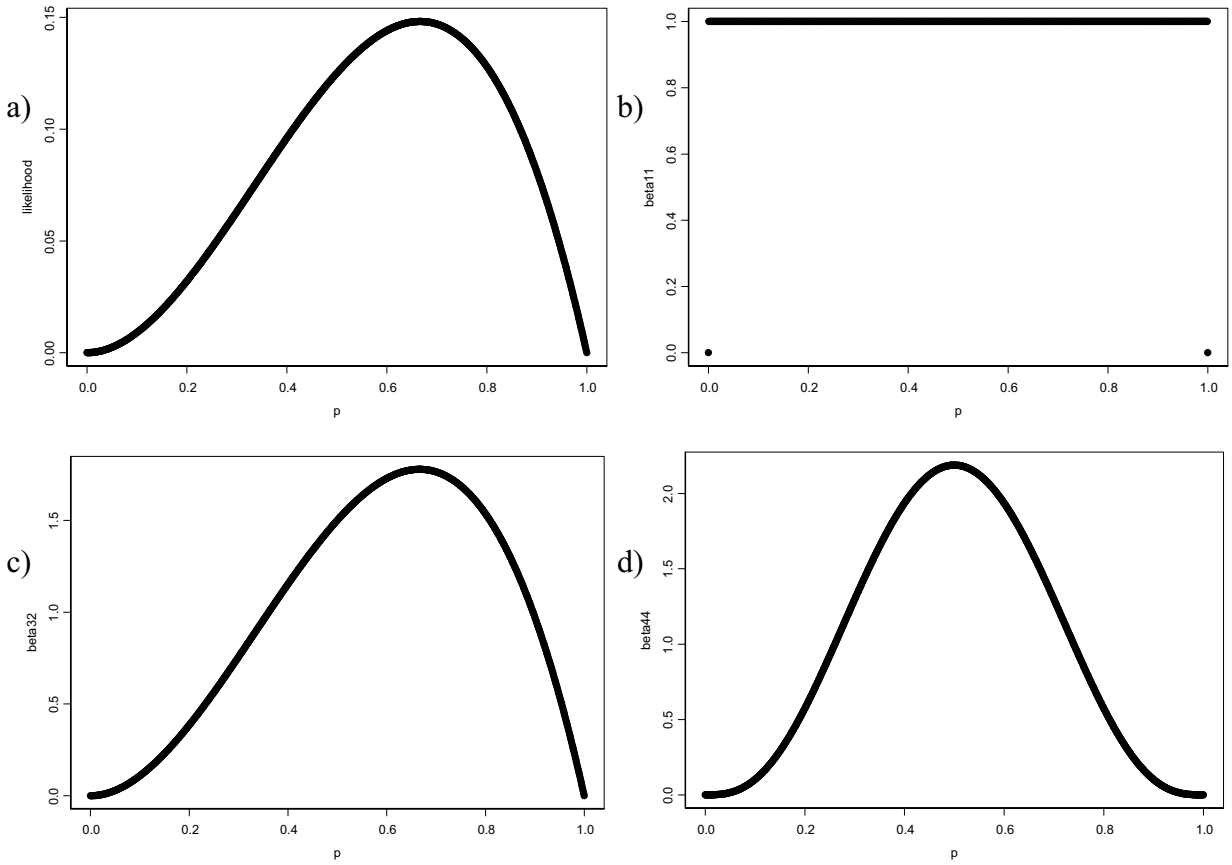

Figure 1— Bayesian statistical analysis for binary datasets, using the binomial model. a) Likelihood p•(1-p) •p = $p^2 - p^3$, for the first dataset {1,0,1}. b) Non-informative beta prior BE(p;1,1), for the first dataset. c) Beta posterior BE(p;3,2), for the first dataset. d) Beta posterior BE(p;4,4), for the second dataset {0,1,0}, based upon the BE(p;3,2) prior.

$$BE(p;\alpha+x,\beta+(n-x)) = BE(p;1+2,1+(3-2)) = BE(p;3,2)$$

Conjugacy theory provides a closed form Bayesian solution for the binomial model B(x;n,p) applied to binary data, with beta prior and posterior distributions, prescribing the addition of x to α and (n-x) to β of the beta prior BE(p; α, β) to obtain the beta posterior BE(p; α +x, β +(n-x)) (Hilborn and Mangel 1997, Carlin and Louis 2000, Gill 2002).

Suppose that we collect a second dataset {0,1,0} with x = 1, n = 3, and likelihood proportional to (1-p)•p(1-p) = p•$(1-p)^2$. The frequentist maximum likelihood estimator for this dataset calculates the maximum value estimate of $\hat{p} = 1/3 = 0.33$. Using the posterior BE(p;3,2) of the first dataset as the prior for this second dataset, we would obtain the new posterior BE(p;3+1,2+2) = BE(p;4,4) (*fig.1d*). The second posterior would represent our most current assessment about *p*, based upon the two datasets. Note that the frequentist maximum likelihood estimate of the combined datasets would be $\hat{p} = 3/6$, occurring at the mode of the second posterior, as we would expect.

A Bayesian Statistical Interpretation of Akaike Weights

Akaike weights estimate the relative likelihoods of the models being the best fitting, among the collection of candidate models. As such, the set of models may be viewed as a "parameter space" with prior probability values assigned to each. The scaled product of the Akaike weights and the priors, scaled to sum to 1, provide a posterior distribution for the parameter space of models, for a given dataset. Furthermore, additional datasets may then be analyzed sequentially, using posteriors obtained from previously analyzed datasets as priors for new datasets, to provide updated new posteriors, based upon all the previously analyzed datasets and the new datasets.

Table 1—*Frequentist and empirical Bayesian statistical analysis summaries of 12 habitat selection models for Northern Spotted Owls in California, for RDA, Hayfork, and Mendocino datasets.*

a) RDA frequentist analysis.

Models (200 ha)	AIC_c	Akaike weight	Correct classification (%)	Sensitivity (%)	Specificity (%)
LOGNRE + LOGNRC + NR + NR^2 + F + F^2	74.6	0.505505	82.4	87.9	78.1
LOGNR + F + F^2	75.3	0.363419	77.0	93.9	63.4
LOGNRFC + NRF + NRF^2 + NRFE	79.4	0.045630	73.0	87.9	61.0
LOGNRE + LOGNRC	79.7	0.041081	73.0	84.9	63.4
LOGNRE	79.7	0.040067	70.3	90.9	53.7
LOGNRFC + NRFE	84.3	0.004037	71.6	90.9	53.1
F + F^2	93.0	0.000052	67.6	84.9	53.7
LOGFEM2	93.0	0.000051	64.9	81.8	51.2
FEME + FEMC	93.3	0.000044	63.5	84.9	46.3
FEM2	93.4	0.000043	63.5	81.8	48.8
LOGFEME + FEMC + FEM + FEM^2	93.5	0.000041	64.9	84.9	48.8
F + F^2 + FE	94.2	0.000029	66.2	90.9	46.3

b) RDA empirical Bayesian analysis.

Models	$Prior_1$	AIC_c	Change in AICc	Likelihood	Prior* Likelihood	$Posterior_1$
FEME + FEMC	0.0833	93.34	18.71	0.00008653	0.00000721	0.00004374
LOGFEME + FEMC + FEM + FEM^2	0.0833	93.46	18.83	0.00008149	0.00000679	0.00004119
LOGNRFC + NRF + NRF^2 + NRFE	0.0833	79.44	4.81	0.09026550	0.00751912	0.04562963
LOGNRFC + NRFE	0.0833	84.29	9.66	0.00798652	0.00066528	0.00403722
LOGNRE + LOGNRC	0.0833	79.65	5.02	0.08126824	0.00676964	0.04108147
LOGNRE	0.0833	79.70	5.07	0.07926172	0.00660250	0.04006717
F + F^2	0.0833	92.98	18.35	0.00010360	0.00000863	0.00005237
F + F^2 + FE	0.0833	94.15	19.52	0.00005771	0.00000481	0.00002918
LOGNR + F + F^2	0.0833	75.29	0.66	0.71892373	0.05988635	0.36341928
LOGNRE + LOGNRC + NR + NR^2 + F + F^2	0.0833	74.63	0.00	1.00000000	0.08330000	0.50550463
LOGFEM2	0.0833	93.04	18.41	0.00010054	0.00000837	0.00005082
FEM2	0.0833	93.36	18.73	0.00008567	0.00000714	0.00004331
				1.97822125	*0.16478583*	*1.00000000*

Table 1— contd.

c) Hayfork empirical Bayesian analysis.

Models	$Prior_2$	AICc	Change in AICc	Likelihood	Prior* Likelihood	$Posterior_2$
FEME + FEMC	0.00004374	211.89	11.48	0.00321477	0.00000014	0.00001408
LOGFEME + FEMC + FEM + FEM^2	0.00004119	256.40	55.99	0.00000000	0.00000000	0.00000000
LOGNRFC + NRF + NRF^2 + NRFE	0.04562963	216.44	16.03	0.00033047	0.00001508	0.00150934
LOGNRFC + NRFE	0.00403722	212.20	11.79	0.00275318	0.00001112	0.00111257
LOGNRE + LOGNRC	0.04108147	205.50	5.09	0.07847305	0.00322379	0.32268309
LOGNRE	0.04006717	232.00	31.59	0.00000014	0.00000001	0.00000055
F + F^2	0.00005237	279.22	78.81	0.00000000	0.00000000	0.00000000
F + F^2 + FE	0.00002918	281.95	81.54	0.00000000	0.00000000	0.00000000
LOGNR + F + F^2	0.36341928	208.40	7.99	0.01840745	0.00668962	0.66959342
LOGNRE + LOGNRC + NR + NR^2 + F + F^2	0.50550463	264.15	63.74	0.00000000	0.00000000	0.00000000
LOGFEM2	0.00005082	200.41	0.00	1.00000000	0.00005082	0.00508691
FEM2	0.00004331	223.57	23.16	0.00000935	0.00000000	0.00000004
				1.10318840	*0.00999057*	*1.00000000*

d) Mendocino empirical Bayesian analysis.

Models	$Prior_3$	AICc	Change in AICc	Likelihood	Prior* Likelihood	$Posterior_3$
FEME + FEMC	0.00001408	39.97	9.21	0.01000170	0.00000014	0.00000502
LOGFEME + FEMC +FEM^2	0.00000000	45.44	14.68	0.00064905	0.00000000	0.00000000
LOGNRFC + NRF^2 + NRFE	0.00150934	32.97	2.21	0.33121088	0.00049991	0.01783906
LOGNRFC + NRFE	0.00111257	30.76	0.00	1.00000000	0.00111257	0.03970156
LOGNRE+LOGNRC	0.32268309	38.72	7.96	0.01868564	0.00602954	0.21516183
LOGNRE	0.00000055	40.22	9.46	0.00882647	0.00000000	0.00000017
F + F^2	0.00000000	44.30	13.54	0.00114769	0.00000000	0.00000000
F + F^2+FE	0.00000000	46.24	15.48	0.00043507	0.00000000	0.00000000
LOGNR + F + F2	0.66959342	37.88	7.12	0.02843882	0.01904245	0.67952257
LOGNRE + LOGNRC + NR + NR^2 + F + F^2	0.00000000	65.45	34.69	0.00000003	0.00000000	0.00000000
LOGFEM2	0.00508691	33.43	2.67	0.26315818	0.00133866	0.04776965
FEM2	0.00000004	35.55	4.79	0.09117268	0.00000000	0.00000013
				1.75372622	*0.02802328*	*1.00000000*

Application to Northern Spotted Owl Data in California

We applied these ideas to a collection of 12 habitat selection models (Manly et al. 1995) for Northern Spotted Owls in California. For this purpose, we analyzed three datasets, a dataset that was randomly sampled globally for Northern Spotted Owl presence or absence of nesting pairs and habitat attributes throughout federal forestlands in northern California, the so-called Research, Development, and Assessment (RDA) dataset, and two local datasets that were completely censused at the Hayfork Adaptive Management Area and the six adjacent Late Successional Reserves and at Mendocino National Forest. We used the RDA dataset as the initial developmental dataset, estimating, comparing, and testing the models for goodness-of-fit. The Hayfork and Mendocino datasets were then used as test datasets, to further test for goodness-of-fit, but also to "calibrate" our posteriors for the models.

The results of the Bayesian statistical interpretation are summarized in *table 1*. Twelve logistic regression habitat selection models for Northern Spotted Owls in California were estimated and compared (Zabel et al. 2002). The 12 models were selected using habitat definitions thought to be important to the owl, based upon current research findings (Thomas et al. 1990, Gutierrez et al. 1995, Gutierrez et al. 1998, Meyer et al. 1998, Ward et al. 1998, Franklin et al. 1999, Thome et al. 1999, Franklin et al. 2000) and a preliminary analysis screening process. We compared the 12 models using AIC and Akaike weights (Burnham and Anderson 1998) and tested for goodness-of-fit using correct classification (proportion of data points correctly classified), sensitivity (proportion of occupied data points correctly classified), and specificity (proportion of unoccupied data points correctly classified) (Hosmer and Lemeshow 2000). Definitions of owl habitat included NR = nesting, roosting; F = foraging; C = core area; E = edge; FEM = FEMAT definition; and FEM2 = revised FEMAT definition (USDI 1992, USDA and USDI 1993, 1994a, 1994b; Zabel et al. 2002). These 12 models were the best-fitting based upon lowest AIC_c from among a larger collection of several hundred models that were analyzed and compared. These models examined total amount of habitat, amount of core habitat, and edge length of habitat, using linear, quadratic, and pseudo-threshold (log-transformed) forms of the owl habitat definitions.

Table 1a summarizes the analysis results of the developmental dataset, with models ranked by order of fit. The LOGNRE+LOGNRC+NR+NR^2+F+F^2 model was the best fitting, of the 12 candidate models, based upon its lowest AIC_c. This model had the log of NR edge and core, quadratic NR, and quadratic F as its covariates. The LOGNR+F+F^2 model was second best fitting. This model had the log of NR and quadratic F as its covariates. These top two models dominated the collection of candidate models, as the best-fitting models, with a combined Akaike weight of 0.8689. The goodness-of-fit results were somewhat similar among models, but tended to be higher for the better fitting models. It was interesting to note that the second leading model, although higher in AIC value, did demonstrate a markedly higher sensitivity than the others, at 93.9 percent. High sensitivity was a particularly important management priority for this application. This observation was to become substantiated with further analyses of the other datasets.

Table 1b summarizes the Bayesian interpretation of this RDA dataset analysis. The priors for the models were assumed equal and non-informative, at 1/12 = 0.0833 each. The posteriors for this first dataset were equal to the Akaike weights. The likelihoods in this table were the un-scaled Akaike weights,

$$e^{-\{(\text{AIC-minimum(AIC)})/2\}}.$$

These un-scaled Akaike weights were then multiplied times the priors (assumed constant), and scaled to sum to 1, to obtain the new posteriors, the scaled Akaike weights.

The Bayesian analysis of the Hayfork dataset is summarized in *table 1c*. It was particularly striking with the results of this second step of the Bayesian statistical interpretation that the new posteriors for the local Hayfork dataset were markedly different from the previous RDA posteriors. The second-ranked model, the LOGNR+F+F^2 model, was now top-ranked, with a posterior probability of 0.6696. The original top ranked model descended to the bottom of the list. A new model, the LOGNRE+LOGNRC model, emerged second on the list, with a posterior of 0.3227. It originally had a posterior of just 0.0411 with the RDA analysis.

Table 1d summarizes the Bayesian interpretation for the Mendocino dataset. Again the original second-ranked model, the LOGNR+F+F^2 model, had the highest posterior, at 0.6795. The LOGNRE+LOGNRC model was second again, with a posterior of 0.2152. The original top-ranked model still had an insignificant posterior and was at the bottom of the list. As we progressed through additional test datasets (not shown), the results stabilized at these rankings.

Discussion: Use of Posteriors for Model Averaging

The posterior probabilities provide weights for model averaging, based upon the entire collection of candidate models. The predicted response values, the estimat-

ed importance of covariates, and the absolute estimates of covariate coefficients and error can then be calculated using model averaging.

Predictions of the response can be averaged over all the models, using the weighted averages of the predicted values of an observation for all the models. For observation x, the model average predicted response value f(x) for all the models $f_1(x)$, $f_2(x)$, ... , $f_k(x)$ is given by

$$f(x) = \Sigma_i p_i \cdot f_i(x)$$

where p_i are the model posterior probabilities. If, for example, the $f_1 = LOGNR+F+F^2$ model had a predicted value of $f_1(x) = 0.20$ with posterior of 0.68 (*table 1d*) and the f_2 = LOGNRE+LOGNRC had a predicted value of $f_2(x) = 0.30$ with posterior of 0.22, then the model averaged predicted value, based upon these two dominant models, would be

$$\begin{aligned} f(x) &= (p_1/(p_1+p_2))\cdot f_1(x)+(p_2/(p_1+p_2))\cdot f_2(x) \\ &= (0.68/0.90)\cdot(0.20)+(0.22/0.90)\cdot(0.30) \\ &= 0.224, \end{aligned}$$

based upon these two dominant models. In actual application, it would be best to take the model averaged predicted value based upon all models in the collection of models under consideration.

The importance of covariates in the models can also be estimated and compared using model averaging. The importance of each covariate x_i can be estimated by taking the sum of the posterior probabilities of the models that include that covariate

$$\text{importance}(x_i) = \Sigma_{j \in S}\, p_j$$

where *j* is indexed with values throughout the set S, the set of models that contain the x_i covariate. In the example above with just the 2 dominant models, x_1 = NR and its forms are in both models, whereas x_2 = F is just in the second model, so the relative importance of NR is 0.90 compared to the importance of F of 0.68.

Similarly, model averaging may be used to obtain an absolute or unconditional estimate $\hat{\beta}_i$ of the coefficient of covariate x_i and its error $se_{\hat{\beta}_i}$, using the weighted average of the individual model estimates $\hat{\beta}_{ij}$ of the coefficient or their standard errors $se_{\hat{\beta}_{ij}}$ (here i indexes the covariate x_i and j is indexed with values in S, the set of models with covariate x_i)

$$\hat{\beta}_i = \Sigma_{j \in S}\, p_j \cdot \hat{\beta}_{ij}$$

$$se_{\hat{\beta}_i} = \Sigma_{j \in S}\, p_j \cdot se_{\hat{\beta}_{ij}}$$

Burnham and Anderson (1998: 134-137) provide an improved estimator for the unconditional standard error based upon mean square error. Shrinkage estimators can also be obtained by taking the weighted average over all models, not just those in S containing the covariate x_i. An absolute or unconditional estimate of error for a covariate coefficient estimate typically contains more error than is normally calculated conditionally for an individual model estimate that assumes that model is correct. This is a reflection of the added uncertainty of the estimates introduced by variation among the competing models. More details on model averaging, along with examples, can be found in Burnham and Anderson (1998).

Conclusions

A Bayesian interpretation of Akaike weights as likelihoods that can be combined with priors to obtain posteriors for a parameter space of models allows an iterative evaluation process for model comparison, based upon multiple datasets. Datasets need not be analyzed independently of each other, as with a frequentist approach, but rather sequentially, with the results of data analyses building on each other. The posterior distribution outputs of one data analysis becomes the prior distribution inputs of the next data analysis, in a sequential process that reassesses an understanding about parameters and is more attuned to the cumulative scientific method and adaptive management.

Acknowledgments

We thank the U.S.D.A. Forest Service, Pacific Southwest Research Station, Redwood Sciences Laboratory, and Humboldt State University, for providing funding for this project.

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Monitoring, Modeling, and Management: Why Base Avian Management on Vital Rates and How Should it Be Done?[1]

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Abstract

In this paper we argue that effective management of landbirds should be based on assessing and monitoring their vital rates (primary demographic parameters) as well as population trends. This is because environmental stressors and management actions affect vital rates directly and usually without time lags, and because monitoring vital rates provides a) information on the stage of the life cycle where population change is being effected, b) a good measure of the health and viability of populations, and c) a clear index of habitat quality. We suggest that modeling lambda (λ, the rate of change in population size) as a function of vital rates provides useful information on potential responses of populations to management actions, but because of covariation among vital rates and density dependence, the predicted responses may not occur. We suggest that modeling spatial variation in vital rates as a function of spatial variation in lambda provides added insight into the proximate demographic "cause(s)" of population change and permits identification of "deficient" vital rates. We illustrate this at two spatial scales with analyses of BBS and MAPS data on Gray Catbird and MAPS data on five other species. We then suggest that the formulation of effective avian management actions should be based on modeling vital rates as functions of habitat characteristics and, because of substantial amounts of annual variation in vital rates, as functions of weather and climate variables. We illustrate these concepts with threshold relationships between productivity and mean forest/woodland patch size in four forest-inhabiting species; relationships between precipitation and annual productivity indices for two landbird species in Texas; and relationships between reproductive indices in Pacific Northwest landbirds and both the El Niño/Southern Oscillation and the North Atlantic Oscillation. These latter results indicate that annual variation in the productivity of Neotropical-wintering birds may be driven more by events and conditions on their wintering grounds and migration routes than on their breeding grounds. Finally, we suggest that, because avian management should be based on vital rates as well as population trends, effectiveness monitoring must include the monitoring of the targeted vital rates along with monitoring the appropriate population trends.

Introduction

Goals for the management of Neotropical migratory birds and other landbird species typically include efforts to reverse population declines, to increase the populations of rare species even if they are not declining, and to expand the ranges of localized species. With the creation in 1990 of the Neotropical Migratory Bird Conservation Initiative ("Partners in Flight;" Finch and Stangel 1993) and the firm establishment of the concept of "keeping common birds common," an additional management goal for landbird species was articulated, to maintain stable or increasing populations. In the process of attempting to achieve these goals, management efforts must sometimes be directed to avian nest predators and brood parasites with the goal of decreasing populations of "problem" species. All of these management efforts thus aim to create or maintain changes in population sizes of some target species. Why then, we might ask, is it appropriate and important to base management on goals related to vital rates or, as they are also known, primary demographic parameters? Why not simply base management on goals related to population size or population trends?

The reason is straightforward: environmental stressors and management actions do not affect population size directly. Rather, they directly affect the vital rates of the population and, through the vital rates, affect the population size and population trend (DeSante and Rosenberg 1998). Moreover, the vital rates are usually affected without substantial time lags, whereas substantial time lags can exist between the time when the vital rate is affected and when that effect is translated into a change in population size or trend (Temple and Wiens 1989).

Other important benefits also accrue when management is based on vital rates. First, assessing and mon-

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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itoring vital rates provides crucial information about the stage(s) of the life cycle at which population change is being controlled (DeSante 1992). This is very important when dealing with Neotropical migratory birds because birth rates and death rates can be driven by processes acting at different times of the year and at locations many thousands of kilometers away from each other. Second, without information on vital rates, the "health" or viability of populations cannot be ascertained (Noon and Sauer 1992). Third, information on vital rates provides a clear index of habitat quality. Because of confounding effects of population sources and sinks, information on presence/absence or even relative abundance or population size can provide misleading indicators of habitat quality (Van Horne 1983, Pulliam 1988). And finally, spatially explicit information on vital rates can provide insights into source-sink dynamics.

Key Vital Rates upon Which Avian Management Can be Based

For landbird species that reach breeding maturity when one year old, we follow DeSante (1995) and identify six key vital rates or demographic events that drive population change. We suggest that these six vital rates should be assessed and monitored, and should be the vital rates upon which management should be based. They include: (1) productivity─the number of young per adult that reach independence from their parents; (2) survival of young─the probability of surviving from independence to the beginning of the first breeding season; (3) recruitment of young─the probability of a surviving young recruiting into the breeding population (this includes the spatial component of natal dispersal); (4) annual survival of adults─the probability of an adult bird surviving from the beginning of one breeding season to the beginning of the next; (5) site fidelity─the probability of a surviving adult returning to the same site and again recruiting into the breeding population; and (6) immigration─the probability of a surviving adult from a different site immigrating to a new site and becoming a breeder there. Note that mortality is the complement of survival and emigration is the complement of site fidelity.

We further identify six components of productivity, using the definition given above, that could be included in demographic modeling: number of breeding attempts per season (which may depend upon whether or not the attempts were successful); clutch size; survival of eggs to hatching; hatching success; survival of nestlings to fledging; and survival of fledglings to independence from their parents. For effective demographic modeling, a complete measure of productivity must include the product of all six components. Nest monitoring efforts typically include only four of these components and neglect both the number of breeding attempts per season (unless all adults are individually color marked and all breeding attempts are monitored) and the survival of fledglings to independence (unless all nestlings are individually color marked and followed after fledging). Monitoring programs that use constant-effort mist netting (e.g., MAPS ─ Monitoring Avian Productivity and Survivorship) provide a complete index of productivity, because they capture dispersing young that have reached independence from their parents (DeSante et al. 1995). Such programs do not, however, provide any information on the six components of productivity discussed above.

Survival also has a number of temporal components. For annual survival of adults, these include survival during the breeding season, during the post-breeding dispersal period, during fall migration, during the overwintering period, and during spring migration. Survival of young, as defined here, lacks the breeding season component, but includes the remaining four temporal components. It should also be noted that most measures of survival generated by mark-recapture protocols, whether in standardized mist-netting programs such as MAPS (DeSante et al. 1995) or in intensive single species resighting studies with study areas of limited size, are actually measures of apparent survival, in which true survival, the complement of mortality, is confounded with site fidelity, the complement of emigration (Cilimburg et al. 2002).

Strategies for Basing Management on Vital Rates

Given, then, that we should base management on vital rates, exactly how can this be accomplished? For example, if our goal is to reverse the population decline of a particular target species, how do we use information on vital rates to accomplish this? Clearly, if we are trying to reverse a population decline, our ultimate goal is to increase lambda, the rate of change in population size, from a negative to a positive value. The proximate goal must be to affect one or more vital rates in such a way that lambda will increase. Recall that the key vital rates include productivity, survival of young, recruitment of young, survival of adults, site fidelity of adults, and immigration of adults. Theoretically, we could design our management efforts to increase any of these vital rates, because enhancing any of them should lead to an increase in lambda. The question then becomes, toward which vital rate should we direct our efforts?

This question was addressed by Nichols and Hines (2002) who discussed three important strategies regarding vital rates and lambda that should be con-

sidered when attempting to formulate effective avian management plans. The first is to enhance the vital rate for which the smallest change would produce the largest increase in lambda. The approach here is to estimate gamma, the relative contribution to lambda of a given proportional change in the vital rate. This approach in many ways is analogous to elasticity analyses (Caswell 2001, Heppel et al. 2000), although there are important distinctions (Nichols et al., this volume). The second strategy is to enhance the vital rate that is most sensitive to management action. This strategy examines the proportion change in vital rates associated with an incremental change in some continuous management action. The third strategy is to enhance the vital rate that is most cost-effective to manipulate. The idea here is to evaluate the cost of implementing a particular incremental change in a given management action.

The Nichols and Hines (2002) approach makes the important point that management decisions should be based not only on elasticity and related issues, but also on the existence and knowledge of management actions that influence the various vital rates and upon the true cost of these management actions. Nevertheless, as they point out, their model is still oversimplified and ignores potential real-world complications such as covariance among vital rates and density dependence. Thus, situations may exist in which a vital rate can be enhanced, but its enhancement will not enhance lambda because another vital rate will be decreased. For example, if survival of young through their first winter is density dependent, management actions that increase productivity might not increase lambda because survival of those young will be decreased proportionally. Moreover, situations may exist in which a vital rate simply cannot be increased any further because it already is at its maximum, has not historically declined, and thus is not "deficient."

Identifying "Deficient" Vital Rates—the Proximate Demographic Cause of Population Declines

This kind of situation suggests that an additional strategy for effective avian management, at least for reversing population declines, is to attempt to identify the deficient vital rate, that is, the vital rate that has "caused" the population decline (the decrease in lambda), and to formulate management actions to increase that deficient vital rate. This approach is not really new; identification of the deficient vital rate has long been the goal of key-factor analysis and, to some extent, provides a guiding principle behind retrospective elasticity analysis. Such efforts attempt to model temporal variation in vital rates as a function of temporal variation in population trends or lambda. The idea here is to focus on *historical* patterns of temporal covariation between vital rates and lambda. Nichols et al. (this volume) demonstrate this approach by focusing on actual temporal covariation between a vital rate (or appropriate component of a vital rate, in this case, the proportion of females that produced two broods) and lambda.

It is important to note, however, that efforts to apply this approach to declining populations will typically require long-term historical monitoring data on both lambda and the various vital rates, data that often do not exist. Moreover, a vital rate does not necessarily need to be currently declining to be deficient and, thus, to be causing a population to decline. All that is necessary is for the deficient vital rate (e.g., productivity) to be too low to balance "normal" mortality of adults or young. In this respect, even an increasing vital rate can be deficient, at least for some period of time.

Modeling Spatial Variation in Vital Rates as a Function of Spatial Variation in Population Trends

An alternative approach for identifying the deficient vital rate is to model spatial variation in vital rates as a function of spatial variation in population trends. The idea is to focus on *current* patterns of spatial covariation between vital rates and lambda, essentially substituting space for time. DeSante et al. (2001) used such an approach at two spatial scales to identify the deficient vital rate(s) for various target species. For the larger spatial scale, mean annual productivity indices and time-constant annual adult survival estimates during 1992-1998 for Gray Catbird (*Dumetella carolinensis*) were modeled from MAPS data from stations located in two areas comprised of physiographic strata where 1992-1998 population trends from the Breeding Bird Survey (BBS) were significantly ($P < 0.01$) positive or negative (*table 1a*). Annual estimates of adult survival probabilities were best modeled as area-dependent, with the survival probability in the area with positive BBS population trends (0.555; 0.033 SE) being substantially greater than in the area with negative BBS population trends (0.443; 0.048 SE). In contrast, mean annual productivity indices (proportion of young in the catch) were best modeled as independent of area (0.295). The difference between the two areas in population changes modeled from MAPS productivity indices and adult survival estimates (0.147) agreed well with the difference between the two areas in BBS population trends (0.157), although the modeled population trends for both areas were substantially more negative than BBS trends, presumably because MAPS productivity indices tend to be biased low. The fact that

Table 1— *Vital rates (SE when available) from selected models (those with lowest AIC), modeled population changes (from those vital rates), and observed population trends (SE) for: (A) Gray Catbird from continent-wide MAPS (vital rates) and BBS (population trends) data; and (B) five selected target species from MAPS (vital rates and population trends) data from stations on military installations in the western (Kansas and Missouri) and eastern (Indiana and Kentucky) Midwest. (From DeSante et al. 2001)*

		Productivity[a]	Survival rate[b]	Modeled population change[c]	Population trend[c]
A. Continent-wide scale, 1992-1998					
Gray Catbird	Positive strata[d]	0.295	0.555 (0.033)	-0.271	0.102 (0.026)***
	Negative strata[e]	0.295	0.443 (0.048)	-0.418	-0.055 (0.013)***
B. Regional (Midwest) scale, 1994-1999					
Carolina Chickadee	Eastern	0.494 (0.161)	0.476 (0.127)	-0.176	0.553 (0.196)**
	Western	0.250	0.476 (0.127)	-0.405	-0.114 (0.052)*
Gray Catbird	Western	0.270	0.634 (0.051)	-0.190	0.055 (0.063)
	Eastern	0.160 (0.026)	0.283 (0.041)	-0.677	-0.123 (0.063)***
Ovenbird	Eastern	0.344 (0.134)	0.489 (0.073)	-0.319	0.004 (0.039)
	Western	0.170	0.489 (0.073)	-0.436	-0.125 (0.039)**
Yellow-breasted Chat	Western	0.164	0.610 (0.067)	-0.300	0.027 (0.084)
	Eastern	0.034 (0.017)	0.329 (0.062)	-0.662	-0.133 (0.025)***
Field Sparrow	Western	0.179	0.453 (0.063)	-0.473	0.033 (0.051)
	Eastern	0.119 (0.031)	0.453 (0.063)	-0.501	-0.100 (0.022)**

[a]Proportion of young in the catch, modeled using logistic regression
[b]Modeled using Cormack-Jolly-Seber mark-recapture analysis (Pollock et al. 1990) with a between- and within-year transient model (Pradel et al. 1997, Nott and DeSante 2002)
[c]Annual proportional change
[d]Includes all BBS physiographic strata for which the 1992-1998 population trend for Gray Catbird was significantly ($P < 0.01$) positive.
[e]Includes all BBS physiographic strata for which the 1992-1998 population trend for Gray Catbird was significantly ($P < 0.01$) negative.
* $0.05 < P < 0.10$; ** $0.01 < P < 0.05$; *** $P < 0.01$.

some degree of spatial variation in survival and productivity should be expected does not negate these results. The important result here is the existence of spatial covariation between survival rates and population trends and the lack of such covariation between productivity and population trends. These results suggest that, at the spatial scale of the entire species' range, annual adult survival in physiographic strata where the species was declining was deficient, and this low survival was the proximate demographic cause of the population decline. These results also suggest that successful management strategies to reverse population declines in Gray Catbirds at the continental scale must address this deficient survival.

At the smaller scale, productivity and adult survival were modeled during 1994-1999 for Carolina Chickadee (*Poecile carolinensis*), Gray Catbird, Ovenbird (*Seiurus aurocapillus*), Yellow-breasted Chat (*Icteria virens*), and Field Sparrow (*Spizella pusilla*) from MAPS stations on military installations in the western (Kansas and Missouri) and eastern (Indiana and Kentucky) Midwest (*table 1b*). Species were selected because their trend in adult captures from the six years of MAPS data was significantly ($P < 0.05$) positive or negative on the installations in either the eastern or western Midwest, and of the opposite sign (but not necessarily significant) on the installations in the other area. We were able to identify the deficient vital rate(s)

causing the population declines for all five species. Deficient productivity was identified as a proximate demographic cause of population decline for all five species, while deficient adult survival was identified as an additional cause for Gray Catbird (again) and Yellow-breasted Chat. Moreover, the regression of modeled population changes on trends in adult captures for the five species in the two areas showed a significant positive relationship (*fig.1*) which suggests that, although the y-intercept of the regression was negative again suggesting that MAPS productivity indices are biased low, the biases are relatively constant between areas and among species.

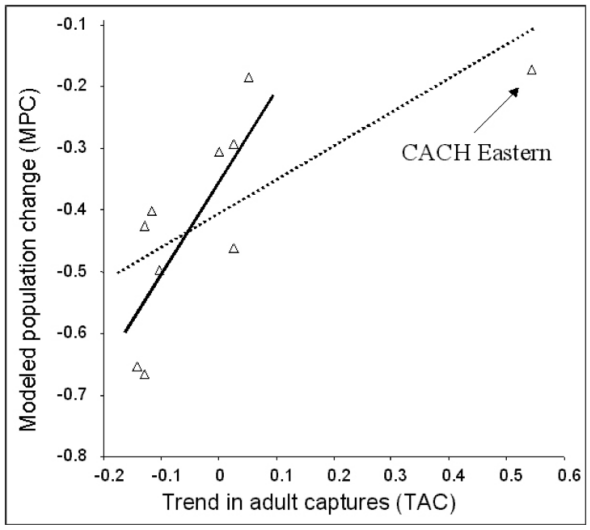

Figure 1— Regression of modeled population changes on trend in adult captures for five selected target species (Carolina Chickadee, Gray Catbird, Ovenbird, Yellow-breasted Chat, Field Sparrow) from 1994-1999 MAPS data from 18 stations on military installations in each of two areas (the western Midwest ─ Kansas and Missouri; and the eastern Midwest ─ Indiana and Kentucky). The dashed line is the regression for all ten points: slope = 0.580, y-intercept = -0.418, r = 0.688, P = 0.028; the solid line is the regression for nine points (eliminating Carolina Chickadee eastern Midwest: slope = 1.507, y-intercept = -0.361, r = 0.747, P = 0.021. (From DeSante et al. 2001).

Modeling Vital Rates as a Function of Habitat Characteristics

These results, at both spatial scales, suggest that this approach is useful for identifying the deficient vital rates that need to be addressed to reverse population declines. Once these proximate demographic causes of population change have been identified, how should we proceed to formulate management strategies to reverse the declines? We suggest that one effective approach is by modeling the appropriate vital rates as functions of the major environmental factors that affect them—habitat and weather.

Habitat affects vital rates primarily by affecting access to food resources and exposure to predation (including nest predation) pressure. Weather also affects vital rates by affecting access to food resources and exposure to predation pressure, but additionally affects the birds and their behavior (and thus their vital rates) directly through exposure to heat, cold, wind, and precipitation. It is possible that the strongest effects of habitat and weather occur through their interactions with each other. Thus, the most illuminating models of the effects of habitat and weather on vital rates might involve multivariate analyses of both factors.

Substantial progress has been achieved on efforts to model vital rates derived from MAPS data as functions of habitat and weather (Nott 2000, Nott 2002, Nott et al. 2002, 2003). One of the most promising approaches is to model MAPS productivity indices as a function of remote-sensed, landscape-level habitat characteristics (such as Shannon′s diversity index of cover types, total amount of forest cover, mean forest patch size, mean forest interpatch distance, total amount of forest edge, total amount of water, etc.) within 2- to 5-km radius areas surrounding the MAPS station (Nott 2000, Nott et al. 2003).

Utilization of an area of this size is appropriate for modeling productivity indices, because the young birds captured by the MAPS protocol do not all originate from within the boundaries of the MAPS station, but include substantial numbers of dispersing young from the surrounding landscape (DeSante et al. 1995). Hard data on the dispersal characteristics of juvenile landbirds are notoriously few, but now include an excellent radio-transmitter study of juvenile Wood Thrushes (*Hylocichla mustelina*) (Anders et al. 1997) that suggests that virtually all of the young Wood Thrushes captured at a MAPS station before August 8 likely originate from nests within a 4-km radius area surrounding the station. It seems likely that many other forest-inhabiting passerine species might have similar juvenile dispersal distances. (Note that juvenile dispersal should not be confused with natal dispersal, which is defined as the vector between where a bird was hatched and where it first attempts to breed, and which could involve much larger distances.)

Nott (2000) provides an example of this approach utilizing data from six MAPS stations on Big Oak National Wildlife Refuge (formerly Jefferson Proving Ground) for four forest-inhabiting species (Acadian Flycatcher [*Empidonax virescens*], Wood Thrush, Ovenbird, and Kentucky Warbler [*Oporornis formosus*]). We plot numbers of adult and young birds captured at each of the six stations as a function of mean forest/woodland patch size at the stations in the four

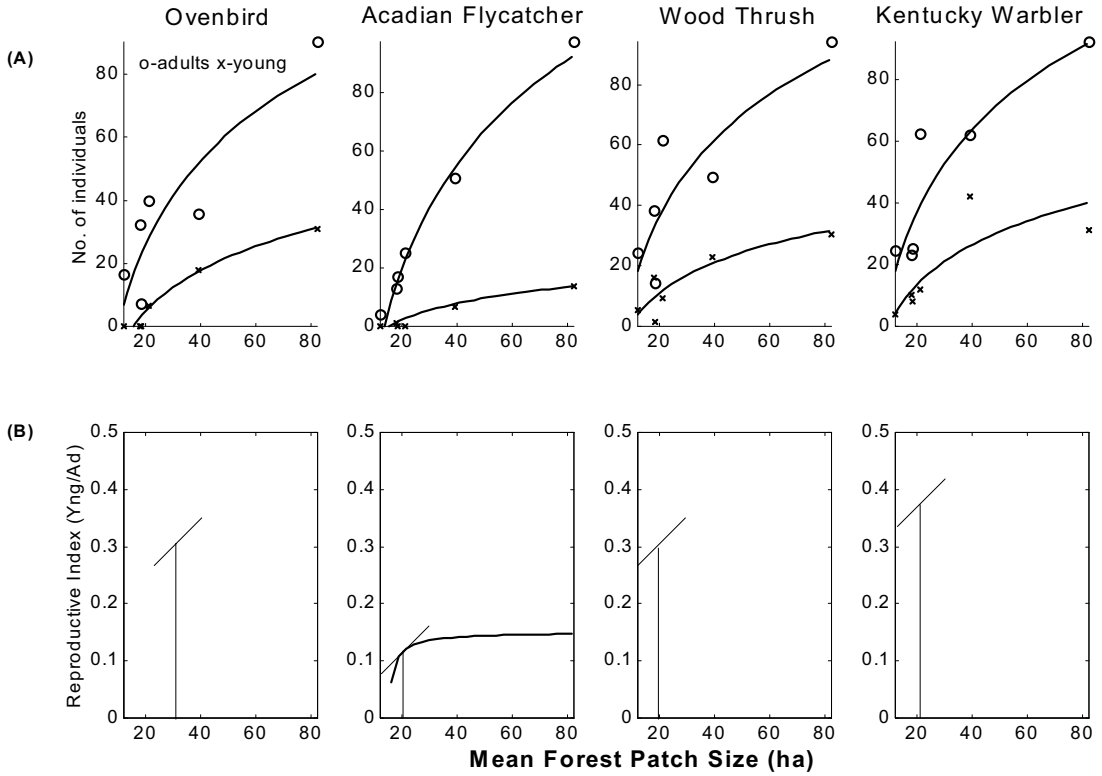

Figure 2— (A) Numbers of individual adult (o) and young (x) birds of four forest interior species captured per 3600 net-hours at six MAPS stations operated during 1994-1999 on Jefferson Proving Ground, Indiana, as a function of mean forest patch size in the 4-kilometer radius area surrounding each station. (B) Relationship between reproductive index (young/adult) and mean forest patch size at Jefferson Proving Ground for these four species (obtained from the linear-log regressions shown in A).

upper panels (*fig.2A*). For each of the four species, mean forest/woodland patch size was the landscape metric having the highest correlation coefficient with (i.e., that explained the greatest variation in) numbers of captures of adults. This metric also provided the most powerful determinant for the number of captures of young for each species except Kentucky Warbler (for which the most powerful determinant was a negative relationship with the percentage of cropland/ grassland). All of these relationships with mean forest/woodland patch size, however, for both numbers of adults and young, were significant. The log-linear regression models fitted to each of these relations are shown in *Figure 2A* for both adults and young.

Finally, for each species, we calculated the reproductive index (the ratio of young to adults) at regular intervals along the fitted curves shown in *Figure 2A*, and thereby found threshold relationships between reproductive index and mean forest/woodland patch size, as shown in *Figure 2B*. Thus, below a threshold patch size for each of the four species (determined by the patch size at which a 45^{o} line is tangent to the curve), productivity decreased dramatically, while above that threshold patch size, productivity increased slowly. The existence of such patch-size thresholds can provide powerful and straightforward management guidelines that can be formulated into specific avian management actions or that can be included in other more generalized land management plans.

We suggest that similar types of relationships can also be developed between adult survival estimates and habitat characteristics. For permanent resident species, such relationships could be developed using habitat characteristics on the breeding grounds. However, since it is likely that annual survival rates for migratory species are affected by events and conditions that occur on the wintering grounds or migration routes (Sillett and Holmes 2002), we will need to model survival as a function of habitat characteristics on the wintering grounds. The newly created Monitoreo de Sobrevivencia Invernal (MoSI—monitoring overwintering survival, see DeSante et al., this volume) Program aims to do exactly that for Neotropical migratory landbirds, that is, to provide habitat-, age-, and sex-specific estimates of overwintering survival rates and indices of physical condition (body mass/wing chord ratio). The ultimate goal of MoSI is to model these estimates of overwintering survival and indices of physical con-

dition as a function of habitat characteristics, and to use these models to formulate management strategies for reversing population declines in species for which deficient survival is driving the decline.

Modeling Vital Rates as a Function of Weather

One of the important results of the MAPS Program is the demonstration of a high level of annual variability in vital rates, especially productivity, presumably caused by annual variability in weather (DeSante and O′Grady 2000). Because of the pronounced effects of weather on vital rates, especially over the short term, vital rates must be modeled as a function of weather, as well as habitat, variables. We have recently begun such modeling of productivity and weather variables. Nott (2002), for example, found that annual productivity indices over the eight years 1994-2001 correlated positively with precipitation in Texas for six species of Texas landbirds, including Bewick's Wren (*Thryomanes bewickii*) and Painted Bunting (*Passerina ciris*) (*fig.3*). Interestingly, for five of the six species, the three months immediately prior to breeding (December-February) was the season for which the strongest correlation was found between precipitation and productivity (March-May for the sixth species). It is not clear from these results whether the increased winter rainfall enhanced productivity the following summer by increasing the winter food supply and enhancing the birds' physical condition at the start of the breeding season, or by increasing the spring and summer food supply available for nesting birds, or both.

Strong evidence that both of these effects can occur has been obtained from MAPS data from 36 stations on national forests in the Pacific Northwest (Nott et al. 2002). There we showed that MAPS reproductive indices (young/adult) for 29 of 33 species tended to correlate positively with both the El Niño/Southern Oscillation (as measured by the El Niño/Southern Oscillation Precipitation Index, ESPI) and the North Atlantic Oscillation (as measured by the North Atlantic Oscillation Index, NAOI). Reproductive indices of Neotropical-wintering species, however, both individually and as a group, correlated much more strongly with ESPI than with NAOI (*fig.4A*), while reproductive indices of temperate-wintering species, again both individually and as a group, correlated much more strongly with NAOI than with ESPI (*fig.4B*). For both groups of species and for both global climate cycles, the season for which the strongest correlations were found between reproductive indices and climate cycle was March-May. This was, again, just prior to their breeding season.

Only weak correlations exist between the March-May ESPI and weather variables in the Pacific Northwest. Very strong correlations exist, however, between the March-May ESPI and both precipitation (positive) and temperature (negative) in western Mexico, both in highlands along the crest of the Sierra Madre Occidental (*fig.4C*) and in lowlands along the Pacific coast. These weather variables result in substantial increases in surface soil moisture during El Niño years (years with a positive ESPI) throughout western Mexico (the wintering grounds for most Neotropical-wintering species breeding in the Pacific Northwest). There is also a tendency during March-May for following winds out of the Southeast during El Niño years, as opposed to headwinds out of the Northwest during La Niña years (years with a negative ESPI), throughout

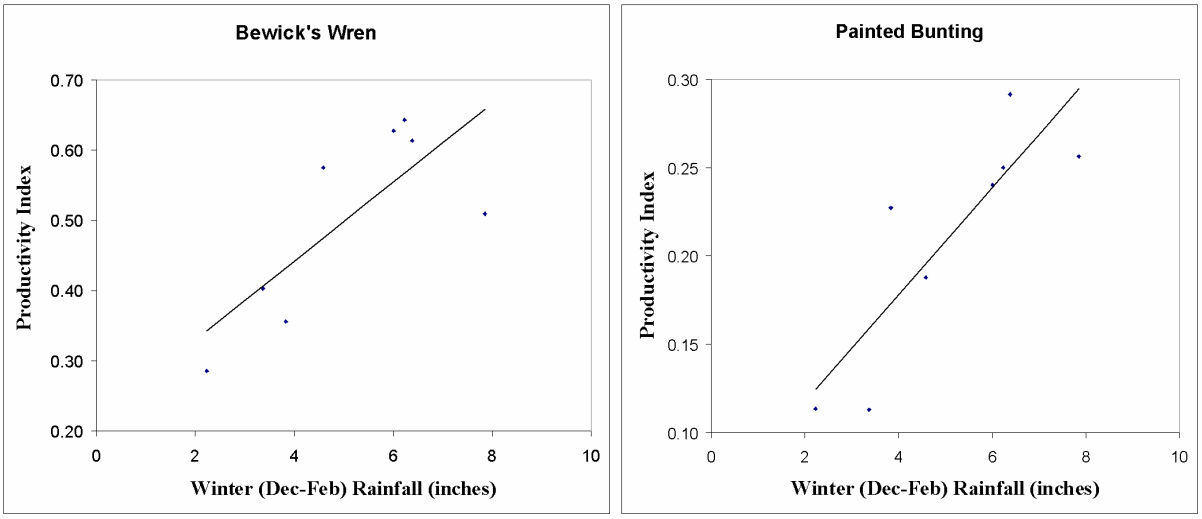

Figure 3— Regressions of annual productivity indices (proportion of young in the catch, 1994-2001) on winter (Dec-Feb) precipitation for Bewick's Wren (R^2 = 0.59, P < 0.05) and Painted Bunting (R^2 = 0.73, P < 0.01) from MAPS data from 18 stations in southeastern Texas. (From Nott 2002)

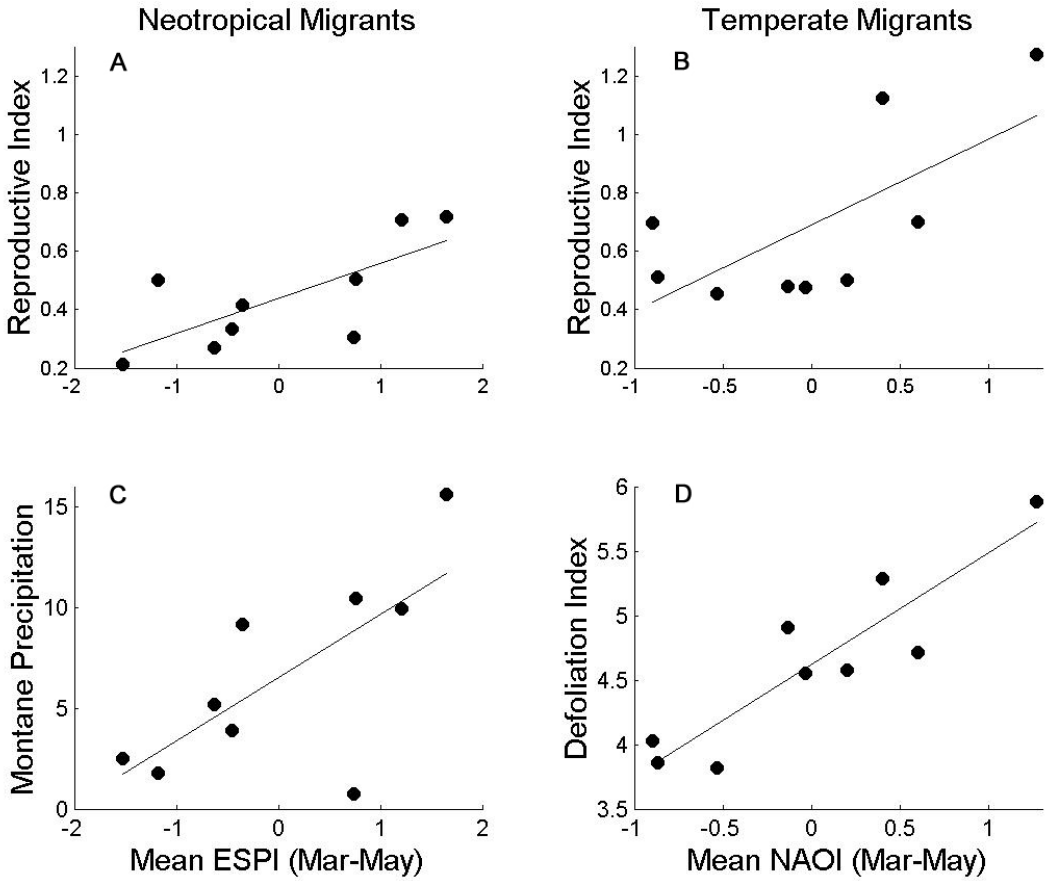

Figure 4— Regressions of annual reproductive index (young/adult, 1992-2001) from 36 MAPS stations on six national forests in Oregon and Washington for (A) all Neotropical-wintering species pooled on mean Mar-May El Niño/Southern Oscillation Precipitation Index (ESPI) (R^2 = 0.528, P = 0.027); and (B) all temperate-wintering species pooled on mean Mar-May North Atlantic Oscillation Index (NAOI) (R^2 = 0.472, P = 0.041). Regressions of (C) Feb-Apr precipitation at montane weather stations along the crest of the Sierra Madre Occidental in western Mexico on mean Mar-May ESPI (R^2 = 0.488, P = 0.036); and (D) annual defoliation index by irruptive insects on the six national forests in the Pacific Northwest on mean Mar-May NAOI (R^2 = 0.817, P = 0.001). (From Nott et al. 2002)

northwestern Mexico and California. We suggest that these weather effects during El Niño years, operating prior to the breeding season and on the wintering grounds or spring migration routes of these Neotropical-wintering species, likely result in their being in better physical condition at the start of the breeding season and/or arriving earlier on their Pacific Northwest breeding grounds, and thus result in their raising more young during El Niño than La Niña years. It has been assumed for some time that annual survival of Neotropical-wintering landbirds might well be driven by events or conditions on their wintering grounds and/or migration routes, but this is one of the first demonstrations that the breeding productivity of these species can also be driven by conditions on their wintering grounds and/or migration routes. Such dynamics likely exist between productivity and winter habitat conditions, as well as winter weather, and must be considered when developing overall management strategies for migratory birds.

In contrast to the situation with ESPI, strong correlations exist between the March-May NAOI and weather in the Pacific Northwest, where less precipitation and warmer temperatures occur during March-May in years with a positive, rather than negative, NAOI. One result of these weather variables is a greatly increased amount of forest defoliation by the western spruce budworm (*Choristoneura occidentalis*) and Douglas-fir tussock moth (*Orygia pseudotsugata*) during positive NAOI years. Indeed, the index of forest defoliation from these species was highly correlated with the March-May NAOI and with reproductive indices of temperate-wintering birds (*fig.4D*). We suggest that these weather effects during years of positive NAOI result in more food available for permanent resident Pacific Northwest species just prior to their breeding season, and for temperate-wintering migrants as soon as they arrive on their Pacific Northwest breeding grounds (which typically occurs earlier than for Neotropical wintering migrants), and thus result in their producing more young than in negative NAOI years.

Again, the weather effects on productivity appear to occur just prior to the breeding season but, in this case, occur on the breeding grounds rather than on the wintering grounds or migration route.

Evaluating the Effectiveness of Management Actions

We have argued that, because management actions affect bird populations (including population size and trends) by affecting vital rates, appropriate management strategies, including generalized guidelines that can be applied whenever land management is done and management actions designed specifically for avian conservation, should be based on targeted vital rates as well as population trends. As a result, a well-designed effectiveness-monitoring program must also monitor the targeted vital rates as well as the resulting population trends. Put simply, if your management goal is to reverse the population decline of a given species by increasing its productivity, you must monitor its productivity as well as population size or trend. Monitoring only its population size or trend is not sufficient, because other vital rates besides productivity could have changed, and your management actions might have contributed nothing to the observed change in population size or trend.

In summary, we suggest that an effective conservation program for landbirds should be built around integrated monitoring, research, and management goals. The monitoring goals should aim to provide annual indices and estimates of critical vital rates as well as population sizes and trends. The research goals should aim to identify temporal and spatial patterns in those indices and estimates, and relationships among those temporal and spatial patterns and ecological characteristics of the target species, landscape-level and station-specific habitat characteristics, and spatially explicit weather variables. The management goals should aim to identify the proximate demographic cause(s) of population change, to formulate management guidelines and actions to reverse population declines and maintain stable or increasing populations, and to evaluate the effectiveness of the management actions implemented. These, in fact, are the objectives upon which the establishment of the MAPS program was based (DeSante, this volume).

Acknowledgments

We thank the various federal and state agencies and private organizations that have supported the MAPS Program and provided financial support for this work, especially the U.S. Department of Agriculture (Forest Service); the U.S. Department of Defense (Legacy Resource Management Program); and the U.S. Department of Interior (National Park Service, Biological Resources Division of the Geological Service, Fish and Wildlife Service, and National Fish and Wildlife Foundation). We are also indebted to the many dedicated MAPS station operators and their volunteers who contribute data from over 500 stations continent-wide. We thank R. B. Siegel and J. R. Sauer for helpful comments on an earlier draft of this paper. This is Contribution No. 204 of The Institute for Bird Populations.

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Approaches for the Direct Estimation of Rate of Increase in Population Size (λ) Using Capture-Recapture Data[1]

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Abstract

Recent developments in the modeling of capture-recapture data permit the direct estimation and modeling of population growth rate Pradel (1996). Resulting estimates reflect changes in numbers of birds on study areas, and such changes result from movement as well as survival and reproductive recruitment. One measure of the "importance" of a demographic vital rate to population growth is based on temporal covariation (i.e., do changes in population growth follow changes in vital rates). If data are available to estimate vital rates or their components, then such data can be combined with capture-recapture data in order to estimate parameters of the relationship between population growth and the vital rate. These methods are illustrated using capture-recapture and nest observation data for Black-throated Blue Warblers, *Dendroica caerulescens*, from a long-term study at Hubbard Brook Experimental Forest, New Hampshire, USA. Population growth rate was found to be positively associated with the proportion of birds that double-brood. We encourage use of these methods and believe they will prove to be very useful in research on, and management of, migratory bird populations.

Introduction

Bird management and conservation programs should be based on knowledge of avian abundance, rate of change in abundance, and factors influencing abundance. In particular, we are interested in the difference between actual abundance and population objectives, and in the influence of management actions on population size and change, as these factors will be the primary determinants of appropriate management actions (e.g., Walters 1986, Williams et al. 2002). Historically, most studies of avian abundance have been based on various kinds of count surveys (e.g., see Ralph and Scott 1981, Ralph et al. 1995). However, the vast majority of such count surveys have not incorporated the need for information about detection probability (this can be equated with the proportion of the population that is counted) into survey design, so resulting estimates of population growth reflect both population change and changes in detection probability (e.g., Thompson et al. 1998, Bibby et al. 2000, Pollock et al. 2002, Thompson 2002).

Direct Estimation of λ_i: Approach

It is possible to estimate bird abundance based on studies of marked individuals (e.g., Nichols et al. 1981), but capture-recapture studies of birds have instead typically focused on estimation of survival (e.g., Brownie et al. 1985, Lebreton et al. 1992, Sillett and Holmes 2002) and movement (e.g., Nichols 1996, Bennetts et al. 2001). Because abundance can be estimated using capture-recapture modeling (Seber 1982, Pollock et al. 1990), it is clear that rate of increase in population size ($\lambda_i \quad \frac{N_{i+1}}{N_i}$, where N_i is abundance at time i) can be estimated from such data as well. Recently, Pradel (1996) developed a model that can be parameterized directly by λ_i, and this model has potential to be very useful in studies of marked birds. Data required for the estimation of λ_i under this model (Pradel 1996) are simply standard capture-recapture or capture-resighting data used for open population studies. A common design for birds involves sampling during a particular season (e.g., the breeding season) each year. Data resulting from such studies are capture histories, vectors of 1's and 0's denoting the sampling occasions (years) at which each individual was, and was not, captured (Seber 1982, Williams et al. 2002). Capture-resighting studies also require counts of unmarked birds at each sampling occasion (Nichols and Hines 2002, Dreitz et al. 2002). Both the intuition and the methodological detail underlying direct estimation of λ_i were presented by Pradel (1996), Nichols and Hines (2002) and Williams et al. (2002).

Note that the parenthetical definition of λ_i provided above involves a ratio of abundances at two points in

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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time. Indeed the λ_i estimated using capture-recapture data reflect the changes in numbers of animals on the study area. Changes in numbers can occur because of recruitment of young animals, mortality, and movement into and out of the area of interest. This λ_i differs from an asymptotic λ computed from survival and reproductive rate estimates using a projection matrix (Caswell 2001). The asymptotic λ is of interest as well, and reflects the growth rate expected of a population exposed to the same set of survival and reproductive rates year after year. However, it is important to recognize the distinction between these two metrics reflecting population growth. In particular, the asymptotic projection matrix λ is not necessarily expected to correspond closely to the observed rate of change in numbers of animals on an area. The λ_i estimated using capture-recapture data should reflect short-term changes in abundance and should be especially useful for modeling efforts directed at assessing temporal covariation between λ_i and environmental and other covariates. See the discussion in Nichols and Hines (2002) for further details.

Direct Estimation of λ_i: Example

We used capture-recapture data for Black-throated Blue Warblers, *Dendroica caerulescens*, from a long-term study at Hubbard Brook Experimental Forest, New Hampshire, USA (Holmes et al. 1996; Sillett et al. 2000; Sillett and Holmes 2002, in press), to estimate λ. Capture-recapture data for adult males and females were obtained every breeding season from 1986-2001. We used the general model of Pradel (1996) to compute annual estimates of λ_i (*fig.1*). Point estimates ranged from 0.71 to 1.39 with estimated coefficients of variation falling in the range of about 16 percent to 23 percent. In addition, we fit a different model in which λ was constant over time (i.e., we imposed the constraint that $\lambda_i = \lambda$) and estimated a single overall λ for the entire period as $\hat{\lambda} = 1.02$, $\hat{SE}(\hat{\lambda}) = 0.02$. Thus, over the entire period, the estimated rate of population growth was slightly larger than 1, but the approximate 95 percent confidence interval covered 1.

"Importance" of Vital Rates to λ_i: Approaches

In addition to the ability to estimate λ_i, scientists and managers are interested in the relative "influence" of different vital rates (i.e., rate of survival, reproduction, movement) and demographic components (birds in different age classes or from different locations) on λ_i. The motivation for this interest typically involves the potential to bring about changes in λ_i by implementing management actions or conservation measures directed at specific vital rates or demographic components. This kind of thinking was important in the establishment of the MAPS avian monitoring program directed at avian survival and production (DeSante et al. 1995). Several approaches exist for assessing the "influence" or "importance" of a vital rate or demographic component on population growth, and two of these use capture-recapture data. One capture-recapture approach is similar to the projection matrix concept of elasticity (Caswell 2001) and addresses the question: "If a certain vital rate or demographic component exhibited a proportional change over a period of interest (e.g., if adult survival between periods *i* and *i* +1 had been reduced by 25 percent), what would the corresponding change in the population growth rate have been (e.g., what would the proportional decrease in λ_i have been)?" This kind of question can be addressed directly with capture-recapture data using reverse-time modeling and estimation methods that are very similar to those used to estimate λ_i (Nichols et al. 2000, Nichols and Hines 2002, Williams et al. 2002).

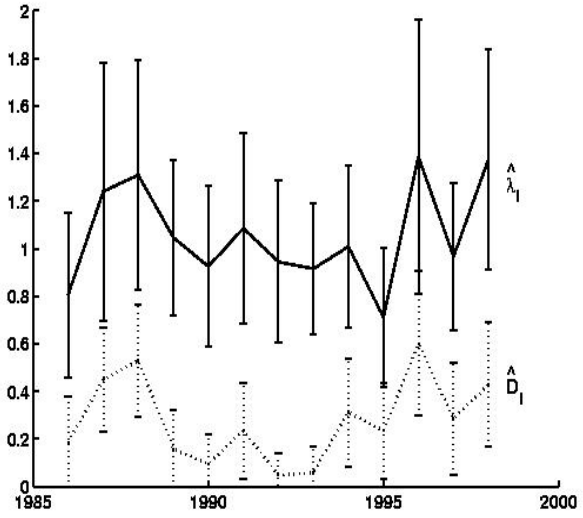

Figure 1—Point estimates of finite rate of population increase, λ_i, and proportion of birds double-brooded, $\hat{D}_i$, for Black-throated Blue Warblers from Hubbard Brook, New Hampshire. Estimates of population growth rate were obtained using capture-recapture models (Pradel 1996) and data, and estimates of double-brooding were obtained as binomial parameters based on observations of nesting birds.

The second approach to assessing "importance" of a vital rate or demographic component to λ_i involves temporal (or spatial) covariation. The sort of question addressed is: "Temporal variation in which vital rate(s) or demographic component(s) is most closely associated with temporal variation in λ_i?" This approach thus focuses on actual temporal covariation over a period of

study rather than potential variation in λ_i resulting from hypothetical variation of a vital rate or demographic component. This approach can be implemented with capture-recapture data by direct modeling of λ_i as a function of a vital rate or a component of a vital rate. Such modeling results in estimation of a slope parameter relating variation in the vital rate to variation in λ_i.

"Importance" of Vital Rates to λ_i: Example

In order to illustrate this approach of modeling λ_i, we again used capture-recapture data for Black-throated Blue Warblers from Hubbard Brook, New Hampshire. We used additional data from this study on the proportion of nesting females that was double-brooded each year (Holmes et al. 1992, Sillett and Holmes in press), as this proportion is an important component of reproductive rate. Data to estimate this proportion were simply the number of nesting females located early in the nesting season each year, and the number of those that produced a second brood. Estimates of this proportion (D_i) varied substantially from year to year and appear to covary with estimates of λ_i (*fig.1*).

There are two approaches for modeling λ_i as a function of this proportion of double broods. The first is to estimate this proportion as a binomial model parameter (D_i) and then to treat this estimate as a covariate of known value in a capture-recapture model of λ_i. The second approach is to develop a joint likelihood in which the double-brooding parameter is directly estimated from the relevant data, and both λ_i and the relevant slope parameter are estimated directly using the joint likelihood. The advantage of this approach is that it properly incorporates the sampling variance associated with the estimation of D_i, rather than treating these parameters as known values. We believe that this joint likelihood approach provides a better basis for inference.

We used the second approach to directly estimate the parameters of the following model:

$$\log(\lambda_i) \quad \beta_0 + \beta_1 D_i ,$$

where D_i is again the proportion of females that were double-brooded in year i, and the β_j are model parameters. The data for double-brooding were included in the analysis, as were the capture-recapture data, 1986-2001. The modeling was done using program SURVIV (White 1983) with cell probabilities generated using both the double-brooding and capture-recapture portions of the likelihood. The resulting estimates for the parameters defining the above relationship between double-brooding and population growth rate were:

$$\begin{array}{ll} \hat{\beta}_0 & -0.18,\ S\hat{E}\,(\hat{\beta}_0) \quad 0.07, \\ \hat{\beta}_1 & 0.79,\ S\hat{E}\,(\hat{\beta}_1) \quad 0.23 \end{array}$$

The positive value of $\hat{\beta}_1$ indicates evidence of a positive relationship between the proportion of birds double-brooding in year i and population growth between spring of year i and spring of year i+1.

Likelihood ratio tests and Akaike's Information Criterion (see, e.g., Lebreton et al. 1992, Burnham and Anderson 1998) indicated that the above model provided a good description of the data. We conclude that this analysis provides strong evidence of temporal covariation between double-brooding and population growth, with years of substantial double-brooding associated with years of high population growth rate. Double-brooding thus appears to be an important component of reproductive rate that is associated with changes in population growth.

Discussion

We believe that these new approaches to the direct estimation of λ_i, and metrics reflecting the importance of vital rates and demographic components to λ_i, have great potential for population studies of marked birds. Although observation-based methods will continue to be important for estimating avian abundance and density, we recommend that ecologists involved in studies of marked birds take advantage these new capture-recapture methods for estimating λ_i.

Finally, we believe that there is great potential for developing models that use both capture-recapture and count data to estimate population growth rate and to investigate sources of variation in population growth. Such joint models would contain one component for each data source. The capture-recapture data would be modeled with capture, survival and population growth parameters as described in Pradel (1996), and the count data would be modeled with an initial abundance parameter and population growth parameters (Nichols and Hines 2002). Thus, the λ_i parameters would appear in both portions of the model, with the consequence that both sources of data contribute to their estimation. We would hope that this sort of modeling should permit more precise estimation of population growth rate and, more importantly, provide additional opportunities for modeling population change as functions of relevant covariates.

Acknowledgments

We thank J. Sauer for constructive comments on the initial draft manuscript.

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An Estimate of Juvenile Survival in Black-capped Vireos and its Implications to Source-Sink Analyses of Songbirds[1]

Joseph A. Grzybowski[2]

Abstract

An indirect estimate of juvenile survival was derived for a closed, small, population of Black-capped Vireos (*Vireo atricapillus*) in the Wichita Mountains, Oklahoma monitored since 1987. I used seasonal fecundities of vireos in years when the population was stable in the formula for intrinsic growth rate to solve for juvenile survival. The derived probability of juvenile survival to breeding was 0.40-0.57, more than two-thirds the annual adult-female survival. This result parallels the observations of Nolan (1978) for Prairie Warblers (*Dendroica discolor*). It suggests that the conservative rule-of-thumb estimate for juvenile survival (i.e., half that of adult females) used in assessing source-sink relations among different groups of songbirds contributes to underestimating their intrinsic growth rates. This, in turn, may alter interpretations of source-sink dynamics for songbirds, and consequent management recommendations derived from such assessments.

Introduction

Few estimates of juvenile survival exist for migrant songbirds, and those that do may significantly underestimate this parameter because juveniles are typically the dispersing groups, and dispersal is difficult to accommodate in re-sampling of banded birds. Juvenile survival, however, is one of three critical parameters needed to assess intrinsic growth rates (λ). Because precise estimates are lacking, researchers attempting to assess the dynamics of migrant songbird populations have approximated a rule-of-thumb estimate, generally 1/2 the annual adult female survival (e.g., Greenberg 1980).

Methods

In monitoring the seasonal fecundity and population size of a small closed population of Black-capped Vireos in the Wichita Mountains from 1987-2001, the seasonal fecundity for years between which population numbers did not change could be approximated. With estimates of annual female survival (0.57-0.63; Grzybowski, unpubl. data), the terms in the intrinsic growth rate (λ) formula could be rearranged to solve for juvenile survival. At $\lambda = 1$, the population is stable. Thus:

Juvenile survival = (1 - annual adult female survival) /female young/female/year

Vireo numbers were estimated through systematic search and direct count, with adjustment for observer detectability determined from more systematic territory mapping for subsets of the surveyed areas. Most direct counts of male vireos were divided by a factor of between 0.8-0.85, the probability of detecting a male vireo in general survey (Grzybowski and Wood 1999). Seasonal fecundity was a female-based estimate of the number of young fledged. Between 33-92 percent of the estimated vireo population in the Wichita Mountains was monitored in any year used in these analyses. A weighted average of seasonal fecundity was used combining higher estimates, from areas where cowbirds were removed, and the lower estimates from areas not protected by cowbird removals. Because the vireo population has increased dramatically in recent years, the useful estimates of seasonal fecundity came from earlier years (1988-1994) when much of the population could be monitored.

Results

Vireo populations remained constant when seasonal fecundity estimates were between 0.76 and 0.92 female young/female/season, increased when higher, and decreased when generally lower. All estimates of seasonal fecundity in recent years have been >2.2 young/female, and vireo numbers have increased dramatically (Grzybowski and Wood 1999).

Using this range of seasonal fecundity estimates, and some generalized estimates for female survival (Grzybowski, unpubl. data), the derived juvenile sur-

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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vival to breeding was 0.40-0.57 (*table 1*). These values are very sensitive to the estimation of female survival.

Table 1— *Estimates of juvenile survival under two estimates of female survival.*

	Female survival = 0.57	Female survival = 0.63
Range	0.48 - 0.57	0.40 - 0.49
Median	0.51	0.44

Discussion

The lower estimate of juvenile survival from this analysis is still greater than two-thirds that of adult females, and much higher than the standard rule-of-thumb that is usually applied by other researchers in some population-modeling efforts (Greenburg 1980, Donovan et al. 1995). This level of juvenile survival for the Black-capped Vireo, a species that maintains a high level of parental investment, may be higher than that of some species. However, it parallels an estimate of Nolan (1978) for Prairie Warblers (>0.39), another Neotropical migrant, and suggests that analyses assuming lower values are overly conservative, and will result in lower estimates of intrinsic growth rates.

table 2 contrasts the estimates of intrinsic growth rates (λ) for several studies with adjustments made for (1) the potential underestimation bias for juvenile survival and (2) additional biases by researchers in estimating seasonal fecundity (see Grzybowski and Pease unpubl. data, and below). Nolan (1978) derived an empirical estimate for juvenile survival he felt was conservative. Donovan et al. (1995) use the previously accepted assumption whereby juvenile survival (to first breeding) is approximately 1/2 annual adult female survival. The uncertainties of parameter estimation led Donovan et al. to develop a range under varying estimates of female survivorship. Median values were used in *table 2*. Ward and Smith (2000) assumed juvenile survival was the same as adult female survival, and also assumed only one nesting attempt per female per season. Both assumptions are quite arbitrary and reflects their limited sampling of Warbling Vireo nesting effort. *table 2* also depicts adjustments made for potential biases in converting nest history data to estimates of seasonal fecundity under assumptions fixing the maximum number of nesting attempts (see Pease and Grzybowski 1995; Grzybowski and Pease 2000, unpubl. data; Farnsworth and Simon, pers. comm.). Quite clearly, intrinsic growth rates are lower under previous assumptions, substantially so in some cases.

Table 2— *Estimates of λ under assumptions and estimations of Donovan et al. (1995) or Ward and Smith (2000), and those herein (see text). Previous estimates of λ are recalculated as: λ = ad. female survival + [(seasonal fecundity X 0.9) (ad. female survival X 0.67] where nest mortality is low, and ... λ = ad. female survival + [(seasonal fecundity X 1.22) (ad. female survival X 0.67] where nest mortality is high (Grzybowski and Pease unpubl. data).*

Species	Site[a]	Treatment[b]	Adult female survival	Published fecundity estimate	Published or derived λ	Revised estimate of λ
Wood Thrush	MO	Frag	0.67	0.85	0.93	1.14
	MO	Cont	0.67	1.75	1.21	1.38
	WI/MN	Frag	0.67	1.12	1.02	1.28
	WI/MN	Cont	0.67	2.40	1.41	1.64
Red-eyed Vireo	MO	Frag	0.56	0.00	0.56	NR[e]
	MO	Cont	0.56	1.46	1.01	1.05
	WI/MN	Frag	0.56	0.63	0.76	0.85
	WI/MN	Cont	0.56	2.00	1.18	1.23
Warbling Vireo	BC	Ripar	0.50[c]	0.708[d]	0.854	1.10
Ovenbird	MO	Frag	0.62	0.74	0.85	1.00
	MO	Cont	0.62	1.32	1.03	1.11
	WI/MN	Frag	0.62	0.59	0.80	0.92
	WI/MN	Cont	0.62	1.35	1.04	1.12

[a] MO = Missouri; WI = Wisconsin; MN = Minnesota; BC = British Columbia
[b] Frag = Fragmented forest patch; Cont = Continuous Forest tract; Ripar = riparian woodland
[c] 0.57 used in re-estimation
[d] probability of nest success first extended out to the sums of up to three nesting attempts (to make comparable with those of Donovan et al. 1995)
[e] Not re-estimated; original observation based on sample of 2 nestings

Management Implications

A developing paradigm is that some populations of songbirds in fragmented habitats, or habitats that are subject to high levels of nest predation or parasitism by cowbirds, have such low nest success that their persistence is maintained by long-distance immigration (Faaborg et al. 1998). A consequent management recommendation is that songbird populations so threatened will only be maintained by such immigration from source populations in large reserves, or continuous blocks of suitable habitat.

An alternative hypothesis, not heretofore considered, is that the low intrinsic growth rates estimated are consequences of the assumptions used to calculate them, rather than a result largely of biological processes. Some populations in these fragmented landscapes may actually be maintaining their numbers, while others may be marginalized only slightly below the reproductive success needed to maintain stable numbers. These populations, in fact, may be declining slowly. This seems to be a more parsimonious explanation of the current maintenance of populations in many fragmented Midwestern habitats, rather than the current belief in maintenance from long-distance immigration. Because the ability of long-distance immigration to maintain distant populations still has no empirical support, and may not be occurring to any significant extent, more locally-focused management strategies need more serious consideration in allowing songbird populations radically affected by nest mortality to persevere into the future.

Acknowledgments

I fear assembling this list, as help came from so many quarters over the course of many years. Access to the Wichita Mountains Wildlife Refuge and Fort Sill Military Reservation, facility use, and various levels of internal support came from B. Karges, S. Smith, S. Waldstein, J. Crabtree, J. and C. Kimball, D. Bartush, J. Gallagher, T. Hodgkins, G. Stout, E. J. Ardoin, D. Tazik, and G. Wampler. Funding came through the Oklahoma Department of Wildlife Conservation, (Nongame Program), Ecological Services Office of the U.S. Fish and Wildlife Service in Tulsa, Wichita Mountains Wildlife Refuge, and U.S. Army. Instrumental in these has been B. Moser, C. Wallace, H. Namminga, J. Skeen and M. Howery. Administrative support from the University of Central Oklahoma was provided by B. Beall, J. Cage, K. Curl, J. Foley, C. Jacob, D. Koehn, J. Perry, J. Mounce, N. Rao, and S. Wagnon. Field Assistants helping in various aspects of the work were P. Ashman, D. Base, V. Bell, J. Bowser, D. and K. Brubaker, C. Buckley, V. Byre, D. Ely, D. Farrell, V. Fazio III, B. Gall, B. Griffin, S. Hull, R. Hylton, T. James, E. and J. Keys, D. Ladd, L. McGee, K. Moholt, R. Moore, E. Munson, J. Parrish, T. Poitras, M. Quinn, P. Shaw, M. Stake, B. and D. St. George, D. Wagner, T. Westmoreland, and R. Wood. C. J. Ralph provided comments useful in improving this manuscript.

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Frederick C. Lincoln and the Formation of the North American Bird Banding Program[1]

John Tautin[2]

The year 2002 marks the 100th anniversary of scientific bird banding in North America.

Credit for the first banding goes to Dr. Paul Bartsch of the Smithsonian Institution, who in 1902, banded 23 Black-crowned Night-Herons (*Nycticorax nycticorax*) at Washington, DC (Bartsch 1904). Others, especially P. A. Taverner, Leon Cole, and the American Bird Banding Association, were involved with in the early development of bird banding in North America, but none was so influential as Frederick C. Lincoln. Building on previous attempts to organize bird banding, Lincoln formed a continental program that today remains a cornerstone of avian research, management and conservation.

Frederick Charles Lincoln was born in 1892 at Denver, Colorado. His adolescent interest in birds matured under the tutelage of L. J. Hershey, Curator of Ornithology at the Colorado Museum of Natural History, and Alexander Wetmore, who was then a University of Kansas student working at the Museum. Foregoing attending the University of Kansas himself, Lincoln instead went to work for Hershey as an assistant in the bird department at the Museum. In 1913, at the age of 21, Lincoln succeeded Hershey as Curator of Ornithology at the Colorado Museum of Natural History. Lincoln held the position until 1920, taking time out in 1918-1919 to serve in the U.S. Army as a Pigeon Expert in the Signal Corps.

In 1920, Lincoln joined the U.S. Bureau of Biological Survey at Washington, DC, where he was assigned the daunting task of organizing the Nation's bird banding program. The Migratory Bird Treaty Act of 1918 had established Federal responsibility for migratory birds, and support for the American Bird Banding Association, which until then had organized bird banding, had waned. Additionally, practicality and comity argued for the development of a uniform, sustainable bird banding program. Lincoln approached his task with the characteristic professionalism, thoroughness, vision and dedication that would see him become an accomplished biologist, writer, and administrator over the next three decades.

Lincoln was in charge of the U.S. bird banding program from 1920 to 1946. Behind the scenes, he organized the banding office, and developed numbering schemes and record keeping procedures. He recruited banders, established standards, fostered international cooperation, and promoted banding as a tool in scientific research and management. But Lincoln is known best for his many published works including:

- *Bird Banding Notes.* This long-running series of communications for, and about, banders and other collaborators, promoted banding and provided comprehensive information on banding policies, processes, and techniques.
- *Returns from Banded Birds, 1920 to 1923.* Early publication of results was important in demonstrating the value of banding. Similar works followed, and by the end of his career, Lincoln had more than 250 publications to his credit. Many were founded in banding.
- *Manual for Bird Banders.* Co-authored with E. P. Baldwin in 1929, the Manual became the definitive work on banding techniques.
- *Calculating Waterfowl Abundance on the Basis of Banding Returns.* Published in1930, this brief circular presented the famous "Lincoln Index" method for estimating abundance from recaptures of marked animals.
- *The Waterfowl Flyways of North America.* In 1935, again relying on data from waterfowl banding, Lincoln espoused the Flyways concept. The concept gained widespread credence and is still applied today in an administrative context with the annual development of migratory bird hunting regulations.
- *The Migration of North American Birds, 1935.* Also a definitive work, *Migration* had both popular and scientific appeal, making Lincoln an authority on bird migration.

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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- *The Migration of American Birds, 1939*. This expanded and more popularized work was illustrated by L. A. Fuertes and published by Doubleday. Lincoln co-authored *American Waterfowl and Birds of Alaska*, and he wrote chapters for numerous other books.

Lincoln remained in charge of the banding program until 1946. As his career progressed, his duties and sphere of influence were ever expanding. He eventually became responsible for a much broader migratory bird program where, just as with banding, he made many lasting contributions to migratory bird conservation.

Frederic C. Lincoln died in 1960, leaving a legacy of accomplishment in the formation of the North American bird banding program. Remarkably, Lincoln's accomplishments were made without his having had the benefit of a college education.

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One Hundred Years of Bird Banding in North America[1]

John Tautin[2]

1902 - Paul Bartsch Bands Birds

"There are still many unsolved problems about bird life, among which are the age that birds attain, the exact time at which some birds acquire their adult dress, and the changes which occur in this with years. Little, too, is known about the laws and routes of bird migration, and much less about the final disposition of the untold thousands which are annually produced" (Bartsch 1904).

With these problems in mind, Dr. Paul Bartsch of the Smithsonian Institution initiated systematic, scientific bird banding in North America in 1902. Bartsch banded 23 Black-crowned Night-Herons (*Nycticorax nycticorax*) at Washington, DC using serially numbered leg bands with the year and a "Return to Smithsonian Institution" address inscribed on them. Bartsch had his first band recovery in September, 1902 and he published his work in 1904 (Bartsch 1904).

Others soon followed Bartsch. In 1905, James Henry Fleming banded the first bird in Canada, an American Robin at his home at Toronto, Ontario. His bands were inscribed with the address "Notify The Auk. N.Y.", and were supplied by noted Canadian ornithologist P. A. Taverner who was an early proponent of bird banding. Another Canadian, Jack Miner, began banding waterfowl in 1909 at his Kingsville, Ontario sanctuary.

Back in the United States, Leon Cole of the University of Wisconsin promoted bird banding and founded the American Bird Banding Association in 1909. The Association oversaw bird banding until the U.S. (1920) and Canadian (1923) federal bird banding offices were established following the 1916 Migratory Birds Convention.

1920 - Frederick Lincoln Expands the Banding Program

Among the many who helped form the North American bird banding program, Frederick C. Lincoln was the most influential. Lincoln joined the U.S. Biological Survey in 1920 and was put in charge of organizing the U.S. banding office. He stayed in charge for 26 years and left a remarkable legacy of accomplishment. An effective administrator, he developed numbering schemes and record keeping procedures. He recruited banders, established standards, and fostered international cooperation. A prolific writer, he produced scores of journal articles, books, manuals and communications related to banding. Also a visionary, he promoted banding as a tool of science, and he developed the "Lincoln Index" population model and the Flyways concept. Frederick C. Lincoln arguably can be credited with laying the foundation for today's North American bird banding program.

2002 - Today's Banding Program

The North American bird banding program has expanded greatly from its small start in 1902 when one person with simple objectives banded one species at one location. Today, the program stretches from the Canadian Arctic to the tropics of Latin America, from Newfoundland to the far Pacific islands, and beyond to places like Siberia, Greenland, and Antarctica. Wherever North American birds go, bird banding is there.

Virtually all species are, or have been, banded. Currently, 1,200,000 birds are banded, and 85,000 recovered, each year. More than 63,000,000 birds have been banded since the beginning of the program, and 3,500,000 have been recovered and reported to the banding offices. Millions more have been recaptured or resighted by banders.

These banders include federal and state conservation agencies; university associates; amateur ornithologists; bird observatories; environmental centers; non-governmental organizations; environmental consulting firms, and other private sector businesses. Currently, more than 6,100 banders are operating in the United States and Canada.

Today's banders augment traditional capture and banding methods with advanced technology. Most use auxiliary marking techniques such colored leg bands, coded neck collars and radio transmitters. Many take blood and feather samples for assays and DNA analysis, and many use sophisticated statistical models to

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analyze their data. Some use satellite transmitters track birds in real time over long distances.

Migration was the focus of the earliest banding studies. Migration studies continue, but today banding has much broader application. Data from banded birds are used to: study avian behavior and ecology; monitor populations; restore endangered species; assess the effects of environmental disturbances; set hunting regulations; educate people about the environment; and to address concerns about human health, safety and economy such as West Nile disease, bird hazards at airports and crop depredations. Results from banding studies support national and international conservation programs such as the North American Waterfowl Management Plan, and Partners in Flight.

The North American bird banding program is jointly supported by the U.S. Geological Survey's Bird Banding Laboratory and the Canadian Wildlife Service's Bird Banding Office. Each office functions as a service and administrative center for banders, issuing permits and bands; supplying forms, instructional materials and technical advice; coordinating the use of auxiliary markers such as neck collars and radio transmitters; serving as the repository for banding records and the clearing house for reports of banded birds; disseminating data to researchers and managers; and assisting in the development and coordination of banding projects. Informal partners in the management of the North American bird banding program include the U.S. Fish and Wildlife Service, state/provincial Waterfowl Flyway Councils, and regional and national banding organizations.

Tomorrow's Program

Tomorrow's bird banding program will differ from today's as technology advances and new research and management needs develop. But as the banding program evolves, the past, present and foreseeable future will remain linked by one fundamental element: that band that uniquely identifies the individual bird and leads to knowledge of its movement, survival and behavior.

The knowledge gained from the first 100 years of bird banding in North America has led to remarkable accomplishments in ornithology and the conservation of birds. Few, if any, other tools available to the ornithologist have been as productive.

May there be another 100 years of bird banding in North America, for as Bartsch said in the beginning, "There are still many unsolved problems about bird life...." (Bartsch 1904).

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A Retrospective Perspective: Evaluating Population Changes by Repeating Historic Bird Surveys[1]

Lawrence D. Igl[2] and Douglas H. Johnson[2]

Abstract

Acquiring an accurate picture of the changes in bird populations often involves a tradeoff between the time and effort required to complete the surveys and the number of years spent surveying the bird populations. An alternative approach to long-term monitoring efforts is to collect current data and contrast those with data collected earlier in a similar fashion on the same study site(s). To evaluate changes in bird populations, we repeated two extensive surveys, one in North Dakota (1967 vs. 1992-1993) and the other in the Platte River Valley of Nebraska (1979-1980 vs. 2001), where large areas of native vegetation had been converted to agriculture. We use these examples and others from the literature to illustrate the advantages and disadvantages of using historical data as a frame of reference for population changes.

Key words: bird populations, historic surveys, long-term monitoring, Nebraska, North Dakota, population changes.

Introduction

Monitoring provides important information about the changes in bird populations, as well as information to assess the consequences of management activities (Johnson 2000, Sauer 2000). An essential component of long-term monitoring is the repeated collection of data over time. Ideally, data-gathering should occur every year for many years, although, realistically, data collection over many consecutive years may not be feasible. Budget, time, and personnel constraints might limit or preclude long-term monitoring programs. In some cases, a monitoring program may have begun too late to provide useful data for conservation or management efforts or to detect incipient population changes. For example, the North American Breeding Bird Survey (BBS), which began in 1966, is the oldest large-scale, long-term monitoring program for breeding birds in North America, but the program is only 36 years old and began well after most of the major habitat changes that occurred after European settlement. Little historical information exists on large-scale changes of breeding bird populations in North America beyond that provided by the BBS (Peterjohn et al. 1995). Moreover, the BBS has provided little insight into the factors responsible for those population changes. Specifically, the BBS was not designed for small-scale, habitat-specific analyses (Sauer 2000), and the resolution of the BBS is too coarse for regional decision making (Hutto and Young 2002).

An alternative approach to understanding bird population changes is to repeat a historical survey, that is, to collect current data and contrast those with data collected earlier in a similar fashion on the same study area(s). A key component of this approach is that the historical survey provides a standard point-in-time measurement against which population changes can be assessed. A flavor of this approach is encapsulated in the following comments by Roberts (1991:180): "Monitoring is usually surveying over time: a series of surveys, repeated to detect changes. If enough is known about how any survey was done, however long ago, it can be repeated and converted into 'monitoring.'"

Historical surveys have played an important role in evaluating bird population changes in North America (*table 1*). Although historical surveys provide a rich source of baseline data, repeating these surveys can be a challenging effort. We used this approach to examine changes in breeding bird populations in two regions in the mid-continent, one in North Dakota (1967 vs. 1992-1993) and the other in the Platte River Valley of Nebraska (1979-1980 vs. 2001), where extensive areas of native vegetation have been converted to agriculture and where the BBS and other long-term monitoring programs provide only sparse coverage. We believe that others will benefit from our experiences in repeating these two historical surveys. This paper is intended to illustrate the advantages and disadvantages in repeating a historical survey (*table 2*) and some of the challenges that might arise when using this approach to

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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Table 1— *Some historical North American studies that were repeated to examine changes in breeding bird populations.*

	Original survey		Repeated survey(s)		Minimum no. years between surveys
Location	**Year(s)**	**Source(s)**	**Year(s)**	**Source(s)**	
Cambridge, MA	1860-73, 1900-04	Brewster 1906	1940-43, 1960-64	Walcott 1974	80
State of IL	1906-1909	Forbes 1913; Forbes and Gross 1922	1956-1958	Graber and Graber 1963	50
Legal section in Woodbury County, IA	1916	Abel 1920	1926	Spiker 1927	10
			1982	Lowther 1984	66
Quaker Run Valley, Allegany State Park, NY	1930-1931	Saunders 1936	1983-1985	Baird 1990	53
Grapevine Mts., Death Valley National Monument, NV	1939-1940	Miller 1945	1971, 1973	Johnson 1974	32
Potosi Mt., Clark County, NV	1939	Miller 1946	1971	Johnson 1974	32
Clark Mt., San Bernadino County, CA	1939	Miller 1940	1973-1977, 1989	Johnson 1995	34
Northern IA	1940	Kendeigh 1941	1989	Bernstein et al. 1990	49
Fairfax County, VA	1942	Aldrich 1942	1979	Aldrich and Coffin 1980	37
Appalachian Mts., NC and TN	1944-1946	Ganier and Clebsch 1944, 1946	1996-1998	Haney et al. 2001	52
Highlands Plateau, Macon County, NC	1946-1947	Odum 1950	1959-1960, 1971-1972	Holt 1974	13
Prince Georges County, MD	1947	Stewart and Robbins 1947	1975-1976	Whitcomb et al. 1977	28
Great Smoky Mountains, TN and NC	1947-1948	Fawver 1950	1982-1983	Wilcove 1988	35
Southern WI	1952-1954	Bond 1956	1979	Ambuel and Temple 1982	27
State of ND	1967	Stewart and Kantrud 1972	1981-1982	Besser 1985 (blackbirds only)	14
			1982	Rolandelli 1986 (crows only)	15
			1990	Nelms et al. 1994 (blackbirds only)	23
			1992-1993	Igl and Johnson 1997, Igl et al. 1999	25
Jackson Hole, Grand Teton National Park, WY	1966-1968	Cody 1974	1991-1992	Cody 1992	25
Platte River Valley, NE	1979-1980	Faanes and Lingle 1995	2001	Igl and Johnson, unpubl. data	22
Southeastern AZ	1985-1986	Strong and Bock 1990	1994-1995	Hall et al. 2002	9

Table 2— *The advantages and disadvantages of repeating a historical survey.*

Advantages	Disadvantages
Study design and methodology already have been developed.	Study design and methodology may be flawed.
Study sites already have been selected.	Study sites may not be representative of area; landowners may deny access to original study sites; study site locations and boundaries may be unknown.
Historical survey collected baseline information on birds and habitats.	Important information may not have been collected in the initial study; original investigators may not have anticipated a repeated study.
Details of field methodology and study design are written in publications.	Details of field methodology and study design may not be written in publications
Original investigators, observers, and field data can provide details of sampling design and methodology.	Original investigators or observers may have passed away or may not be able to recall details concerning sampling design or methodology; original field data may no longer exist.
Can examine changes in bird populations and habitats between the two periods.	Comparisons between the two periods may not be valid; results may reflect observer differences or annual variation rather than real population changes.
Original data-gathering occurred many years or decades in the past, often before many long-term monitoring efforts began.	Data were collected for only two periods; no data were collected between the two time periods.
Can verify population changes using independent surveys (e.g., historical vs. BBS).	Populations changes may differ between independent surveys (e.g., local vs. regional); population changes in independent surveys may reflect different phenomena.

evaluate population changes. We hope that our experiences and those in the literature (*table 1*) will serve to highlight these issues. Finally, we make suggestions for present surveys that would improve the quality of future historical surveys and facilitate repeating surveys at a future date.

Case Studies

In this section, we briefly describe the North Dakota and Nebraska surveys and the sources of data that were available to us to repeat those surveys (*table 3*). Both of these historical surveys were developed and conducted by staff at Northern Prairie Wildlife Research Center, a federal research facility that has been in existence since 1965. Being a government facility, the Center has had some stability in its infrastructure, staff, and mission for over 30 yrs, which enabled us to repeat these surveys with a certain level of ease. In particular, Northern Prairie maintains an archive of electronic and paper data files for most major research efforts. Nonetheless, we were not immune from many of the challenges in repeating historical surveys.

North Dakota

In 1967, Robert E. Stewart and Harold A. Kantrud (1972) conducted an extensive survey of breeding bird populations throughout North Dakota to obtain baseline estimates of statewide breeding bird abundance and frequency of occurrence. Stewart and Kantrud divided the state into eight major strata based on biogeographical, physiographical, and ecological characteristics. From these eight strata, Stewart and Kantrud 130 sample units by random selection without replacement (*fig. 1*). Breeding bird surveys were conducted by Stewart and Kantrud on foot. Each observer surveyed breeding birds on a rectangular half (805 x 402 m; 32.37 ha) of a legal quarter-section (64.75 ha each) by following a standardized survey route. Stewart and Kantrud (1972) estimated population means and totals (*table 4*), and their standard errors, using standard methods for stratified random samples with proportional allocation (Cochran 1977). They calculated Bayesian confidence intervals (95 percent confidence limits; Box and Tiao 1973) in lieu of the usual confidence intervals, using the methods described in Johnson (1977).

In 1992 and 1993, a quarter-century after the original survey, we repeated the Stewart-Kantrud survey using the same sample units, methods, and statistical analyses (Igl and Johnson 1997, Igl et al. 1999). Our objectives were to examine changes in breeding bird populations in North Dakota, to identify habitats used by breeding birds in North Dakota, to estimate densities of breeding birds in those habitats, and to evaluate changes in their

Table 3— *Primary and secondary sources of historical data and information for the North Dakota (Stewart and Kantrud 1972) and the Nebraska (Faanes and Lingle 1995) studies.*

Sources of information	Survey	
	North Dakota	Platte River Valley, Nebraska
Primary		
Original investigator(s)	✔	✔
Original observer(s)	✔	✔
Original field data / journals	✔	
Original statistician(s)	✔	✔
Original statistical analyses	✔	✔
Historical photographs	✔	
Secondary		
Publication(s)	✔	✔
Annual report(s)	✔	✔
Archived electronic file(s)	✔	✔

Table 4— *Population estimates of breeding birds by habitat association and migration strategy in North Dakota and the Platte River Valley of Nebraska.*

	Population estimates			
	North Dakota		Platte River Valley, Nebraska	
	1967	1992-1993	1979-1980	2001
Habitat associations				
Wetland	6,681,000	5,057,000	767,000	798,000
Grassland	12,113,000	10,230,000	931,000	865,000
Shrubland	1,607,000	1,896,000	329,000	397,000
Open habitat with scattered trees	1,071,000	1,922,000	591,000	481,000
Open woodland or edge	2,933,000	3,870,000	2,135,000	1,354,000
Woodland	102,000	168,000	40,000	34,000
Residential or human structures	791,000	1,613,000	610,000	1,232,000
Other	204,000	271,000	10,000	112,000
Migration strategy				
Resident	357,000	894,000	296,000	209,000
Short-distance migrant	17,187,000	15,903,000	2,823,000	2,445,000
Long-distance migrant	7,956,000	9,103,000	2,294,000	2,619,000
Total	25,500,000	25,900,000	5,414,000	4,553,000

densities within habitats between 1967 and 1992-1993. In 1992-1993, we conducted surveys on 128 of the 130 quarter-sections originally surveyed in 1967 by Stewart and Kantrud (1972); landowners denied access at the other two quarter-sections. LDI and Christopher J. Johnson conducted the surveys during the recent period. Data from this survey indicated that significantly declining species were primarily grassland- and wetland-breeding birds, whereas significantly increasing species were primarily species associated with human structures and woody vegetation (*table 4*).

During the recent surveys, several sources of historical information or data were available (*table 3*), including the original field notes and data (*fig. 2*), the original statistical analyses, historical photographs (*fig. 3*), archived electronic data files, and publications (e.g., Stewart and Kantrud 1972). The original field notes of Stewart and Kantrud contained count information by habitat (i.e., information that was not in the electronic data files or publications), which allowed us to compare changes in habitat (*fig. 3*) and densities of birds within habitats (*fig. 4*) between periods. The study sites (i.e., legal quarter-sections) were based on the Federal System of Rectangular Land Survey, which divided the land into square tracts and allowed us to relocate the original study sites and boundaries. To ensure consistency in methodology between the two periods, we worked closely with Harold A. Kantrud (one of the original participants in the 1967 survey), who was still

working at the Center at the time of the recent survey. DHJ was involved with the statistical analyses in both the historical and the recent surveys.

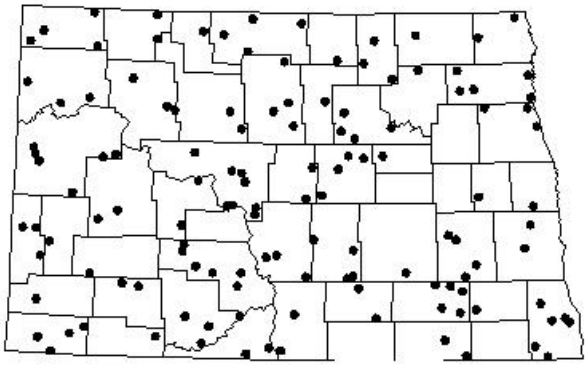

Figure 1— Distribution of 128 quarter-sections in North Dakota where bird surveys were conducted during 1967 and 1992-1993.

Figure 2— Original field notes of Robert E. Stewart and Harold A. Kantrud from 1967.

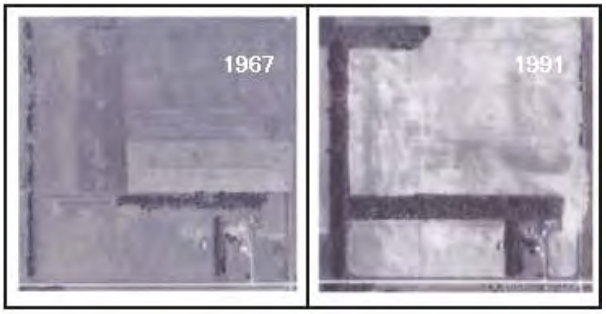

Figure 3— Increase in woody vegetation between 1967 and 1991 on an original study site surveyed by Stewart and Kantrud (1972) in Logan County, North Dakota.

Platte River Valley in Nebraska

In 1979 and 1980, Craig A. Faanes, Gary R. Lingle, and Wayne Norling conducted an extensive survey of breeding bird populations within 13 counties bordering the Platte, North Platte, and South Platte rivers in Nebraska (Faanes and Lingle 1995). The main objectives of their survey were to determine the species of breeding birds using the Platte River Valley, to estimate their population sizes, and to determine their habitat preferences.

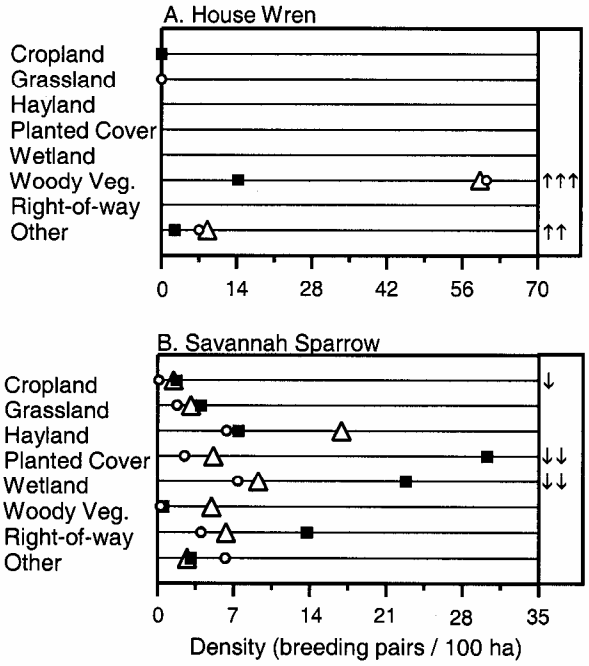

Figure 4— Habitat associations and within-habitat changes in densities of House Wren and Savannah Sparrow. Within each figure, average densities are indicated by habitat and year: a solid square indicates densities for 1967, an open circle for 1992, and an open triangle for 1993. If the species was not observed in a habitat in a given year, its density is not shown for that year. Changes in densities within habitats were indicated at the right of each graph: ↓ (decreasing) at $P < 0.10$, ↓↓ at $P < 0.05$, and ↓↓↓ at $P < 0.01$; ↑ (increasing) at $P < 0.10$, ↑↑ at $P < 0.05$, and ↑↑↑ at $P < 0.01$.

Surveys of breeding birds were conducted on randomly selected plots of habitat within each of several predetermined strata. The first level of stratification was defined by the legal boundary of each county. Within counties, the next level of stratification was the legal township. During selection of study sites, only one plot of a particular habitat type was surveyed per township. The third level of stratification was based on the predominant soil type of the region. Census plots were then randomly selected within these strata. Plot size varied according to habitat complexity. All native prairie and cropland plots were 16.2-ha, residential and riparian plots were 8.1-ha. Wooded river islands were chosen within the selected 16.2-ha plot. Shelterbelts were surveyed when they occurred on selected native prairie or cropland plots. Faanes and Lingle (1995) chose smaller plot sizes than Stewart and Kantrud (1972) because they considered smaller plots to be bet-

ter suited for surveying smaller, inconspicuous species. Each plot was visited once during the 1979 season. In 1980, about 10 percent of those plots surveyed in 1979 were revisited to examine year-to-year variation. Additional plots were surveyed only in 1980. Two-hundred eighteen study sites were surveyed (*fig. 5*). Each plot was surveyed by one of two observers. Birds were counted while the observer followed a zig-zag course within each census plot. Faanes and Lingle (1995) estimated population means and totals (*table 4*), and their standard errors, using the same methods as Stewart and Kantrud (1972) described above.

In 2001, two decades after the original survey, we repeated the Faanes-Lingle survey using the same sample units, methods, and statistical analyses. The objectives of this recent survey were to examine changes in breeding bird populations in the Platte River Valley in Nebraska, to identify habitats used by breeding birds and estimate densities of breeding birds in those habitats, and to evaluate changes in their densities within habitats between 1979-1980 and 2001. In 2001, we visited 189 of the 218 study sites originally surveyed by Faanes and Lingle (1995) in 1979-1980 (*fig. 5*); landowners denied access at the other sites. Gary R. Lingle and Jennifer A. Gulbransen conducted the surveys during the recent period.

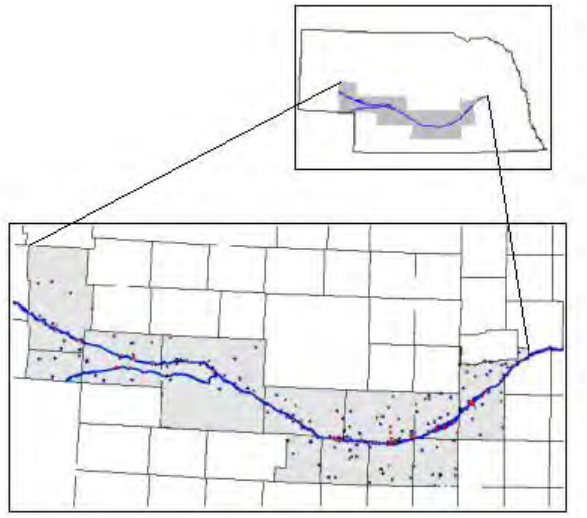

Figure 5— Distribution of 218 study sites in the Platte River Valley of Nebraska where bird surveys were conducted during 1979-1980 and 2001.

We used several sources of historical information or data to repeat the Faanes-Lingle survey (*table 2*), including the original statistical analyses, archived electronic data files, and publications (Faanes and Lingle 1995). The original field notes were missing and likely were destroyed by flooding at Northern Prairie Wildlife Research Center in 1993. The study-site descriptions of the Faanes-Lingle survey were based on the Federal System of Rectangular Land Survey, but only up to the level of a legal quarter-section. Without the original data sheets, we were unable to pinpoint the exact locations of some of the study sites, although we knew the study plots occurred within one of four quarters of a legal quarter-section. DHJ was involved with the statistical analyses in both the historical and the recent surveys.

Which Historical Surveys Should be Repeated?

Historical surveys are an attractive data source for evaluating bird population changes because the study design, field methodology, and study sites already have been determined and because the initial data-gathering may have occurred many years or decades in the past, before most long-term monitoring efforts (e.g., BBS) were initiated. In theory, most historical surveys should be repeatable. A key consideration is whether the historical survey is worth repeating, which should be evaluated on a case-by-case basis. Determining whether a historical survey is suitable for repeating requires consideration of a number of factors: Are the exact locations of the study sites known or documented? Can access to enough of the original study sites be obtained? Is the field methodology written down? Are the original investigators or observers still alive? Do the original field notes or completed data forms still exist? Are there archived electronic data files? Is the original study design adequate to accomplish the stated objectives of the repeat survey? Has sufficient time elapsed for changes in bird populations or habitats to have occurred? Are habitats sufficiently similar to the original habitats to permit meaningful comparisons?

A well-planned study design with well-documented field methodologies is critical for any monitoring or research effort, whether short-term or long-term. In many ways, the advantages of repeating a historical survey are also the drawbacks of repeating a historical survey (*table 2*). When repeating a historical survey, one must recognize that both the study design and methodology are constrained by the study design and methodology of the original survey. Poorly planned or poorly documented historical studies preclude repeating at a future date. Moreover, the design of the original survey may be inadequate to detect changes (Elzinga et al. 1998). In some cases, important information may not have been collected or documented during the historical survey, because the original investigators were not anticipating that the study would be repeated. Well-planned studies with detailed documentation of methods and study site locations help ensure the repeatability of a survey, even if future repetition was not anticipated by the original investigators. Some historical surveys (e.g., Stewart and Kantrud

1972, Faanes and Lingle 1995) were specifically designed to provide a baseline to evaluate changes in habitats and birds populations at a future date, which facilitates repeating at a later date.

Sources of Historical Data and Information

When compiling sources of data from a historical study, it is important to remember that "... only a part of what was observed in the past was remembered by those who observed it; only a part of what was remembered was recorded; only a part of what was recorded has survived; only a part of what has survived has come to the historian's attention ..." (Gottschalk 1956: 45). In historical studies, there are two main sources of data or information: primary and secondary (Touliatos and Compton 1988). Primary sources include the original study design or proposal, recollections of the original investigator(s), original field data, original statistician(s) and analyses, historical photographs, and field data and journals. Secondary sources include records or accounts that are one or two steps removed from the original source, such as electronic files, publications, annual reports, newspaper articles, abstracts from meetings, etc. Data that have passed through several levels may bear little resemblance to the original version; thus, using more primary sources of historical data or information will allow more types of questions to be addressed when the historical survey is repeated.

In this age of advanced technologies—including satellite imagery, global positioning systems, geographical information systems, and personal computers—it is difficult to appreciate the obstacles that early field biologists had to endure to conduct bird surveys, often armed with little more than a field notebook, a pencil, a compass, a pair of binoculars, and perhaps a map or aerial photograph. One of the most valuable sources of historical data or information is the original field notes and data (*fig. 2*), which not only indicate what types of data were collected and in what fashion, but also include information that may not have been addressed in publications or included in electronic data files. For example, the methods described in Stewart and Kantrud (1967) do not mention that bird data were collected separately for each habitat type within each study site. These data also were not included in the archived electronic data files. Having the original field data allowed us to evaluate changes in habitat composition within the original study sites (*fig. 3*) and changes in breeding bird densities among habitats (*fig. 4*). Similarly, Johnson (1974) consulted Alden H. Miller's field notes to determine details of abundances of some species that were not published in Miller (1945). Hall et al. (2002), however, were unable to compare their data to those from one of the three original years (Strong and Bock 1990) because the historical data files from that year were missing.

Besides written documentation and publications, individuals associated with the original survey can provide valuable information on the methodology and standards used during the original survey. These people include the original principal investigators, observers, and any others (e.g., statisticians) involved with the historical survey or development of the study design. For example, during the repeats of the North Dakota and Nebraska studies, we worked closely with the original investigators and observers to ensure consistency of methodology between the historical surveys and the recent surveys. Furthermore, DHJ was involved with the statistical analyses in both the historical and the recent surveys in the North Dakota and the Nebraska studies. Richard R. Bond's original field notes were lost, but Ambuel and Temple (1982) were able to consult Bond for details of the study design and methodology (e.g., survey dates) that were not included in Bond (1956). Graber and Graber (1963) used correspondence, journals, and the original field notes of Alfred O. Gross to determine the survey technique used by Forbes (1913) and Forbes and Gross (1922). Consultations, however, may result in low levels of return; Gurevitch et al. (2001) cautioned that requests for missing data or information might be very time-consuming and often results in low levels of return.

Consistency vs. Optimality of Field Methodology

A variety of methods have been used to survey birds. One of the most important considerations for any monitoring system is that the system needs to be repeatable; in turn, repeatability demands that standardized methods be used (Johnson 2000). Field methodology must be precisely documented, understood by the participants beforehand, and adhered to closely. Consistency of field methodology and effort among years is critical to maintaining the comparability of any survey (e.g., Ralph et al. 1995). All methods of sampling bird populations have their shortcomings and constraints, and biases are inherent in all data-gathering procedures (Ralph and Scott 1981). In that respect, historical surveys are no different; for field methodology, consistency is more important than optimality.

A major obstacle to repeating a historical survey is the inconsistent or incomplete fashion in which investigators describe details of their study design, methodology, study sites, and statistical analyses within reports or publications. The finest—and often some of the most important—details of sampling design and meth-

odology usually are not included in publications. In a recent review on meta-analysis, Gurevitch et al. (2001) expressed concern about the difficulties arising from the incomplete reporting in primary literature, despite attention to statistical rigor in the editorial policies of most ecological journals. The overall result is the loss of valuable information needed to repeat a survey. For example, Kendeigh (1941) did not record the methodology or the time spent delineating territories and nest searching, so Bernstein et al. (1990) attempted to emulate Kendeigh's study by censusing at different times of the day, using a combination of strip census with spot mapping, and searching for all nests within the study plot.

One should not alter the methods or study design excessively or the changes will influence comparisons between past and future results. For example, Ambuel and Temple's (1982) survey methods, survey dates, and area of coverage did not duplicate those of Bond (1956). In particular, Ambuel and Temple began their surveys two weeks earlier than Bond had, included forest edge habitats that were excluded by Bond, and covered a greater area within each forest than Bond. Ambuel and Temple acknowledged that larger study sites have a higher probability of including uncommon species. Wilcove (1988) surveyed birds using the methods provided by Fawver (1950), but he increased the number of visits per site. Wilcove recognized that the increased sampling effort may have influenced the interpretation of the results.

Repeating a historical survey can be done at various levels of intensity, depending on the objectives to be accomplished and the resources available. In some situations, surveying all of the species or visiting all of the original sites may not be necessary or practical, based on the objectives of the study. For example, Nelms et al. (1994) visited a subset of the original Stewart and Kantrud (1972) study sites in 1981-82 in a portion of North Dakota to estimate population sizes and examine changes in populations of three species of blackbirds that depredate sunflower crops. Rolandelli (1986) surveyed American Crows (*Corvus brachyrhynchos*) on a subset of the Stewart and Kantrud study sites in 1983 to evaluate crow distribution and abundance in North Dakota.

Some of the original methods or objectives of the historical survey can be modified or augmented in future surveys without compromising comparisons between the two periods. For example, in 1967, Stewart and Kantrud (1972) based the number of breeding pairs of the Brown-headed Cowbird (*Molothrus ater*) on the number of males seen per sample unit. Recognizing the potential impact of female cowbirds on their hosts, we surveyed both male and female cowbirds in 1992 and 1993. This minor adjustment in methodology allowed us to make comparisons between our data and those from the historical survey (Igl and Johnson 1997) as well as those from concurrent or recent studies that are based on counts of females (e.g., Johnson and Igl 1995), without compromising the quality of the data. In addition, we were able to calculate statewide population estimates and their confidence limits for male and female cowbirds in the two recent years (Igl and Johnson, in prep.), which has never been done for this species over an extensive area. Nelms et al. (1994) followed Stewart and Kantrud's survey methods, but allowed for a higher acceptable sustained wind speed during their censuses of three blackbird species, because Besser and Brady (1984) had found no effect of winds up to 56 km per hour on the ability of observers to detect blackbirds. Although Forbes (1913) and Forbes and Gross (1922) originally surveyed bird populations in all seasons of the year, Graber and Graber (1963) limited their survey to the winter and summer seasons because annual bird populations during the two migratory seasons were too variable to provide meaningful comparisons between the historical and recent surveys.

Biases in Field Methodology: Past and Present

Biases associated with the methodology of historical bird surveys often are not quantified. For example, Stewart and Kantrud (1972) admitted that they did not quantify the biases associated with their survey methodology, but recognized that both negative and positive biases may be present. Our recent survey (Igl and Johnson 1997) was conducted as similarly as possible to the methods used in the historical survey (*table 3*). Although standardization in methodology is essential, it will not eliminate biases from a study. Moreover, it is unreasonable to assume that all biases in field methodologies can be controlled or eliminated. Undoubtedly, biases related to differences in observers, years, weather, sampling time, etc. will be present in the historical and recent surveys, but variations associated with methodology in the two periods should be relatively consistent among years.

Any discussion of bias in avian surveys will include a discussion of observer bias. Undoubtedly, observers vary in their abilities to conduct bird surveys (Faanes and Bystrak 1981, Sauer et al. 1994). Moreover, an observer's abilities often change with time and experience. In any monitoring system, however, it is best to use the same observer for as many years as possible. If it is necessary to change observers, training will minimize the disruption in the monitoring scheme and lessen the variation among observers between periods (Kepler and Scott 1981, Hanowski and Niemi 1995).

During long-term monitoring efforts, new observers eventually will replace earlier observers. This statement is especially true for studies that involve repeating historical surveys. The longer the interval between the original survey and the future survey, the less likely the original observers or investigators will be available to repeat the survey. In many cases, the original observers may no longer be alive or might lack the physical abilities, interest, or time to repeat the survey in the future. In rare cases, the original observers might be available to survey several decades after the historical survey. For example, during our repeat of Faanes and Lingle's (1995) survey in the Platte River Valley of Nebraska in 2001, one of the original observers, Gary R. Lingle, participated in the bird surveys, 22 years after the historical survey. John W. Aldrich participated in a survey of breeding birds in a mature eastern deciduous forest in Virginia in 1942 (Aldrich 1942) and again 37 years later (Aldrich and Coffin 1980). Martin L. Cody (1992) repeated his 1966-68 (Cody 1974) study 25 years after the original survey.

Relocating Original Study Sites

Critical to the success of repeating any bird survey, be it annual or historical, is relocating the original study sites and boundaries. Many studies cannot be repeated exactly because the original study site locations were poorly documented, could not be relocated, or had unknown boundaries. Historical studies that involve one (e.g., Abel 1920) or a few study sites (e.g., Odum 1950) usually provide details on the locations or boundaries of study sites in publications, but often the exact study site locations are not given within a publication because their descriptions are either too lengthy or numerous to include (e.g., Stewart and Kantrud 1972) or are deemed unimportant for the publication by the principal investigators or the journal editors. Besides publications, data sources for study site locations and boundaries include the detailed study proposals, original field notes, maps, electronic data files, and the original investigators. For example, Wilcove (1988) relocated most but not all of Fawver's (1950) study sites using directions in Fawver's dissertation, old maps, and information provided by Fawver and long-term residents in the area. In some cases, the location of the study site might be known, but the exact boundaries of the study site might not be obvious. For example, Bernstein et al. (1990) could not locate the exact boundaries of Kendeigh's (1941) study area, although the general location of the study area (a small, undisturbed prairie remnant) was known. In other cases, the boundaries of the study sites may no longer exist. For example, Holt (1974) found that the exact boundaries of one of Eugene P. Odum's (1950) study sites had been obliterated. Hall et al. (2002) could not relocate nine of 132 point-count stations originally surveyed by Strong and Bock (1990).

For monitoring purposes, it is probably best to use the same study sites as those used in the original survey (Johnson 2000). Using the same study sites increases the efficiency of the study in measuring change, both in bird populations and habitat conditions. A system with some old and some new locations might offer somewhat better statistical properties (Johnson 2000) but may not be optimal when repeating a historical survey. For example, Walcott's (1974) study site in 1940-43 and 1960-64 was about 50 m from William Brewster's (1906) original study site. Graber and Graber (1963) did not duplicate exactly the census route of Forbes (1913) and Forbes and Gross (1922) but instead selected survey routes that were representative for the area. In some situations, some or all of the original study sites may no longer be accessible, especially those on privately owned land. For example, private land owners denied access to two (1.5 percent) of the original 130 study sites in our North Dakota study and 29 (13 percent) of the original 218 study sites in our Nebraska study.

Old maps and aerial photographs can be useful in locating original study sites. Historical photographs also can be useful in evaluating historical conditions and mapping and monitoring landscape features (e.g., land use) or major habitat changes between two study periods. We evaluated changes in habitats on the original study sites of Stewart and Kantrud (1972) by contrasting recent aerial photographs with aerial photographs from the late 1960s (*fig. 3*). Bernstein et al. (1990) used recent and historical aerial photographs to document woody succession into a prairie remnant since Kendeigh (1941) conducted his survey in 1940.

Sample Sizes

To this point, we have not addressed the issue of sample size. Ultimately, statistical power in monitoring bird population changes depends on surveying numerous sites (Verner 1985, Johnson 2000). In planning to repeat a historical study, however, the sample size is less readily adjusted because it is constrained by the number of study sites of the historical survey. For example, several historical surveys in *table 1* involved only a single study site in a small area (e.g., Kendeigh 1941), whereas others involved several hundred study sites over an extensive area (e.g., Faanes and Lingle 1995). Because of the advantages of large sample sizes and the limitations of small sample sizes, we emphasize the importance in defining objectives before repeating a historical survey (e.g., Johnson 2000).

Survey Dates

As with study site locations, the exact dates and times of individual counts at a historical study site rarely are included in publications, but rather authors typically only include the start and end dates for the entire survey. Data sources for survey dates and times include both the original field notes and electronic data files. Because breeding bird populations can change dramatically over the course of the breeding season, counts in subsequent years should be conducted on or near the date of the original count. For example, in repeating the North Dakota and Nebraska surveys, we matched the date that a study site was surveyed as closely as feasible to the date that it was originally surveyed by using the information recorded in the original field notes or electronic data files. For the repeat of the Stewart and Kantrud (1972) study, the overall absolute difference between the dates of 1967 surveys and the 1992 and 1993 surveys averaged 2.5 days.

Habitat-Specific Analysis

Although the BBS has been effective in documenting long-term patterns of population change in breeding birds, the BBS does not provide comparable data on habitat changes. Hutto and Young (2002) argued that describing patterns of habitat use will make a much more effective program than one based on monitoring long-term population trends alone. Evaluating changes in bird populations is most useful if comparable habitat information is available for both the historic and recent surveys. For example, the inclusion of habitat data with our bird count data allowed us to evaluate changes in habitat composition within the original study sites (*fig. 3*) and changes in breeding bird densities among habitats (*fig. 4*).

Two Points in Time: Interpretation and Statistical Concerns

The primary objective of most long-term monitoring efforts is to detect changes in bird populations over time. One caveat to repeating historical surveys is that the data cover only two (sometimes more) points in time during a long period, whereas populations of birds may show tremendous short-term variability (Lowther 1984, Wilcove 1988, Igl and Johnson 1999). Skeptics of repeating historical surveys have questioned the validity of determining long-term changes by using data from only two periods separated by several decades, owing to the perceived shortcomings in the analytical techniques (e.g., Askins et al. 1990). Yet, there is nothing inappropriate in addressing questions of differences between two periods. Moreover, the data collected during historical surveys often are the same as or similar to those collected during long-term monitoring efforts.

Repeating a historical survey does pose some statistical concerns. Obviously, two points do not provide much information on a species' population trend. The changes between the two periods may reflect only normal year-to-year variation in a population rather than a consistent pattern. For example, conditions in the recent year might be different from those in the historical year. We suggest two remedies to this problem. First, one can repeat a historical survey twice, and thereby assess annual variation. This approach was taken by Igl and Johnson (1997), who repeated Stewart and Kantrud's (1972) historical survey in two years (1992 and 1993) rather than one. (Alternatively, as in the Platte River study, the historical survey had been partially repeated in two separate years.) Igl and Johnson (1997) claimed that a significant change had occurred only if the difference between 1967 and 1992 values and the difference between 1967 and 1993 were both significant ($P < 0.10$) *and* if both differences were in the same direction.

If multiple repeats of a survey cannot be done, an ad hoc and approximate remedy may be useful if comparable information from a monitoring program, such as the BBS, is available. If, for example, the BBS value provides a reasonably consistent index to the population that is being censused in the repeated survey, then the coefficients of variation of the BBS values and the true population numbers will be roughly equal. That is, if a population increases, say, 15 percent from one year to the next, an index to that population should increase about 15 percent during that same time frame. Accordingly, one could compare the relative magnitude of change between a historic survey and its repeat to the analogous variation in the time series of an index. If the changes are comparable, there is no evidence that the difference is unusually large and therefore reflects a real change between the historic and current times. If the difference between historic and repeated values is substantially greater than the variation in an index, there is reason to believe that true population values have changed.

Shorter intervals between the historical survey and subsequent surveys might enhance the ability to detect short-term changes but, as mentioned above, also increase the time and resources required to repeat the historical survey. The survey in 1947 by Stewart and Aldrich (1949) has been repeated every five years since 1948 (Hall 1984), which reflects a compromise between annual surveys and surveys separated by several decades.

Supplement to Long-Term Monitoring Programs

Repeating historical surveys should be viewed as a supplement to, rather than a substitute for, long-term, large-scale surveys. Some species or regions are poorly sampled by long-term monitoring efforts such as the BBS. Historical surveys can provide a valuable–and often overlooked–source of baseline data on breeding bird populations in such areas. Several studies have attempted to verify population trends from the BBS with data from independent, long-term surveys (e.g., breeding bird atlases: Robbins et al. 1989; checklists: Temple and Cary 1990; Christmas Bird Counts: Hagan 1993; migration counts: Dunn and Hussell 1995). Historical surveys can be used similarly. Parallel trends derived from studying the same populations in different ways may provide corroborating evidence and strengthen the assessment of population trends of the BBS. A secondary objective in repeating the North Dakota and Nebraska studies was to compare patterns in breeding bird population changes with trends from the BBS for the same periods (*table 5*). In the North Dakota study, we found similar patterns of long-term population change evident in our data and those from the BBS. This concordance illustrates that both these independently derived measures of population change likely were recording similar phenomena. We found less concordance with the Nebraska study (*table 5*), possibly because the two measures of population change covered different areas (i.e., Platte River Valley vs. statewide).

Conclusions

Historical surveys provide an important source of baseline data for examining changes in bird populations, provided that researchers are aware of the limitations and challenges in using these data. Although historical surveys have been used widely in the literature to evaluate long-term population changes (*table 1*), there are a number of issues that pose serious impediments to repeating historic surveys. These issues are not unique to repeating historical surveys but represent limitations that apply to other studies as well.

Gurevitch et al. (2001) listed four components of data collection: data extraction and recording, data entry, data proofing, and data storage. The most serious impediments to repeating historic surveys are associated with data storage. These range from methodological limitations (e.g., the failure of the original investigators to document study site locations and field methodologies) to those concerned with the lack of standards in data storage and archiving. Gurevitch et al. (2001) further listed two levels of data from a study: 1) metadata, which includes background information for subsequent analyses and interpretation and details of methodologies, and 2) response data, which are the numerical and categorical data quantifying the responses of the species or the system. Repeating a historical survey requires that both data types were accurately and completely recorded and archived during the original survey. Clearly, all studies benefit from foresight, advance planning, and good organization.

Finally, it is important to recognize that all present surveys are potential "future" historic surveys. As mentioned earlier, one of the most important considerations for any study is repeatability. If present surveys are to serve as historical surveys in the future, then investigators must: 1) be precise and thorough in providing details of their methodologies, study site locations, and study design, and 2) implement procedures to archive electronic and paper data files. Providing detailed guidelines and methodologies in publications and archiving data will improve the repeatability of any study and ensure consistency in data collection, whether within the same year, the following year, or 100 years later.

Acknowledgments

We are grateful to C. A. Faanes, H. A. Kantrud, G. R. Lingle, and W. Norling for their advice and guidance throughout all phases of the recent surveys. L. M. Cowardin assisted in the development of the original study design of the North Dakota study. We thank J. A. Gulbransen, C. J. Johnson, G. R. Lingle, and M. D. Schwartz for assistance in the field during the recent surveys. This study would not have been possible without the cooperation of the many land owners, operators, and managers who allowed us to survey birds on their land in North Dakota and Nebraska. H. A. Kantrud, W. E. Newton, T. Rich, C. S. Robbins, and M. A. Sovada commented on earlier drafts of this manuscript.

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Table 5— *Populations changes of some breeding birds in North Dakota (1967 vs 1992-1993) and the Platte River Valley in Nebraska (1979-1980 vs 2001) compared to those from the North American Breeding Bird Survey for North Dakota and Nebraska. Declines and increases are statistically significant; populations that are not statistically significant are indicated by no change.*

	North Dakota		Platte River Valley in Nebraska	
Species	**Repeat survey (1967 vs. 1992-1993)**	**BBS (1967 to 1993)**	**Repeat survey (1979-1980 vs. 2001)**	**BBS (1980 to 2000)**
Canada Goose (*Branta canadensis*)	No change	Increase	No change	No change
Blue-winged Teal (*Anas discors*)	Decline	Decline	No change	No change
Swainson's Hawk (*Buteo swainsoni*)	Increase	Increase	No change	Decline
American Coot (*Fulica americana*)	Decline	Decline	No change	No change
Mourning Dove (*Zenaida macroura*)	No change	Increase	No change	Decline
Western Kingbird (*Tyrannus verticalis*)	Increase	Increase	No change	Decline
Eastern Kingbird (*Tyrannus tyrannus*)	Increase	Increase	No change	Decline
American Crow (*Corvus brachyrhynchos*)	No change	No change	Increase	No change
Horned Lark (*Eremophila alpestris*)	No change	No change	No change	No change
Black-capped Chickadee (*Parus atricapillus*)	Increase	No change	No change	No change
House Wren (*Troglodytes aedon*)	Increase	Increase	No change	No change
American Robin (*Turdus migratorius*)	Increase	Increase	No change	No change
Gray Catbird (*Dumetella carolinensis*)	No change	No change	Increase	No change
Chipping Sparrow (*Spizella passerina*)	Increase	Increase	No change	No change
Dickcissel (*Spiza americana*)	No change	No change	No change	No change
Red-winged Blackbird (*Agelaius phoeniceus*)	Decline	Decline	No change	Increase
House Sparrow (*Passer domesticus*)	Increase	Increase	No change	Decline

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An Overview of a Landbird Monitoring Program at Tortuguero, on the Caribbean Coast of Costa Rica[1]

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Abstract

Since 1994, the Tortuguero Integrated Bird Monitoring Program has been monitoring birds in a coastal lowland rain forest of northeast Costa Rica. The Program has combined the use of area searches, constant-effort mist netting, and migration counts into a long-term landbird monitoring and training program following the recommendations of the Partners In Flight – Aves de las Américas monitoring guidelines. We briefly summarize the methods and results from our monitoring, including the numbers of bird species captured, censuses from 1994 through 2002, and age ratios for five species of migrant landbirds. Additionally, we describe our accomplishments in methods training and information exchange within the Americas.

Key words: area search census, Costa Rica, landbird, migration count, mist netting, monitoring, neotropics.

Introduction

In light of growing concerns about the status of the birds of the rain forests in Mesoamerica, both tropical residents and migrants, we have established long-term monitoring stations in the area of Tortuguero, in northeast Costa Rica, in a program called the Tortuguero Integrated Bird Monitoring Program. To our knowledge, this is the longest constant-effort monitoring program of the landbirds of Costa Rica. The program has established the following broad objectives:

- Maintain a long-term monitoring program for the study of nearctic-neotropical migrants and the relatively little-known tropical resident landbirds, and
- Provide training opportunities and exchange information with Latin Mesoamerican and Caribbean students and biologists.

More than 100 biologists, students, scientists, and interns have contributed to the monitoring as well as methods training and information exchange in continuing the monitoring program. Here, we present a preliminary description of our results and discuss the importance of monitoring migrating birds en route to their wintering sites.

Study Area

The monitoring stations are all within 6 km of the village of Tortuguero on the northeast coast of Costa Rica, Limón Province (Latitude 10°32' N.; Longitude 83°30' W.). This region is dominated by the Holdridge (1987) forest type of Lowland, Very Wet Broadleaf Tropical Forest, laced with rivers and canals and, increasingly, areas altered for agriculture and other human use. The region has a mean annual temperature of 29.9°C and receives a mean annual rainfall of >500 cm, making it the wettest region of the country. The area's importance as a nesting habitat for sea turtles has led to the protection of the surrounding lands and a growing ecotourism culture in Tortuguero. The majority of forested lands surrounding the village are protected within the 19,211-ha Tortuguero National Park and the nearby Barra del Colorado National Wildlife Refuge. Our monitoring stations are located in both primary and secondary forest types within 1 km of the Caribbean Sea, some with a narrow scrub zone between the forest and sand beach, and others bordered by either river or canal.

Methods

The Program uses the standardized methods of mist-net arrays, migration counts, and area search censuses described by Ralph et al. (1993) and recommended by the

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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Partners In Flight – Aves de las Américas – Monitoring Working Group (Hussell and Ralph 1998). In August 1995, after an initial testing period in fall 1994, we began constant-effort operations at five primary stations and two satellite stations, covering about 9 to 10 months each year. Most of the analyses in this paper are based on the data recorded between August 1995 and December 2002. The dates of operation were primarily from August to December and mid-January to May annually. Each station is composed of 10 to 15 12-m mist net locations, a diurnal migration count location, and two area search routes. The primary stations were usually operated once every 7 days, and the satellite stations once a month, with some stations operated up to three times every 7 days during migration. The season referred to as "fall" in this paper refers to the postbreeding period of the migrants from the temperate region of the Americas. Mist nets were operated for 6 hours, beginning at sunrise. Captured birds were banded and biometric information recorded as outlined by Ralph et al. (1993), including weight, body fat class, molt status, age, and sex. We defined age ratio as the percentage of young of all birds captured each year, without adjustment for effort between years. Tropical resident species were photographed to document their plumage and molt. The migration counts were a 10-minute unaided scan of the sky facing the direction of the oncoming migration in which only the migrating birds were recorded. The counts were conducted opportunistically throughout the day, usually at 2-hour intervals, and at a prescribed location at each station. Thus, counts were usually conducted 50-60 minutes in a day, weather and schedule permitting. The area searches lasted 20 minutes, and a minimum of two searches were conducted within the netting station for each netting effort, during which all birds detected were recorded.

Results and Discussion

Resident and Migrant Species Captured

Between 1994 and 2002, we operated mist nets for almost 93,000 net-hours and captured more than 27,000 birds of 182 species, of which approximately one-third were migratory species and two-thirds were tropical resident species (*Appendix A*). Forty resident and migrant species have each been represented by more than 100 captures.

The White-collared Manakin (scientific names are given in *Appendix A*) was the most frequently captured resident species during all years of the study, comprising about 25 percent of all resident captures (*Appendix A*). Three of the next most frequently captured resident species were hummingbirds: Bronzy Hermit, Long-billed Hermit, and Rufous-tailed Hummingbird. The Variable Seedeater was also very common. These five species made up almost 75 percent of the resident species that were captured and were among the 10 most commonly netted residents during each year of our study.

The five most common migrant species captured were "Traill's" (the essentially inseparable Alder and Willow complex) Flycatcher, Swainson's Thrush, Prothonotary Warbler, Northern Waterthrush, and Veery, and they accounted for more than one-half of the migrants captured.

We have had one banded bird recovered in North America, a Gray-cheeked Thrush near Toronto, Ontario, Canada, 18 months following its original capture at Tortuguero in October 1996.

Age Ratios of Migrants

We examined the age ratios for the five most common migrant species between August and December for 1995-2002 (*figs. 1-5*) for their magnitude and between-year consistency. All the species had, in most years, more young birds than adults. The Prothonotary Warbler had more than about 75 percent young (Hatch Year) each year, whereas the other species had lower percentages of young, and the percentages varied more between years.

The numbers of all species were rather variable between years, and these differences may reflect reproductive success. In the Traill's Flycatcher, the 2 years with relatively few young were also the 2 years with the lowest number of total captures, perhaps indicating poor years for breeding. This coincidence was not seen in other species, so occasional low percentages of young may be indicative of other causes.

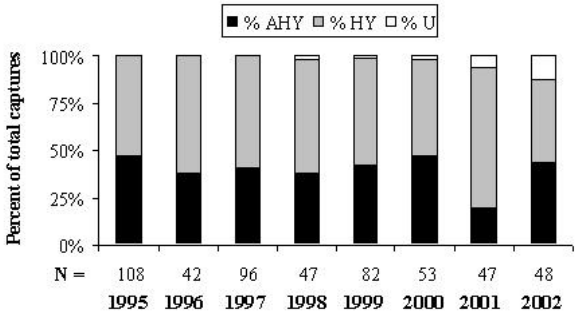

Figure 1— Age classes for the Northern Waterthrush, with the percent of total captures (N) of After Hatch Year (AHY), Hatch Year (HY), and Unknown (U), captured from August to December, 1995–2002.

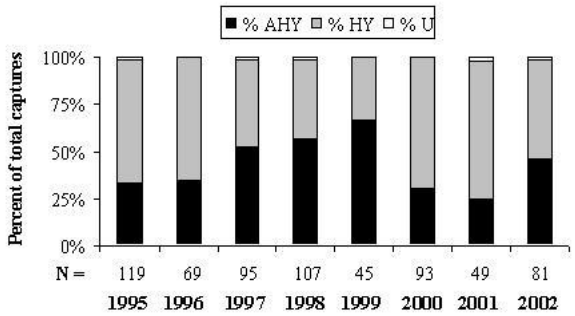

Figure 2— Age classes for the Veery, with the percent of total captures (N) of After Hatch Year (AHY), Hatch Year (HY), and Unknown (U), captured from August to December, 1995–2002.

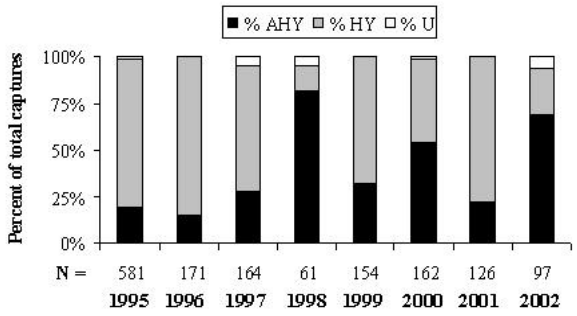

Figure 3— Age classes for the "Traill's" Flycatcher, with the percent of total captures (N) of After Hatch Year (AHY), Hatch Year (HY), and Unknown (U), captured from August to December, 1995–2002.

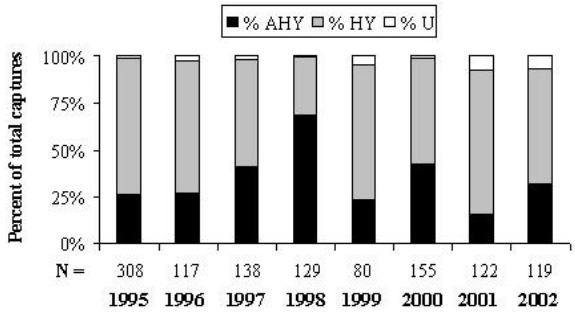

Figure 4— Age classes for the Swainson's Thrush, with the percent of total captures (N) of After Hatch Year (AHY), Hatch Year (HY) and Unknown (U), captured from August to December, 1995–2002.

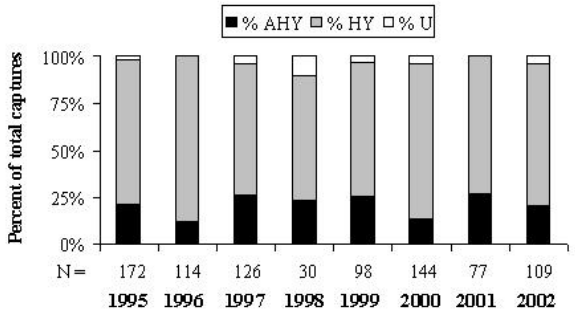

Figure 5— Age classes for the Prothonotary Warbler, with the percent of total captures (N) of After Hatch Year (AHY), Hatch Year (HY), and Unknown (U), captured from August to December, 1995–2002.

By monitoring the age classes of migrants, population-limiting factors may be better understood as well as productivity changes between years. The factors that limit the populations of a species during the migratory period are poorly understood (Sherry and Holmes 1993). We strongly urge increased efforts, during migration, to investigate the factors influencing the routes taken, stopover habitats used, timing of passage, and demographic fluctuations.

For example, in North America, age ratios have been used to suggest routes of migration (Ralph 1978). At North American coastal stations, young birds often make up more than 95 percent of captured migrants in the fall, probably indicating that the young have become disoriented (Ralph 1978), with the main route inland. The occurrence of a lower proportion of young birds, in at least some species at this coastal location, suggests that age classes have largely integrated as the birds moved farther south.

Diurnal Migration Counts

We conducted 4,928 migration counts at our stations from fall 1995 through 2002. The species we detected most often, excluding the unidentified swallow and hawk species, were the Barn Swallow, Cliff Swallow, Eastern Kingbird, Broad-winged Hawk, and Chimney Swift (*table 1*). Migration counts have been used extensively elsewhere to census diurnal migrants (Moore et al. 1995) and have the advantage of sampling birds that are not routinely captured by mist nets. Researchers have usually focused on raptor migration counts and worked in areas where specific topographic features funnel the raptors through a survey area.

The most notable overall result was the marked differences between years in some species. The total numbers of individuals of the two swallow species were fairly consistent between years, with differences of less than one order of magnitude (*table 1*), even if the counts were corrected for effort. By contrast, the numbers of hawk, kingbird, and swift can vary more than three orders of magnitude. This annual variation is possibly due to differences in migration routes between years, with birds at times moving more inland, closer to the mountains, about 100 km away. The variation between years could also reflect that we only sample, rather than make a continuous count, as is typical of other studies. During the intervals between counts, substantial numbers of birds could move through, as evidenced by the passage in 1999 of an estimated

Table 1— *Total number of birds observed and number of counts (N) per year for the five most abundant migrant species detected during 10-minute migration counts in Tortuguero, Costa Rica, 1995–2002.*

Species	1995	1996	1997	1998	1999	2000	2001	2002	Total
N =	283	713	1033	331	316	736	701	815	4,928
Barn Swallow	12,912	12,179	11,962	2,704	5,475	8,691	8,278	8,912	71,113
Cliff Swallow	16,853	6,777	6,079	1,753	11,137	10,168	3,590	12,521	68,878
Eastern Kingbird	9,119	7,221	7,622	50	21	8,620	1,859	14,125	48,637
Broad-winged Hawk	16,366	2,120	25	3	10,000	297	5	8	28,824
Chimney Swift	3,913	3,602	12,920	39	1,167	1,417	114	5,102	28,274

10,000 Broad-winged Hawks in one 10-minute period, the only observation of that species in that year.

Seasonal patterns differed considerably between the five species we examined, when all years and stations were pooled, and counts were corrected for effort. Barn Swallows (*fig. 6*) were recorded in the spring between mid-March and mid-May. During the fall, they were much more abundant, with a protracted migration from the end of August over a 3-month period, peaking through mid-October (with a maximum of 16,000 individuals recorded in one 10-minute count). The Cliff Swallow migration (*fig. 7*) occurred mostly in the fall and was much briefer, occurring over a month in September and October (with peak counts of nearly 10,000). Eastern Kingbirds (*fig. 8*) were similar, migrating at the same time as the Cliff Swallows, primarily in the fall, with a maximum count of 6,000. Broad-winged Hawks (*fig. 9*) moved through quickly, almost entirely in October (with a peak of 10,000 on one 10-minute count). Only the Chimney Swift (*fig. 10*) was detected in any numbers during the spring migration, peaking in mid-March (with a 5,000 maximum in a 10-minute count). In the fall, fewer swifts were counted, and they peaked in October, later than the swallows and kingbirds.

We examined the annual variation in timing and migration rates for the Cliff and Barn swallows during the fall migration period, from August 1 to November 30. Cliff Swallows exhibited some similarity in timing between years (*fig. 11*), moving through each year in a single pulse. Following their first movements in late August and early September, the number of Cliff Swallows typically increased for a period of 10 to 20 days, reaching peak migration rates most commonly in late September. This species deviated from this pattern only in 2001, when peak passage rates occurred largely in early September. Although the timing of movement was usually similar between years, relative abundance varied to a greater extent. During the peak of migration in 1997, a mean of 49 birds were observed during each 10-minute count. In 2002, however, a mean of 350 Cliff Swallows were recorded on the counts during the peak of migration.

The Barn Swallow had greater variability between years in its passage, in both timing of peak abundance and in its amplitude (*fig. 12*). As was the case when all years were combined, we found that its passage was similarly protracted in each year when each year was considered separately. We also found that the timing of the peak of the passage was quite variable between years, contributing to the protracted nature of the Barn Swallow's passage.

Area Search Censuses

An integral component of our monitoring program is conducting time- and area-constrained area searches at each of our stations. By incorporating this method into our demographic station protocol, we were able to monitor several species that are rarely captured in nets. Nearly 200 species have been recorded on our area search censuses, including 46 North American migratory species described as declining by DeGraaf and Rappole (1995) and six listed by Partners In Flight and the National Audubon Society as WatchList Priority Species (Rich et al. 2004). From these results and other sources, we have compiled an annotated checklist of 285 species that have been seen in the area, with common names in both Spanish and English, and notes on status, habitat, and abundance (Widdowson and Widdowson 2002). Our checklist has been a conservation tool for Tortuguero National Park, local ecotourism, and the public. Using area search data, we have also begun to estimate population trends for the 10 most common species observed. We also have been developing techniques to compare the estimates from census and capture data in order to compare the different methods in their ability to estimate the population size and trends of both resident and migrant species.

Research and Monitoring Outlook

Within the broad research and monitoring mandate of the Program, we are recording many data to answer many important questions about the migrants and residents. Primary among the questions are those involving the descriptive life histories of the many little-studied species of resident birds as well as the

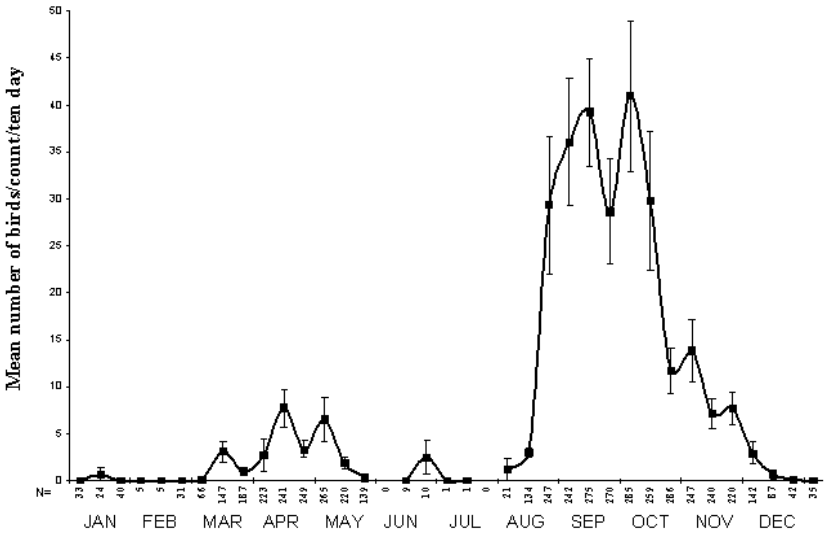

Figure 6— Mean number (±standard error) of Barn Swallows observed per 10-day period during 10-minute migration count surveys at all stations and times combined in Tortuguero, Costa Rica, 1995–2002. N = number of surveys per 10-day period.

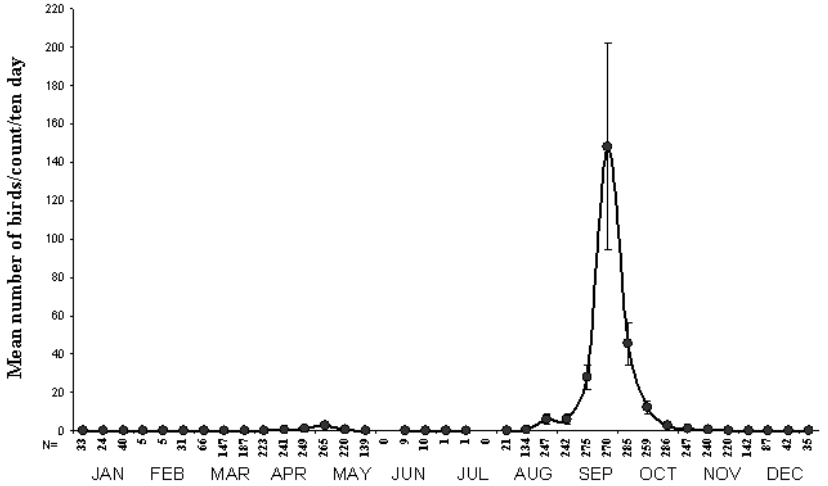

Figure 7— Mean number (±standard error) of Cliff Swallows observed per 10-day period during 10-minute migration count surveys at all stations and times combined in Tortuguero, Costa Rica, 1995–2002. N = number of surveys per 10-day period.

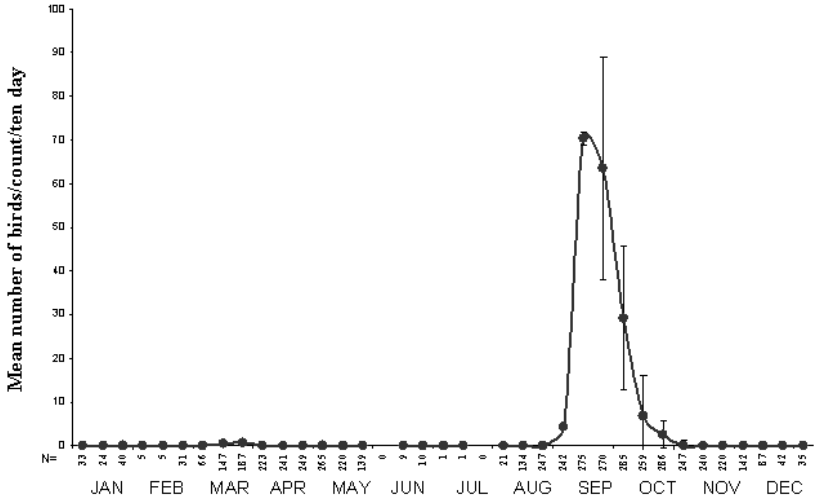

Figure 8— Mean number (±standard error) of Eastern Kingbirds observed per 10-day period during 10-minute migration count surveys at all stations and times combined in Tortuguero, Costa Rica, 1995–2002. N = number of surveys per 10-day period.

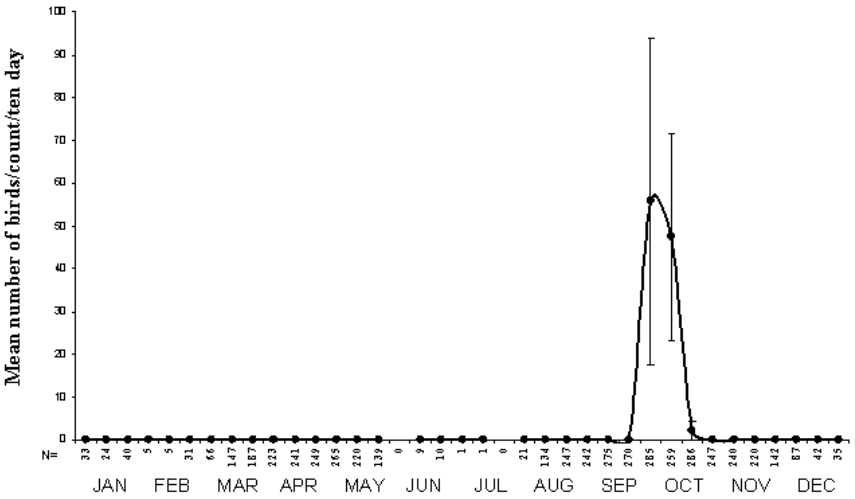

Figure 9— Mean number (±standard error) of Broad-winged Hawks observed per 10-day period during 10-minute migration count surveys at all stations and times combined in Tortuguero, Costa Rica, 1995–2002. N = number of surveys per 10-day period.

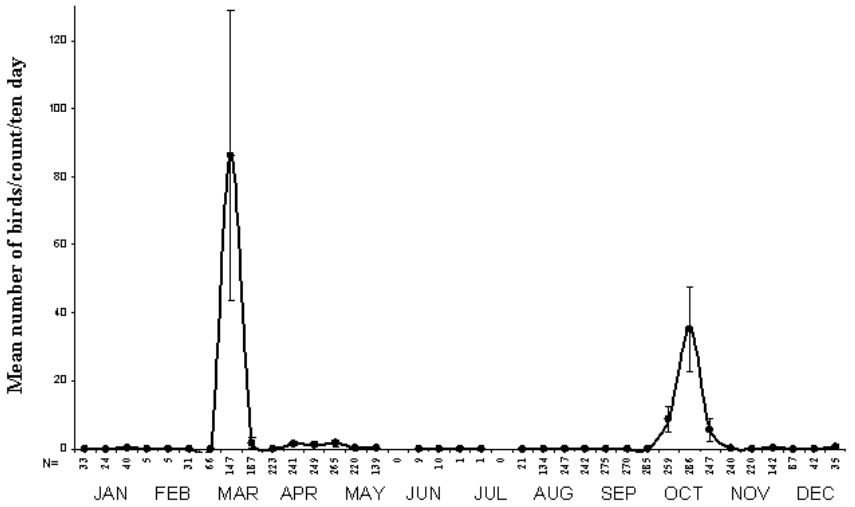

Figure 10— Mean number (±standard error) of Chimney Swifts observed per 10-day period during 10-minute migration count surveys at all stations and times combined in Tortuguero, Costa Rica, 1995–2002. N = number of surveys per 10-day period.

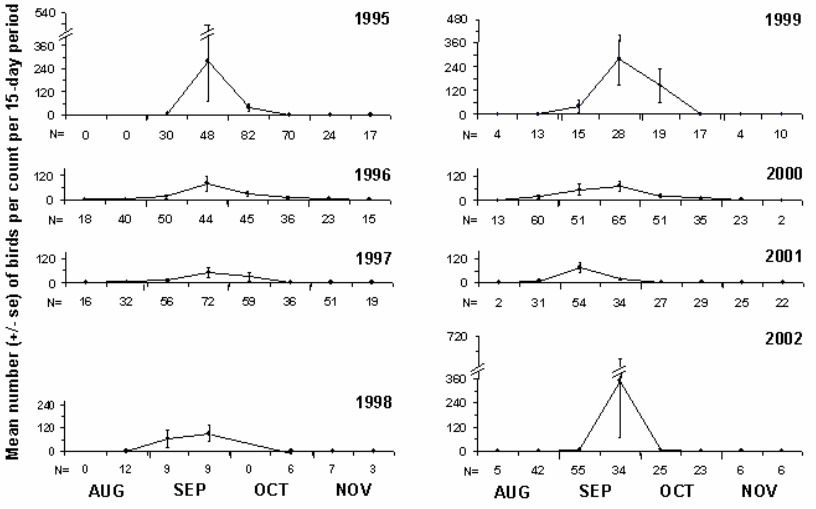

Figure 11— Mean number (±standard error) of Cliff Swallows observed per 15-day period during 10-minute migration count surveys at all stations and times combined in Tortuguero, Costa Rica, 1995–2002. N = number of surveys per 15-day period.

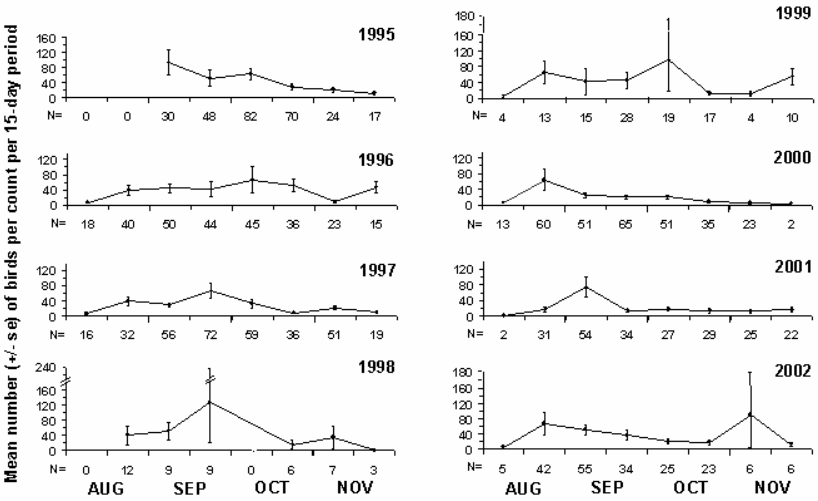

Figure 12— Mean number (±standard error) of Barn Swallows observed per 15-day period during 10-minute migration count surveys at all stations and times combined in Tortuguero, Costa Rica, 1995–2002. N = number of surveys per 15-day period.

overwintering migrants from North America. The long-term nature of the monitoring has laid the foundation for comparing the between-year timing of movements, the productivity, and the survivorship of various resident and migratory species. This baseline database of resident individuals, whose ages are known, and the documentation of plumages and molt of individual birds of various species through photographs are a unique resource in the neotropics.

Training and Information Exchange

The Tortuguero Integrated Bird Monitoring Program's internships and training workshops contribute to the international cooperative effort to implement Partners in Flight – Aves de las Américas monitoring and conservation goals in the neotropics.

Our long-term objective has been to establish a network of monitoring stations in Mesoamerica and the Caribbean to better understand the status and distribution of nearctic-neotropical migrants, as well as neotropical resident birds (Ralph and Milá 1994). We have identified skill sets (for example, monitoring methods, field techniques, ageing and sexing criteria, data management, data analyses, statistical methods, geographical information systems, and technical writing) that will effectively address training needs, provide training and mentorship, and facilitate the establishment of demographic monitoring projects in Mesoamerica and the Caribbean. To achieve this, our objective is to increase the capacity of biologists in Mesoamerica and the Caribbean area to create effective habitat management and long-term monitoring programs by providing training in internationally recognized bird-monitoring techniques. Training in their own region will enable biologists to focus on their own local conservation priorities and increase the likelihood of successful bird conservation through a grassroots approach to the establishment of a Landbird Monitoring Network of the neotropics.

Since 1995, we have presented eight training workshops on landbird monitoring methods at Tortuguero and hosted more than 100 interns from Mesoamerica and the Caribbean. This has led directly to the establishment of more than 20 independent monitoring projects throughout the region. Most recently, in 2003, the program presented a 5-day training workshop on bird-monitoring methods at Tortuguero, in partnership with Point Reyes Bird Observatory Conservation Science, and the University of Costa Rica. The workshop participants were primarily students from the University of Costa Rica, and biologists from Costa Rica, El Salvador, Guatemala, Nicaragua, and Panama. All interns and workshop participants were given intensive instruction on landbird-monitoring methods and provided with English- or Spanish-language handbooks of field methods for monitoring landbirds.

Our information-exchange efforts within the Americas have included the completion of refined ageing and sexing criteria, descriptive studies for many tropical resident species, and the distribution of a landbird monitoring methods handbook in both English and Spanish (Ralph et al. 1993, 1996). We assisted in the production of a guide to molt, age, and sex in selected Costa Rican landbirds (Pyle 2001). A description of the plumages and molt patterns of the Variable Seedeater, based on banding and photographic records collected at Tortuguero, has been completed and is being prepared for publication (Frey 2004, pers. comm.). These descriptive studies will greatly enhance the ability of Mesoamerica and Caribbean biologists to accurately determine age and sex classes of many little-understood resident species of the neotropics.

Acknowledgments

The Program has been successful through our partnership with the Caribbean Conservation Corporation, the Humboldt Bay Bird Observatory, and the Point Reyes Bird Observatory. Critical to our success has been the active collaboration of Costa Rica National University, University of Costa Rica, Costa Rica National Park Service, Canadian Organisation for Tropical Education and Rainforest Conservation, and Costa Rica Expeditions. We thank David Godfrey, Daniel Evans, Roxana Silman, and the staff of the Estación Biología at Tortuguero of the Caribbean Conservation Corporation for their tireless support. William Widdowson provided excellent project coordination, Jim Zook gave us continuous technical help on identification and plumages, and Jim Lewis provided logistical help along the way. Thanks also go to Geoff Geupel, Steve Latta, and the Point Reyes Bird Observatory for financial support and assistance with training during the monitoring workshops. Most of all, many thanks go to all the volunteers, student interns, and biologists who have conducted the field work and training for the program. We thank John Alexander, Geoff Geupel, Sherri Miller, Carol Pearson Ralph, and William Widdowson for helpful comments on the manuscript. We will always be grateful to the late Daniel Hernandez for his inspiration and leadership in the early years of this project.

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Appendix A— *Total number of individuals captured, number of days nets were operated, and total net hours combined annually for all constant-effort mist-netting stations in Tortuguero, Costa Rica.*

Common name	Scientific name	1994	1995	1996	1997	1998	1999	2000	2001	2002	Total
Migrants											
Broad-winged Hawk	*Buteo platypterus*	0	0	0	0	1	1	1	0	0	3
Spotted Sandpiper	*Actitis macularius*	0	1	0	0	0	0	1	0	0	2
Yellow-billed Cuckoo	*Coccyzus americanus*	1	0	1	0	1	3	0	2	1	9
Chuck-will's-widow	*Caprimulgus carolinensis*	0	2	0	0	0	0	0	1	0	3
Chimney Swift[1]	*Chaetura pelagica*	0	0	0	0	0	0	0	0	0	0
Ruby-throated Hummingbird	*Archilochus colubris*	0	0	0	0	0	0	1	0	0	1
Western Wood-Pewee	*Contopus sordidulus*	0	9	1	0	7	7	0	0	0	24
Eastern Wood-Pewee	*Contopus virens*	11	93	43	60	36	40	81	37	70	471
Yellow-bellied Flycatcher	*Empidonax flaviventris*	5	47	10	52	11	22	48	49	32	276
Acadian Flycatcher	*Empidonax virescens*	13	10	24	29	1	14	6	6	2	105
Alder Flycatcher	*Empidonax alnorum*	0	6	0	4	0	48	10	9	19	96
Willow Flycatcher	*Empidonax traillii*	4	2	0	0	0	0	0	3	7	16
Traill's Flycatcher	*Empidonax alnorum/traillii*	39	592	184	172	76	156	163	143	109	1,634
Least Flycatcher	*Empidonax minimus*	0	1	0	0	0	0	0	0	0	1
Great Crested Flycatcher	*Myiarchus crinitus*	2	42	10	6	2	14	9	8	8	101
Sulphur-bellied Flycatcher	*Myiodynastes luteiventris*	0	1	0	0	0	1	0	0	0	2
Eastern Kingbird	*Tyrannus tyrannus*	0	0	0	0	1	0	0	0	0	1
Gray Kingbird	*Tyrannus dominicensis*	0	0	1	0	0	0	0	0	0	1
White-eyed Vireo	*Vireo griseus*	0	0	0	0	0	2	7	12	1	22
Yellow-throated Vireo	*Vireo flavifrons*	0	4	0	0	1	0	0	0	0	5
Philadelphia Vireo	*Vireo philadelphicus*	0	0	0	0	0	1	0	0	0	1
Red-eyed Vireo	*Vireo olivaceus*	3	162	30	49	46	41	44	32	30	437
Yellow-green Vireo	*Vireo flavoviridis*	0	10	0	0	5	0	1	0	1	17
Purple Martin	*Progne subis*	0	0	0	0	0	1	0	0	0	1
Cliff Swallow[1]	*Petrochelidon pyrrhonota*	0	0	0	0	0	0	0	0	0	0
Barn Swallow	*Hirundo rustica*	0	1	0	0	0	0	0	0	0	1
Veery	*Catharus fuscescens*	8	122	70	96	132	45	93	52	82	700
Gray-cheeked Thrush	*Catharus minimus*	10	125	41	68	100	36	77	43	69	569
Swainson's Thrush	*Catharus ustulatus*	24	311	148	181	337	98	187	144	157	1,587
Wood Thrush	*Hylocichla mustelina*	3	5	13	31	8	23	23	14	12	132
Gray Catbird	*Dumetella carolinensis*	13	7	24	38	4	69	31	24	17	227
Golden-winged Warbler	*Vermivora chrysoptera*	0	4	2	1	2	6	0	3	0	18
Tennessee Warbler	*Vermivora peregrina*	1	7	1	4	5	4	3	4	2	31

Appendix 1— continued.

Common name	Scientific name	1994	1995	1996	1997	1998	1999	2000	2001	2002	Total
Northern Parula	*Parula americana*	0	0	0	0	0	0	0	1	0	1
Yellow Warbler	*Dendroica petechia*	1	29	9	11	10	25	9	14	24	132
Chestnut-sided Warbler	*Dendroica pensylvanica*	2	13	5	14	14	15	13	8	12	96
Magnolia Warbler	*Dendroica magnolia*	0	2	2	7	1	4	2	3	5	26
Black-throated Blue Warbler	*Dendroica caerulescens*	0	0	0	1	0	1	2	1	0	5
Blackburnian Warbler	*Dendroica fusca*	0	0	1	1	0	1	0	0	0	3
Bay-breasted Warbler	*Dendroica castanea*	1	59	8	19	3	27	8	1	5	131
Cerulean Warbler	*Dendroica cerulea*	0	4	0	0	1	2	3	0	0	10
Black-and-white Warbler	*Mniotilta varia*	0	6	2	3	3	6	1	2	8	31
American Redstart	*Setophaga ruticilla*	0	2	4	6	5	8	4	5	5	39
Prothonotary Warbler	*Protonotaria citrea*	13	178	128	143	56	127	173	94	135	1,047
Worm-eating Warbler	*Helmitheros vermivorum*	2	2	1	6	1	1	1	2	4	20
Ovenbird	*Seiurus aurocapilla*	3	8	12	29	17	7	23	10	8	117
Northern Waterthrush	*Seiurus noveboracensis*	4	113	85	135	100	130	125	93	148	933
Louisiana Waterthrush	*Seiurus motacilla*	0	4	3	0	3	5	6	12	8	41
Kentucky Warbler	*Oporornis formosus*	2	41	27	45	32	43	30	16	23	259
Mourning Warbler	*Oporornis philadelphia*	1	36	51	29	15	40	35	27	23	257
Common Yellowthroat	*Geothlypis trichas*	1	2	2	4	2	6	11	4	0	32
Hooded Warbler	*Wilsonia citrina*	0	6	0	1	2	3	11	11	5	39
Wilson's Warbler	*Wilsonia pusilla*	0	3	0	1	0	0	0	2	0	6
Canada Warbler	*Wilsonia canadensis*	0	78	25	40	29	58	39	13	19	301
Yellow-breasted Chat	*Icteria virens*	0	1	0	0	1	0	3	0	0	5
Summer Tanager	*Piranga rubra*	4	25	17	14	17	19	32	15	12	155
Scarlet Tanager	*Piranga olivacea*	0	16	1	3	9	2	5	3	1	40
Rose-breasted Grosbeak	*Pheucticus ludovicianus*	0	2	0	0	0	2	4	1	0	9
Indigo Bunting	*Passerina cyanea*	0	3	5	3	1	5	7	4	0	28
Painted Bunting	*Passerina ciris*	0	0	0	0	0	0	0	0	1	1
Dickcissel	*Spiza americana*	0	0	2	0	0	0	1	0	0	3
Orchard Oriole	*Icterus spurius*	0	0	0	0	0	1	0	0	0	1
Baltimore Oriole	*Icterus galbula*	1	2	0	0	0	0	0	0	1	4
	Migrant Total	172	2,199	993	1,306	1,098	1,170	1,334	928	1,066	10,266
Residents											
Green Heron	*Butorides virescens*	0	0	0	0	1	0	0	1	0	2
Black Vulture	*Coragyps atratus*	0	0	0	0	0	0	0	0	1	1
Turkey Vulture	*Cathartes aura*	0	0	0	1	0	0	0	0	0	1

Appendix 1— continued.

Common name	Scientific name	1994	1995	1996	1997	1998	1999	2000	2001	2002	Total
Gray-headed Kite	*Leptodon cayanensis*	0	0	0	1	0	0	0	0	0	1
Double-toothed Kite	*Harpagus bidentatus*	0	0	0	0	0	0	1	0	0	1
Crane Hawk	*Geranospiza caerulescens*	0	0	0	0	0	0	0	0	1	1
Semiplumbeous Hawk	*Leucopternis semiplumbeus*	0	0	0	0	0	1	0	0	2	3
Common Black-Hawk	*Buteogallus anthracinus*	0	0	0	1	0	0	0	0	0	1
Pale-vented Pigeon	*Patagioenas cayennensis*	0	1	0	0	0	0	0	0	1	2
White-tipped Dove	*Leptotila verreauxi*	0	0	0	0	0	1	0	0	0	1
Gray-chested Dove	*Leptotila cassini*	3	5	12	15	8	4	3	7	10	67
Ruddy Quail-Dove	*Geotrygon montana*	0	1	0	0	0	2	0	0	2	5
White-crowned Parrot	*Pionus senilis*	0	1	0	0	0	0	0	0	0	1
Mangrove Cuckoo	*Coccyzus minor*	0	0	0	0	1	0	1	1	0	3
Squirrel Cuckoo	*Piaya cayana*	0	2	1	0	0	0	0	1	0	4
Groove-billed Ani	*Crotophaga sulcirostris*	0	1	1	0	0	0	2	2	0	6
Common Pauraque	*Nyctidromus albicollis*	0	0	0	0	0	1	0	1	0	2
Bronzy Hermit	*Glaucis aeneus*	82	355	324	337	174	356	340	310	312	2,590
Band-tailed Barbthroat	*Threnetes ruckeri*	0	8	11	14	12	6	7	15	19	92
Long-billed Hermit	*Phaethornis longirostris*	18	194	150	229	154	152	190	182	242	1,511
Stripe-throated Hermit	*Phaethornis striigularis*	0	15	18	28	9	12	13	11	14	120
Violet Sabrewing	*Campylopterus hemileucurus*	0	2	0	0	0	0	0	0	0	2
White-necked Jacobin	*Florisuga mellivora*	0	0	5	7	11	12	11	24	42	112
Green-breasted Mango	*Anthracothorax prevostii*	0	4	22	25	13	32	22	75	143	336
Violet-crowned Woodnymph	*Thalurania colombica*	1	18	18	27	18	33	27	31	55	228
Blue-throated Goldentail	*Hylocharis eliciae*	0	0	19	16	12	14	5	12	24	102
Blue-chested Hummingbird	*Amazilia amabilis*	0	6	10	13	5	7	1	5	7	54
Rufous-tailed Hummingbird	*Amazilia tzacatl*	17	203	233	242	160	256	236	301	373	2,021
Cinnamon Hummingbird	*Amazilia rutila*	0	0	0	0	0	0	0	0	1	1
Bronze-tailed Plumeleteer	*Chalybura urochrysia*	0	0	0	0	0	0	0	0	1	1
Purple-crowned Fairy	*Heliothryx barroti*	0	0	0	0	1	0	0	0	1	2
Long-billed Starthroat	*Heliomaster longirostris*	0	0	0	0	4	0	0	1	1	6
Black-throated Trogon	*Trogon rufus*	1	1	1	1	1	2	0	0	3	10
Slaty-tailed Trogon	*Trogon massena*	0	0	2	2	0	0	4	1	7	16
Green Kingfisher	*Chloroceryle americana*	0	0	0	0	0	5	6	1	0	12

Appendix 1— continued.

Common name	Scientific name	1994	1995	1996	1997	1998	1999	2000	2001	2002	Total
Green-and-rufous Kingfisher	*Chloroceryle inda*	0	2	1	0	0	0	0	0	1	4
American Pygmy Kingfisher	*Chloroceryle aenea*	0	4	12	11	14	24	17	8	19	109
White-whiskered Puffbird	*Malacoptila panamensis*	0	2	1	1	2	1	4	2	2	15
Collared Aracari	*Pteroglossus torquatus*	0	0	2	2	0	1	2	0	3	10
Black-cheeked Woodpecker	*Melanerpes pucherani*	0	0	1	0	0	0	0	0	0	1
Chestnut-colored Woodpecker	*Celeus castaneus*	0	0	1	0	0	0	0	0	0	1
Lineated Woodpecker	*Dryocopus lineatus*	0	0	1	0	0	0	0	0	2	3
Pale-billed Woodpecker	*Campephilus guatemalensis*	0	0	0	0	0	0	0	0	1	1
Plain Xenops	*Xenops minutus*	0	0	0	0	0	0	0	0	3	3
Scaly-throated Leaftosser	*Sclerurus guatemalensis*	0	0	0	1	0	0	0	0	0	1
Plain-brown Woodcreeper	*Dendrocincla fuliginosa*	0	1	5	4	5	2	3	2	2	24
Olivaceous Woodcreeper	*Sittasomus griseicapillus*	0	0	2	0	1	2	2	0	1	8
Wedge-billed Woodcreeper	*Glyphorynchus spirurus*	0	2	2	3	5	2	7	3	3	27
Northern Barred-Woodcreeper	*Dendrocolaptes sanctithomae*	1	16	11	22	8	22	12	8	13	113
Cocoa Woodcreeper	*Xiphorhynchus susurrans*	0	0	0	0	0	0	0	1	0	1
Spotted Woodcreeper	*Xiphorhynchus erythropygius*	0	0	1	0	0	0	1	1	0	3
Streak-headed Woodcreeper	*Lepidocolaptes souleyetii*	0	8	5	13	6	21	20	20	24	117
Barred Antshrike	*Thamnophilus doliatus*	7	10	12	9	9	5	1	7	18	78
Western Slaty-Antshrike	*Thamnophilus atrinucha*	0	7	13	12	12	22	10	17	32	125
Checker-throated Antwren	*Myrmotherula fulviventris*	0	1	5	0	1	1	0	1	1	10
White-flanked Antwren	*Myrmotherula axillaris*	0	0	1	2	0	0	6	0	5	14
Dusky Antbird	*Cercomacra tyrannina*	0	2	1	0	0	1	1	0	3	8
Chestnut-backed Antbird	*Myrmeciza exsul*	0	12	8	13	9	4	18	8	17	89
Spotted Antbird	*Hylophylax naevioides*	0	0	0	1	0	1	4	0	0	6
Bicolored Antbird	*Gymnopithys leucaspis*	0	6	6	7	7	7	27	13	11	84
Black-faced Antthrush	*Formicarius analis*	0	0	0	1	0	0	0	2	0	3
Yellow-bellied Elaenia	*Elaenia flavogaster*	1	0	3	4	4	1	12	4	5	34
Ochre-bellied Flycatcher	*Mionectes oleagineus*	0	9	17	11	6	9	17	15	18	102

Appendix 1— continued.

Common name	Scientific name	1994	1995	1996	1997	1998	1999	2000	2001	2002	Total
Black-capped Pygmy-Tyrant	*Myiornis atricapillus*	0	0	0	0	0	1	0	1	1	3
Common Tody-Flycatcher	*Todirostrum cinereum*	2	14	21	12	12	21	13	14	27	136
Black-headed Tody-Flycatcher	*Todirostrum nigriceps*	0	0	0	0	0	0	0	0	1	1
Eye-ringed Flatbill	*Rhynchocyclus brevirostris*	0	0	0	0	1	0	1	3	2	7
Yellow-olive Flycatcher	*Tolmomyias sulphurescens*	0	0	0	0	0	0	1	0	1	2
Yellow-margined Flycatcher	*Tolmomyias assimilis*	0	0	0	1	0	0	2	1	0	4
Golden-crowned Spadebill	*Platyrinchus coronatus*	0	0	0	0	2	0	0	0	1	3
Royal Flycatcher	*Onychorhynchus coronatus*	0	0	0	0	1	0	0	0	0	1
Ruddy-tailed Flycatcher	*Terenotriccus erythrurus*	0	0	1	0	0	0	1	0	0	2
Tropical Pewee	*Contopus cinereus*	0	0	22	11	0	30	18	1	0	82
Bright-rumped Attila	*Attila spadiceus*	0	1	4	8	5	4	7	2	15	46
Rufous Mourner	*Rhytipterna holerythra*	0	0	3	0	0	0	0	1	0	4
Dusky-capped Flycatcher	*Myiarchus tuberculifer*	0	1	0	1	0	2	1	0	1	6
Great Kiskadee	*Pitangus sulphuratus*	0	11	11	9	6	5	10	12	15	79
Boat-billed Flycatcher	*Megarynchus pitangua*	1	5	7	2	1	5	2	5	3	31
Social Flycatcher	*Myiozetetes similis*	0	7	2	3	2	7	8	13	7	49
Tropical Kingbird	*Tyrannus melancholicus*	0	9	2	0	0	2	3	2	2	20
Cinnamon Becard	*Pachyramphus cinnamomeus*	0	0	0	0	0	0	1	0	0	1
White-winged Becard	*Pachyramphus polychopterus*	0	0	0	0	0	0	1	0	0	1
Masked Tityra	*Tityra semifasciata*	0	0	0	0	1	0	0	0	0	1
White-collared Manakin	*Manacus candei*	21	297	426	634	468	602	630	439	542	4,059
White-ruffed Manakin	*Corapipo altera*	0	3	1	0	0	0	2	1	0	7
Red-capped Manakin	*Pipra mentalis*	1	15	22	56	32	18	28	25	46	243
Lesser Greenlet	*Hylophilus decurtatus*	1	12	30	33	30	44	38	44	45	277
Mangrove Swallow	*Tachycineta albilinea*	0	0	0	0	0	0	0	0	1	1
Black-throated Wren	*Thryothorus atrogularis*	0	0	2	5	3	2	2	2	0	16
Bay Wren	*Thryothorus nigricapillus*	1	24	15	23	23	28	31	19	11	175
Stripe-breasted Wren	*Thryothorus thoracicus*	0	0	6	5	0	4	4	8	12	39
Plain Wren	*Thryothorus modestus*	1	8	12	4	0	2	7	1	0	35
House Wren	*Troglodytes aedon*	4	3	7	5	3	6	7	13	15	63
White-breasted Wood-Wren	*Henicorhina leucosticta*	0	8	17	1	3	17	13	18	17	94

Appendix 1— continued.

Common name	Scientific name	1994	1995	1996	1997	1998	1999	2000	2001	2002	Total
Song Wren	*Cyphorhinus phaeocephalus*	0	8	5	1	0	0	2	8	1	25
Tawny-faced Gnatwren	*Microbates cinereiventris*	0	2	0	0	0	2	0	0	0	4
Long-billed Gnatwren	*Ramphocaenus melanurus*	0	2	2	1	3	4	1	3	3	19
Clay-colored Robin	*Turdus grayi*	5	16	9	13	22	20	47	33	41	206
Olive-crowned Yellowthroat	*Geothlypis semiflava*	0	1	3	0	2	0	1	0	2	9
Buff-rumped Warbler	*Phaeothlypis fulvicauda*	0	0	0	0	0	1	0	0	0	1
Dusky-faced Tanager	*Mitrospingus cassinii*	0	0	1	1	0	0	0	0	2	4
Tawny-crested Tanager	*Tachyphonus delatrii*	0	0	3	0	0	3	0	13	0	19
Red-throated Ant-Tanager	*Habia fuscicauda*	2	8	14	6	1	3	3	8	15	60
Passerini's Tanager	*Ramphocelus passerinii*	1	9	2	13	6	4	10	6	6	57
Blue-gray Tanager	*Thraupis episcopus*	1	41	20	18	11	33	17	29	9	179
Palm Tanager	*Thraupis palmarum*	0	5	1	3	4	1	2	2	2	20
Golden-hooded Tanager	*Tangara larvata*	0	0	0	0	1	0	0	0	0	1
Blue-black Grassquit	*Volatinia jacarina*	0	2	2	0	0	0	1	0	2	7
Variable Seedeater	*Sporophila americana*	47	216	225	294	165	220	248	300	346	2,061
White-collared Seedeater	*Sporophila torqueola*	0	0	0	0	0	2	0	0	1	3
Thick-billed Seed-Finch	*Oryzoborus funereus*	1	10	16	20	9	12	15	24	18	125
Orange-billed Sparrow	*Arremon aurantiirostris*	0	0	9	8	3	8	2	2	2	34
Black-striped Sparrow	*Arremonops conirostris*	11	9	14	14	11	22	12	19	9	121
Grayish Saltator	*Saltator coerulescens*	0	0	0	0	1	1	0	0	0	2
Buff-throated Saltator	*Saltator maximus*	1	8	10	9	2	0	3	1	2	36
Blue-black Grosbeak	*Cyanocompsa cyanoides*	0	0	1	0	0	0	0	0	0	1
Great-tailed Grackle	*Quiscalus mexicanus*	0	0	0	0	0	0	0	1	2	3
Black-cowled Oriole	*Icterus prosthemelas*	0	1	0	0	2	4	0	1	2	10
Yellow-billed Cacique	*Amblycercus holosericeus*	0	0	0	1	0	1	0	0	1	3
Montezuma Oropendola	*Psarocolius montezuma*	0	0	0	0	0	0	0	0	1	1
Olive-backed Euphonia	*Euphonia gouldi*	0	0	2	3	3	4	6	3	11	32
	Resident Total	232	1,655	1,888	2,294	1,512	2,167	2,234	2,172	2,689	16,843
	Grand Total	404	3,854	2,881	3,600	2,610	3,337	3,568	3,100	3,755	27,109
	Number of days per year	21	91	172	194	170	160	171	167	216	1,362
	Net hours per year	1,559	6,329	10,919	14,327	11,505	10,744	11,612	11,637	14,238	92,870

[1]Species not captured, observed only during censuses.

Singing Rate and Detection Probability: An Example from the Least Bell's Vireo (*Vireo belli pusillus*)[1]

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Abstract

We used 4-hr tape recordings to assess singing activity of a Least Bell's Vireo (*Vireo belli pusillus)* on 7 d distributed throughout the breeding season of 2001. We logged 9873 songs, for a mean singing rate of 5.84 min^{-1}, but despite this level of activity, the bird was silent during 33 percent of the 1691 minutes of the study. Availability, the proportion of minutes in which singing activity occurred (and hence the probability of at least one song occurring in any randomly selected minute) varied from 0.36 to 0.96. As availability is a major component of detection probability, we tested several ways of estimating availability from data that can be obtained during a brief point count. Singing rate (songs/min), estimated in 10 or more 1-min samples randomly distributed through the morning provided a good (r^2 = 0.8) estimate of availability for the entire morning. Measures based on a comparison of singing activity (presence/absence) in contiguous 1-min samples yielded poor estimates of availability, regardless of sample size, presumably because of the highly clumped bout structure (i.e., serial auto-correlation of singing and silence).

Key words: detection probability, singing rate, bird survey, bioacoustics, *Vireo belli*, Least Bell's Vireo, endangered species.

Introduction

Accurate and precise estimates of numbers of migratory birds are vitally needed both to assess population status and to evaluate management decisions. This is especially true for threatened and endangered taxa. Various methods exist for counting birds, but most yield only indices, not true population estimates (Thompson 2002). The need to improve these index methods with estimates of detection probability is now widely appreciated, and several techniques have been suggested for obtaining such estimates (e.g., Nichols et al. 2000, Bart and Earnst 2002, Rosenstock et al. 2002, Farnsworth et al. 2002, Farnsworth et al. this volume).

Three of the four "new" methods rely on brief surveys, typically aural point counts, to obtain counts of individuals. Count data are subdivided in various ways (e.g., distance) that permit estimation of detection probabilities. A question of interest for aural surveys is the effect of singing rate on detection probability. While a high singing rate would seem to make detection likely, songs often come in bouts of intense singing, followed by periods of silence. The effect of this "bout structure" on detection has not been addressed, theoretically or empirically. Here we document the bout structure, throughout the breeding season, of a Least Bell's Vireo (*Vireo belli pusillus*), an endangered subspecies. We use these data to elucidate the relationships among singing rate, bout structure, and detectability.

One of the objectives of the larger study of which this is a small part was to estimate the optimal date and time of day for conducting point counts in the riparian areas of southern California. Here we illustrate the procedure with data on diel and seasonal variation in singing rate.

A Heuristic Model of Detection Probability

McCallum (this volume) elaborates the conceptual framework we use here. Briefly, the true number of resident individuals in a population, N, is estimated with a sample count, C, that must be adjusted by a correction factor or detection probability, p, for individuals present but not detected (Thompson 2002), such that $p = C/N$ (Nichols et al. 2000). Detection probability is subdivided into two independent components (Farnsworth et al. 2002): (1) *availability*, the probability that an average bird performs a detectable

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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act or *cue*, and (2) *detectability*, the probability that it is detected if it gives a cue. Heuristically,

$$p = p_s\,(1-(1-p_{1d})^s) \quad (1)$$

where p_s is cue availability and the expression to its right is detectability. Detectability is a function of cue conspicuousness, p_{1d}, and cue abundance, s, i.e., the number of songs produced during a count period. Note that detectability = 1 if conspicuousness = 1, regardless of cue abundance ($s > 0$). Detectability approaches 1 as cue abundance increases, regardless of conspicuousness. See McCallum (this volume) for elaboration of these points.

This model does not provide a means of estimating parameters. It is a conceptual model that was devised in an attempt to account for all the relevant biological contributions to detection probability. McCallum (this volume) used this model to evaluate the conceptual adequacy of the four recently-published methods for estimating p in studies of bird populations. In this study we investigated the relationship between a component of detectability (s, cue abundance) and availability with direct counts (i.e., not estimates based on sampling procedures) obtained during the diel period in which point counts are typically taken, throughout the breeding season.

Methods

Study Areas

We studied singing rates of upland birds at four riparian sites in southern California in the breeding season of 2001. The four sites were Big Morongo, Riverside County; Lake Skinner, Riverside County; Hidden Valley, Riverside County; and Whiting Ranch, Orange County. Each site was surveyed once per week (with a few interruptions caused by inclement weather), from late March through late June. The data reported here were collected exclusively at Hidden Valley (HV).

Data Collection

During exploration in February, 2001, a central recording location was chosen at each site. A Sennheiser ME-62 omni-directional microphone with K-6 power supply and a Sony TCD-D8 digital audio tape recorder were used to make a continuous 4-hr recording at the recording site on each survey date. The microphone was positioned approximately 3 m above ground level to enhance detection of distant birds. The "long-play" setting on the Sony TCD-D8 was used, sampling at a rate of 22050 points sec^{-1}. The automatic input level was set to "manual," i.e., off, to produce an accurate record of relative amplitude of ambient sounds.

After starting the long-play recording, the observer departed to allow equilibration of the local bird community and conducted point counts elsewhere on the study site. Approximately 0.5 hr later, and subsequently at 1-hr intervals, the observer returned to the recording site and conducted a standard 5-min point count from that location. In keeping with standard protocol, the observer approached as unobtrusively as possible. The approach of the observer had no detectable effect on the production of Bell's Vireo song. Additionally, the observer recorded point counts away from the long-play site with a Sony Walkman Professional (WM-D6C) cassette-recorder.

Data Processing

Digital data were downloaded directly to a Windows computer, with Sony optical cables, Sony Digital I/O adaptor (RMR-D100), and Creative Recorder 1.01 software. Each day's recording was saved as a single file (approximately 0.65 gB) in 16-bit Windows (.wav) format. These were archived on compact disc, and the digital audio tape was erased for re-use. Digitized acoustic data were analyzed with Signal (Engineering Design, Belmont, MA) versions 3.1 and 4.0 software. Each tape was viewed spectrographically in its entirety, in 10 sec segments. When necessary, the sound was listened to, and/or a larger-scale spectrogram was viewed. The beginning and ending times of each LBVI song (*fig. 1*) detected in this way (*fig. 2*) were written to an ASCII text file for further analysis.

Data Analysis

The beginning and ending times of the vireo songs were converted to clock times in SAS, version 6.02. SAS commands were used to count the number of songs ending in each minute of the tapes. These counts were converted to 0/1 binary data for presence or absence of at least one song in the 1-min period.

The output of these basic data-handling procedures were (1) seven "s-functions," which gave the number of songs produced per minute, as a function of time of day, and (2) seven sets of "availability functions," which gave presence/absence of song as a function of time of day. To test for randomness of these time series, we performed runs tests (Sokal and Rohlf 1995:797).

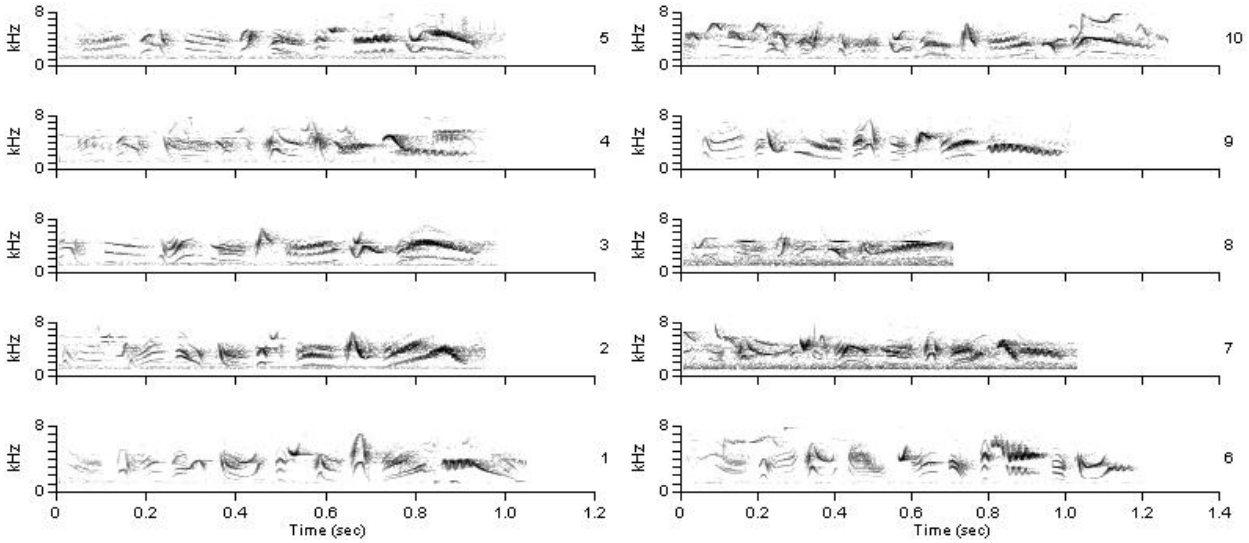

Figure 1– Sound spectrograms of the ten song-types recorded in the Hidden Valley study area, with type numbers to the right of each spectrogram. Individual songs were easily scored because of extremely high stereotypy among and within recording sessions. Despite different durations and note-type composition, all types ended in a note-type exhibiting periodic frequency modulation (FM), as indicated by the zigzag traces on the spectrograms. This is typically the most conspicuous part of the song, and we listened and looked for these sounds in logging tapes.

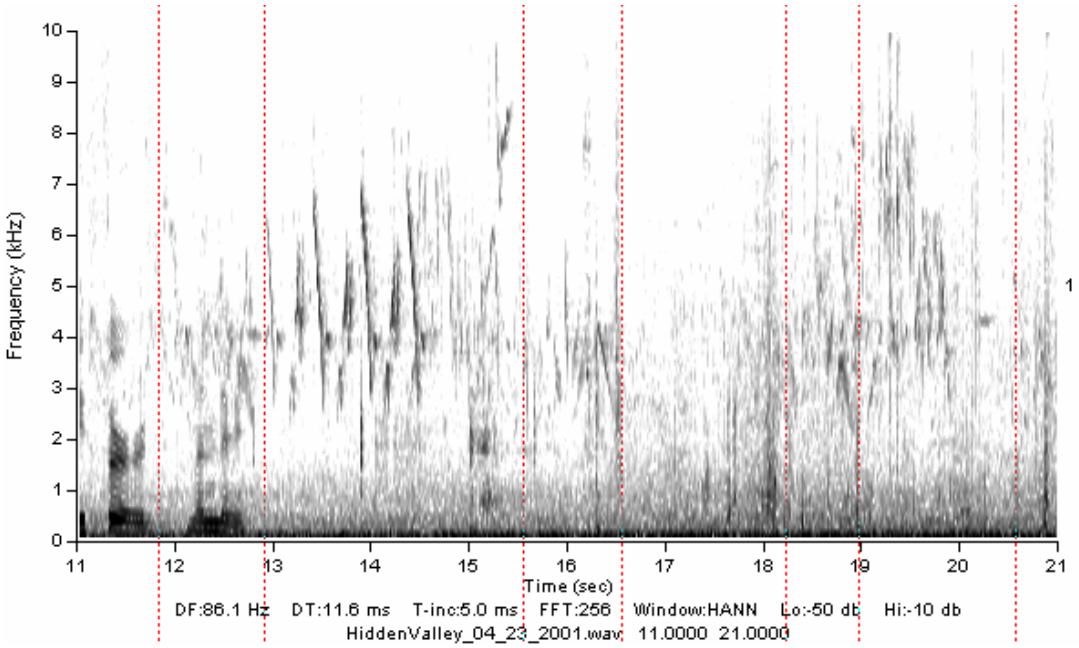

Figure 2– Spectrogram of a typical 10-s segment of recorded sounds analyzed in this study. Beginning and end of the three Least Bell's Vireo songs are marked with vertical broken lines; beginning of a fourth is near the end of the segment. Both acoustic and visual inspection was used to log all 9873 songs in this way. All analyses were performed on the beginning and ending times so derived.

We assessed the relationship between availability and parameters that can be estimated during point counts of a few minutes' duration. First, we compared the correlation of the daily value of availability with two measures of overall singing rate, (1) songs per active minute, calculated as total songs divided by the number of minutes containing at least one song, and (2) songs per minute, calculated as total songs divided by total minutes. We then produced random samples of 1, 2, 5, 10, 25, and 50 1-min segments from each day's data. We did this by reordering the minutes randomly and then selecting the first 1, 2, ... 50 data entries for each date. (An advantage of this nested approach to randomization is that the differences among sample sizes are wholly attributable to sample size, without a stochastic effect due to separate random draws.) We counted the number of songs in each of these randomly drawn time segments for brief estimates of singing rate. We also calculated two direct estimates of availability by comparing the presence/absence of song in the randomly drawn minute with the presence/absence of song in the minute following it chronologically (i.e., not randomized): Continuation probability was the proportion of minutes with songs followed by a minute with songs. Recapture probability was the proportion of subsequent (second) minutes with song preceded by a minute with song. To assess seasonal trends in availability and singing rate, we plotted these parameters against Julian date, and conducted regression analysis where appropriate.

Throughout the range of the species, songs have terminal notes that are frequency-modulated (zigzag frequency contours in *figure 1*) and either falling or rising. Songs ending with falling notes are said to be up to 15 times more frequent early in the season, but from incubation onward the two types are delivered in couplets, with the first song ending on a rising note and the second on a falling note (Barlow 1962, cited in Brown 1993). To test for such a pattern in our data, we examined four sequences of 100 songs from each tape (beginning at 600, 4200, 7800, and 10400 seconds from the beginning of the tape), and scored the terminal note "up" or "down." Because we encountered a high degree of stereotypy during this analysis, we classified each song into one of ten song-types (*fig. 1*).

Results

Descriptive Statistics

The Least Bell's Vireo was found at only one site, Hidden Valley (HV), where we obtained samples on 8 d (*table 1*). Recordings ranged in duration from 191 to 254 minutes (*table 1*). We did not detect a Bell's Vireo by any means on 30 March. Thereafter, song production exceeded 3 songs/min for each recording. The maximum number of songs in a minute, 23, accords with the results of Barlow (1962, cited in Brown 1993). This result, and the fact that none of the 9873 songs we logged overlapped another, suggest that only one male was in our study area at any one time.

Bout Structure

The distribution of *s*, the number of songs counted each minute, was extremely skewed to the right. The overall mode was 0, with silent minutes ranging from 4 percent to 74 percent of the daily samples. The converse of these percentages is the realized availability (p_s) of these samples (*table 1*). If the 558 min with no songs are omitted, the remaining data display an apparent truncated normal (i.e., lognormal) distribution, with a mode at 7-9 songs (*fig. 3*). Songs per active minute (i.e., total songs divided by the number of taped minutes in which at least one song occurred) varied from 6.6 to 12.5 (*table 1*).

Songs were clumped in time, as were periods of silence (*fig. 4, fig. 5*). The average duration of a bout of singing (defined as an interval in which at least one song occurs in every minute) was 11.71 (SD = 6.55), while a bout of silence averaged 5.96 min (SD = 5.45). (*table 2*). All seven runs tests were significantly nonrandom, with negative t-values (*table 2*), which indicates significant clumping of active and/or inactive minutes. In other words, once singing or silence had begun, the bias was to continue rather than to change to the other state.

Detection Probability

Despite the lack of serial independence in singing behavior (see above), availability increased as a roughly linear function of songs per total minute (*fig. 6*). The short-term estimator of singing rate was also a good (although not perfect) predictor of availability (*fig. 7*). A sample size of approximately 10 1-min samples was optimal, with greater effort yielding little increase in the coefficient of determination (r^2), while smaller sample sizes performed poorly. The direct estimates of availability performed very poorly, regardless of sample size.

Table 1– *Recording and singing data for eight survey dates distributed approximately evenly through the Least Bell's Vireo breeding season of 2001 at Hidden Valley, Riverside County, California. Continuous recordings, beginning within 20 min of dawn, were made with a Sony TCD-D8 digital tape recorder and a Sennheiser ME62 omni-directional microphone with K6 power supply. Mean and standard deviations summarize the seven recordings in which target songs were found. Availability is the proportion of 1-min time segments in which at least one song was detected. Songs per active minute is the singing rate when the bird is singing, i.e., total songs/(total minutes*availability). Detectability is the likelihood of detecting the bird in 1 min, given an arbitrary but low conspicuousness value of 0.1, when it sings $\bar{s}$ songs per min.*

Date	Minutes recorded	Total songs	Availability ($p_{s(1min)}$)	Songs/active min ($\bar{s}$)	Detectability ($p_{ds\|p1=.1}$)	Detection probability (p)
3/30/01	246	0	0.000	0.00	0.000	0.000
4/16/01	253	1124	0.356	12.49	0.732	0.260
4/23/01	242	1249	0.690	7.48	0.545	0.376
4/30/01	243	1990	0.885	9.26	0.623	0.551
5/8/01	254	1746	0.787	8.73	0.601	0.474
5/14/01	254	643	0.366	6.91	0.517	0.189
5/21/01	191	813	0.649	6.56	0.499	0.324
6/4/01	254	2308	0.961	9.46	0.631	0.606
Mean	241.6	1410.4	0.671	8.70	0.593	0.397
Std. Dev.	22.9	620.2	0.237	2.02	0.080	0.153

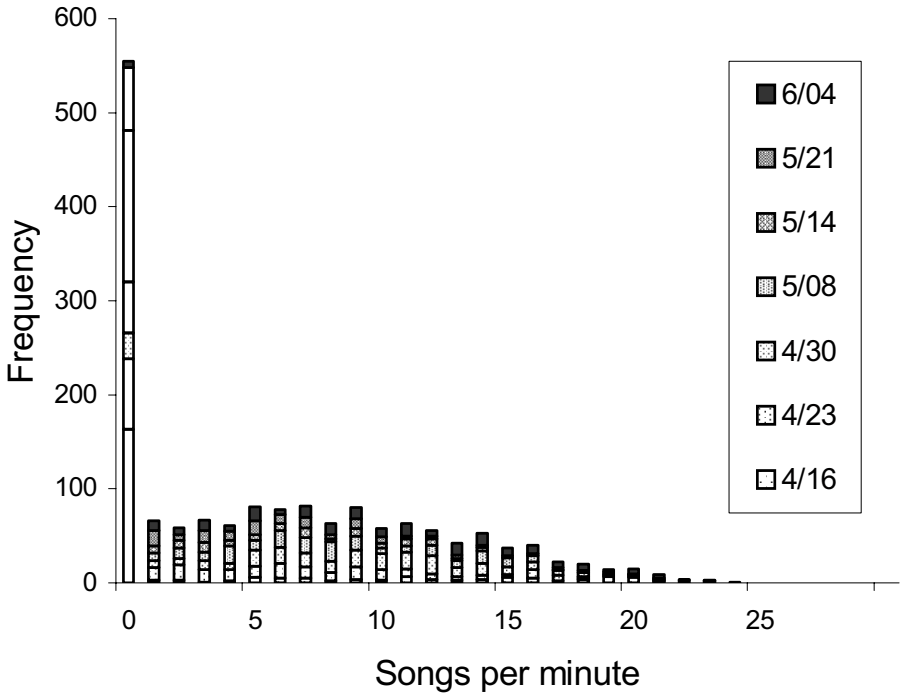

Figure 3– Frequency distributions of *s*, the number of songs produced in each clock minute during the morning survey period, on 7 days distributed throughout the breeding season. These results are based on actual counts of songs in each of the 1945 min in the study. Note the approximately lognormal distribution of nonzero values.

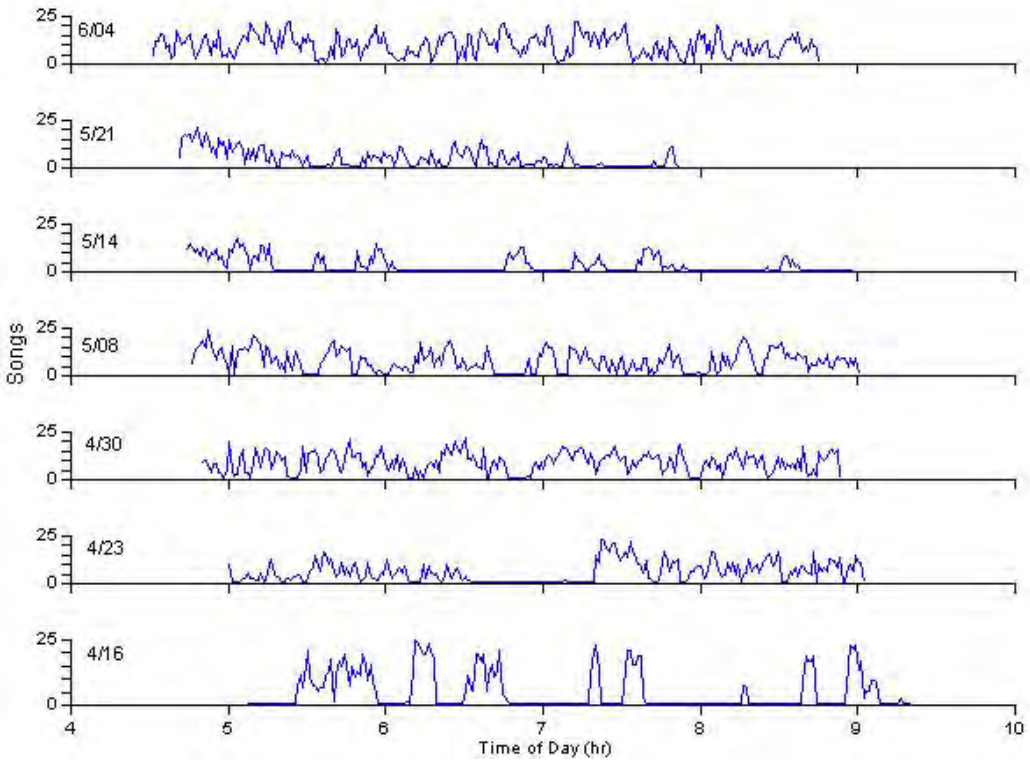

Figure 4– Song production, *s*, of a Least Bell's Vireo during the first 4 hr of 7 days in the breeding season of 2001.

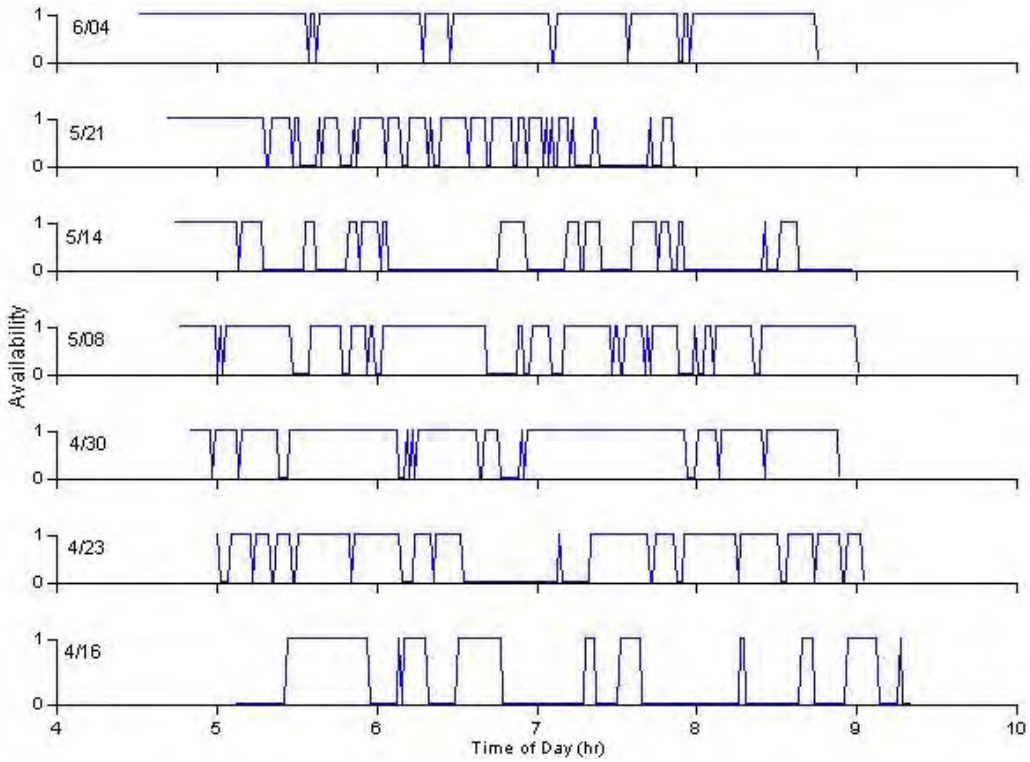

Figure 5– Availability of a Least Bell's Vireo for detection, calculated by converting all nonzero values in *figure 4* to ones. Availability is 1 for each 1-min period in which at least one song is delivered, 0 otherwise.

Table 2–*Bout-structure statistics for a Least Bell's Vireo at Hidden Valley, Riverside County, California. A run is a time segment in which a binary classification (in this case, singing vs. non-singing) does not change. The negative t-values indicate under-representation of runs in all samples; the very low* p*-values indicate that this under-representation is highly significant. In other words, once the bird began to sing, he continued singing much longer than expected by chance, and likewise for silence.*

		Mean bout duration (min)					
Date	Minutes	Song	Silence	Runs	*t*-value	*p*-value	Runs/hr
4/16/01	253	9.00	16.00	21	-13.1938	0.001	4.98
4/23/01	242	10.73	5.00	31	-11.0786	0.001	7.69
4/30/01	243	15.67	2.33	25	-8.1033	0.001	6.17
5/08/01	254	9.65	3.18	35	-9.6032	0.001	8.27
5/14/01	254	6.64	10.85	28	-12.3157	0.001	6.61
5/21/01	191	5.64	3.14	44	-7.0112	0.001	13.82
6/04/01	254	24.63	1.25	17	-2.7317	0.01	4.02
Mean	241.6	11.71	5.96	28.7			7.366
Std. Dev.	22.9	6.55	5.43	9.0			3.202

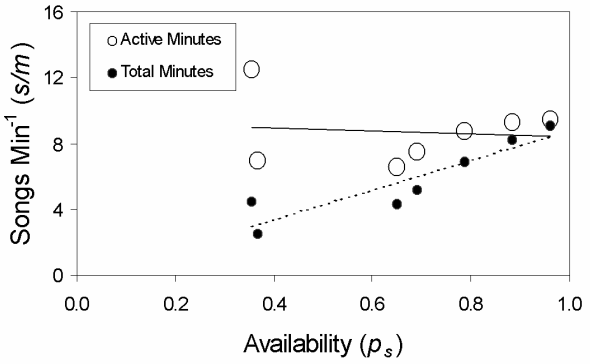

Figure 6–The relationship between mean cue abundance and availability for the seven dates on which some singing occurred. Mean cue abundance ($\bar{s}$) was calculated as total songs in the sample divided by (1) total minutes in the sample (closed circles) and (2) the number of minutes in the sample containing at least one song (open circles), i.e., active minutes, see equation 3 of McCallum (this volume). In this data set, availability is highly correlated with songs per total minute, but not with songs per active minute. Ordinarily availability would be estimated from cue abundance; cue abundance is plotted on the vertical axis here to facilitate comparison.

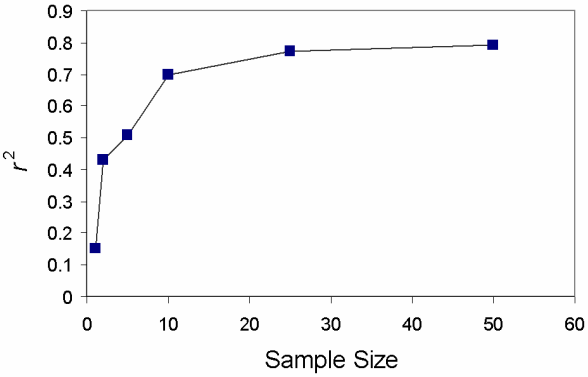

Figure 7–Improvement in predictability of availability from 1-min samples of singing rate with increasing sample size. One, 2, 5, 10, 25, and 50 1-min samples were randomly drawn from each day's data, and the per-minute singing rate was averaged across the daily samples. Availability was regressed on average singing rate for each sample size. The measure of predictability is the coefficient of determination (r^2) for each regression. The random samples were nested, that is, any sample that was in a smaller sample size was also in a larger sample size. Two other potential estimators of availability were not correlated with availability (see text).

To assess the overall detection probability of this bird, we substituted daily estimates of conspicuousness (p_{1d}), cue abundance ($\bar{s}$), and availability (p_s) in equation 1. As mentioned above, this is a heuristic formula; a method for estimating conspicuousness has not been devised. We set conspicuousness at 0.1, which we judge to be a low value (see McCallum this volume for the components of conspicuousness). Calculated in this way, conspicuousness ($p_{ds|p1}$ = 0.1) was surprisingly consistent at ($\bar{p}_{ds}$ = 0.593 ± 0.080 SD. Mean detection probability (p) was 0.397 (SD = 0.153) (see *table 1*).

Diel Variation and Phenology

Somewhat surprisingly, song production showed no obvious hourly trend during the morning hours when most surveys are conducted (*fig. 4*). Binary plots of inactivity/activity (i.e., "availability functions," *fig. 5*) similarly reveal that periods of inactivity (nonavailability) were distributed throughout the recordings.

Although availability did not exhibit an hourly trend, a seasonal trend was apparent (*fig. 8*). Availability climbed to 0.88 by the end of April, dropped precip-

itously to 0.27 by the middle of May, then climbed again to nearly 1.0 by early June (*fig. 8*).

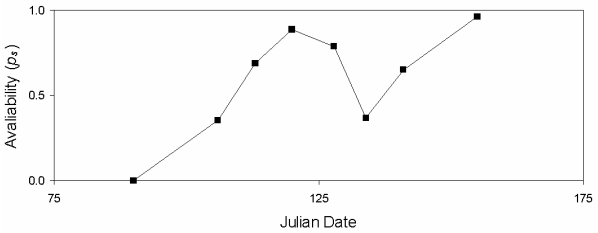

Figure 8–The phenology of availability. Availability increased seasonally, then dipped, then recovered, perhaps as a function of time invested in nesting activities.

Contrary to expectation, we did not find that the terminal notes of songs sorted readily into "rising" and "falling" categories. These terminal notes were, however, highly stereotyped, and were easily sorted visually into 10 types (*fig. 1*). Moreover, this stereotypy extended to the entire song. The bird's repertoire was limited to 10 distinctive song-types (*fig. 1*), which were rendered with great fidelity.

A preliminary analysis of the probability of transition from one song-type to another revealed that all song-types except type 6 repeated roughly 10 percent of the time. Type 6 did not repeat. Three pairs of song-types (1-2, 3-4, 7-8) tended to alternate (reciprocal transition probabilities >0.5). The remaining four song-types were inter-related, but seldom transitioned to the other six. Further analysis of this unexpectedly complex data set is beyond the scope of this paper, but will be reported elsewhere.

Discussion

Although these results from a single bird should not be generalized to other Least Bell's Vireos, the nearly 10,000 songs distributed among 8 days of recording should be adequate for describing this bird's singing behavior. Because records this intensive are laborious to produce and thereby rare, these results are therefore of general interest.

Bout Structure

Songs per minute, calculated over the entire duration of each tape, varied from 2.5 to 9.0, suggesting that sufficient activity was occurring for the bird to be detectable at any time during the first 4 hr of the day, throughout the breeding season. Drawing this conclusion from average singing rate would, however, lead to serious error. This bird was inactive from 4-61 percent of the time (reckoned in minutes), depending upon the date. These periods of inactivity were, moreover, clumped, rather than being distributed randomly through the morning. Although alternation of singing and other activities is probably adaptive from the standpoint of the bird's time budget, it exacerbates the problem of detection for surveyors. Clearly, estimates of availability would be needed to correct counts of birds exemplified by our subject.

Detection Probability

Detection probability is the product of availability and detectability. In this study we focused on the former, because it is a new concept that has not been studied extensively. Given that availability was both <1 and variable from day to day, a robust means of estimating it is needed. We first determined the correlation of availability with overall singing rate, and then explored ways of estimating availability from the sort of short samples that can be taken concurrent with point counts.

Singing Rate

Availability was correlated with songs per total minute, but not with songs per active minute. This was true with or without inclusion of the data point for March 30, when the bird was effectively (and possibly physically) absent (*fig. 6*). Accordingly, 1-minute estimates of songs per minute, averaged over at least 10 samples, also provided a good estimate of availability.

Although it seems intuitively clear that availability and singing rate should be correlated if each song is an independent event, songs were highly clumped in this study. A simulation study (McCallum, unpubl. data) shows that, under such circumstances, fairly good correlations between singing rate and availability can be expected when songs are not too frequent (<15 song per min). Note that despite the tight correlation between availability and singing rate, averaged over the entire recording (*fig. 6*), only 80 percent of the variation in availability could be explained by 1-min estimates of singing rate, even when a large number of such samples were averaged (*fig. 7*).

Presence/Absence of Song

Another simple way of estimating availability, conceptually similar to the removal method of Farnsworth et al. (2002) is to calculate the proportion of time segments containing a song that are preceded by a segment containing a song. This is equivalent to the recapture rate in a mark-recapture design. A second estimator, also based on the presence/absence of song in 1-min periods, is the proportion of minutes containing a song followed by a minute containing song. Note that these are contingent probabilities, i.e., given that the bird sings, what is the probability that it will sing (or will have sung) in the next or preceding minute? Estimating availability requires knowing that the bird is present,

and singing is the only way it can demonstrate its presence. Estimating availability from raw presence/absence of song would confound presence of the bird with presence of song, which is contingent upon the presence of the bird.

These estimates of availability apparently performed poorly because of the serial correlation in song production (*table 2*). Even using the entire data set did not improve this situation. Although the estimates for six of seven days did stabilize at high sample sizes, the resulting values were all above 0.9, not in line with the true values of availability (*table 1*). Estimators such as these have been successful with other data sets (Farnsworth et al. 2002; McCallum, unpubl. data); the present results simply indicate that under certain circumstances, apparently resulting from clumping of on- and off-duty minutes, such estimators are not dependable.

Diel Variation and Phenology

We expected singing rate and availability to decline over the course of the morning, but such a trend was not discovered. If such a trend does exist, the decline must begin later in the morning. Even when availability was low, there was no diel trend (*fig. 4*, *fig. 5*). This is good news for surveyors, because it indicates that a wide time window is available in which to conduct surveys, if this individual is typical.

Largely unexploited by biologists monitoring bird populations is the information on breeding phenology and/or pairing status encoded in the singing behavior of males (B. Walker, pers. comm.). In many species, males sing much less after pairing. We did see a decrease in time devoted to singing, following an initial increase (*fig. 8*), but singing increased again after the mid-May low. Unfortunately, we lack independent behavioral data that might shed light on this interesting pattern. In some species males use one song-type before pairing and another after pairing. Bell's Vireos are reported to alternate songs that end with rising notes with songs ending with falling notes from the incubation period onward (Barlow 1962, cited in Brown 1993). Our subject alternated song-types (i.e., sang with immediate variety) throughout the breeding season, which seems unlikely to have been correlated with incubation. Both the seasonal changes in availability and the alternation of song-types suggest that studies of the singing behavior of individually recognizable Least Bell's Vireos could provide useful information on phenology.

Acknowledgments

We wish to thank Nanette Pratini, Tracy Tennant, and Sheila Kee for collecting the data at the Hidden Valley field site. Brett Walker and C.J. Ralph offered helpful suggestions for improving the manuscript.

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Shorebird Habitat Availability Assessment of Agricultural Fields Using a Digital Aerial Video System[1]

Clinton W. Jeske,[2] Scott Wilson,[2] Paul C. Chadwick,[2] and Wylie Barrow[2]

Abstract

Field and wetland conditions in the rice prairies of Louisiana and Texas are highly dynamic habitats. Rice prairies are important habitat for many species of migratory birds, including shorebirds, wading birds, and waterfowl. Ground sampling a variety of fields to assess habitat availability is very labor intensive, and accessibility to private lands makes statistical habitat sampling almost impossible. Aerial video is a tool we can use for assessing availability of these highly ephemeral habitats because of the short-duration repeatability of the surveys. The strong statistical basis of line transect theory allows quantitative estimation of habitat availability. We used ground surveys of field conditions and shorebird ground counts to correlate spectral signatures with shorebird habitat availability. This video system can also be used to identify and map distribution of invasive plant species known to affect suitability of stopover habitat for shorebirds and landbirds.

Key words: aerial videography, agricultural fields, habitat assessment, Louisiana, remote sensing, shorebirds.

Introduction

Field and wetland conditions in the rice prairies of Louisiana and Texas are highly dynamic habitats. Rice prairies are important habitat for many species of migratory birds, including shorebirds, wading birds, and waterfowl. For example, Wood Storks (*Mycteria americana*) arrive in the rice prairies during post-nesting dispersal in July. Being a tactile feeder, they are dependent on wetlands, especially ephemeral wetlands that are drying up which concentrates their prey. Permanent crawfish ponds are usually drained during the summer months, providing ideal habitat for Wood Storks. Because draining crawfish ponds only provide stork habitat for a few days, the birds are continuously sampling the landscape. Currently, there are no generally accepted methods of sampling these habitats. Accessibility to private lands makes statistical habitat sampling difficult, at best.

Several studies have used Landsat Thematic Mapper (TM) imagery to identify shorebird nesting habitats in the arctic (Gratto-Trevor 1996, Morrison 1997). These studies have classified habitats, determined breeding species composition and densities for identified habitats, and extrapolated breeding populations for relatively large habitat areas in the arctic. Yates and Goss-Custard (1997) used Landsat TM imagery to determine intertidal sediment distribution and developed models to predict abundance of shorebird species. Spell et al. (1995) used Landsat TM imagery to determine acreage of winter-flooded rice available to wintering birds. They used summer imagery to determine acreage of rice in production, and winter images to measure extent of flooding. Due to few cloud-free-days, the authors experienced problems obtaining winter images.

Aerial video would provide methodology for assessing availability of these highly ephemeral habitats because of the short-duration repeatability of the surveys. The strong statistical basis of line transect theory would provide the methodology for providing quantitative estimation of availability (Buckland et al. 2001). Additionally, for species such as Wood Storks, differential use of wetland classes could be determined, providing habitat use information as well. For habitats, which are more stable than agricultural wetlands, aerial videography would provide a method of obtaining statistically valid samples, which could be applied to questions of spatial distribution of different habitat categories.

The proliferation of low cost multi-spectral CCD video technology in combination with the Global Positioning System (GPS) has progressed to the point where quantifiable and meaningful results can be derived from low altitude aerial digital video systems. This low cost technology will provide meaningful and sometimes critical data that will be required for regional and site-specific land management. Historically, video has not had the resolution to be used for spatial processing, but newer digital systems have expanded the capabilities. Linking with GPS systems allows repeatability of sampling that was unavailable in the past. When

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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Table 1– *Comparison of sensor characteristics and costs of commonly used images in remote sensing.*

Sensor platform	Num. of bands	Spatial resolution (m)	Swath width (km)	Repeat cycle (days)	Approx. cost[1] per scene ($)
CIR Photo[2]	3	2.4	6.6	Varies	60
Landsat	7	30	185	16	1,000
Spot 4	4	20	60	3	2,500[3]
Ikonos	4	4	11	11	5,000[4]

[1] Image acquisition only, no special processing.
[2] Acquired at 1:24,000 scale and scanned at 300 dpi.
[3] Custom acquisition (customer controlled new image acquisition).
[4] CARTERRA Precision $66/sq. km to $99/sq. km depending upon level of preprocessing required. Partial scene purchase available. $5,000 minimum purchase.

compared to satellite acquisition systems, such as Landsat TM imagery, airborne video systems have the additional capability of varying the temporal and spatial resolution to fit the needs of individual projects. In addition, these systems have the potential for extremely fast post-processing and at a low cost (*table 1*).

The objective of this study was to develop a process of image acquisition, image processing, and incorporation of field characteristics and shorebird abundance to evaluate aerial videography for predicting shorebird use of agricultural fields.

Methods

Our study focused on agricultural fields within the Mermentau River Basin in southwestern Louisiana (*fig. 1*). Roadside transects sampling from 10-16 fields were established in 1996-97 and have been monitored periodically for avian use since. A stratified random sample of fields was established. The number of transects per Parish was weighted for rice production. Random coordinates within the Parish were used to establish a starting point. Fields actively being farmed for rice were selected for transects in 1996-97. We have maintained these fields in the study even if they have been removed from rice production, or are used for alternative crops (i.e., soybeans). Each transect averages approximately 6.5 km in length.

We used aerial videography to assess habitat conditions on 7 transects containing 83 identified fields from the earlier study (W. Norling, National Wetlands Research Center, unpubl. data). Within a rice field, contour levees exist to allow control of water levels. Because each section of a field within a contour levee may provide different habitat conditions (i.e., when a field is being flooded, some sections may be flooded while others are dry), we treated each section within contour levees as separate units. Consequently, the 83 fields consisted of over 300 units that were sampled with both ground-truthing and counts of shorebirds using the units.

For each flight, the image acquisition phase consists of the actual flight, acquiring the images and raw data, and then the post processing to geo-rectified images. This involved an airplane equipped with a GPS unit linked to a natural color video camera and a color infrared camera (*fig. 2*). GPS coordinates were recorded in the audio tracks of both video cameras and were later extracted in order to match the video frames with their exact positions. These video frames along with their GPS coordinates were then used to make geographically correct mosaics.

The processing phase consists of spatial processing. This involved a manual interpretation of field conditions using pre-existing methodologies used by previous National Wetlands Research Center rice field studies (W. Norling, NWRC, unpubl. data). Index conditions were entered into the existing GIS rice field database along with the ground-truth field collected data for accuracy comparisons. Individual frames from the video have been extracted to develop a mosaic image of each transect and imported into Arcview for analysis (*fig. 3*).

The final phase consisted of using the processed data to determine meaningful biological results. Concurrent with the aerial data acquisition, transects were surveyed from the ground. Field conditions were recorded and numbers and species of waterbirds using the fields recorded. Field conditions from aerial video were determined by an observer without prior knowledge of the field conditions reported by the ground observer. Fields were classified as to amount of flooding and green vegetation using both the color infrared and natural color video. Classification levels were 0, 1-24, 25-49, 50-74, 75-99, and 100 percent coverage. Results from the video observer were compared with the ground observations to determine error rates of classification. Classification error was determined by comparing the video classification with the ground observation for each unit. Because there were 6 possible classifications, 0 coverage was given a 1 and 100 percent coverage a 6, we compared classification by subtracting ground

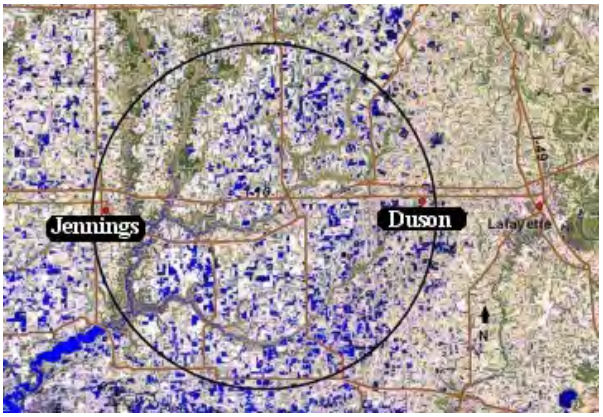

Figure 1— Study area in southwest Louisiana. The Mermentau Drainage has extensive agricultural areas between riparian zones. Most agricultural lands are farmed for rice, with fallow or soybean rotations. Notice the extensive flooding of agricultural fields in this Thematic Mapper image.

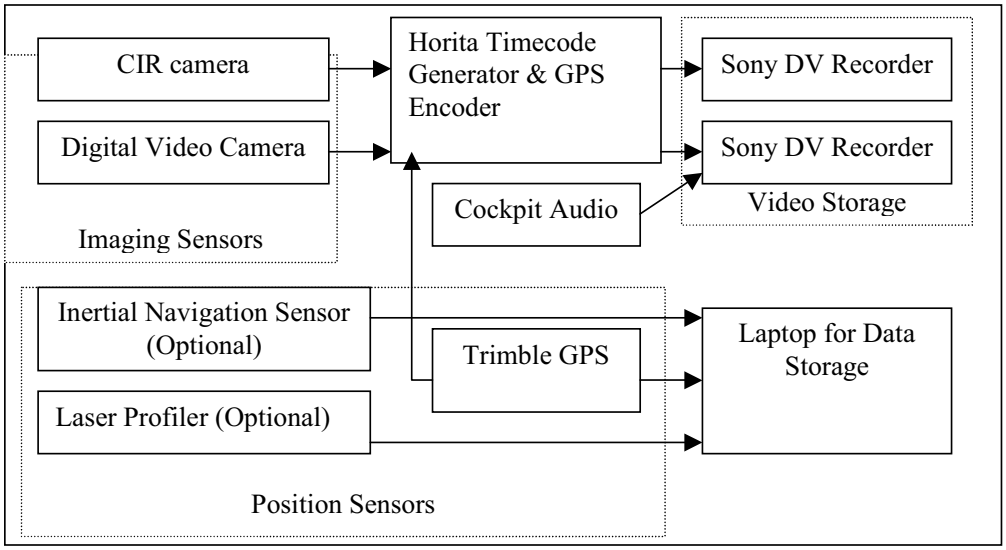

Figure 2— Links of video sensors with the GPS unit to allow exact locations of video frames to be determined.

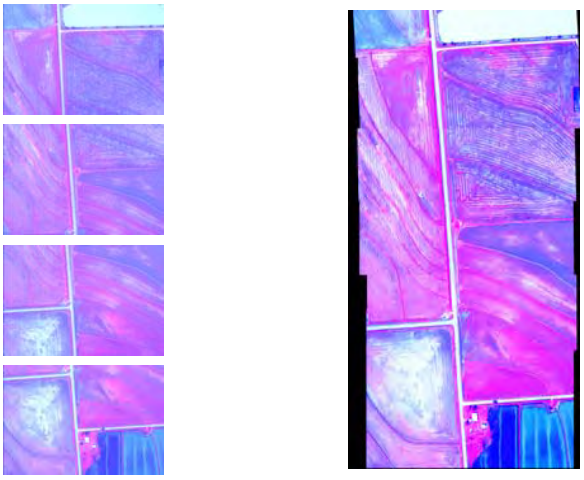

Figure 3— Individual frames from the video are captured to develop a mosaic of the surveyed area.

observation from the video classification. A comparison value of 0 corresponds with complete agreement in classification, while a ±5 is a complete disagreement in classification. For example, if a dry field was classified as 100 percent flooded, classification agreement would be calculated as 1-6, or –5, complete disagreement.

Amount of flooding and amount of green vegetation were chosen because they can be determined from the aerial video, such conditions are also known to influence relative abundance and species richness of shorebirds (W. Norling, NWRC, unpubl. data).

Results

Four concurrent flight-ground counts were completed for this study. Over 750 field units were available for comparison between photointerpretation and ground

observations. Misclassification rates were higher for determination of flooding than for estimates of green vegetation for both Color Infrared Video (CIVR) and Natural Color Video (NCV; *tables 2, 3, 4, and 5*). In several instances interpretation of the aerial images were misclassified when newly worked soil was classified as shallow, turbid flooding. Turbid water in CIRV has an indistinct spectral signature compared with clear that has a distinct spectral signature.

If value levels of 0 or ±1 are accepted as reasonable agreement between classifications over all flights, CIRV was most accurate for determination of flooding with 62.4 percent of the classifications in agreement. Classification agreement for NCV was 55.9 percent. Classification agreement was less for green vegetation for both formats, with CIRV being 46.6 percent, and NCV being 46.6 percent. Values suggesting misclassification, ±4 or 5, were similar for both formats for both vegetation and flooding, ranging from 28.5 percent for NCV for vegetation to 38.3 percent NCV for flooding.

Discussion

Aerial videography provides researchers the ability to rapidly assess habitat availability with a high degree of repeatability. Shorebird habitats in the rice prairies of Louisiana and Texas are highly dynamic habitats. Fields may be plowed in fall or spring, then flooded in the spring, leveled while flooded, and then seeded. In Louisiana, aerial seeding of rice is common, with fields flooded for approximately two weeks before being drained to allow the rice to sprout. During draw down, fields are heavily used by shorebirds. Fields are re-flooded after the rice has sprouted and the fields again receive substantial shorebird use. Because these habitats are so dynamic (Lawler 2001), aerial videography allows sampling of habitat to be repeated over short time intervals, allowing managers to monitor habitat availability throughout the period. During peak shorebird migration along the Gulf Coast, cloud cover often limits the availability of scenes for satellite based collection systems. Spell et al. (1995) identified the difficulty of obtaining Landsat images during the winter in the Central Valley of California.

Many remote-sensing platforms are either cost prohibitive, are too coarse of a scale to identify specific habitat characteristics, or timing of imagery is inappropriate for measurement of availability of the habitats of interest. Aerial videography is an efficient method of collecting habitat data that is less expensive, repeatable over short time duration, and able to collect fine-scale spatial data. Initial costs for equipping the fixed-wing aircraft with the aerial videography components was a one-time cost of approximately $20,000. After equipping the aircraft, costs are limited to those incurred by flight time, and personnel to extract individual frames from the video to be used to develop a mosaic of the study area (*fig. 3*). Once geo-referenced, the data can be used as data layers in a GIS analysis of habitat availability and change.

Table 2— *Comparison of percent of a field flooded from Color Infrared Video when compared with ground observations. Fields were classified as being 0, 1-24, 25-49, 50-74, 75-99, and 100 percent flooded. Value of 0 corresponds to agreement between observers, while a value of ±5 corresponds to complete classification difference.*

Survey number	Fields surveyed	Value = 0	Value = ±1	Value = ±2	Value = ±3	Value = ±4	Value = ±5
1	162	43	13	6	2	29	69
2	162	128	9	15	5	15	24
3	205	113	26	2	9	15	40
4	203	127	19	5	3	15	34
Totals	766	411	67	28	19	74	167

Table 3— *Comparison of percent with green vegetation from Color Infrared Video when compared with ground observations. Fields were classified as 0, 1-24, 25-49, 50-74, 75-99, and 100 percent vegetated. Value of 0 corresponds to agreement between observers, while a value of ±5 corresponds to complete classification difference.*

Survey number	Fields surveyed	Value = 0	Value = ±1	Value = ±2	Value = ±3	Value = ±4	Value = ±5
1	162	73	22	18	11	24	14
2	185	49	24	26	7	58	21
3	205	52	17	29	39	53	15
4	203	86	34	18	25	31	9
Totals	766	260	97	91	82	166	59

Table 4— *Comparison of percent of a field flooded from Natural Color Video when compared with ground observations. Fields were classified 0, 1-24, 25-49, 50-74, 75-99, and 100 percent flooded. Value of 0 corresponds to agreement between observers, while a value of ±5 corresponds to complete classification difference.*

Survey number	Fields surveyed	Value = 0	Value = ±1	Value = ±2	Value = ±3	Value = ±4	Value = ±5
1	187	61	14	4	2	22	84
2	197	86	11	7	5	34	54
3	207	122	12	8	9	18	38
4	203	127	11	3	9	9	45
Totals	794	396	48	22	25	83	221

Table 5— *Comparison of percent of a field with green vegetation from Natural Color Video when compared with ground observations. Fields were classified 0, 1-24, 25-49, 50-74, 75-99, and 100 percent vegetated. Value of 0 corresponds to agreement between observers, while a value of ±5 corresponds to complete classification difference.*

Survey number	Fields surveyed	Value = 0	Value = ±1	Value = ±2	Value = ±3	Value = ±4	Value = ±5
1	187	87	21	15	16	17	31
2	196	54	25	23	24	35	35
3	207	51	14	46	34	42	20
4	202	69	43	20	24	38	8
Totals	792	261	103	104	98	132	94

Several factors may influence interpretation of the video when compared with ground observations. Vegetative cover was probably overestimated from ground observations. Oblique observation angles suggested more dense vegetative coverage than the overhead angle revealed, affecting correspondence with the video classification. Consequently, best agreement would be among fields with no vegetation or extremely dense vegetation and less agreement with intermediate vegetation densities asking whether a field was 30 percent vegetated or 75 percent covered with green vegetation. Similarly, an oblique angle tends to reduce the apparent size of the field, resulting in an inflated estimate of percent flooded for ground observations.

Sun angle influenced the ability of the video observer to distinguish field characteristics. Flooding was most easily detected by reflectance off the water surface. Light cloud cover made detection of flooding more difficult. Optimal flight conditions were during midday with minimal cloud cover. Because of reflectance, flight paths in an east-west direction made detection of flooding easier than north-south orientations.

Training of the video interpreter improved correspondence between observations. In our study, initial classification was done with no training of the video interpreter. When we compared misclassifications, it became apparent that recently disked fields were classified as shallow flooding by the video interpreter because of the similarity with shallow, turbid water. After comparing several shallow, flooded fields with recently disked fields, subtle differences in the spectral signatures could be detected, resulting in improved classification of other fields. Combining both CIRV and NCV improved classification compared to using only one format. Training in all aspects of the data collection is important for accuracy and consistency of interpretation of video data.

We recommend that individuals using aerial videography standardize data collection with regard to time of day of flights, flight altitude, cloud cover, and orientation to the sun to optimize the video quality. Additionally, ground-truthing observations are necessary for quality control of data, and to use in training interpreters of the video. Linking wildlife use with habitat characteristics with easily identified spectral characteristics simplifies the data analyses. We originally had too many habitat categories and it affected interpretation.

Optimization of data collection to address specific needs can be controlled by determining optimal scale of data collected through flight altitude (*fig. 4*) and timing. Researchers in remote locations can use this system to collect and acquire meaningful data in a relatively short time period. Airborne video systems also have the capability to provide information for efficient rapid response during emergency situations, such as hurricanes. We envision applications of videography for other applications where land managers

require quick response, such as oil spill clean up, fires, monitoring exotic species, and storm or pest damage.

Acknowledgments

We thank S. Creed for piloting the aircraft. J. Roan and S. Chimmula with post-flight processing. W. Norling shared unpublished data and assisted with identifying sampling locations and field classification. Funding was provided by the National Wetlands Research Center.

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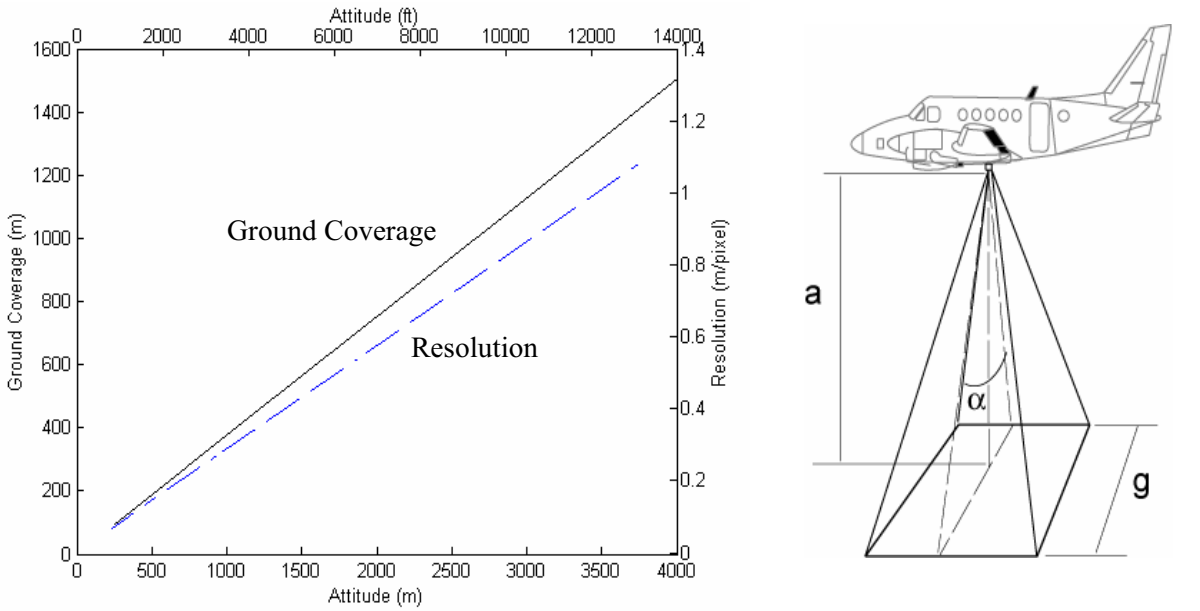

Figure 4— Relation between ground coverage and resolution for mission planning.

Migration Monitoring with Automated Technology[1]

Rhonda L. Millikin[2]

Abstract

Automated technology can supplement ground-based methods of migration monitoring by providing: (1) unbiased and automated sampling; (2) independent validation of current methods; (3) a larger sample area for landscape-level analysis of habitat selection for stopover, and (4) an opportunity to study flight behavior. In particular, radar-acoustic sensor fusion can provide information on species-specific landing behavior to indicate what portion of the population that pass over a site are available for ground-based monitoring using mist-net capture or census. In this paper, I examine the benefits of radar, infrared and acoustic technologies in the monitoring of bird migration and discuss how automated technology can augment mist-net and census data.

Key words: radar, acoustic, technology, migration, stopover, landbirds, critical habitat, data fusion, infrared.

Introduction

The monitoring of bird populations provides a barometer of environmental health. For species that are sensitive to disturbance or habitat change, a relative change in population trends can indicate a problem in the environment that is not otherwise apparent. Furthermore, population monitoring can provide data indicating the effect, positive or negative, of conservation programs that were undertaken to recover declining populations.

Monitoring during migration is an efficient means of amassing data from large geographic areas and multiple breeding habitats. Landbird migrants travel in multi-species, multi-age groups as evidenced by daily captures in mist-nets. Therefore, migration monitoring provides indices of reproductive success such as the number of young per breeding pair (HY/AHY ratios). In some cases, the recapture rate is high enough to delineate populations and provide survival data.

Automated technology can supplement ground-based methods of migration monitoring by providing unbiased sampling, independent validation of current methods, a larger sample area to follow birds for landscape-level analysis of habitat selection for stopover, and an opportunity to study flight behavior. Automated monitoring technologies provide important tools for use in migration monitoring networks, and they can be easily integrated into networks using global positioning systems and synchronized clocks. With technology-based monitoring systems, information transfer is more efficient, covers a greater distance and can be more accurate.

Automated technology includes radar and other electronic, mechanical and computerized inventions. These inventions have been used to study bird flight since radar was first used in World War II (see Lack and Varley 1945, Eastwood 1967, Williams et. al. 1972, Able 1973, Vaugh 1985). They have provided important information to augment conservation efforts. Some examples are: (a) the delineation of migration routes of endangered birds by satellite tracking (Beekman and Klaasen 2000); (b) long-range movements of night migrants by weather radar (Gauthreaux and Belser 1998, Koistinen 2000); (c) the importance of physiological condition on migration decisions by infrared (Fortin et al. 1999); (d) the influence of weather on timing and direction of flight by surveillance radar (Richardson 1978); and (e) local flight decisions of individual birds by radio-tracking (e.g. Frietag et al. 2001). Orientation and experiments involving migration energetics have been conducted using military tracking and phased array radar (Bruderer and Steidinger 1972, Bruderer et al. 1995, Buurma 1995). However, the high cost of these radar systems is prohibitive to their use in most conservation programs.

A number of challenges remain in the use of automated technology for migration monitoring networks. With infrared sensors, there are limitations in size and range of detection, as well as separation by species. For acoustic-only sampling methods, non-vocal individuals are not detected. For radar-only methods, the challenges include management of the data, species identification, error and worker fatigue associated with manual tracing from the radar screen, and relating data from long-range weather radar to site-selection for stopover. These challenges can be mostly overcome by

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California**.

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combining technologies and choosing the appropriate technology for the development phase of the network.

This paper includes some background on the use of technology in migration research, proposed benefits of technology for a migration monitoring network, and suggestions for future directions. The focus is on landbirds and therefore, detection and monitoring of night migrants.

Background on the Use of Technology in Migration Research

Not all technologies used to monitor birds are useful for monitoring landbird migration. They must be affordable so enough stations can be set up as an effective network. Five technologies were selected that could augment the information, efficiency and accuracy of mist-net and census-based methods in migration monitoring networks, at a price affordable through cost-sharing or the use of existing data sets (e.g. WSR-88D weather data). The five technologies include long-range radar, short-range radar, acoustic-sensing, acoustic-location and infrared (*table 1*). In each case, the technology can enhance detection of birds in flight well beyond the visibility and audibility of humans (*fig. 1*). The important characteristic of all five is that they are passive, requiring no handling of birds. Radio-tracking is not included as it is not passive, and therefore, does not improve on the risk of handling birds.

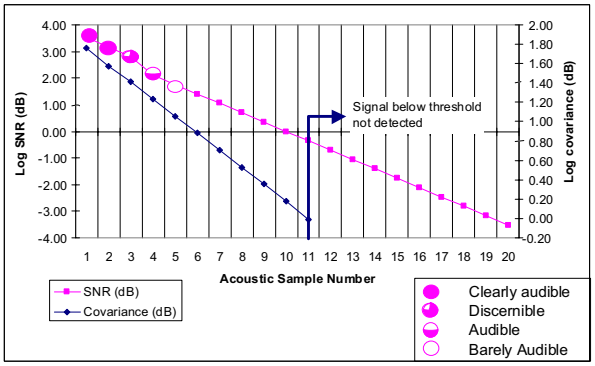

Figure 1—Acoustic detection of bird calls beyond the capability of the human ear. A bird call (signal) was progressively concealed in noise so sample 1 was clearly audible by a human, sample 5 was barely audible and samples 6 to 10 were only detectable using automated acoustic processing.

In this paper, a distinction is made between acoustic-sensing and acoustic-location. Acoustic-sensing provides a traffic rate, measured as the relative number of birds of a species, passing a geographic point (e.g. Birdcast®). By contrast, acoustic-location provides the originating location of each call expressed as the number of each species at particular heights and lateral distributions (e.g. Millikin 2001).

Long-range or weather radar (*fig. 2*) is also distinguished from short-range or surveillance radar (*fig. 3*), in range of detection, resolution, minimum altitude, and portability (Skolnik 1990). Long-range radar is suited to a large area and coarse monitoring (i.e., a range = 230 km and a resolution of flocks, versus 0-5 km and resolution of individual birds for short-range radar). The downside of a long-range radar is that the

Table 1—*Current technologies, their application and limitations to migration monitoring.*

Technology	How applicable[1]	Limitations
Long-range radar e.g. WSR-88D	Long-range movements; General routes; Predict "big days"; Pre-migration flights (Purple Martin); Roosting (Starling)	Birds fall below the beam so cannot be tracked to landing; No species information; No information on individuals
Short-range radar e.g. X-band Surveillance	Traffic rate; Landing habitat; Nesting sites (Marbled Murrelet); Impact assessment (Towers and Wind turbines)	Large-scale movements and routes require multiple units or moving between sites; Data management; 3-D position
Acoustic-sensing e.g. BirdCast®	Traffic rate and species complex	No information on individuals; Some species not known to call
Acoustic-location e.g. Expanding hemispheres™	Landing and nesting sites of priority species; Flight path, spacing, grouping of species	Large-scale movements and routes require multiple units or moving between sites; Some species may not call; Incomplete library of calls; Data management; Rain
Infrared e.g., LORIS, IRTV-445L	Traffic rate, flight path 300-3000 m above ground level (unfocused to 25 m)	Beam 1.45º; Identify to passerine but not species; No height; Data management; Rain and cloud

[1]Purple Martin, *Progne subis*; European Starling, *Sturnus vulgaris.*

increasing distance from the radar increases the minimum detectable altitude for the birds, and therefore, many birds fall below the beam at greater distances. Only within 5.6 km, 2 percent of the range of weather radar, would the image include birds fully within landing heights (i.e., below 100 m). Whereas, depending on interference, short-range radar can detect birds to altitudes below 1 m. With a modification to include height, short-range radar could detect landing heights over the entire range of 5 km. For networks wanting to share the cost of an automated tracking system, short-range radar is portable whereas long-range radar is not.

To develop a migration network that will involve mist-netting for population structure and survival data, the first task is to select the funneling routes of the populations of interest. For example, the three founding stations of the British Columbia (Canada) migration monitoring program were selected in ecoprovinces with the greatest concentration of passerine species (i.e., the Georgia Depression and South Interior, where 91 percent and 80 percent of passerines breed, respectively), and where species were not adequately monitored by Breeding Bird Survey (i.e., the Northern Boreal Mountains). Funneling routes were selected based on topography and convenience to volunteers. In a region with WSR-88D coverage, funneling routes could be confirmed by images of expanding "circles" at dusk and areas of concentration close to the radar, taking care to avoid assuming that birds no longer detectable have landed, because their disappearance may be due to the radar beam projecting out over the curvature of the earth.

After determining the funneling routes of interest the decision of where to situate the migration station should be based on knowledge of where the birds prefer to land. To track individual birds to landing sites, surveillance radar with the lower minimum altitude and better resolution of individuals is required. Short-range radar has been successfully used to track flights of the Marbled Murrelet (*Brachyramphus marmoratus*), to and from their nests (Hamer et al. 1995), and for impact assessments related to ground objects (Cooper 1995). In cases like the Marbled Murrelet when there are few other species exhibiting similar flight behavior, it is not necessary to know the species. However, with the multi-species flocks of landbirds, the special management of species at risk and the need to correlate with mist-net data, automated species identification is required.

Using automated technology to determine where priority species land, can provide an unbiased selection of sites for the monitoring of population trends and the identification of critical stopover sites to protect. Proper site selection is crucial to the establishment of an effective migration-monitoring network. Given that population trend analysis of migration data can require a ten-year commitment to a site, incorrect site selection can result in a waste of scarce monitoring resources.

An example of radar tracking of stopover behavior is given from the author's work. The surveillance radar was modified to provide height information so birds closer to the ground, either leaving or landing, could be separated from those flying over (*fig. 4*). The length of the vector indicates the bird's altitude. The direction of the vector indicates the direction of flight. The data in *Figure 5* were collected in fall at Prince Edward Point on the north shore of Lake Ontario. At dawn, a larger portion of birds flew in a reversed direction from the main direction of migration (south), to land within 2 km of the radar. This was confirmed with ground-based methods. I propose that by tracking individual birds at close range, the onset and volume of reverse migration can indicate the importance of that site for stopover. A number of sites could then be compared to select the optimum site for the species of interest, before expending resources to prepare the site for the banding station.

Most migration at Prince Edward Point, between 28 August and 19 September 1999 was below 300 m (*fig. 6*). As expected, a larger proportion of birds flew below 300 m at dawn, but many birds were also flying below 200 m at midnight. A bias due to reduced detection at higher altitudes is unlikely since birds were tracked up to altitudes of 790 m above ground. Birds dispersed straight up at dusk to heights (maximum 660 m) above the average height of continued migration at midnight (average 197 ± 11 [95 percent CI]). Many of the low flying birds at midnight were likely landing, based on the reversed flight direction northward of 13 percent of the midnight migrants. The ability to discern a change in height and direction during the night migration will be important for environmental assessment of the risks to bird conservation such as communication towers and city lights.

Radar and infrared alone cannot provide species identification (*table 1*). This can be accomplished by acoustic-sensing or acoustic-location. Acoustic-location has the added potential to augment population trend indices, by providing a measure of the portion of the birds landing at a site that are available for capture in mist-nets. The implication for migration monitoring is the potential to select sites for priority species.

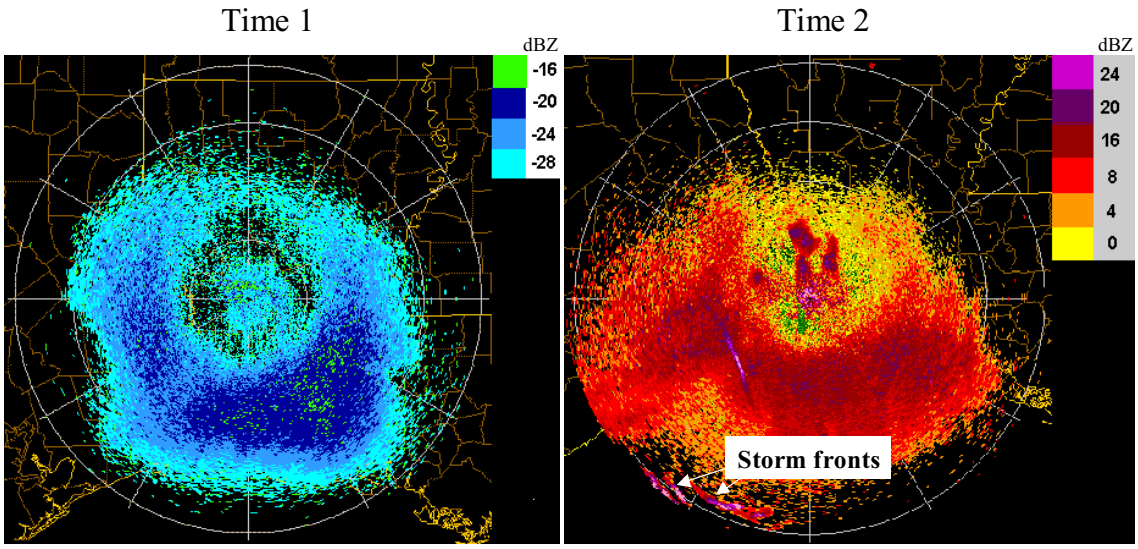

Figure 2—WSR-88D images depicting the spring migration of birds across the Gulf of Mexico in 1999 (adapted from http://virtual.clemson.edu/groups/birdrad). The images show regions of high base reflectivity (16-20dBZ) representing water particles (e.g. storm fronts) and birds. The series, time 1 to time 2, simulates the start and spread of migration as the bird density increases from an estimated 0 birds/km^3 (-16dBZ) to 227 birds/km^3 (20dbZ). WSR-88D is an example of long-range radar having a range of 230 km, 50-100 times that of short-range radar. Doppler information can be used to show the speed of particles and their direction. The advantages of WSR-88D for migration monitoring are the large geographic coverage and the potential, though not yet realized, for automated analysis. The disadvantages are that it does not differentiate individual birds, it is difficult to calibrate and birds cannot be tracked to landing.

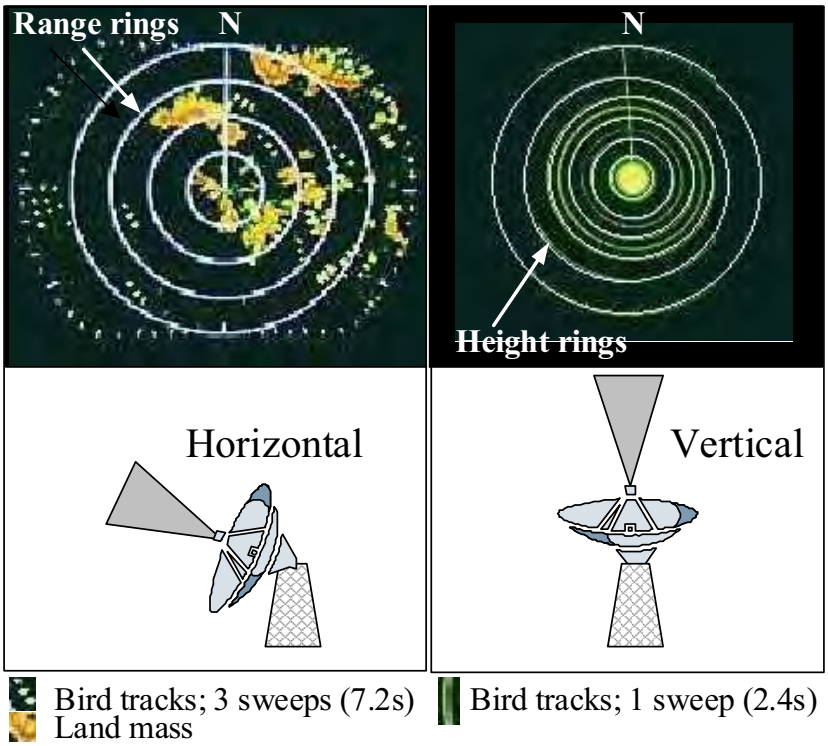

Figure 3—Fall migration across the Juan de Fuca Straight, British Columbia, in 1996, depicted on the planned-position indicator (PPI) of a dual antenna system (Millikin, unpublished). Birds resemble staple-shaped bars that move across the screen when the slotted waveguide antenna is oriented at the horizon (left) and comet-like streaks when a parabolic antenna is oriented straight up (right). Bird speed is calculated as the distance traveled per 2.4s sweep. A composite 3-D image is obtained by combining information from each antenna. The slotted waveguide was 200 cm (25° vertical beam width and 1.2° horizontal beam width), on a 10 kW X-band Furuno FR-810D. The parabolic antenna (2°) was on a 5 kW X-band Furuno FR-805D. A generator powered both units. X-band radar is an example of short-range radar.

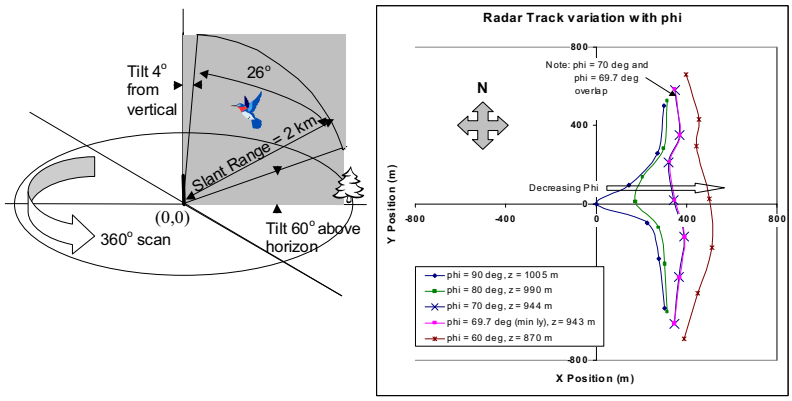

Figure 4—With adaptation to an X-band radar antenna (left) and neutral regression to select the straightest track (right), one antenna can provide the height of individual tracks of birds (patented; Millikin 2001). The radar is located at (0,0) with the antenna tilted 60° above the horizon for a 26° vertical scan of the full 360° coverage out to 2km. The target position in the beam is adjusted (increasing phi) until the track is most straight and this position provides the target height (z).

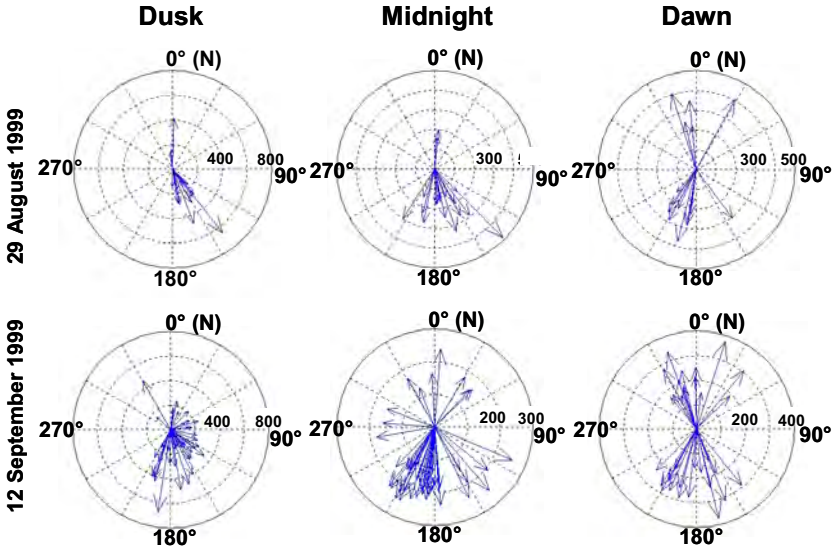

Figure 5—Individual tracks of fall migrants at Prince Edward Point, Ontario, ascertained by the adapted short-range radar (Millikin 2001). The vector length represents the bird's height and the compass direction represents the direction of flight. Note the reversed direction of flight at dawn.

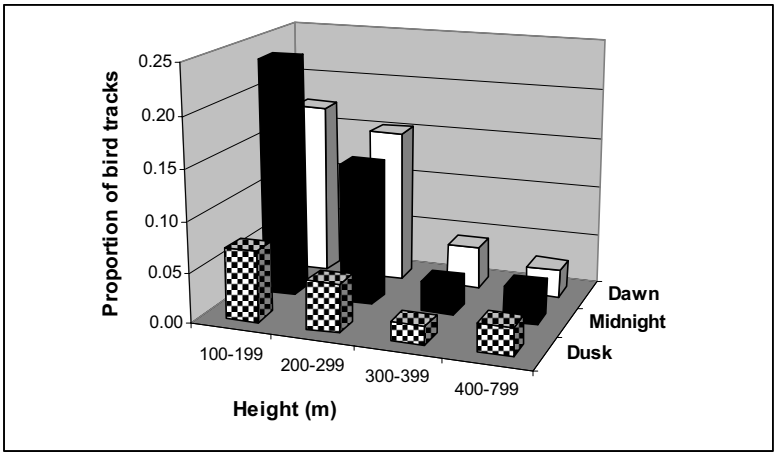

Figure 6—Height distribution of bird tracks at three time periods during the night migration over Prince Edward Point, Ontario, between 28 August to 19 September 1999. Proportions are of all heights and time periods combined, corrected for sample size.

Questions can then be asked of species-specific spacing and flight behavior, then the correlation of traffic rate to mist-net capture and census techniques, for a better understanding of diurnally measured population trends.

Using an example from the author's research, by locating species-specific calls, species can be grouped (*table 2*, Millikin 2001) to determine their spacing, then co-located with radar tracks for further analysis of flight behavior (*fig. 7*, Millikin 2001). By combining the radar track with the acoustic-location, it is apparent that the Swainson's Thrush, *Catharus ustulatus*, experiences Lake Ontario as a barrier and reverses its direction of migration to land at Prince Edward Point. As expected, birds flying together in time (*table 2*, birds less than one second apart), and therefore experiencing the same atmospheric conditions, are more similar in flight behavior with less spread in height and direction between individuals. Birds flying together of the same species were more similar in flight speed with less spread in speed between individuals than pairs of different species (*table 2*). This snapshot of species-specific calls supports the hypothesis that passerines migrate in loosely spaced, multi-species flocks.

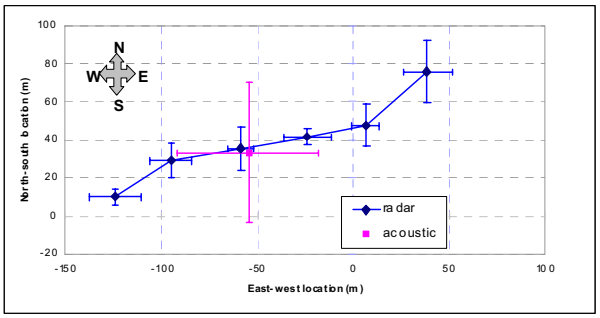

Figure 7—Co-location of a Swainson's Thrush call (acoustic) onto a radar track (radar). The bird was flying SW at a height of 150 m. Of three one-hour dawn samples 12, 18 and 19 September, 28 out of 129 tracks were co-located.

Table 2—*Three minutes of calls ordered by time elapsed between pairs. Birds traveling together experience the same atmospheric conditions such that differences in flight behavior of birds that are paired in time indicate the species' flight behavior.*

	Three minutes on 18 September[1]			Spread between birds[5]		
	Time of call[2]	Elapsed[3]	Species[4]	Height (m)	Speed (m/s)	Direction (°)
<1 second apart	***5:42:35:274***	***0.093***	***swth***	***2***	***7***	***14***
	5:42:35:367		***swth***			
	5:41:37:557	0.344	zeep	2	12	67
	5:41:37:901		swth			
	5:42:26:113	0.469	zeep	9	14	77
	5:42:26:582		swth			
	5:39:51:112	***0.532***	***swth***	***5***	***5***	***13***
	5:39:51:644		***swth***			
>1 second apart	***5:42:24:331***	***1.056***	***zeep***	***104***	***2***	***110***
	5:42:25:387		***zeep***			
	5:42:35:749	1.459	zeep	11	21	97
	5:42:37:208		swth			
	5:39:52:825	2.372	zeep	10	11	150
	5:39:55:197		swth			
	5:41:31:123	3.661	swth	50	5	80
	5:41:34:794		zeep			

[1]calls of birds paired in time that are of the same species are italicized and bold.
[2]presented in hours, minutes, seconds and milliseconds
[3]ordered by the increasing time that elapsed between each pair of birds.
[4]swth = Swainson's' Thrush and zeep = group of eight warblers not easily distinguished.
[5]numbers indicate the spread in height, velocity and azimuth measurements between each pair of birds flying together in time. Birds traveling closer together in time (<1 second apart) have a lower spread or difference in height and direction, but a lower spread in speed is more typical of birds flying together of the same species.

What Technology Can Do for Migration Monitoring

Having discussed the current technology, the specific role of technology in migration monitoring can be explored. The three aspects covered include current problems in migration monitoring with solutions from technology, current unknowns affecting migration monitoring with the potential input from technology, and knowledge gained by technology related to migration monitoring.

Current Problems in Migration Monitoring and Solutions from Technology

Some current problems in migration monitoring are listed in *table 3*, with proposed solutions from technology. The problems include site selection, weather, sampling bias, avian mortality risk, identification of species, and networking of multiple areas.

Site selection: As mist-net sampling requires intense labor to prepare and run the site, it is difficult to monitor a large area. Census can be used to compare sites, habitat or landscapes, but during migration, birds are difficult to detect because they rarely sing. Long-range radar can cover extensive areas, but birds falling below the minimum height of the beam will be missed, giving a misleading picture of the landing sites. Short-range radar can track birds to their landing but to compare sites, multiple units are required or one unit must be moved between sites. Acoustic-location also requires multiple units or moving between sites. Acoustic-sensing has no location information to separate fly-over from landing birds. Infrared cannot identify species and may miss landing birds below 300 m. Therefore, a combination of long-range radar, short-range radar, and acoustic-location, is required for unbiased and landscape-level site selection.

Confounding effects on flight behavior (e.g. weather): Short-range radar can be used in all-weather conditions, day and night, so can provide trend data over all conditions and times. Acoustic-location and infrared cannot be used under certain weather conditions (cloud for infrared; rain for acoustic-location). Even under ideal weather, other confounding effects may be difficult to distinguish with long-range radar and acoustic-sensing, as they do not sample individuals.

Eliminating sampling bias: The greatest advantage of automated technology is to remove problems of sampling bias and avian mortality risk (below). By separating landing birds from fly-over birds, short-range radar can help separate fluctuations in the number of migrants that land due to weather from the changes in population trends that are due to breeding or overwintering success. Long-range radar does not separate landing birds from fly-over birds. Short-range radar should be combined with acoustic sensors to separate weather effects on individual species. Infrared still requires human interpretation and therefore is subject to bias. The automated technologies should be selected for an independent validation of current ground-based methods.

Table 3—*Current problems in migration monitoring with potential solutions from technology. Each technology is ranked as having significant, moderate or no improvement in resolving the problem. Most migration stations currently use census and/or mist-netting.*

Problem	Solution	Census	Mist-netting	Long-range radar	Short-range radar	Acoustic-sensing	Acoustic-location	Radar & acoustic	Infrared
Site selection for observation / sampling	Use a combination of unbiased sensors		–			–		+	
Unrelated flight behavior (weather)	Account for confounding variables in trend data	–	–		+			+	
Sampling bias (human factor)	Automate data collection	–	–	+	+	+	+	+	
Avian mortality risk	Use a passive sensor		–	+	+	+	+	+	+
Identification of species	Direct observation or by call		+	–	–	+	+	+	–
Networking of multiple areas	Sample over a larger area	–		+			+	+	–

+: significant improvement.
-: marginal improvement.
blank: no improvement.
Notes: Improvement is subjectively ranked based on experience and reference materials.

Mortality risk: Mortality risk can be removed by using passive methods. Bruderer et al. (1999) found no change in flight behavior induced by X-band radar. Yet, strong light was found to induce a pronounced shift in flight direction (8-15º over a 10 sec interval), a mean reduction in flight speed of 2-3 m/s (15-30 percent of normal flight speed) and a slight increase in climbing rate.

Identification of species: Mist-netting provides the best detail on species (age, sex, molt, physiology, and parentage), but only for those individuals caught. Acoustic sensors sample all calling species but not all individuals call. Therefore, to relate information obtained from mist-nets to the larger population of landing birds, acoustic sensors should be combined with radar to determine what portion of landing birds call. By tracking landing behavior of a particular species, radar-acoustic sensor fusion provides a measure of the portion of a population available for ground-based monitoring.

Networking: Long-range radar provides route information to link sites. However, short-range radar is a better choice in the mountains (Williams et al. 2001). To follow movements of priority species, acoustic-location can provide landing information important in assessing the potential success of mist-nets. Mist-nets cannot provide sufficient recapture information to link sites.

Summary: The recommended approach to establish a migration monitoring network would be to use automated technology for an unbiased assessment of where to locate the stations. If there is WSR-88D coverage, this can be used to determine the funneling routes of the populations of interest. Then, the preferred landing sites of species at risk can be estimated using short-range radar fused with acoustic-location. The mist-nets and census route should be situated within the range of coverage of the radar-acoustic system to facilitate for a more detailed understanding of flight behavior.

Roughly, the cost of adding automated radar-acoustic data to a migration station would be 1-3 times the cost of a volunteer-based mist-netting program (*Appendix I*). Renting, leasing or sharing the automated equipment could minimize the cost to each monitoring station. The cost would also be offset by the improved data. Sites could be selected more efficiently so more could be monitored immediately. Those selected would be more productive for the species of interest, which would minimize the loss of data when a site is moved because it was not as productive as expected from diurnal observation.

Current Unknowns Affecting Migration Monitoring and Potential Input from Technology

A major concern when establishing a migration monitoring network is whether population trends can be monitored using migration. Mist-netting and census methods monitor population trends based on the portion of birds landed that can be caught or observed. Whereas, long-range radar and acoustic-sensing detect a larger number of birds passing over the site. To separate the population passing over from those coming in to land, a combined system of short-range radar and acoustic-location can be used. Technology can relate the population available for mist-net sampling to the overall migrating traffic.

Traditional migration monitoring capture rates are low, particularly for priority species. To determine if acoustic and radar technology could enhance the population sample, capture rates were compared across methods for a selection of nocturnal migrants that are priority species for Partners in Flight-Canada (*table 4*). The comparisons included the current capture rate over a network of Canadian Migration Monitoring Network (CMMN) stations, capture rate at an individual station (Mackenzie Bird Observatory), acoustic detection by BirdCast® (i.e., available for acoustic-location) and tracked at landing heights by an adapted short-range radar (i.e., available for mist-nets). The average traffic rate was converted from 2/min to a number comparable to mist-net captures (i.e., 12,000 /100 hr). As only 50 percent of tracks are likely to have calls (Millikin 2001), the potential acoustic detection is estimated to be 6,000/100 hr. The Gray-cheeked Thrush (*Catharus minimus;* GCTH), was used as an indicator of catchability, since stations with the priority species, the Bicknell's Thrush (*Catharus bicknelli*), are not yet contributing data to the CMMN. The low mist-net capture rate could be augmented by using short-range radar and acoustic-location to select sites that concentrate these species and/or by simultaneous measurement with independent sampling methods.

Knowledge Gained by Technology Related to Migration Monitoring

As mentioned, significant findings have come out of Europe and North America from the use of technology to understand migration (Eastwood 1967, Williams and Williams 1972, Able 1973, Richardson 1978, Schaefer 1979, Bloch and Bruderer 1982, Clark et al. 1986, Cooper and Ritchie 1995, Hamer et al. 1995, Nisbet et al. 1995, Akesson et al. 1996, Bruderer and Leitchi 1998, Bruderer et al. 1999, Evans and Mellinger 1999, Fortin 1999, Klaassen and Biebach. 2000, Russell and Gauthreaux 1999, Williams et al. 2001, Zehnder et al.

2001). A selection of authors and their contributions is provided in *table 5*. WSR-88D would be an example of pulse Doppler radar. The blank row in *table 5* shows a gap in information that is required to correlate the number of birds landing with population trends.

The examples of contributions below support the further use of automated technology in migration monitoring: (1) Zehnder et al. (2001) using tracking radar, found weather factors explained two-thirds of the variation in intensity of bird migration; (2) Williams et al. (2001) using short-range radar found mountain ridges act as landscape barriers; (3) Fortin et al. (1999) used infrared to show that levels of dehydration and fat affect a bird's decision to stop or go; and (4) Nisbet et al. (1995) showed the bulk of evidence for transoceanic flights of Blackpoll Warbler, *Dendroica striata*, (19 out of 25 papers) came from radar studies.

Table 4—*Comparison of the capture rate by current migration monitoring methods (census and mist-net; CMMN), acoustic sampling (BirdCast®), and radar sampling (Tracked SRR) of selected nocturnal migrants that are priority species of Partners in Flight-Canada.*

Priority species[1]	CMMN		BirdCast®	Tracked SRR[3]
	No. stations	No. /100 nhr[2]		
Bicknell's Thrush (GCTH)	4/10	0.042	√	√
Blackpoll Warbler	7/10	0.641	√	√
American Tree Sparrow	3/10	0.006	√	√
Clay-colored Sparrow	3/10	0.174	√	√
White-throated Sparrow	9/10	0.184	√	√
Purple Finch	1/10	0.099	√	√

[1]selected from Dunn and others 1999
[2]1998-2001 average from 17,091.22 hrs, Mackenzie Bird Observatory
[3]SRR = Short-range radar
Notes: Current capture rate was calculated using the rate over a network of Canadian Migration Monitoring (CMMN) stations and at one station, Mackenzie Bird Observatory. BirdCast® results illustrate acoustic sampling capability; a check mark indicates the species could be detected and located. Radar capability was illustrated using short-range radar; a check mark indicates the species could be tracked to landing and thus indicates the capture rate. This does not imply species identification by radar alone. To compare the radar capture rate with netting results, the average migration traffic rate of 2 birds/min translates to 12,000 birds/100hr. Only 50 percent of radar tracks are likely to have calls (Millikin 2001), so the potential calls for species identification were estimated to be 6,000/100hr.

Table 5—*Knowledge gained by six technologies on issues affecting the success of migration monitoring.*

Issue	Short-range radar	Tracking radar	Pulse Doppler radar	Phased-array radar	Acoustic sampling	Infrared	Reference
Correlation between numbers landing and population trends							
Effect of weather	√	√	√			√	Eastwood 1967; Able 1973; Bloch and Bruderer 1982; Richardson 1978; Zehnder and others 2001
Behavior at ecological barriers	√					√	Fortin and others 1998; Klaasen and Biebach 2000
Migration routes	√	√		√		√	Nisbet and others 1995; Bruderer and Leichi 1998; Williams and others 2001
Migration spatial distribution	√	√			√		Williams and Williams 1972; Larkin 1982; Millikin 2001
Threats to survival in migration	√						Cooper and Ritchie 1995; Hamer and others 1995
Use of species-specific night flight calls					√		Evans and Rosenberg 2000

Notes: WSR-88D is an example of pulse Doppler radar.

Summary

In this paper, I discussed how automated radar, infrared, and acoustic technologies can augment mist-net and census data in the monitoring of bird migration. Automated technology can supplement ground-based methods of migration monitoring by providing unbiased and automated sampling, independent validation of current methods, a larger sample area for landscape-level analysis of habitat selection for stopover, and an opportunity to study flight behavior. In particular, radar-acoustic fusion can provide information on species-specific landing behavior to indicate what portion of the population that pass over a site are available for ground-based monitoring using mist-net capture or census.

The recommended approach would be to use long-range radar to suggest funneling routes, then sample within those regions with short-range radar for preferred landing sites. Add acoustic-location to select landing sites that concentrate species of concern. Situate the mist-nets and census route within the range of detection of the radar-acoustic system for a better comparison between sampling methods.

Suggestions for Future Directions

In establishing a network of migration monitoring stations, site selection should be conducted using unbiased observations of landing behavior. Radar-acoustic fusion could be used at a long-term banding site such as Long Point Bird Observatory, to determine under different flight conditions, what portion of the migrant population land to then be available for mist-net and census. Historical data could be reanalyzed with the adjusted population trend indices. By locating individual birds in flight, it is now possible to ask which species do not call and therefore, cannot be monitored using acoustic-sensing or acoustic-location methods. A combination of methods can be used to understand the importance of landscape barriers and the validity of critical habitat for stopover.

Acknowledgments

I am grateful to the Department of National Defense and the Royal Military College of Canada for supporting my research on radar and acoustic technology. Special thanks to V. Lambie, J. Blondek and M. Stivers for providing costing information, and to C. Francis and J. Carlisle for reviewing the manuscript.

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Appendix 1—*Rough cost comparison between the five technologies and the traditional ground-based method of migration monitoring.*

Cost comparison of technology versus traditional migration monitoring methods[1]

	Sampling						
Method	**Equipment**	**Personnel[2]**	**Analysis**	**Total cost**	**Relative cost**	**Area[3] (ha)**	**Source**
Mist netting and census[4]	15K	10K	2K	27	1	10	Lambie, pers. comm.
Long-range radar[5]	4K	1K	6K	11	0	40	www.intellicast.com
Short-range radar[6]	25K	20K	5K	50	2	10	Cooper 1995
Acoustic-sensing[7]	5K	4K	6K	15	1	8	Personal experience
Acoustic-location[8]	30K	4K	6K	40	1	8	Personal experience
Sensor fusion[9]	75K	4K	6K	85	3	8	Personal experience
Infrared[9]	31K	20K	3K	54	2	1	www.infrared.com

[1]costs estimated from web pages, personal experience and personal communication; K = $1000 CDN.
[2]assuming 0.03K/hr per technology personnel; actual costs for mist netting and census; actual costs for analysis.
[3]estimated ground coverage in hectares (1 hectare = 2.47 acres).
[4]average equipment and expenses for one traditional migration station (MacKenzie Bird Observatory) monitored 6 hr/day for 60 days.
[5]radar images from one WSR-88D (about 40 ha) for 11 hours per day for 60 days.
[6]one non-automated X-band surveillance radar (about 10 ha) for 11 hours per day for 60 days.
[7]one location set of acoustic stations (about 8 ha) for 60 days.
[8]one automated sampling of an 8 ha area of ground for 11 hours per day for 60 days.
[9]one 10-ha migration station for 11 hours per day for 60 days.

Radar Ornithology and the Conservation of Migratory Birds[1]

Sidney A. Gauthreaux, Jr.[2] and Carroll G. Belser[3]

Abstract

It is possible to study with surveillance radar the movements of migrating birds in the atmosphere at different spatial scales. At a spatial scale within a range of 6 kilometers, high-resolution, 3-centimeter wavelength surveillance radar (e.g. BIRDRAD) can detect the departure of migrants from different types of habitat within a few kilometers of the radar. The radar operator can also sample the flight speeds of targets in an attempt to classify birds by their velocity. At a larger spatial scale (10-60 kilometers), Doppler weather surveillance radar (WSR-88D) can be used to measure the density of birds in the radar beam as they begin a migratory movement (exodus) within 60 kilometers of the radar. Within minutes of the onset of nocturnal migration, the distribution and density of echoes in the radar beam can provide information on the geographical sources of migrants on the ground (migration stopover areas), and satellite imagery can be used to identify the topography and habitat type that characterizes these areas. At a continental scale, the national network of WSR-88D radars can be used to monitor bird migration over the United States on an hourly basis at different altitudes dependent on distance from the radar. The latter achievement is significant because it provides a means of monitoring the season-to-season and year-to-year variation in the patterns of migration at different altitudes for different geographical regions and the nation as a whole.

Key words: bird, conservation, habitat, migration, radar, scale, stopover areas.

Introduction

In the early 1940s shortly after its invention, ornithologists began using radar to study the movements of birds through the atmosphere (Eastwood 1967). Investigators began using low-powered surveillance radars (airplane and marine units) to monitor the movements of birds within a range of a few kilometers of the radar in the early 1960s (Graber and Hassler 1962, Casement 1966, Flock 1972, Williams et al. 1972). Since that time, low-powered (5-25 kW) marine radars have been used to monitor bird migration and assess the impact of transmission lines, wind turbines, and other man-made structures on bird movements (Gauthreaux 1985, Cooper et al. 1991, Harmata et al. 1999, Deng and Frederick 2001) and to monitor the movements of endangered and threatened species between feeding and breeding areas (Bertram et al. 1999, Burger 2001). Researchers have also used high-powered weather and airport surveillance radars to detect migrating birds at ranges out to 240 km (Flock 1968; Gauthreaux 1970; Gauthreaux and Belser 1998, 1999; Koistinen 2000) and have used long term data sets to monitor the decline in migratory birds returning from the tropics (Gauthreaux 1992). These studies demonstrate how radar can be used in the conservation of migratory birds, and in this paper we discuss some new approaches to the conservation of migratory birds using radar ornithology.

BIRDRAD

We currently have four projects with a radar we call BIRDRAD (bird radar). All of the projects emphasize bird movements studied at small spatial scales (within a range of 6 km) but the radar can detect large flocks of birds (migrating raptors) at ranges out to 15 km. The unit is a high resolution, marine surveillance radar (Furuno 2155 BB) with a 50 kW transceiver that transmits at 3 cm (X-band, 9415 MHz ± 30 MHz) wavelength at pulse lengths from 0.07 μsec to 1.2 μsec depending on the range selected (*fig. 1A*). The black box (BB) version eliminates the large radar monitor because the radar processor is in a flat black box mounted on a wall (*fig. 1B*) and the video display can be virtually any size non-interlaced, multi-sync personal computer monitor (CRTs as well as flat panel color LCDs with SXGA – 1280 x 1024 – resolution).

Instead of the slotted waveguide array (T-bar) antenna we use a parabolic antenna (1 m diameter) attached to the transceiver unit by a special mount (*fig. 1A*). This configuration produces a beam of 2.5º that can be elevated from 0º to 90º.

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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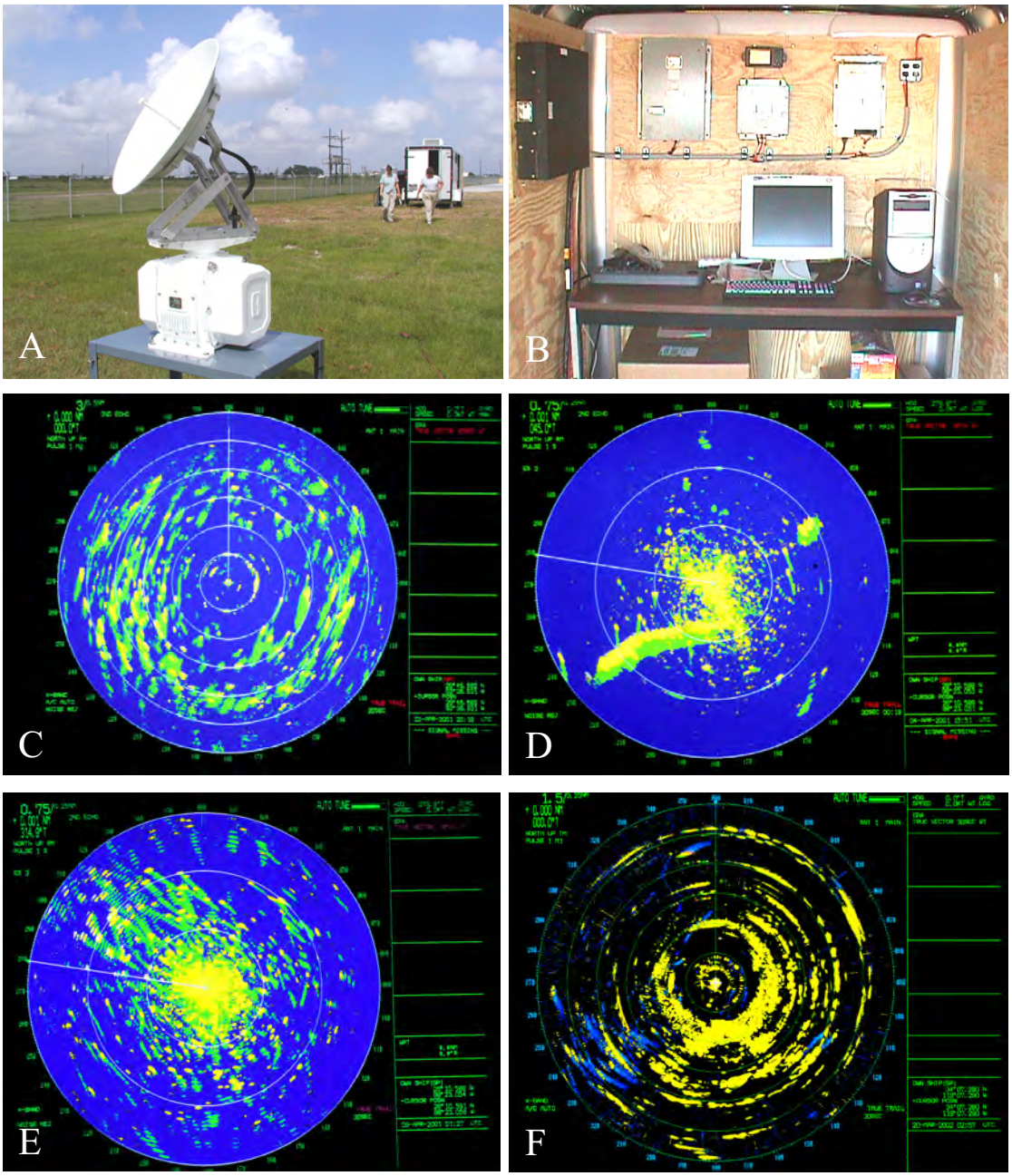

Figure 1— The high-resolution surveillance radar BIRDRAD. (A) The parabolic antenna-antenna mount-transceiver attached to metal cart. The transceiver is connected to the radar processor and electrical power with an 18.2 m cable; (B) the black box radar processor is attached to the left wall of the utility trailer and other power packs (e.g., rectifier) and a GPS display are mounted on the forward wall. The radar display controller keyboard, the personal computer, and monitor are on the desktop; (C) a radar image (5.6 km or 3 nautical mile range and 30° antenna elevation) showing the arrival of flocks of trans-Gulf migrants over the southwestern Louisiana coast on 22 April 2001 at 20:19 UTC; (D) a radar image (1.42 km or 0.75 nautical mile range and 22° antenna elevation) showing a stream of migrating raptors during the glide phase over Bentsen-Rio Grande Valley State Park, Texas on 4 April 2001 at 15:51 UTC; (E) a radar image (1.42 km range and 22° antenna elevation) showing the beginning of an exodus of migrants from Bentsen-Rio Grande Valley State Park, Texas on the evening of 9 April 2001 at 01:27 UTC. More bird targets are departing from the area just north of the radar site (above center) where trees have thicker foliage than from the area just south of the radar site (below center) where trees have less foliage and are dying; (F) a radar image (2.84 km or 1.5 nautical mile range and 10° antenna elevation) showing the departure of waterfowl from wetlands to the lower left of the display at Pt. Mugu Naval Air Station, Ventura, CA. In images C-E the echo trail color is green; in image F the echo trail color is blue. Echo-trails are set for 30 sec.

Moving targets on the radar display are readily detected because of the radar's echo-trail feature. The current position of a target is shown in one color while the previous positions of the target are shown in a different color (*figs. 1C-F*). Echo-trail duration can be selected from 30 sec to continuous. Because targets may leave the radar beam before 30 sec or enter the beam after the start of a 30 sec sample, it is not possible to determine the speed of movement from echo trails. It is also possible to plot manually the speed and direction of 10 individual targets on the display using an electronic plotting aid (EPA). A target is marked and then after a period of time (at least 30 sec) the target is marked again and the following data are generated on the display: range, and speed and direction of movement. The radar is also integrated with a Geographical Positioning System (GPS) so that the latitude and longitude of targets under the control unit cursor can be easily determined. All pertinent radar data (e.g., mode, pulse length, echo-trail length, date, time, and GPS coordinates) are displayed as alpha-numerics in the image. Additional characteristics of the Furuno 2155 BB can be found at the Furuno web site (http://www.furuno.-com/).

We record radar images with a frame grabbing board (Foresight Imaging HI*DEF Accura) in a Pentium processor personal computer. Auto-SYNC software automatically configures the HI*DEF Accura board to the radar analog video source and the software also enables individual image capture at original resolution (SXGA – 1280 x 1024). Images are saved in a bitmap file format. We are currently using BIRDRAD to monitor the arrival of trans-Gulf migrants on the northern coast of the Gulf of Mexico (*fig. 1C*), the migration of raptors through south Texas in the spring (*fig. 1D*) and South Carolina in the fall, the exodus of migrants from different types of habitat (*fig. 1E*), and bird movements in the vicinity of military airfields (*fig. 1F*). The benefits of using BIRDRAD to study the movements of birds through the atmosphere outweigh the costs. The radar unit is less expensive (about $30,000 US) than larger more powerful surveillance radars and can be easily moved from location to location and operated on a gasoline generator. Because of the high resolution of the radar (short pulse length and narrow beam width) we can often see the shapes of large flocks and can estimate altitudes of targets. The echo trail and EPA plotting features provide detailed data on the direction and speed of target movement. By using a frame grabber we do not need to photograph the video display. Ground clutter (radar echoes returned from stationary ground objects) can sometimes dominate a display, but it is still possible to detect moving targets (*fig. 1F*). The radar would be more useful if it displayed quantitatively the reflectivity of targets, had moving target indicator (MTI) circuitry that displayed only moving targets without stationary ground clutter, and provided radial velocity of targets. However these features would greatly increase the cost of the radar.

WSR-88D (Doppler Weather Surveillance Radar)

We currently have two projects that use the WSR-88D. One emphasizes the mapping of migration stopover areas throughout the United States and monitoring input to and output from those areas. The other concerns mapping the distribution and abundance patterns of migration over the United States based on data from the national network of WSR-88D stations. The WSR-88D (referred to as NEXRAD for next generation radar during the developmental and early operational years) has a peak transmitter power of 750 kW and a frequency range of 2.7 GHz to 3.0 GHz (10.3-11.1 cm or S band). The antenna is 9 m and the beam width is 0.96º with pulse widths of 1.57 μsec to 4.5-5.0 μsec. The characteristics of bird echoes on the WSR-88D and its use for studying bird movements can be found in Gauthreaux and Belser (1998, 1999).

Migration Stopover Areas

We use two WSR-88D products: base reflectivity and base velocity images to detect migration stopover areas during spring and fall. The base velocity image shows the radial velocity of radar echoes and is used with winds aloft data to distinguish birds from other reflectors in the atmosphere. The 2-5 reflectivity images that show the beginning of bird migration on a given night and are free of obscuring precipitation or other radar interference within 120 km of the radar are compiled for further processing. Generally from 8 to 17 nights per site per year meet the above criteria. The reflectivity images are then processed to emphasize areas of high relative bird density (birds km^{-3}) and the resulting imagery is converted to rectangular raster and imported into ArcInfo. The map showing important migration stopover areas is then compared with land cover maps based on classified Landsat data (*figs. 2A* and *B*).

Preliminary findings suggest that most stopover areas along the Gulf and Atlantic Coasts are associated with floodplain topography and upland areas are used less. Forested wetlands are used almost exclusively as important stopover areas and extensive pine flatlands are rarely used (Gauthreaux, unpubl. data).

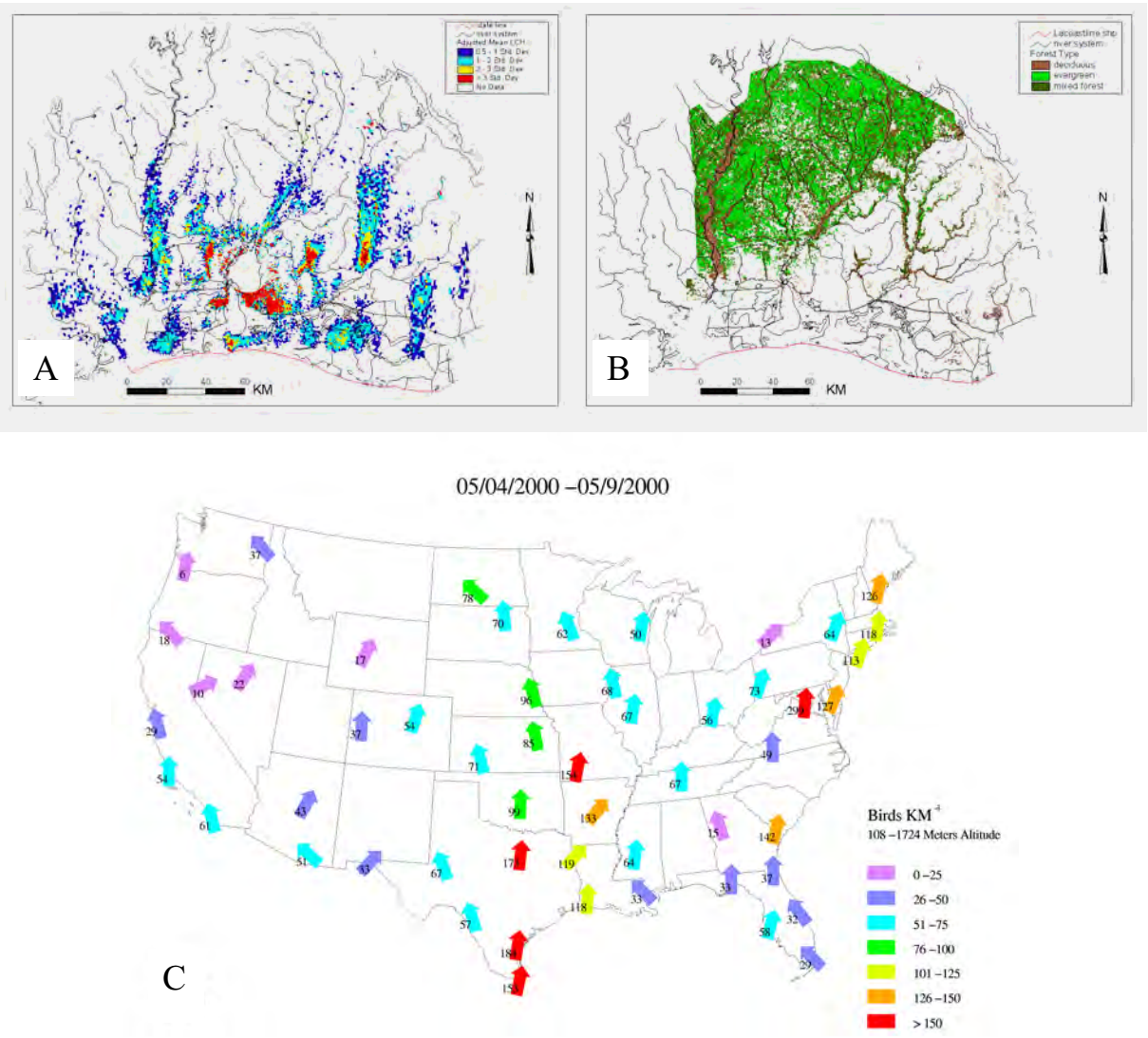

Figure 2— WSR-88D migration projects. (A) migration stopover areas based on radar data from southwestern Louisiana collected during spring migration from 1998 through 2001. All the pixels represent bird densities at least 0.5 standard deviations above the mean, (B) classified forest type from LANDSAT data showing deciduous forested wetlands (brown), evergreen pine forest (light green) and mixed deciduous and pine forest (dark green). Migration stopover areas are associated with the floodplain forest, (C) national migration map for the nights 4-9 May 2000 showing the mean density and direction of migration between 108 and 1724 m above ground level. The colors represent mean numbers of birds km^{-3} (see text for additional details).

Mapping Patterns of Migration over the United States

To construct national migration maps of the relative density and direction of bird migration for each night during spring and fall we used two WSR-88D products—base reflectivity and base velocity images. Images were collected each night between 2-3 hours after sunset and near the peak of a night's migration from each of 70 WSR-88D stations near weather stations that measured winds aloft, because winds aloft data were necessary for subsequent processing of radar imagery. Each station reflectivity image was previewed to eliminate those containing obscuring weather or other interference. To determine the extent of insect contamination or other aerial plankton in an image, we used winds aloft data. The tabular wind data from the atmospheric sounding (radiosonde) were converted to raster GIS to produce a wind base velocity product, and this product was used to threshold the radar base velocity raster data. If the mean radial velocity of a resolution cell (pixel) did not exceed a threshold of 10 knots above the radial velocity of the wind, the resolution cell was eliminated. The surviving radar base velocity raster data (containing velocities appropriate for birds) were used to mask the radar base

reflectivity data so that only reflectivity resolution cells containing velocities defined as birds were selected. We then used velocity to infer direction by finding the direction of maximum outgoing velocity within an altitudinal zone (*table 1*) and then calculating the mean number of birds km^{-3} in a 30° wedge centered on that direction. In the map an arrow shows the direction of migration for a radar station, and the color of the arrow indicates the average number of birds km^{-3} in the 30° wedge (*fig. 2C*). As the radar beam moves out from the location of the radar it samples increasing altitudes. Because of the expansion of the radar beam, its tilt, and the curvature of the earth, at increasing ranges the altitudinal strata sampled by the radar beam overlap (*table 1*). Because of this we generate a migration map for each altitudinal zone.

Table 1— *The altitudes sampled by the WSR-88D with a 0.96° beam width when the antenna is tilted 0.5° above the horizontal.*

Range from radar	Altitudes sampled (AAH)[a]
antenna to 40 km	antenna height to 754 m
40 km to 80 km	108 m to 1724 m
80 km to 120 km	431 m to 2909 m
120 km to160 km	970 m to 4309 m

[a]Above radar level

The use of a standardized procedure to generate national migration maps based on radar data will not only document the temporal and spatial patterns of migration for four altitudinal zones nationwide but also permit quantitative season-to-season and year-to-year comparisons among different regions of the United States (Gauthreaux et al. 2003). In the long term the maps can be used to monitor the health of the North American bird migration system.

Acknowledgments

Radar work at the Clemson University Radar Ornithology Laboratory is supported by the Department of Defense, Legacy Resource Management Program and the Department of the Navy, Naval Facilities Engineering Command Headquarters. Houston Audubon Society provided initial funding for our WSR-88D work along the northeastern Gulf coast of Texas. We wish to thank D. Van Blaricom and A. Cunningham for their work on the file format of the WSR-88D products, development of computer programs and GIS work. We appreciate the helpful reviewer comments from D. Bonter and R. Millikin.

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Introduction to the WSR-88D (NEXRAD) for Ornithological Research[1]

Robert H. Diehl[2,3] and Ronald P. Larkin[4]

Abstract

The system of Doppler weather surveillance radars known as WSR-88D or more popularly as NEXRAD helped transform radar ornithology in the United States into a field that today attracts considerable attention from scientists and laypersons alike. As interest in ornithological applications of WSR-88D grows, so does the need to provide perspective on its use. In this paper, we introduce WSR-88D and consider issues associated with interpretation of WSR-88D imagery and quantification of data. Because particular interest surrounds radar's potential to associate bird numbers with specific habitats or land use features, we address some of the challenges in making such associations focusing specifically on migrating landbirds. Readers interested in applying WSR-88D should gain appreciation of the technical challenges as well as the biological potential of this radar system for ornithological research.

Introduction

New technology spurs scientific progress. Bird migration research benefited greatly from the introduction of radar as a biological tool (Lack and Varley 1945). Radar revealed the structure and intensity of nocturnal bird migration (e.g. Nisbet 1963, Eastwood 1967, Gauthreaux 1971) beyond the pioneering moon watching studies which first showed nocturnal migration on a continental scale (Lowery 1951, Lowery and Newman 1966). Nisbet (1963) and Gauthreaux (1970) developed novel approaches to quantifying bird densities from the analog displays of WSR-57 (Weather Surveillance Radar, design year 1957), the United States' first generation of weather surveillance radar. Years later, commissioning of the WSR-88D (Weather Surveillance Radar, 1988 Doppler) or NEXRAD (NEXt generation weather RADar) in the mid-1990's represented a substantial leap in radar technology available to ornithologists, entomologists, and others. This system of radars differs from its predecessor in several important ways: it is Doppler capable and considerably more sensitive; it is digital and established and increasingly sophisticated data distribution channels allow ready access to data for a large user community; radars within the system are uniform by design and widely distributed.

With these improvements, the system boasted enormous potential to advance our understanding of behaviors and patterns of animal distribution and movement across many spatial and temporal scales. As striking radar imagery of bird migrations began to appear in scientific presentations and the popular media, many biologists, governmental and non-governmental organizations, and members of the general public realized the potential of WSR-88D for avian conservation, management, and education. However, imagery from WSR-88D failed to convey the complexities of treating these data quantitatively while avoiding sources of bias.

In this paper, we present a brief introduction to methodological issues concerning use of the WSR-88D for ornithological research. Although many concepts presented here apply to other radars, this paper is not intended as an exhaustive review of applied radar methods in ornithology (see also Eastwood 1967; Vaughn 1985; Bruderer 1997a, b). Rather, our goal is to provide perspective and raise awareness regarding some applications of WSR-88D in studying migrating birds.

Patterns of radar echo have numerous biological and non-biological causes that must in part be understood to interpret and apply this technology properly. We introduce basic WSR-88D operation and its base products (reflectivity, velocity, and spectrum width) and consider range bias, resolution, identity of echo sources, aspect effects, clutter, and refraction in properly interpreting and quantifying radar echoes from WSR-88D. These are interacting factors. For example we present clutter and refraction as separate sections, but when atmospheric conditions permit, refraction may dramatically increase the influence of clutter. Finally, we consider the association between radar echoes from migrating birds just after takeoff with their source stopover habitats. Understanding and recognizing radar artifacts such as velocity aliasing and second-trip echo, however, are beyond the scope of this paper. Doviak and Zrnic (1993) and Rinehart (1997) consider these in some detail. For simplicity, we emphasize landbird migration, but the principles often apply more broadly.

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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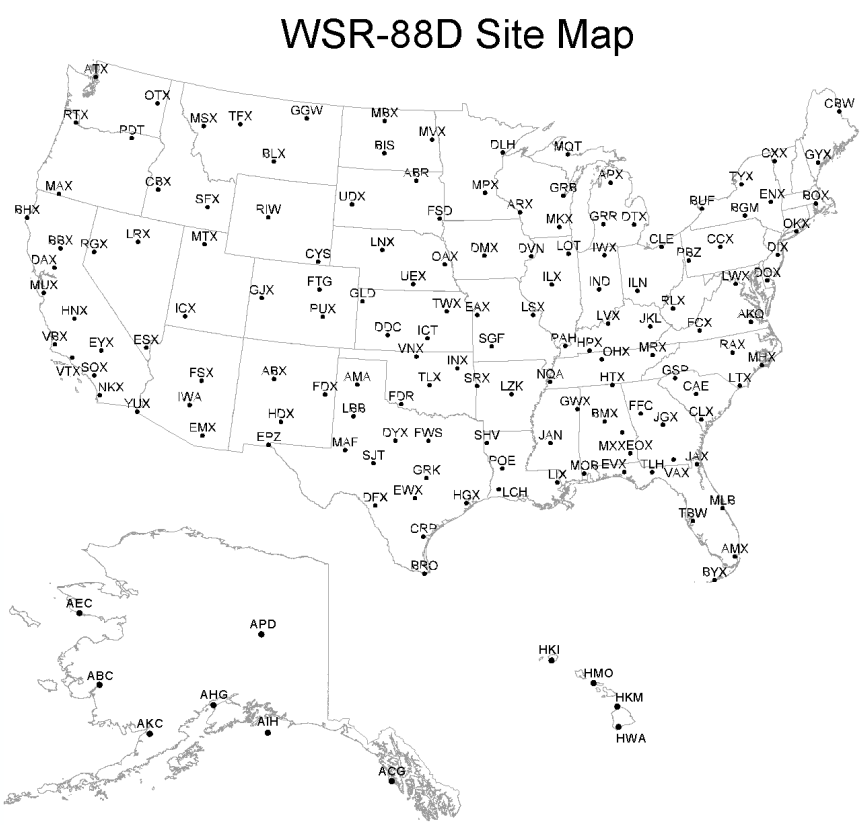

Figure 1— Locations of 154 radars comprising the current WSR-88D system. Radars in Guam and Puerto Rico are not shown.

WSR-88D Products and Operation

WSR-88D is a system of 154 S-band (10-cm wavelength) radars distributed across the continental United States, Alaska, Hawaii, Guam, and Puerto Rico (*fig. 1*). Because WSR-88D by design monitors weather systems over large geographic areas, the system is inherently well suited to studying the larger spatial scales of bird distributions and movements aloft (Gauthreaux and Belser 2003, Gauthreaux et al. 2003). The distribution of radars in the WSR-88D system does not define the spatial extent that bird movements can be studied by surveillance radar in North America. Both Canada (http://weatheroffice.ec.gc.ca/radar/index_e.html) and Mexico (http://smn.cna.gob.mx/radares/radares.html) maintain weather surveillance radar systems that together increase the spatial scale of monitoring that might be possible if data from these different systems were merged.

Radars within the WSR-88D system are identical in design, simplifying system-wide understanding and application. However, operational parameters (see also 'Resolution and Data Sources') and other factors such as ground clutter rejection and radar siting (see below) vary by radar (Crum and Alberty 1993). Analyses involving multiple radars, therefore, might require that data from each radar be treated individually.

Each radar in the WSR-88D system switches between two modes of operation and characterizes echoes through three base radar products–reflectivity, radial velocity, and spectrum width. These modes differ primarily in the number of sweeps in a volume scan, temporal resolution, and for Level III data, scaling and resolution of reflectivity. In clear-air mode, the radar's beam sweeps through five different elevations between ~0.5° and ~4.5° in ~1° increments to complete a volume scan. Precipitation mode volume scans contain either 9 or 14 sweeps in varying increments ranging from ~0.5° to ~19.5°. All figures depicting radar imagery in this paper show data from the 0.5° elevation sweep. Stacking the sweeps from these volume scans, we can view vertical structure in bird density and movements (Diehl et al. 2003). However, earth's curvature frequently limits the usefulness of such cross-sections to short ranges.

Reflectivity

Each image in *figure 2* depicts echo strengths, or radar reflectivity factor (hereafter referred to as "reflectivity"), as colors that vary with reflectivity. Reflectivity is

usually presented in units of Z, a standard measure from radar meteorology which describes the amount of echo caused by distributed targets (such as rain, insects, and birds) in the volume of space being measured (see 'Beam Geometry' below). Because Z varies greatly depending on the size and number of targets, it is usually presented logarithmically as dBZ. Under suitable circumstances, WSR-88D Z serves as a proportional substitute for bird density, although understanding the relationship between Z and bird density remains an important and complex area of research (Gauthreaux and Belser 1998, Black and Donaldson 1999, Gauthreaux and Belser 1999, Diehl et al. 2003). However, many applications of WSR-88D do not require absolute estimates of bird numbers or density. Comparing reflectivities may be perfectly adequate.

Radial Velocity

Radars in the WSR-88D system measure target speeds toward or away from the radar using Doppler shift. Measured Doppler speeds reflect birds' true ground speeds only when those birds move directly toward or away from the radar, otherwise measured speeds represent that fraction of birds' ground speed toward or away from the radar. Birds exhibiting relatively uniform speeds and directions of travel typically appear on velocity imagery as in *figure 3 (left)*.

Velocity data challenge even skilled interpreters of radar imagery. Velocities of bird targets seldom appear quite as uniform as in *figure 3*, because birds' directions of travel vary in response to differing wind fields and other factors (Myres 1964, Diehl et al. 2003). As an example, we briefly discuss the common and relatively simple case of "bird shear" below (see 'Range Bias').

Spectrum Width

Spectrum width describes variation in Doppler speeds of targets. As of this writing, the National Climate Date Center (NCDC, http://www.ncdc.noaa.gov) distributes spectrum width data as part of its "Level II" and "Level III" radar product suite (Crum and Alberty 1993, Crum et al. 1993). This product is not frequently used in meteorology and the only mention of bird spectrum widths in the ornithological literature is by Larkin (1991, but see Larkin and Diehl in press). In short, spectrum width remains a radar moment with unexplored potential for biological targets.

Beam Geometry

Weather surveillance radar is not designed to monitor single or "point" targets, but rather multiple targets distributed throughout a volume of space known as a pulse volume. Complete description of this term is beyond the scope of this paper; however the size of a pulse volume is determined by the width of the radar's beam and the resolution in range along the beam. The WSR-88D beam is conical in shape and nominally 1° wide. Along the beam, the amount of radio energy returning to the radar is recorded every kilometer for reflectivity, and every 250 m for velocity and spectrum width. The pulse volume increases in size with distance from the radar and represents the smallest quantifiable measure of reflectivity or velocity.

Figure 4 shows details of the beam geometry in reflectivity and velocity. In this two-dimensional view, each rectangle represents a top down view of one pulse volume. Because the beam is conical, we know its height matches its width. Notice range resolution in velocity is four times that in reflectivity and that reflectivity pulse volumes appear nearly square because the beam is ~1 km wide at 60 km range.

Armed with a basic understanding of reflectivity, velocity, beam geometry, and a little biology, this example of waterfowl movements on radar (*fig. 4*) proves quite informative. A local feeding flight and a migratory flight are closely juxtaposed. Arriving waterfowl represent birds returning from feeding and moving toward the radar (shown as green in velocity), while departing waterfowl represent those initiating migration and moving away (shown as red in velocity). Without velocity, these separate behaviors would be difficult or impossible to distinguish. Ten minutes later, radar showed no waterfowl in flight toward the radar as feeding birds arrived at Lake Springfield (shown in blue on *figure 4*), and migrating birds had completely departed from the lake and continued to head toward the SE.

Assuming birds flew at similar heights (see 'Range Bias' below), it would appear from reflectivities (*fig. 4*) that waterfowl returning from feeding outnumbered those departing the lake on migration. Although the exact relationship between reflectivity and waterfowl density remains unknown, we can enumerate the total reflectivities (total Z) associated with birds returning from feeding and the total reflectivity of those migrating to determine which were more numerous. Velocity reveals which corresponding reflectivity pulse volumes should be associated with arriving or departing birds. Birds arriving from feeding outnumbered migrants by more than 3 to 1 (1177 Z v. 353 Z) even while migrating birds covered 4 times the area (29 v. 114 km^3). Using $Z \cdot km^{-3}$ as a relative measure of average bird density aloft, arriving birds were 13 times more dense in their airspace than migrating birds were in theirs.

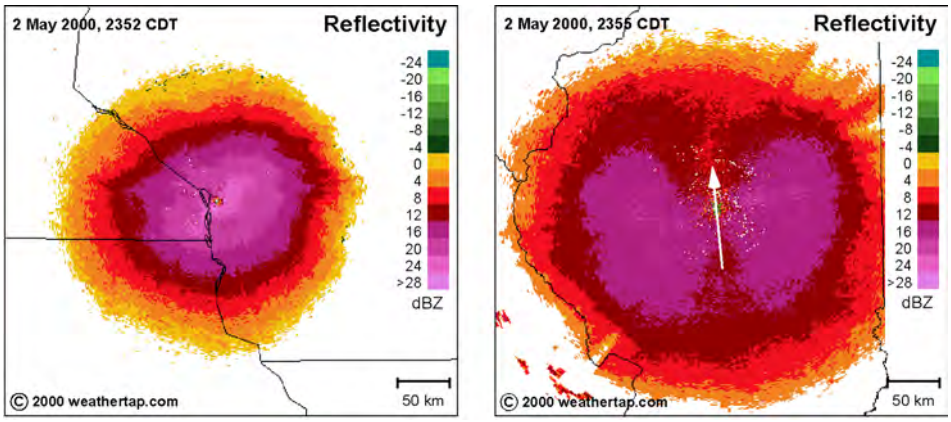

Figure 2— Mid-nocturnal migratory bird reflectivities at La Cross, Wisconsin (KARX, left) and Lincoln, Illinois (KILX, right). In each image the radar is located central to the pattern, and both depict migration on 2 May 2000 (at 00:55 CDT [left] and 00:53 CDT [right]). Birds having similar orientations around KILX cause a butterfly-shaped pattern of reflectivity. The arrow indicates the direction of birds' headings suggested by this pattern. (See text for full description of aspect.)

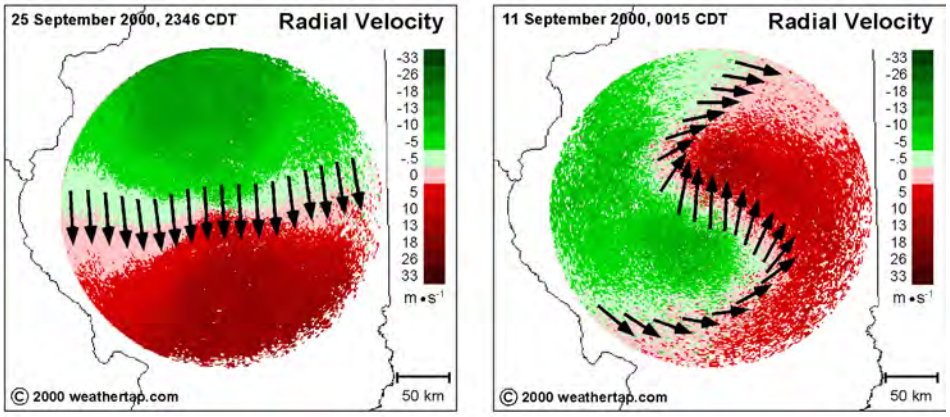

Figure 3— Uniform (left) and shear (right) radial velocity fields on WSR-88D. Greens show movement toward the radar, reds away, and darker shades indicate higher speeds. Pink ranges between -0.5 to 2.5 $m \cdot s^{-1}$ and includes the Doppler null, where speed toward the radar is zero (B. Hibbert, National Weather Service, pers. comm.). Arrows indicate direction of travel under uniform (left) and shear (right) wind conditions (see 'Range Bias').

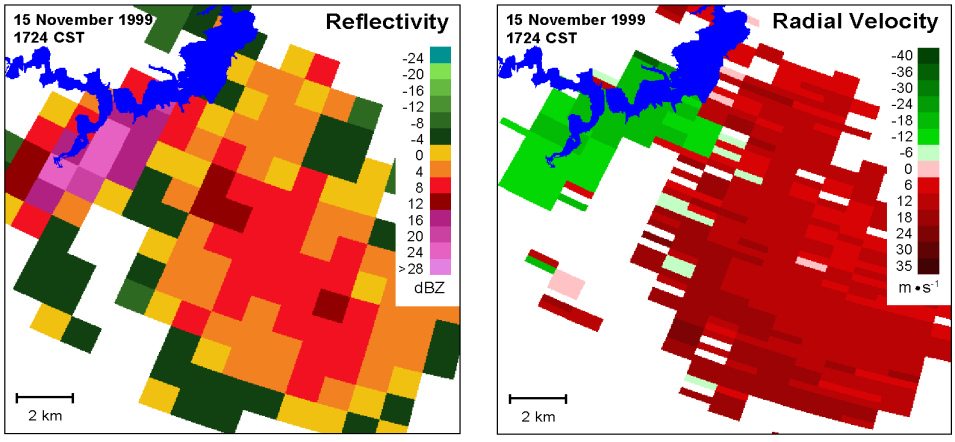

Figure 4— A close view of reflectivity (left) and radial velocity (right) generated by different flights of waterfowl simultaneously arriving to and departing from Lake Springfield, Illinois (shown in blue) on 15 November 1999. The radar at Lincoln, Illinois (KILX) is located ~60 km NNE from the center of these images. Reflectivity pulse volumes measure 1° in width by 1 km in depth; velocity pulse volumes measure 1° by 250 m. Velocity (right) shows waterfowl arriving from feeding (in green moving toward the radar) and waterfowl departing on migration (in red moving away from the radar). Although arriving waterfowl occupy less airspace than those initiating migration, high values of reflectivity (left) show arriving birds outnumber departing birds by more than 3 to 1.

Range Bias

Quantifying reflectivities requires that we account for range bias introduced as an artifact of the radar looking through a migratory layer. This bias appears in imagery as a decrease in reflectivity with range from the radar as the beam increasingly passes over the migratory layer (*fig. 5*). This geometric constraint, and not the sensitivity of the radar's receiver, usually limits the maximum range birds can be detected (but see 'Refraction' below). Range bias varies in degree depending on height of migration, the distribution of biological targets below that height (layered or even), radar siting, refraction, and relief in terrain. As a result, attempts to correct for such bias before quantification must be adaptive and radar site specific.

Frequently we compare reflectivities from different regions within a radar's coverage (e.g. see Larkin et al. 2002, Diehl et al. 2003). In the absence of correction, one should accommodate range bias by limiting such analyses to similar concentric ranges (Diehl et al. 2003). We do not know how similar in range compared regions should be to sufficiently nullify the effects of bias, however this probably varies with conditions.

Assuming propagation of the radar's beam with standard refraction (see 'Refraction' below), the height of the center of the radar's beam above the earth's surface at a specific range from the radar, h_{br}, can be calculated as (modified from Rinehart 1997),

$$h_{br} \quad \sqrt{(R'^2 + r^2 + 2 \cdot R' \cdot r \cdot \sin(\phi))} - R' + (h_a - h_r) \qquad (1)$$

where ϕ is the elevation angle or tilt of the radar's beam above the horizon (0.5° for many biological applications), r is range from the radar, $R' = 4/3 \cdot R$ where R is the earth's radius (again see 'Refraction' below), h_a is the height of the radar antenna above sea level (ASL), and h_r is height of terrain ASL at the range and azimuth of interest. Partial or complete beam blockage occurs when $h_r \geq h_{br}$ (but see 'Clutter' below).

To know the range of heights above ground level (AGL) of a radar's beam is to know something about the height of birds in the beam. However, WSR's tend to be broad-brush instruments (see 'Resolution' below), and compared to most weather echoes, the migratory layer is rather shallow, often not exceeding 2 km AGL. Nonetheless, equation 1 and *figure 5* show that radars see higher flying birds at longer ranges. As a result, the radial pattern of echoes seen in the data (and on the resulting imagery) is shaped by factors that influence migratory behavior and that vary with height in the air column.

Shear in velocity with height demonstrates this also (*fig. 3*). Arrows in both frames of *figure 3* show the direction of movement tangential to the radar along the Doppler null (see 'WSR-88D Products and Operation' above). The left panel shows bird migration in a nearly uniform wind field. Several phenomena may produce velocity patterns shown in the right panel, but most likely birds are responding to wind shear, on this night a change in wind direction of >60° with height AGL. The beam intersected low flying birds close to the radar (where the effects of earth's curvature are not pronounced) which experienced different winds than higher flying birds intersected by the beam further from the radar. In response to winds, birds varied in their direction of travel some 100°, toward ~0° at ground level to ~100° at around 2000 m AGL.

In the absence of substantial refraction, our planet is too small and the layer of most nocturnal migration over land to shallow for the radar to see birds much beyond 200 km range. Even seemingly small increases in the beam's elevation dramatically reduce the range of detection due to earth's curvature and height of migration. (Increasing beam elevation from 0.5° to 1.5° decreases the range radars detect birds by more than a factor of two.)

Resolution and Data Sources

Design limits impose boundaries on a technology's range of applications. Usually with any measuring technology there are trade-offs in resolution. Because the WSR-88D is designed to monitor the behavior of large weather systems, it is ill-equipped to monitor small-scale atmospheric motion. For example, WSR-88D performs admirably in detecting tornados but reveals almost nothing about their internal structure (a task left to smaller portable radars [e.g. Wurman et al. 1996]). The same kind of thinking should be applied to radar ornithology and the role of WSR-88D in the broader study of bird migration (see Moore et al. 1995). Different biological questions require measurements of varying resolution, and what is "sufficient resolution" is context-specific. In terms of temporal resolution for example, ideally, the time scales over which events occur determines the rate at which those events are sampled. However, presently-fixed maximum sampling rates, as is the case with WSR-88D, set limits on the ability to quantify or understand events that occur over relatively short time scales as will be shown below (see 'Habitat-migrant Associations' below). In this section we consider resolution in four parameters as they vary with data source–space, time, reflectivity, and Doppler velocity–and which in part define WSR-88D as a tool for studying patterns of animal movements.

WSR-88D resolution varies depending on the source of data. Level II data from NCDC offer the highest

resolution in all parameters (*table 1*). As of this writing, Level II data are accessible via the internet (see http://has.ncdc.noaa.gov/plclimprod/plsql/HAS.DsSelect, Droegemeier et al. 2002), but until recently, special software is required to view the data as imagery (see WATADS 2000, Murray et al. 2003). Alternatively, Level III data (or raster imagery based on these data) which are derived from Level II data, represent a less costly, lower resolution, and presently more commonly used source of data from WSR-88D. Prior to January 2001, Level III data were distributed by the NEXRAD Information Dissemination Service or NIDS. Now the National Weather Service distributes Level III data directly in near real time (see http://www.nws.noaa.gov/tg/rpccds.html). Compared to Level II data, Level III data offer identical temporal resolution, but lower spatial resolution in Doppler products and in the product value itself (the amount reflectivity, radial velocity, or spectrum width; *table 1*).

Table 1– *Comparison of WSR-88D data types (see also Crum et al. 1993 and Klazura and Imy 1993).*

Parameter	Level II	Level III[a]
Spatial resolution (deg x km)		
Reflectivity	1° x 1	1° x 1
Radial velocity	1° x 0.25	1° x 1
Spectrum width	1° x 0.25	(1° x 1)
Temporal resolution[c] (min)	5–10	5–10
Reflectivity resolution (dBZ)	0.5	4–5[b]
Doppler resolution ($m \cdot s^{-1}$)	0.5	ca. 9–18
Number beam elevations	all 5–14[c]	lowest 4
Archived	yes	yes
Near real time availability	yes/no[d]	yes

[a]Formerly available in near real time only through NIDS (NEXRAD Information Dissemination Service). The National Weather Service (NWS) also provides access in near real time via ftp (see http://www.nws.noaa.gov/tg/rpccds.html). Competition among ftp users (see 'a' above) for scarce bandwidth limits this as a viable source for large quantities of data.

[b]Resolution varies with the radar's mode. Precipitation mode: updates every 5-6 min, 5 dBZ resolution in Level III. Clear-air mode: updates every 10 min, 4 dBZ resolution in Level III.

[c]The volume scan strategy, and therefore the number of elevations or tilts, varies with mode.

[d]As of writing, a maturing pilot project to disseminate Level II data to the end user in near real time (Droegemeier et al. 2002) includes as data recipients private companies and public research institutions.

Spatial constraints in WSR-88D data are determined in part by pulse volume dimensions, beam elevation, volume scan strategy (see 'WSR-88D Products and Operation' above), range, and distribution of radars in the system (*fig. 1*). The size of pulse volumes imposes hardware design limitations on small scale spatial resolution. This is not to suggest that this spatially-constraining property of the radar necessarily prevents study of patterns at sub-volumetric scales. However, achieving spatial resolutions beyond that imposed by this technological boundary will likely require software with some sophistication.

As with spatial resolution, the adequacy of existing temporal resolution in WSR-88D data varies depending on the phenomena being observed. Short term behaviors such as takeoff and landing patterns may or may not be adequately sampled (e.g. see 'Habitat-Migrant Associations' below). Other biological patterns or phenomena might require decades to measure, such as changes in migration intensity in response to large scale changes in land use, changes in migratory routes or timing of migration in response to climate change, changes in habitat use with succession, habitat loss, or restoration. Weather radar technology should prove well suited and valuable for monitoring such changes; however, on these time scales, the radar equipment itself changes (e.g. receiver sensitivity, coverage, polarization diversity [Zrnic and Ryzhkov 1999]), and care will be required to avoid bias introduced by an evolving technology.

Changes in the radar's mode of operation (see 'WSR-88D Products and Operation' above) coupled with the manner in which Level III presents data from different modes result in competing resolution issues–as temporal resolution increases, resolution in reflectivity decreases. In clear-air mode, data update about every 10 min and reflectivity is binned into 4 dBZ wide categories and span a range well suited to those useful for monitoring birds, bats, and insects (e.g. *figs. 2, 4, 5,* and *6*). In precipitation mode, data update every 5-6 min, but range bins are wider, 5 dBZ, and reflectivities below 5 dBZ are suppressed. Thresholding and the larger bin sizes in precipitation mode accommodate a greater range of reflectivities for meteorological applications but limit resolution of bird reflectivity patterns that may be biologically important.

Because Level III data present reflectivity in 4 and 5 dBZ wide bins in clear-air and precipitation mode respectively (8 to 10 times more coarse than Level II data, *table 1*), bird densities that vary by a factor of 2.5 to 3.2 are not resolved as different levels of reflectivity. This lack of precision obscures subtle variations in the distributions of birds (e.g. Diehl et al. 2003) and contributes to uncertainty in the relationship between bird densities and WSR-88D reflectivity (Gauthreaux and Belser 1998, Diehl et al. 2003).

Identity of Echoes

Lifetimes could be spent identifying the sources of surveillance radar echoes. WSR-88D echoes originate from many sources including smoke, dust, insects,

birds, bats, many forms of precipitation, chaff, clutter of all kinds, and so on. In addition, echoes from different taxonomic groups of birds are often so broadly overlapping in WSR-88D radar characteristics that they exhibit little identifying signature per se without considering the broader non-radar context of those echoes (Russell et al. 1998, Harmata et al. 1999; see also Emlen 1974). Landbirds, waterfowl, and roosting birds might remain as mysterious unidentified radar "angels" (to borrow a term from the early history of radar meteorology, Eastwood 1967, pp. 60-76) without information on the timing of migration, feeding behavior, and habitat preferences. Although the list is not exhaustive, bird echoes exhibit the following characteristics:

- occur in strength only certain times of year
- occur in strength only certain times of day
- tend to emanate from particular habitats in particular ways depending on taxa
- tend to appear over large geographic areas
- tend to appear when weather is suitable for migration
- tend to exceed in strength echoes caused by insects (but there is overlap)
- exhibit velocities (speed and direction) that differ considerably from the wind's (Gauthreaux and Belser 1998, see below)
- exhibit patterns consistent with known migratory behavior aloft (e.g. aspect effects [see above], dawn ascent and reorientation [Diehl et al. 2003])
- tend to decrease in reflectivity radially because most birds are low flying and concentrate in the lower two kilometers of the troposphere (see 'Range Bias' above)
- exhibit characteristic spectrum widths (Larkin and Diehl in press)

Most non-bird echoes are avoided by including only data that meet most of these criteria (although ground clutter can remain a problem, see below). However, because birds and insects often migrate together, analyses of bird migrations almost invariably include some insects. Research in progress seeks to learn the degree to which insects contribute to reflectivities, radial velocities, and spectrum widths.

In quantifying bird migrations using WSR-88D, the contribution of insects which bias measured reflectivities, velocities, and spectrum widths attributed to birds should be minimized. This might be accomplished in several ways. First, include only the strongest migrations that produce echo strengths generally not attainable by insects (Larkin 1983, Gauthreaux and Belser 1998). A preferable alternative method considers the velocities of birds and insects with respect to the wind. Prevailing winds largely determine the speed and direction of migrating insects. Birds by comparison exhibit velocities that differ from wind in speed, direction, or both. In this way insect-dominated migrations can be detected and removed from analysis (Gauthreaux and Belser 1998). Finally, migrations dominated by insects often differ from those dominated by birds in spectrum width (Larkin and Diehl in press).

Future versions of WSR should boast polarization diversity, the ability to transmit and receive radio energy where the electric field varies in its polarization with respect to the surface of the earth (the 88D is currently fixed at horizontal polarization). Research surveillance radars equipped with polarization diversity already demonstrate potential to separate bird from insect echoes (Mueller and Larkin 1985, Zrnic and Ryzhkov 1999).

Sunset

Because each radar measures bird movements at large spatial scales, the setting sun might introduce bias in reflectivity along an east-west gradient as birds take flight following the terminator. As an example, consider the influence of the terminator passing through typical WSR-88D coverage at 42° latitude on the appearance of birds on radar shortly after takeoff. At this latitude, the east-west span of echoes shortly after takeoff when birds are most closely associated with their source habitats is approximately 130 km. The terminator passes over this coverage area in about 6 minutes at ~20 $km \cdot min^{-1}$. Compared to the duration of takeoff (ca. 30 min.; Hebrard 1971, Akesson et al. 1996), the terminator passes rather quickly and could introduce bias in measures of bird reflectivity at a single radar. However, studies comparing data from multiple radars at similar latitudes will have to adjust for this effect.

Aspect

Birds and insects scatter different amounts of radar echo depending on which aspect of these animals' bodies faces the radar. Animals detected side-on reflect more radar energy than when detected head- or tail-on (Edwards and Houghton 1959). It follows that similar bird and insect densities aloft may produce reflectivities that vary greatly in strength at different azimuths

depending on the orientation of animals' bodies with respect to the radar (*fig. 2*; Edwards and Houghton 1959, Schaefer 1976, Mueller and Larkin 1985, Buurma 1995). The effect is most apparent during mid-migratory flight and is especially pronounced in *figure 2* (right).

Aspect effects indicate that targets are biological, however, such effects complicate use of surveillance radar in relating bird numbers to radar reflectivity or comparing reflectivities at different azimuths (Diehl et al. 2003). *Figure 2* (right) shows aspect responsible for order-of-magnitude differences (12 dBZ between azimuths 353° and 79°) at similar ranges in reflectivity during cruising flight. Bias caused by aspect effects (if present at all) may be swamped by the strong influence of other factors on birds' behaviors, particularly during times other than cruising flight. For example, the distribution of stopover habitat in the landscape is often strongly reflected in the pattern of echoes during takeoff.

The strength of aspect effects varies depending on the proportion of targets that assume similar headings, the dimensions of targets, and possibly the size of targets with respect to the wavelength of the radar (further description of this later point is beyond the scope of this paper, but see Doviak and Zrnic 1993, pg. 35). Under certain migratory conditions, aspect effects may become more apparent as birds encounter circumstances that cause them to be oriented similarly, such as during dawn reorientation (Myres 1964, Diehl et al. 2003). Also, the proportion of high aspect (length/width ratio) targets such as insects in the migratory pool, when oriented similarly, will amplify aspect effects.

Regarding *figure 2*, it remains unclear why the effects of aspect differ so dramatically in these images from two separate radars while occurring at the same time within ~400 km of each other. The spatial coverage and rate of decrease in reflectivity with range also differs considerably between the images. Such differences may reflect real biology, for instance that on this night birds migrated lower over SW Wisconsin than over central Illinois. Alternatively, such patterns might emerge if the amount of refraction varied at the two cites or if KARX was sited considerably higher than KILX. (KARX height exceeds KILX's by only 52 m, not enough to fully account for a ~50 km difference in maximum range of detection.) Such uncertainties highlight some of the discrepancies that emerge when comparing observations between different radars.

Clutter

One scientist's noise is another's signal. This succinctly describes the often competing interests of radar meteorologists and radar biologists where "clutter" is a matter of opinion. Rinehart (1997) describes clutter as "…echoes that interfere with observation of desired signals on a radar…". Clutter includes airborne targets (e.g. from a meteorological or ornithological perspective - chaff, smoke, aircraft) although the term is usually used in reference to targets on the ground or the ground itself where topographic relief obstructs the radars beam either partially or completely.

Human infrastructure represents a common source of unwanted ground clutter echoes which appear in WSR-88D data. Recurring ground clutter idiosyncratic to each radar can be mapped locally. These clutter maps then mask out areas of strong clutter. Nonetheless echoes caused by more dynamic sources such as vehicles on overpasses or trains find their way through existing WSR-88D clutter filters (Chrisman et al. 1995) and into data. Ground clutter echoes are often strong and their inclusion in the data could severely bias measures of reflectivity attributed to birds if not avoided or removed through further filtering. Because ground clutter concentrates near the radar, conservative approaches to avoiding the effects of clutter might include discarding echoes within a certain range or along particular azimuths. Unfortunately, these rather straightforward approaches often discard bird echoes along with the clutter. More sophisticated approaches employ software to identify and specific "clutter like" radar data while leaving biological or other desired echoes.

Relief in terrain often obstructs a radar's beam either partially or entirely (Klazura and Imy 1993) depending on the obstructing object's size, height, and distance from the radar, and the elevation of the beam and beam width at the range of the obstruction. Complete obstruction of the beam is easily seen, usually as a wedge devoid of echo (*fig. 6*). Similar wedge shaped areas of reduced reflectivity occur during partial beam blockage. Because partial blockage effectively eliminates low height targets as sources of echo, range is also reduced at these azimuths (*fig. 6*). Sometimes radars detect targets behind obstructing objects when diffraction spreads the radio energy that comprises the radar's beam into the geometric shadow of those obstructions.

For these reasons, beam blockage limits the efficacy of some radars for ornithological studies; at least reported reflectivities at such radars should be open to suspicion. The simplest way to minimize ground clutter as a source of bias is to avoid quantifying suspect regions of radar coverage. Alternatively, using data from higher elevation sweeps of the radar's beam reduces the beam's encounters with ground based clutter. Unfortunately, this also reduces the radar's usefulness for low-height applications such as habitat-migrant associations (see below).

During atmospheric conditions that promote non-standard or anomalous propagation of the beam (see 'Refraction' below), ground clutter may appear in unusual places or at exceptionally long ranges from the radar. Therefore quantifying reflectivities at longer ranges (and presumably at greater heights, see 'Range Bias' above) does not necessarily eliminate the likelihood of encountering ground clutter. Ground clutter may variously appear at many ranges depending on whether and how the atmosphere influences refraction.

Refraction

Radar radio energy propagates in straight lines only in a uniform medium. The earth's atmosphere is not uniform, so the direction radar energy propagates changes as it passes through the atmosphere. Under certain circumstances, the propagation path of a refracting radar beam can be calculated. During standard atmospheric conditions, temperature and moisture gradients that decrease monotonically with increased height produce a "standard refraction" gradient which tends to bend the beam along a path, R', equal to 4/3R where R is earth's radius. For this reason, estimates of beam height must take standard refraction into account (see Eqn. 1 and 'Range Bias' above).

Steeper than normal gradients in moisture or temperature cause superrefraction, resulting in anomalous propagation of the radar's beam. A superrefractive atmosphere can change the propagation of a radar's beam strongly enough to detect low targets such as migrating birds at exceptionally long ranges ($4/3R > R' \geq R$). For example in *figure 2*, a superrefractive atmosphere around KLOT might explain differences in the maximum range radars at KARX and KLOT detected birds. In more extreme cases, radar energy can be refracted back toward earth resulting in ground clutter echoes ($R' < R$) or propagated along layers in the atmosphere called ducts. In *figure 6*, a radar beam likely propagating though an atmospheric duct echoes off relief along the coast of Michipicoten Island and Pukaskwa National Park, Canada.

Habitat-Migrant Associations

Probably the most anticipated ornithological application of WSR-88D to date involves associating patterns of bird echoes at takeoff with the stopover habitats from which they departed (Moore et al. 1995; see also Moore 2000). WSR reveals birds' stopover habitats as nocturnal migration begins with a sudden exodus around evening twilight. After several minutes, birds climb high enough to be visible as radar echoes, where stronger echoes represent more birds. At this early stage of a night's migration, bird reflectivities throughout the coverage range of a radar can vary by orders of magnitude, with stronger echoes occurring over habitat that held more birds during the day. In short, radars reveal stopover habitat use from the birds' migratory behavior at takeoff, and this capability can be exploited to estimate relative bird densities associated with specific landscapes or habitat types (Gauthreaux and Belser 1998).

This method leads to large scale quantitative information on where migratory birds stopover, in what numbers or densities, and what land use and other characteristics of the landscape act to explain observed distributions of birds. By quantitatively identifying areas exhibiting high landbird use during stopover, these observations have implications for on-the-ground landbird conservation. Accurately quantifying habitat-migrant associations, however, requires that biologists who apply WSR for these purposes overcome or at least consider several challenges.

Displacement and Dispersion

Birds initiating migration move away from their stopover habitats at speeds and directions that vary with season, prevailing winds, and other factors. Birds may require several minutes flight time after takeoff to gain sufficient altitude to become visible as radar echoes. As a result of flight beneath the radar's beam, migrating birds might first appear as echoes several kilometers from their departing stopover habitats. The resulting spatial separation or displacement between bird echoes and their source habitats, if corrected, yields more appropriate associations between stopover habitats and the number of birds (i.e. amount of reflectivity) emanating from those habitats. This is depicted conceptually in *figure 7* where, in the absence of correction, direct spatial association between the landcover and bird echoes would result in the strongest echoes (red) improperly being associated with agriculture. As the shaded gray of *figure 7* implies, habitat-migrant associations improve in accuracy if made earlier in the takeoff phase. The trade-off to this strategy is that earlier in the migration, birds are closer to the ground and even less visible to radar at range due to earth's curvature. To account for this spatial separation between bird echoes during takeoff and the stopover habitats from which birds emerged, reflectivities can be shifted to directly overlay departure locations. However, methods for determining the amount of displacement should avoid assumptions about which habitats are associated with which bird echoes.

The amount of displacement may vary with range from the radar. In the absence of refraction and other confounding factors, birds detected at longer ranges are flying at higher altitudes (*fig. 5*) and presumably have

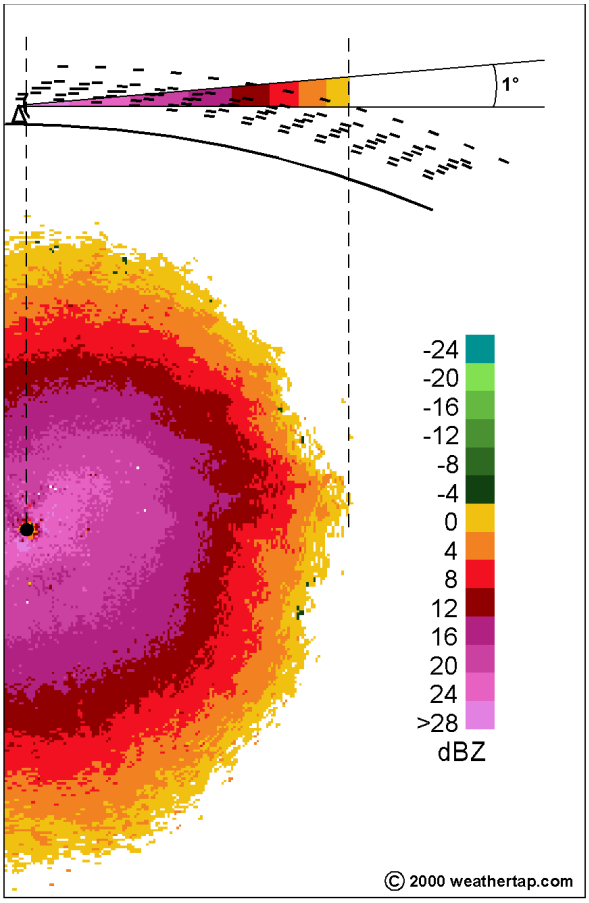

Figure 5— A conceptual cross-section above (not to scale) is matched to real echo typical of bird migration around the middle of the night. The radar, indicated by a black dot, is detecting birds out to ca. 150 km. Because the earth curves out from under the radar beam, a layer of echo that is limited in height (here a hypothetical migratory bird layer) will be visible only out to a certain distance. Colors show decreasing echo strength with increased range from the radar as the beam passes over the migratory layer.

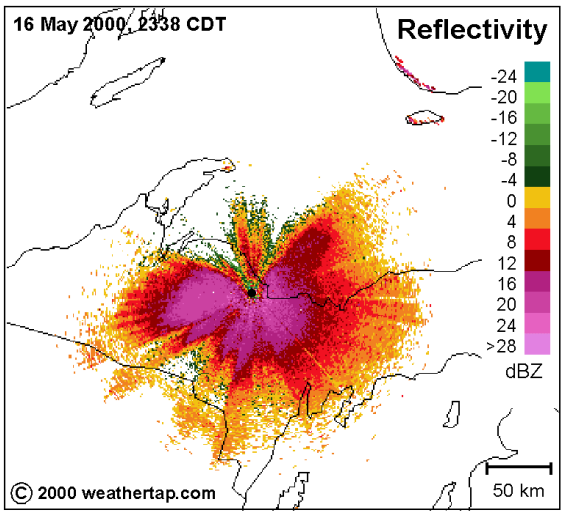

Figure 6— Ground clutter dominates reflectivity patterns of migrating birds around KMQT (Marquette, Michigan). An intermittently obstructed beam leaves wedges of reduced or absent reflectivity at many azimuths. At longer ranges northeast of the radar, a refracted beam illuminates relief along the coast of Michipicoten Island and the Pukaskwa National Park area shoreline in Canada.

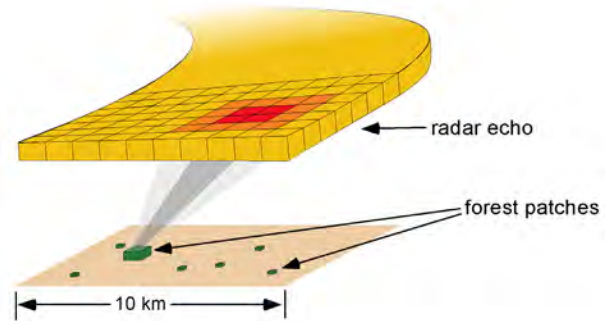

Figure 7— A hypothetical cross-section of radar echoes caused by birds over an agricultural landscape containing scattered forest fragments. During takeoff, birds become dispersed (gray) and become spatially offset or displaced from their source stopover habitat. Birds departing smaller fragments and insects contribute to the din of echo (yellow) not specifically associated with a particular patch.

been aloft longer. Because the distance birds fly after takeoff determines the magnitude of the displacement, birds aloft longer have presumably flown further. Therefore, birds detected at longer ranges may be more displaced from their source habitats than those at shorter ranges. Implementing range-specific corrections for this possibility adds considerable complexity to achieving best possible habitat-migrant associations.

If delayed much past twilight, habitat-migrant associations are further muddied by the manner in which birds depart from source habitats. First, birds continuously streaming out of habitats will tend to blur habitat associations by making it impossible to offset the data to account for displacement without appreciably influencing other nearby habitat-migrant associations. Second, echoes from nearly adjacent habitat patches will blend, complicating association with habitat. For this reason, small-scale habitat-migrant associations are limited by both the spatial resolution of commonly available data (see 'Resolution' above and *table 1*) and the dispersion of migrants into airspace that, in the case of small source habitats, may span over several times the land area of the source stopover habitat (e.g. *fig. 4,* see also *fig. 7*). We view the latter as one of the more

profound obstacles to using WSR-88D to make small scale habitat-migrant associations.

Data Selection

Once echoes are determined to be caused predominantly by birds, radar data suitable for habitat-migrant associations must be selected. As indicated above, these data typically occur during takeoff when birds are still spatially associated with the habitats they recently departed. Usually, only two or perhaps three sweeps of the radar's beam capture data suitable for association with habitat. The process of choosing which of these sweeps best represents the distribution of birds in stopover habitat before takeoff balances (1) selecting data where migration is sufficiently developed against (2) selecting data where migration has not advanced so far as to allow displacement and dispersion (see above) to compromise tight habitat-migrant associations. Ideally, objective data selection emerges from simple criteria having a biological basis.

Nonetheless, objective methods of selecting data can be limited by the low temporal resolution of the WSR-88D and the relatively brief duration of takeoff. To demonstrate this we consider the time course of landbird migration as seen by KILX in Lincoln, Illinois on 20-21 May 2000 (*fig. 8*). This example typifies temporal patterns of migration captured on other days and by other radars. Takeoff occurs over a relatively narrow time window, about 30 min (Hebrard 1971; see also Akesson et al. 1996), where the number of birds entering the airspace increases by a factor of 15 in 30 min. In clear-air mode, WSR-88D sweeps the same airspace every 10 min. At this sampling rate, the radar might capture two sweeps useful for habitat-migrant associations.

Naturally, the onset of migration and the timing of WSR-88D data collection are not synchronized. As a result, daily measures of reflectivity during takeoff reflect both real differences in bird density and differences in the timing of WSR-88D sweeps along a rapidly changing continuum of reflectivities (*fig. 8*, ca. 20:59 CDT). For this reason, WSR-88D samples the fast changes in reflectivity during takeoff too slowly, introducing error into comparisons between takeoff reflectivities across days at the same radar or between radars. When habitat-migrant associations are not a consideration, daily comparisons are best attempted between the takeoff and landing phases of migration when the rate of change in reflectivity is considerably lower as shown in *figure 8* around 2200 CDT.

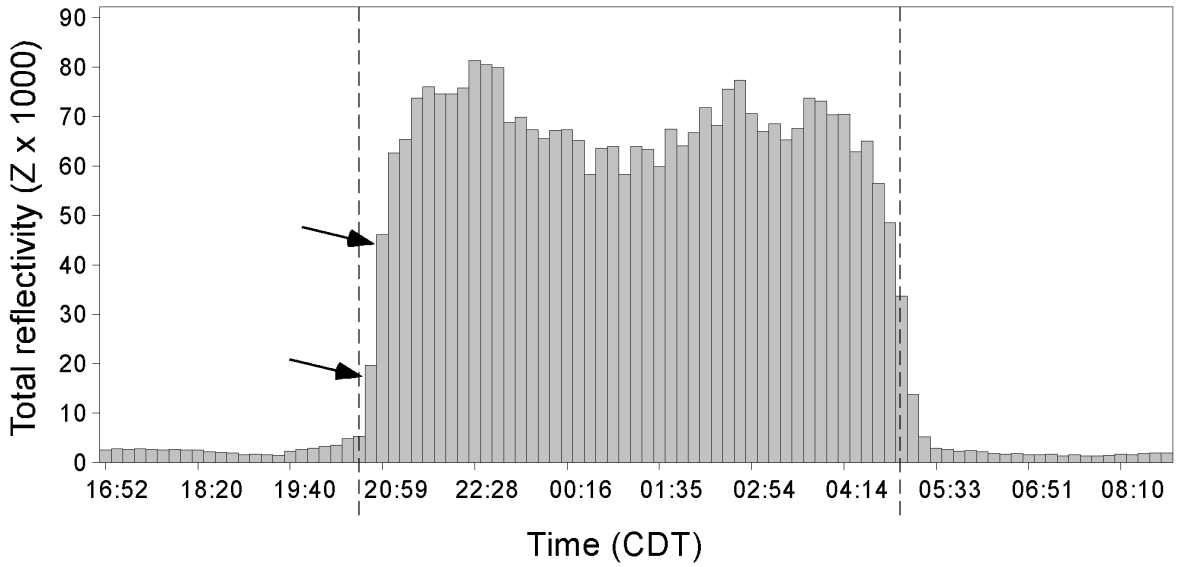

Figure 8— Total reflectivity 35-50 km from KILX (Lincoln, Illinois) before, during, and after migration on 20-21 May 2000. The bimodal appearance is common although its origin remains unknown. Such patterns may result when a migratory bird layer passes through the beam at 35-50 km range on takeoff and through again toward the end of the night. Each of 93 bars is separated by 10 min and represents an independent sweep of the radar. Arrows indicate sweeps that are candidates for analysis of takeoff patterns on this day. Dashed lines show evening and morning local civil twilight at 20:43 CDT and 05:05 CDT respectively.

Summary

Over the past few years, Imagery of bird migration from the WSR-88D system rekindled interest in radar ornithology in the United States. However, correctly using these data to advance knowledge of avian behavior during flight, stopover biology, and bird conservation and education challenges research biologists. In this paper we explored many factors, often interacting, that may influence interpretation and quantification of WSR-88D echoes for ornithological research.

We hope that practical boundaries to the range of ornithological applications for WSR emerge from this paper. The physics and geometry constraining most weather radars' views of the world remains fixed and must be accommodated when applied to biological research, yet we hesitate to suggest many absolute limits to its use in such studies. The potential of WSR-88D and related systems for ornithological research remains largely unexplored, and weather surveillance radar itself is an evolving technology (Serafin and Wilson 2000).

In the future, improved radars and methods of distributing data will advance radar ornithology considerably. Higher precision Level II data is already becoming broadly available (Droegemeier et al. 2002) and other surveillance radar systems (specifically TDWR or Terminal Doppler Weather Radar; see Serafin and Wilson 2000, Droegemeier et al. 2002) may provide more resolute and complementary coverage of migration. If and when existing radars in the WSR-88D system are outfitted with dual-polarization (Zahrai and Zrnic 1997), new base products will become available. These may be capable of enhancing the radar's ability to discriminate migration dominated by birds versus insects (Zrnic and Ryzhkov 1998), improve ground clutter filtering and suppress 2nd trip echo (Zrnic et al. 1998), and reveal biological behaviors with greater clarity (e.g. aspect effects, see Zrnic and Ryzhkov 1999).

Acknowledgments

We thank J. Black for helpful discussions and anonymous reviewers for their comments on an earlier draft of this paper. We also thank M. Woodrey for inviting us to present on this subject at the 3rd International Partners in Flight Conference, and thanks to our colleagues at the Moss Point, Mississippi workshop for providing perspective toward content. R. Parsons and Weathertap.com generously provided data from WSR-88D for support of this and other radar biological work. This work was supported in part by National Science Foundation grant DEB-0073114.

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Linking Breeding and Overwintering Areas of Five Nearctic-Neotropical Migratory Passerines Using Molecular Genetic Markers[1]

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Key words: connectivity, phylogeography, mtDNA, Neotropical migrants.

Introduction

Demographic studies of Nearctic-Neotropical migrant songbirds have been limited by the difficulty of following them through a complete annual cycle (Webster et al. 2002). As population regulation may conceivably occur on either the breeding area, wintering areas, or on migration routes, determining levels of connectivity of populations between a species' breeding and wintering areas is fundamental to understanding the dynamics of migrant populations. An alternative to marking and tracking individuals (of limited use in small passerines) is to use population-specific genetic markers. A major advantage of this approach is that it relies on the genetic characteristics of the whole population (based on the relatedness among its individuals), and therefore a particular individual does not have to be recaptured or followed.

Molecular genetic markers have been used successfully to examine connectivity in shorebirds (Wenink and Baker 1996, Haig et al. 1997) and more recently in some small passerines (Buerkle 1999, Milot et al. 2000, Kimura et al. 2002, Ruegg and Smith 2002, Lovette et al. in press). In order to apply molecular methodologies effectively to the question of connectivity between populations, genetic variation in these populations needs to be geographically structured (geographic populations need to be genetically differentiated) and the chosen molecular marker must be sensitive enough to detect existing structure. The finer the scale of geographic structure resolved by a particular genetic marker, the more useful it will be in resolving breeding origins.

We have assessed the utility of mitochondrial DNA (mtDNA) markers in determining breeding origins of five long-distance Neotropical migrants: the Yellow-breasted Chat (*Icteria virens*), Nashville Warbler (*Vermivora ruficapilla*), Common Yellowthroat (*Geothlypis trichas*), Wilson's Warbler (*Wilsonia pusilla*), and Swainson's Thrush (*Catharus ustulatus*). We assessed the extent of mtDNA phylogeographic structure and used these data to assign individuals captured on wintering sites in Mexico, Central America, and South America to their respective breeding areas.

Methods

Sampling and Molecular Approaches

Blood and feather samples were collected from adult birds mist-netted at breeding sites in Canada and the United States, and at overwintering sites in Mexico, Central America, and South America. Blood samples were obtained by sub-brachial venipuncture, and feather samples by plucking the outermost two rectrices. See Kimura et al. (2002) and Ruegg and Smith (2002) for methods of DNA extraction, sequencing, and restriction enzyme digests.

For each species, we first reconstructed a phylogeny based on mtDNA sequence using samples from across the breeding range. We then identified restriction enzymes that were diagnostic of statistically well-supported, geographically defined lineages. Enzyme assays were used to screen samples from individuals captured on overwintering areas to assign them to geographically-defined breeding areas.

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California**.

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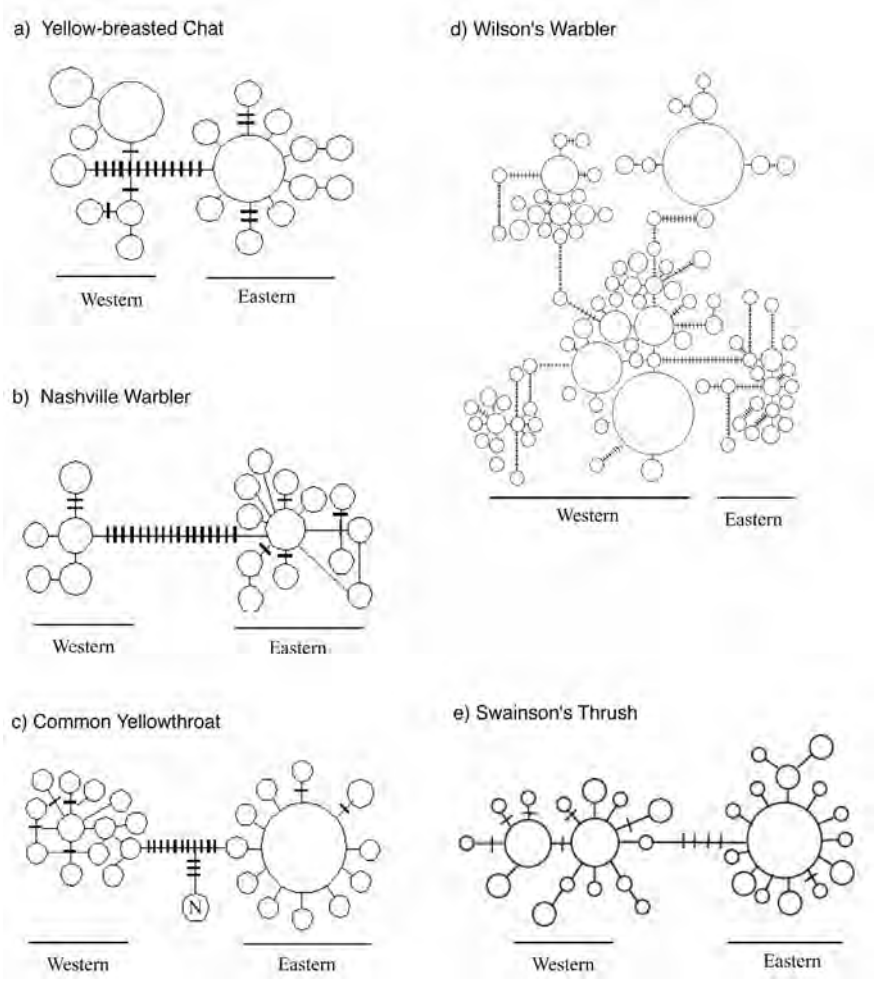

Figure 1— Minimum-spanning network with each unique haplotype indicated by a circle and area proportional to the number of individuals sampled. Hatch marks along branches indicate inferred haplotype differences. Eastern and western geographic lineages indicated below each network. (a) Yellow-breasted Chat - mtDNA ATPase sequences were obtained from 34 individuals, including 11 eastern and 7 western individuals. A total of 18 unique haplotypes with 17 nucleotide substitution (1.8 percent sequence divergence) between eastern and western populations (Lovette et al. in press); (b) Nashville Warbler – sequences obtained from 27 individuals, including 18 eastern and 9 western individuals. Eastern and western haplotypes differed by 16 to 22 substitutions, 1.7-2.3 percent sequence divergence (Lovette et al. in press); (c) Common Yellowthroat – sequences from 47 individuals with a maximum of 19 nucleotide substitutions (2 percent) (see Lovette et al. submitted); (d) Wilson's Warbler – mtDNA control region sequences from 200 individuals. 94 unique haplotypes were identified and eastern and western haplotypes differed by a minimum of 22 substitutions (see Kimura et al. 2002). Divergent Nevada haplotype indicated by "N'; (e) Swainson's Thrush - mtDNA control region sequences from 183 individuals showing with a net sequence divergence between lineages of 0.69 percent (Ruegg and Smith 2002).

Results and Discussion

Patterns of Variation on the Breeding Grounds

A number of common patterns in population genetic structure are evident among all five species (*fig. 1a-e*). The most obvious similarity is that each species is divided into two main haplotype groups associated to varying degrees with eastern and western sampling sites. The level of divergence between these groups was between 0.5 and 2 percent, consistent with a late Pleistocene divergence when using the prevailing molecular clock for mtDNA of 2 percent per million years (Avise and Walker 1998, Kimura et al. 2002, Ruegg and Smith 2002). Another similarity among the five species was the relative lack of geographic structure within eastern and western haplotype groups. These relatively low levels of variation could be due to current or historical gene flow, or past demographic events such as demographic bottlenecks followed by rapid range expansions (e.g. Milá et al. 2000). The high level of homogeneity across broad geographic areas, most evident in the eastern lineage of all sufficiently sampled species, suggests that eastern and western lineages may have had different demographic histories. In general, there was a slightly higher degree of geo-

graphic structure within western groups (*fig. 1*), possibly stemming from less severe effects of glaciation in the west, or the maintenance of higher levels of population subdivision over long periods. In addition, some species showed hints of greater phylogenetic structure that are important to note. In the Common Yellowthroat, there was a divergent haplotype from Nevada separated from the eastern group by 7-9 nucleotide substitutions (point mutations) and from the east by 12-16 substitutions (*Fig. 1c*). This population begs further investigation and may represent a distinct migratory population, or possibly a non-migrant population that may extend southward where we did not sample (Lovette et al. submitted). In Wilson's Warbler, more structure was detected among western populations than we found in the other species. An analysis of molecular variance (AMOVA) revealed both significant within and between-population variation (Kimura et al. 2002). It is possible, however, that similar complexities could be revealed in the other species if sampling were conducted with similar intensity as that for these western Wilson's Warbler populations.

Distribution of Genetic Lineages at Overwintering Sites

The distribution of eastern and western lineages on the wintering grounds differed among species (*fig. 2a-e*). This ranged from complete segregation to some geographic mixing of eastern and western groups at locations on the wintering grounds. In the Yellow-breasted Chat there was no evidence of mixing of eastern and western groups at wintering locations, although samples for any given site were small (*fig. 2a*). Overwintering western groups of the chat were distributed from Southern Baja California to Oaxaca, Mexico. Eastern groups were found from Vera Cruz south through Chiapas, and at sites in Belize and El Salvador. Samples for the Common Yellowthroat were restricted to only three sites, but nevertheless are informative (*fig. 2b*). Only western individuals were found in southern Baja, a mixed population was found in Oaxaca, and only eastern individuals were found in Belize. In contrast, haplotype distributions for the Nashville Warblers revealed only two out of out nine sites with western birds (a site in Sinaloa with 9 individuals and a site in Oaxaca with one individual), while eastern individuals were distributed throughout the wintering range (*fig. 2c*). Limited mixing of breeding lineages at overwintering sites was evident for Wilson's Warbler, mostly in Vera Cruz and Chiapas. Western haplotypes predominated throughout the wintering range (*fig. 2d*). In Swainson's Thrush there was a nearly complete segregation of eastern and western groups on the wintering grounds (*fig. 2e*). Eastern groups were found primarily from Panama to northern South America, while western groups were found in southern Mexico and Central America.

In conclusion, results from the five species examined suggest that connectivity between breeding and wintering areas can be resolved at large geographic scales using mitochondrial DNA variation. The use of other, more variable molecular markers may ultimately increase resolution and the ability to link populations at a finer scale. Also, molecular genetic markers may ultimately be most successful when combined with other types of data such as banding returns, morphologically based subspecific variation, stable isotope markers, radio and satellite telemetry, and disease strain variation.

Acknowledgments

We thank D. DeSante and the Institute for Bird Populations, the Monitoring Avian Productivity and Survivorship Program (MAPS) banders, the Point Reyes Bird Observatory, and the many independent contributors for donating genetic samples. For sharing their study sites and/or facilitating fieldwork, we thank Y. Aubry, P. Bichier, R. Carlson, A. Cruz, O. Cruz, R. Dickson, O. Figueroa, T. Gavin, K. Holl, L. Imbeau, O. Komar, B. Murphy, E. Rodriguez, E. Ruelas, E. Santana, W. Schaldach, C. Spytz, P. Thorn, and the Belize Audubon Society. This work was supported by grants from San Francisco State University, NIH Office of Research on Minority Health (grant #5P20RR11805), The Turner Foundation, the Environmental Protection Agency (R827109-01-0) and National Science Foundation (DEB-9726425 and IRCEB-9977072) to TBS.

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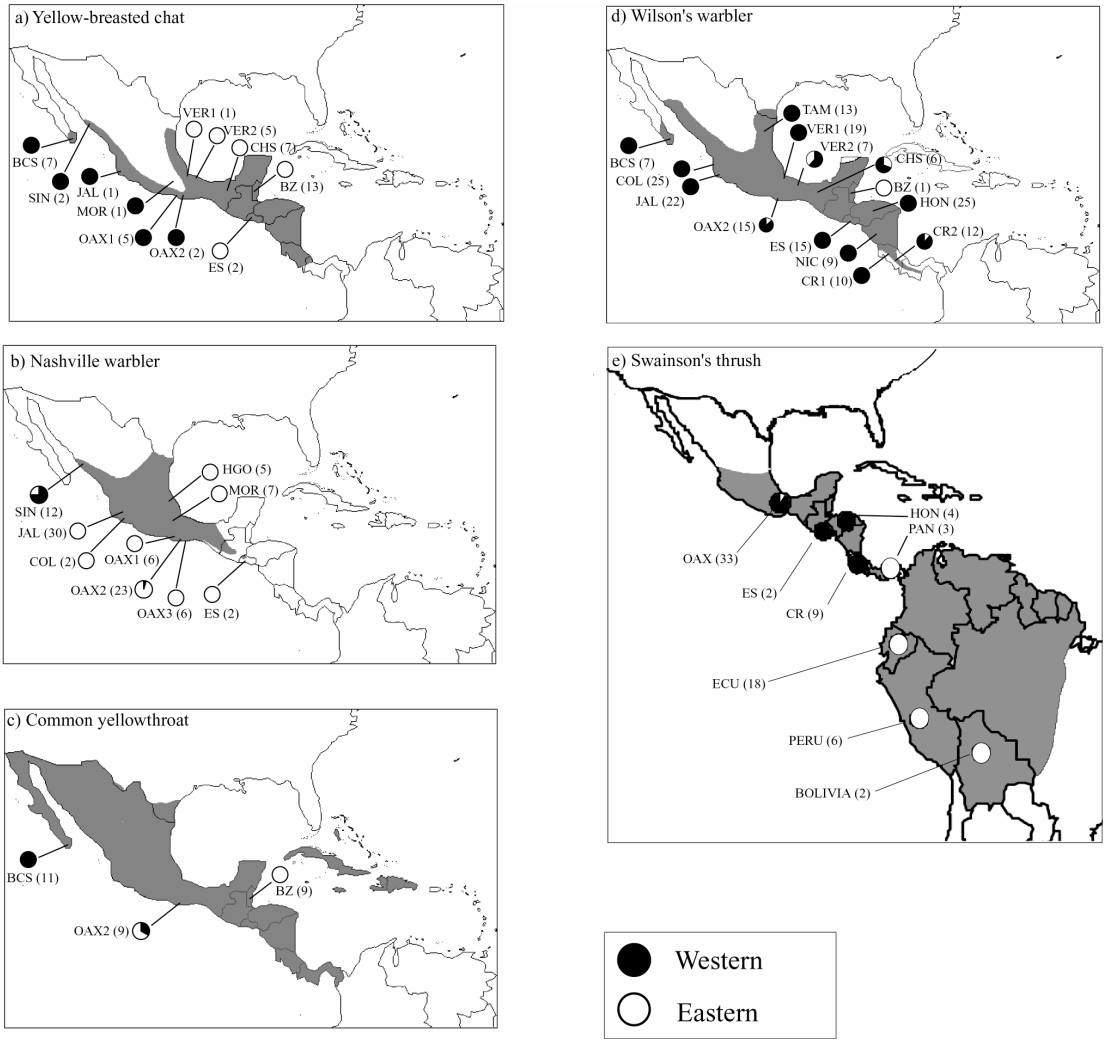

Figure 2— Distribution of eastern and western haplotypes in (a) Yellow-breasted Chat, (b) Nashville Warbler, and (c) Common Yellowthroat superimposed on a their overwintering distribution. Western and eastern haplotypes are shown in black and white respectively. Numbers in parentheses indicate sample sizes. Location abbreviations are: BCS, Baja California Sur; BZ, Belize; CHS, Chiapas; COL, Colima; CR (1 &2), Costa Rica; ECU, Ecuador; ES, El Salvador; HGO, Hidalgo; HON, Honduras; JAL, Jalisco; MOR, Morelos; NIC, Nicaragua; OAX (1, 2, and 3), Oaxaca; PAN, Panama; SIN, Sinaloa; TAM, Tamaulipas; VER (1 and 2), Vera Cruz. Modified from Kimura et al. 2002, Ruegg and Smith 2002; and Lovette et al. 2004.

The Program for Regional and International Shorebird Monitoring (PRISM)[1]

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Abstract

This report describes the "Program for Regional and International Shorebird Monitoring" (PRISM). PRISM is being implemented by a Canada-United States Shorebird Monitoring and Assessment Committee formed in 2001 by the Canadian Shorebird Working Group and the U.S. Shorebird Council. PRISM provides a single blueprint for implementing the shorebird conservation plans recently completed in Canada and the United States. The goals of PRISM are to (1) estimate the size of breeding populations of 74 shorebird taxa in North America; (2) describe the distribution, abundance, and habitat relationships for each of these taxa; (3) monitor trends in shorebird population size; (4) monitor shorebird numbers at stopover locations, and; (5) assist local managers in meeting their shorebird conservation goals. PRISM has four main components: arctic and boreal breeding surveys, temperate breeding surveys, temperate non-breeding surveys, and neotropical surveys. Progress on, and action items for, each major component are described. The most important major tasks for immediate action are carrying out the northern surveys, conducting regional analyses to design the program of migration counts, and evaluating aerial photographic surveys for migration and winter counts.

Introduction

This document describes the Program for Regional and International Shorebird Monitoring (PRISM). PRISM is a single blueprint for monitoring shorebirds in Canada and the United States and is based on the Canadian and United States shorebird conservation plans (Brown 2001, Donaldson 2001). The goals of PRISM are to: (1) estimate the size of breeding populations of shorebirds in North America; (2) describe shorebirds' distribution, abundance, and habitat relationships; (3) monitor trends in shorebird population size; (4) monitor shorebird numbers at stopover locations.; and (5) assist local managers in meeting their shorebird conservation goals.

Most of this report is focused on the goal of estimating trend in population size because we believe this is technically the most difficult goal. PRISM has adopted goals and standards for comprehensive avian monitoring programs proposed by Bart and Francis (2001). Their general goal, building on earlier work by Butcher et al. (1993), is 80 percent power to detect a 50 percent decline occurring during 20 years, using a two-tailed test with the significance level set at 0.15 and acknowledging effects of potential bias. They analyze existing and feasible levels of accuracy for shorebirds and show that relatively few species meet the proposed standard at present but that if the Canadian and United States bird conservation initiatives are implemented, the standard will probably be met for most shorebird species breeding regularly in North America.

A four-part approach for estimating trends in population size has been developed:

1. Arctic and boreal breeding surveys.
2. Temperate breeding surveys.
3. Temperate non-breeding surveys.
4. Neotropical surveys.

The rationale underlying this scenario is that trends in population size can best be studied during the breeding season, on the breeding grounds. At this time, populations are stable rather than mobile, surveys are relatively straightforward because the birds

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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are dispersed, and extrapolation from sampled plots to the entire population can be made using standard methods from classical sampling theory. This approach works well in temperate latitudes. In northern areas, where gaining access is difficult and costly, we propose an initial survey on the breeding grounds, to obtain estimates of population size, and then opportunistic data collection from these areas and a comprehensive program of surveys in staging, migration, and wintering areas at lower latitudes, where access is reasonably easy, to provide indications of population declines. When such warning signs appear, or at intervals of 10-20 years, the breeding ground surveys can be repeated to get updated population sizes and thus estimates of change in population size. This approach avoids the high cost of annual surveys in remote northern areas but also avoids complete reliance on trend estimates from the migration period when several sources of bias are possible.

The U.S. Plan suggested that selected subspecies and distinct populations, in addition to all species that breed regularly in the United States and Canada, should be included in the monitoring and assessment program. The rationale for this suggestion was that many subspecies, and a few populations, have such different breeding and/or non-breeding ranges that separate management efforts would be needed if they declined. For example, the three subspecies of Dunlins (*Calidris alpina*) in North America winter in different parts of the world, and evidence exists that one (*C. a. arcticola*) of them may be declining whereas this is not true for the other two. Computing a single species-wide trend for Dunlins does not provide managers the information they need. Furthermore, it is relatively straightforward to calculate separate trends for the three subspecies since they spend both the breeding and non-breeding periods in almost completely non-overlapping areas. The same rationale holds for a few distinct populations. For example, small populations of Marbled Godwits (*Limosa fedoa*) breed near James Bay and in western Alaska. They are separated from the main population by hundreds of kilometers, and certainly each warrant population-specific conservation actions by managers. It thus seems appropriate to identify them as separate taxa in monitoring and assessment program.

The U.S. shorebird plan identified 72 species, subspecies, or distinct populations that warrant separate monitoring and assessment efforts. With slight modifications following review by Canadian shorebird specialists, this list now covers 74 taxa including 49 species. The complete list is available at http://amap.wr.usgs.gov.

Arctic and Boreal Breeding Surveys

A substantial amount of work has been carried out recently to develop breeding surveys for shorebirds in remote areas in the arctic and boreal regions. The current proposal has three components: (1) an extensive survey, to be carried out at 10-20 year intervals, using random sampling and methods that permit estimating abundance (not just an index to it) across all arctic and boreal regions of North America; (2) annual or semi-annual surveys at 10-20 non-randomly selected permanent shorebird sites using either index or density methods; and (3) collection of checklist data, using a standard protocol, at as many sites and as often as possible.

This program is based on the assumption that reliable information on breeding populations, as has been collected on waterfowl for many years, is also needed for shorebirds. Unlike waterfowl, breeding shorebirds cannot be counted by aerial surveys, and annual surveys on the ground of all or a large portion of northern North America would be prohibitively expensive. Thus, periodic surveys, to be carried out at an interval of 10-20 years, are proposed to provide reliable information on population size. This program will be augmented by surveys every 1 to 5 years at a series of sites selected non-randomly on the basis of practical issues such as high quality habitat, frequent visitation by shorebird biologists, and easy access. We expect to define a variety of protocols that would differ in methods, cost, and precision of estimates. The third component is a checklist program. A protocol is being developed that can be used any time qualified observers visit shorebird breeding areas. This component of the program will yield information from many more areas than the regular surveys. Taken together, these components will provide annual data from numerous, but non-randomly selected, sites and periodic comprehensive surveys that will provide essentially unbiased estimates of actual population size and thus of change in size since the last major survey. The program will provide information of value in many ways other than monitoring. For example, new information on distribution and local abundance will be collected as will information on how weather affects shorebird distribution and nesting activity. Providing regular reports on these topics will help ensure continued funding. The three major components of this approach are each described in more detail below.

Continental Survey

The continental surveys use a combination of GIS methods to select plots and double sampling to collect the bird information. In much of the arctic, shorebirds are concentrated in irregularly shaped

patches that cover only a small fraction of the landscape. Stratified sampling is therefore used to separate the good and less good habitat so that sampling effort can be concentrated in the higher quality areas. When patches are small, plots follow their borders and thus are of unequal size. When patches are large, regularly-shaped, equal-size (10-16 ha) plots are established.

Double sampling, which is being used to estimate bird abundance on the sample plots, is a standard statistical method from the survey sampling literature (Cochran 1977, Thompson 1992). When used to estimate bird density, the method involves one sample surveyed using a rapid method such as area searches, point counts, or variable circular plot counts, and a second subsample of these plots on which actual density is determined through intensive methods. The ratio of the result using the rapid method to actual density is used to adjust the results from the large sample of plots. The method yields unbiased estimates of density – and thus of trend in density – if the subsample is selected randomly and the intensive methods provide accurate counts. No assumptions are required about how the index ratio in the initial surveys varies with observer, time of day, habitat or other factors. Thus detection rates may vary, even considerably, with these factors. In addition to providing unbiased estimates of density, and thus trend in density, double sampling has several other advantages: (1) the rapid method can be changed as new methods become available, (2) domains can be compared even if detection rates differ (though separate estimates of the detection rates are then needed), (3) total population size can be estimated, and (4) valuable ancillary information (e.g., nest success) can be obtained on intensive plots with little additional effort. Double sampling has been used to survey waterfowl for many years (e.g., Eberhardt and Simmons 1987, Prenzlow and Lovvorn 1996) and has also been used occasionally in other wildlife studies (Handel and Gill 1992, Anthony et al. 1999). See Bart and Earnst (2002) for additional description of the method in bird surveys.

Results from the plot surveys are used to build regression models that predict the number of birds that would be recorded on rapid surveys covering each plot in the study area. The sum of these numbers is the estimated number that would be recorded if the entire study area were surveyed using the rapid method. This number is divided by the detection rate obtained from the intensive plots to produce an unbiased estimate of population size. For more details of the approach see Bart et al. (2002).

Regular Surveys at Permanent Sites

These surveys will permit more intensive monitoring in a sample of areas that are of known importance to shorebirds. There are often sharp differences in spring weather from year to year at a given site, and surveys in consecutive years will help avoid erroneous conclusions caused by erratic weather conditions. Preference should be given to sites that are easy to access, or that host ongoing, long-term research programs and facilities, and that have high-quality shorebird habitat. Some sites should also be contained within existing protected areas (where there is reasonable certainty that sites will not be disturbed, and where wildlife-oriented habitat classifications of satellite data often exist). Possible sites for these surveys in arctic regions of Canada include Cambridge Bay, Victoria Island; East Bay Bird Sanctuary, Southampton Island; Polar Bear Pass National Wildlife Area, Bathurst Island; Truelove Lowland, Devon Island; Prince Charles Island, Foxe Basin; Coats Island; Dewey-Soper Bird Sanctuary, Baffin Island; Creswell Bay, Somerset Island; and Bathurst Inlet. In Alaska, possible sites in the arctic include the Arctic National Wildlife Refuge, Prudhoe Bay, the Colville River Delta, Barrow, Wainwright, and one or more locations in each of the six National Wildlife Refuges (Selawik, Yukon Delta, Togiak, Alaska Peninsula, Izembek, Alaska Maritimes) in western Alaska. Potential sites in boreal regions have not yet been identified.

A Checklist Program

In 2001, the Canadian Wildlife Service started work on a network of arctic locations where the NWT/ Nunavut Bird Checklist Survey will be conducted each year. Special consideration will be given to shorebirds in site selection. Checklist Survey data can be used to identify annual variation in shorebird distribution, breeding locations and breeding phenology, and over time it can provide a general indication of trends in distribution and abundance. Surveys are easy so the network of survey locations can be extended to other jurisdictions.

Boreal Regions

Seven shorebird species breed extensively (and in four cases largely) in boreal zones. It is not clear what method of monitoring will be most appropriate for boreal North America; different surveys may be needed for different species. In the Northwest Territories the Canadian Wildlife Service will test the use of "mini-Breeding Bird Survey" routes (walking routes that will replace conventional driving routes in roadless portions of the Territory) to monitor population trends of boreal-nesting shorebirds such as

Common Snipe (*Gallinago gallinago*) and Lesser Yellowlegs (*Tringa flavipes*). River Breeding Bird Survey (BBS) routes in Alaska have high encounter rates of boreal-breeding shorebirds. It may be possible to extend the double-sampling survey methodology south of the treeline. Aerial surveys to identify staging lakes might be coupled with breeding ground surveys to identify important areas within the boreal region. More planning is needed before a boreal shorebird monitoring program is implemented. This effort should be coordinated with planning for boreal songbird monitoring as it is desirable to combine monitoring efforts for these two groups of birds.

Other Projects in Support of the Northern Surveys

An extensive literature review is being conducted to capture and summarize all existing information on the distribution and abundance of shorebirds nesting in boreal and arctic regions of North America. A considerable proportion of arctic shorebird data resides in unpublished government and industry reports that are not widely accessible. The literature review will make this information available for such purposes as selecting survey sites and estimating historical and recent population size. A map showing distribution and abundance for each species is being prepared from this database. The database contains the following information: (1) location data (place name, geographic coordinates, habitat type); (2) species presence/absence; (3) species breeding status and general abundance; (4) species densities; and (5) literature citation.

Natural history information of use to field surveyors in deciding how many individuals are nesting on plots they have surveyed is being compiled for each of the northern-nesting species. These "Survey Tips" are being prepared by species specialists following uniform guidelines prepared for this project. All accounts will be posted on a web site, and shorebird specialists will be invited to contribute their own observations to the accounts, which will be updated frequently.

An "Atlas of Beringian Shorebirds" is being created to increase access to the large amount of information collected on shorebird distribution, abundance, biology and migration in Beringia (western Alaska, eastern Siberia and nearby areas) over the past two decades. Beringia is the most significant center of shorebird diversity within the Holarctic region. Numerous species, such as Western Sandpipers (*Calidris mauri*), Baird's Sandpipers (*C. bairdii*), Pectoral Sandpipers (*C. melanotos*), and Rock Sandpipers (*C. ptilocnemis*), occur in both the Alaskan and Russian parts of Beringia. Several Beringian endemics have relatively small ranges in Russia (e.g., Great Knot [*C. tenuirostris*]) or Alaska (e.g., Black Turnstone [*Arenaria melanocephala*]) and several nesting species are rare and may require special protective measures (e.g., Bristle-thighed Curlew [*Numenius tahitiensis*], Spoonbill Sandpiper [*Eurynorhynchus pygmeus*]). In addition, some species that nest in Northeast Asia migrate through Alaska enroute to wintering grounds in Central and South America. The Atlas and accompanying electronic database will be used to assess the status of specific shorebird populations in the region and identify future needs for management, research, and conservation.

Temperate Breeding Surveys

Seventeen shorebird species breed in the temperate region of North America, in areas of Canada and the United States that are generally accessible by roads. A large portion of the breeding range of three species (Spotted Sandpiper [*Actitis macularia*], Upland Sandpiper [*Bartramia longicauda*], Common Snipe) extend into northern areas inaccessible by roads, and this portion of their ranges will be monitored by the northern surveys (see Arctic and Boreal Breeding Surveys, above). Although all shorebird species will eventually be monitored under this plan, current resources should focus on the highest priority species. Setting priorities for the temperate breeding species depends on their conservation status (Brown et al. 2001) and on the adequacy of their coverage under existing surveys. Priorities for designing and implementing new surveys should focus on species with high conservation concerns (scores of 4 or 5) under the United States and Canadian shorebird plans, and on surveys that can combine species with similar ranges and natural histories. Four of the temperate breeding shorebird species are "Highly Imperiled" (score 5) and seven are "High Concern" (score 4; *table 1*; Brown et al. 2001).

One "Highly Imperiled" species, the Piping Plover (*Charadrius melodus*), is listed as threatened under the Endangered Species Act (ESA) and is monitored on the breeding grounds by the International Piping Plover Census (Plissner and Haig 1997). One species of "High Concern", the American Woodcock (*Scolopax minor*), is monitored by the North American Woodcock Singing-ground Survey (Bruggink 1998).

Table 1— *Standard errors (SEs) for annual rates of change (expressed as a percent) for shorebird species breeding in accessible areas calculated from BBS data (Sauer et al. 2000).*

Species	SE < 0.90	SE 0.91 to 1.30	SE 1.31 to 1.86	SE > 1.86
Killdeer	0.23			
Mountain Plover[1]				4.51
Black-necked Stilt[2]				2.00
American Avocet			1.36	
Willet	0.80			
Spotted Sandpiper		0.97		
Upland Sandpiper	0.58			
Long-billed Curlew		1.10		
Marbled Godwit			1.38	
Common Snipe	0.42			
American Woodcock				2.13
Wilson's Phalarope[3]			1.57	

[1] *Charadrius montanus*
[2] *Himantopus mexicanus*
[3] *Phalaropus tricolor*

The Breeding Bird Survey (BBS) may adequately monitor additional species. It has been suggested that species are adequately monitored by the BBS if the standard error (SE) of the estimated rangewide trend, expressed as a percent, is less than 0.9 and if there is no reason to believe that bias (e.g., roadside bias) is especially large (Bart and Francis 2001). This SE criterion is met for Killdeer (*Charadrius vociferus*), Willet (*Catoptrophorus semipalmatus*), Upland Sandpiper, and Common Snipe (*table 1*), and is nearly met for Spotted Sandpiper (SE = 0.97; Sauer et al. 2001, Bart and Francis 2001). More evaluation is needed to assess whether roadside or other bias is particularly large for these five species. Upland sandpiper is a priority level 4, but covered by the BBS with a SE = 0.58. Therefore, it would be a lower priority for implementation of a new survey, although a closer analysis of BBS coverage for this species is warranted due to its high level of concern. Spotted Sandpiper is a priority level 2 and covered by the BBS at a level (SE = 0.97) that would result in a lower priority for implementation of a new survey. Coverage by the BBS for these species, as well as for the American Avocet (*Recurvirostra americana*), Long-billed Curlew (*Numenius americanus*), and Marbled Godwit, could be improved by increasing the number of routes and/or by reducing potential survey biases; these options may be worth exploring, although currently the BBS does not adequately monitor these species. Standard errors for all other species are >1.5 percent per year suggesting that even with substantial improvement, the BBS will not provide adequate coverage for them. However, there is an overall need to examine in more detail the usefulness of the BBS for all of the temperate zone breeders, as well as determining which species can be effectively monitored on a regional basis by this method. This is particularly important for subspecies, and for species where significant portions of the breeding range habitat may be treated differently in different geographic regions of their range (e.g. CRP program in United States versus no such program in Canada; eastern versus western Upland Sandpipers).

The United States and Canadian shorebird plans presently suggest survey designs for some species but these survey designs have not been prioritized, analyzed for possible species combinations, or subjected to rigorous peer review. The next step to achieve our goal of monitoring the temperate breeding species should be a formal peer review and analysis of the survey designs in Brown et al. (2001) by researchers familiar with survey design and the particular species. This review should consider: (1) alternative methods, (2) recommend a detailed design and field evaluation, and (3) recommend a plan for eventual implementation. Species with lower conservation scores hopefully could be combined in surveys of the species of high concern.

One aspect that should be considered in the design and review of these new protocols is the use of 'direct' or 'unbiased' counts. Many specialists in avian population biology recommend that, whenever possible, new monitoring programs should use methods that yield direct or essentially unbiased estimates of population density (e.g., counts when all birds are visible), rather than relying on indirect, or index, methods (Nichols et al. 2000, Bart and Francis 2001). The rationale for this recommendation is that too many sources of bias exist with index methods for a high level of confidence in the trend estimates that they produce. An additional advantage is that direct counts also yield estimates of population size that are essentially unbiased and thus achieve the first PRISM goal. We believe that this recommendation should be

followed whenever possible in designing new breeding surveys for accessible species of special concern, although this criterion is not met in existing surveys. See the complete PRISM report at http://amap.wr.usgs.gov for additional recommendations on designing the species-specific surveys.

Temperate Nonbreeding Surveys

Surveys during the nonbreeding period will monitor use at stopover locations, elucidate habitat relationships during this period, and help local managers meet their shorebird management goals. There is some debate at present over whether nonbreeding counts can also provide useful information about population trend, some people believing this is possible for most species, others feeling the potential inaccuracies are so great that such surveys might be misleading too often to be of any value. Most people seem to be agreed that counts during the nonbreeding period in the foreseeable future will not provide sufficient reliability to be the only basis for trend estimation, and will, at a minimum, have to be supplemented by the breeding surveys discussed above. Because nonbreeding surveys will be carried out in many areas for other purposes, and because many people feel that they do have considerable potential as trend estimators, we believe that the issues should be explored in detail by identifying potential problems, designing a comprehensive survey to minimize them, and carrying out a careful assessment of reliability of the resulting program. This section discusses ways to implement this approach.

The rationale, and challenge, in using nonbreeding surveys to estimate trends in population size may be explained as follows. Suppose that each year about the same fraction of birds is in the study area during the study period, apart from random year effects, and that the survey provides a good estimate of this number. In this case, trend in the survey result will be a good estimate of trend in population size. On the other hand, suppose that the ratio of the survey result to population size gradually falls from 0.10 to 0.05 during several years. Then the survey result will suggest a 50 percent decline even if the population is actually stable. The key issue in designing and evaluating nonbreeding surveys is thus whether a long-term trend is likely in the ratio of the survey result to population size (the "index ratio"). Low precision of the survey result is also a possible problem, but investigation of this issue (Bart unpub.) shows that large enough samples can probably be obtained that sampling error will be relatively small (e.g., CVs < 0.10). The potential for bias is thus the major problem to be solved in designing the nonbreeding surveys.

We have identified three potential problems – referred to below as frame bias, selection bias, and measurement bias - that would cause a long-term trend in the index ratio, and thus cause bias in the trend estimate. Frame bias is a long-term trend in the proportion of birds in the population that is in the study area during the study period. Selection bias is a long-term trend in the proportion of the birds in the study area during the study period that is in inaccessible areas. Measurement bias is a long-term trend in the ratio of birds recorded to birds present during surveys. Quantitative expressions for frame, selection, and measurement bias are presented in the complete description of PRISM available at http://amap.wr.usgs.gov.

A detailed procedure has been developed to design the temperate, nonbreeding surveys. "Shorebird monitoring regions" were defined by intersecting a States and Provinces map with a Bird Conservation Regions map and eliminating small polygons (*fig. 1*). A separate sampling plan must be developed for each region that

(1) is based on all existing information on shorebird distribution and timing of use in the region,

(2) designates a survey period, usually 6-8 weeks during spring or fall migration, based on when shorebirds are present in the region,

(3) subdivides the region into (a) "Type 1" habitat that is regularly used by shorebirds and will be surveyed (usually by sampling) 3-6 times annually; (b) "Type 2" habitat that contains few, but some, shorebirds and will be surveyed every several years to document continued low use, and (c) "Type 3" habitat which is assumed to have virtually no shorebirds and will not be surveyed, and

(4) describes the monitoring plan including maps and detailed descriptions of areas to be surveyed along with survey protocols.

The potential for selection and measurement bias at the site, stratum, and regionwide level is also discussed, and pilot studies needed before the sampling plan can be completed are identified. The procedures for conducting these assessments, and examples of the products produced during the assessment, are available on the PRISM website http://amap.wr.usgs.gov.

Neotropical Surveys

There is clearly a need to evaluate the efficacy of surveys in Central and South America. Winter surveys may be especially valuable for species that primarily winter in southern South America (e.g., Buff-breasted Sandpiper [*Tryngites subruficollis*], American Golden-plover [*Pluvialis dominica*], Baird's Sandpiper), for species which pose special problems during breeding and migration surveys (yellowlegs and some *Calidris* species), and for species which appear to be concentrated in certain areas in winter (Black-bellied Plover [*Pluvialis squatarola*], Ruddy Turnstone [*Arenaria interpres*], Whimbrel [*Numenius phaeopus*]; Morrison and Ross 1989). Aerial surveys of South America (Morrison and Ross 1989), Panama (Morrison et al. 1998), Central America (Morrison et al., in prep), and Mexico (Morrison et al., in prep.) identified major shorebird concentration areas along these coastlines. Additional information is available from some sites in the Caribbean. These sites could be included in the sampling frame for selection of monitoring sites. Specific issues of site access and survey timing would need to be developed for each survey site.

Surveys along the coasts of South America would sample several North American breeding species, such as the Hudsonian Godwit (*Limosa haemastica*); however, some shorebirds are dispersed among inland wetlands and grasslands. These areas also support austral shorebird migrants, resident shorebirds, and other rare, endemic birds.

Approaches to estimate densities of wintering migrant shorebirds and residents could be adapted from methods developed for accessible, temperate breeding grounds. An initial step would be to identify sites in South America.

Cooperative shorebird projects are already underway in many parts of Latin America and the Caribbean (e.g., Red Knot project, WHSRN sites, Western Sandpiper project, Pan American Shorebird Project, identification of major sites in Baja, Mexico by the Point Reyes Bird Observatory). In addition, NABCI (North American Bird Conservation Initiative) emphasizes that bird conservation must be addressed internationally and linkages with other countries should be encouraged. We fully realize that monitoring is but one tool that can be used to accomplish the hemispheric conservation of shorebirds. We hope to use these projects and their underlying philosophies as a foundation to build a comprehensive monitoring strategy for shorebirds across the western hemisphere.

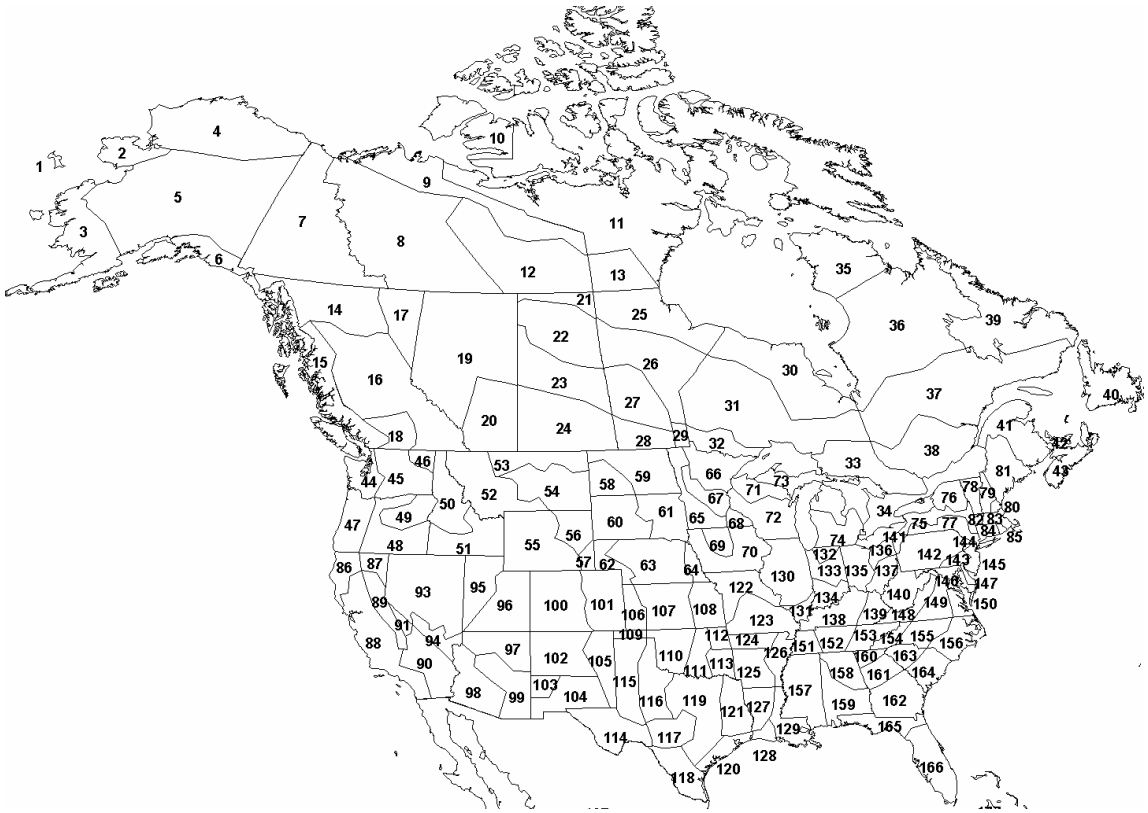

Figure 1— Bird monitoring regions in Canada and the United States.

Many of the theoretical approaches previously outlined in this document are equally applicable to areas south of the United States - Mexico border. Close collaboration among colleagues in North, Central, and South America and the Caribbean is crucial to realistically assess the feasibility of implementing monitoring approaches at sites in Latin America and the Caribbean. Although numerous, effective partnerships currently exist, a wider network of shorebird enthusiasts needs to be encouraged. Conversely, knowledge of programs in other countries needs to be more widely distributed among shorebird workers in the United States.

Assistance to Local Managers

Providing assistance to local managers in meeting their shorebird conservation goals is one of the PRISM goals. Little work has been done on this goal to date because the monitoring program is not yet in place. A few examples, however, are beginning to emerge that illustrate ways in which the monitoring infrastructure can be of use to managers concerned about shorebirds. The South Atlantic Migratory Bird Initiative is coordinating a regionwide program in the southeastern United States to investigate drawdown procedures for shorebirds. The Point Reyes Bird Observatory has hired a shorebird conservation specialist to work with local managers in implementing the Southern Pacific Regional Shorebird Conservation Plan. The Western Shorebird Survey developed an arrangement with the State of Utah to provide analytic assistance for their water bird survey in exchange for assistance in identifying shorebird survey sites and preparing survey protocols. The International Shorebird Survey has a long history of working with local managers on their conservation issues through holding workshops and providing direct technical assistance. Thus, a few cases exist in which people with monitoring and management expertise have joined forces. We hope that many more such collaborative efforts will occur during the next few years; promoting such efforts should be a major goal of the PRISM.

Acknowledgments

PRISM grew out of earlier efforts by R. Gill, M. Howe and numerous shorebird experts that culminated in the shorebird conservation plans for Canada and the United States. We appreciate the comments of G. Beyersbergen, B. Collins, S. Dinsmore, C. Elphick, L. Oring, B. Peterjohn, and E. Syroechkovski, Jr. on earlier drafts of this manuscript.

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Preparation of Regional Shorebird Monitoring Plans[1]

Jonathan Bart,[2] Ann Manning,[3] Susan Thomas,[4] and Catherine Wightman[2]

Introduction

Shorebird monitoring programs in Canada and the United States are being developed under the auspices of PRISM, the Program for Regional and International Shorebird Monitoring. PRISM provides a single blueprint for implementing the monitoring proposals in the shorebird conservation plans prepared recently in Canada and the United States. It includes four segments: arctic and boreal breeding surveys, temperate breeding surveys, temperate nonbreeding surveys, and neotropical surveys. A separate document, available at http://amap.wr.usgs.gov, provides an overview of PRISM. Temperate non-breeding surveys have the potential to contribute to four of the five goals of PRISM: monitor stopover sites during the spring and fall migration, elucidate habitat relationships, help local managers meet shorebird conservation goals, and measure population trends. This program seeks to standardize site selection, data collection, and data storage among existing initiatives including the International Shorebird Survey, Maritimes Shorebird Survey, and Western Shorebird Survey. The temperate non-breeding surveys involve a major effort to identify shorebird concentration sites and develop ways to survey them for shorebirds. These analyses are termed "regional assessments" and are being conducted throughout southern Canada and the United States. This document provides guidelines for preparing regional assessments. It is intended for people who will use the shorebird survey data, so they can understand the sampling plans used to select sites, and for other waterbird specialists who may be interested in adapting the approach for their species. More detailed procedures and examples are available at http://amap.wr.usgs.gov.

The goal of the temperate, non-breeding surveys is to produce good estimates of the average number of shorebirds present during the "study period" for each "focal species." The study period is 6-8 weeks in spring or late summer. A survey period during winter may also be defined. Final selection of the study period should often not be made until other investigations, especially the design of waterbird monitoring programs, have been completed. The focal species occur in the monitoring region during the study period in high enough numbers that trends in the mean number of them present might be important in making management decisions at the regional, national, or international level. Trends for some additional species may be important at the local level (e.g., a Wildlife Management Area). A tentative list of focal species for the planning region is given in the introduction of each regional analysis.

Canada and the United States have been sub-divided into 158 "Bird Monitoring Regions" formed by intersecting a map of the Bird Conservation Regions with a map of Provinces and States (*fig. 1*). Small polygons were dissolved and edges were smoothed. A regional assessment is being prepared for each Bird Monitoring Region. The biologists preparing each regional assessment sub-divide the Bird Monitoring Region into "domains," and sub-divide domains into "zones." Domains are delineated using readily recognized features such as roads, water bodies, and administrative boundaries (*fig. 2*). Domains are kept small enough that all major shorebird sites within them can be depicted on a single page. Although they are useful for organization, domains are not a sampling unit and domain boundaries are not used in calculating population trend estimates. Therefore, the boundaries of domains can be changed without affecting trend estimates. Zones within domains are also delineated using readily recognized features. Typically, each major shorebird site within a domain is assigned to a separate zone, and zone boundaries are established at some point between these sites (*fig. 3*). Domains, and zones within a given domain, are each numbered sequentially starting with 1. The complete identifier for a zone includes the Bird Monitoring Region. Thus zone 63.5.2 is the 2nd zone in the 5th domain of Bird Monitoring Region 63.

The "shorebird-day" is used to measure and describe shorebird use. A shorebird-day is one shorebird spending 24 hours within the area of concern during the study period.

The mean number of shorebirds present in the area during the study period equals the total number of shorebird-days during the study period divided by the number of days in the study period. In deciding which areas to focus survey efforts on, we use rules based on

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California**.

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the fraction of the shorebird-days that occur within different portions of the area. "Type 1" areas have shorebirds present during the survey period in substantial numbers. "Type 2" areas have shorebirds present but in small numbers. "Type 3" areas have virtually no shorebirds present during the study period. The goal in delineating Type 1, 2, and 3 areas within a Bird Monitoring Region is that >75 percent of the shorebird-days for each focal species occur in Type 1 habitat; <20 percent of the shorebird-days occur in Type 2 habitat, and <5 percent of the shorebird-days occur in Type 3 habitat. Type 1 habitat will be surveyed each year using a detailed protocol that provides an estimate of the mean number of shorebirds present in the habitat during the study period. Type 2 habitat will be surveyed every few years, using more flexible methods, to verify the assumption that <20 percent of the shorebird-days for each focal species occur in these areas. Type 3 habitat will not be surveyed regularly but bird watchers and biologists will be notified that these areas are thought to be virtually devoid of the focal shorebirds during the study period, and they will be asked to contact us if they find evidence that this assumption is wrong. Zone borders are often drawn so that most of the area within each zone is in one or two habitat Types. Zones are sometimes referred to by the highest quality habitat they contain. Thus, a Type 2 zone has some Type 2 habitat and may have some Type 3 habitat but does not have any Type 1 habitat. Because surveys from Type 1 habitat only are used to estimate population trends, much of the regional assessment focuses on sampling plans for Type 1 habitat. Surveys in Type 2 habitat are used primarily to verify that there has not been a shift in shorebird use areas.

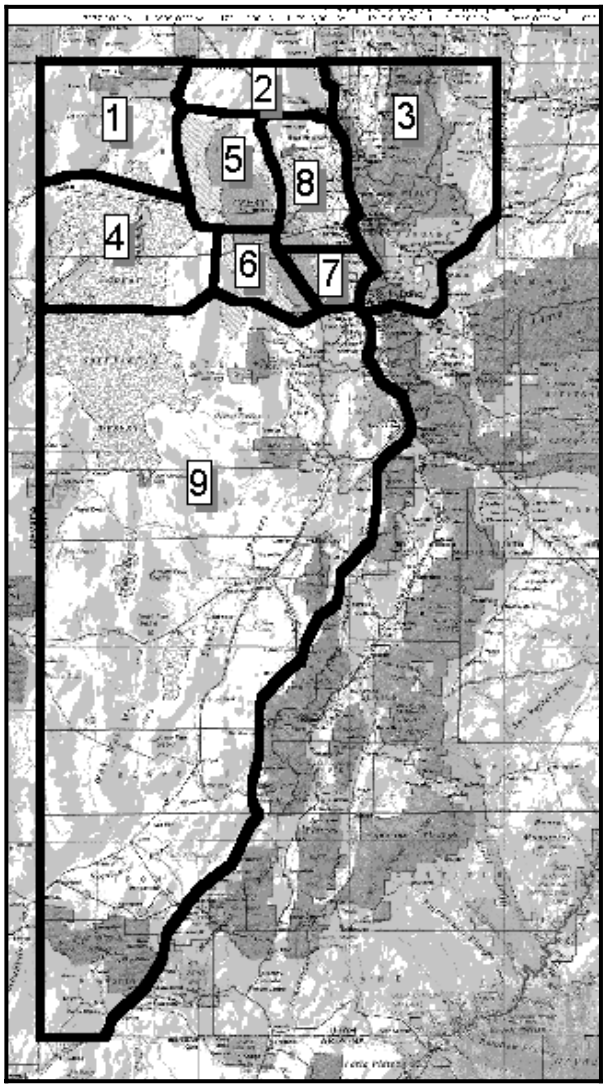

Figure 2— Example of a Bird Monitoring Region (Utah-BCR 9 - Great Basin) subdivided into domain.

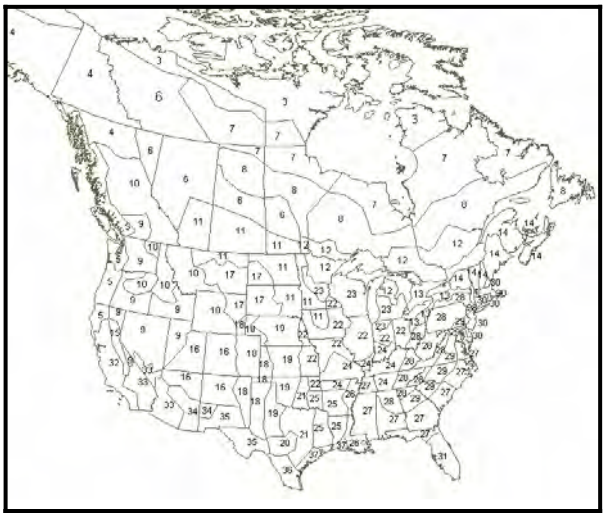

Figure 1— Bird Monitoring Regions in Canada and the United States.

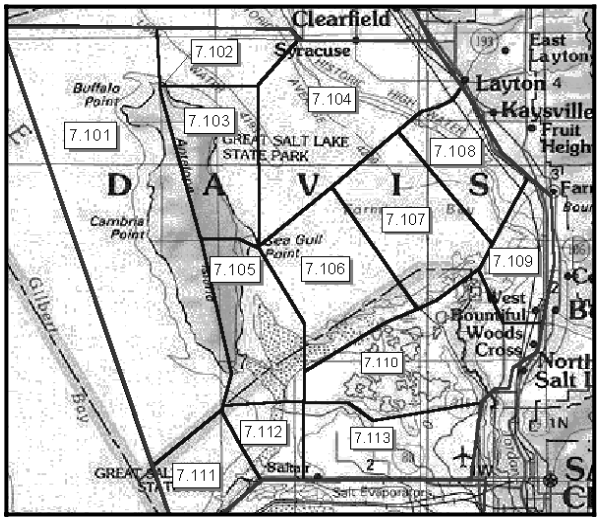

Figure 3— Example of a domain sub-divided into zone.

Much attention is given, in preparing each regional assessment, to "measurement error," "measurement bias," and "selection bias." The objective on surveys is to detect all shorebirds present in the survey area (e.g., a plot) at the time of the survey. Pilot studies are often recommended to develop the needed survey methods. Measurement error is the difference between the number recorded and the number present. Measurement bias is a long-term trend in the index ratio, defined as "number recorded"/"number present." The reason for the distinction between measurement error and measurement bias is that measurement error alone does not necessarily cause any bias in the trend estimate. For example, if about half the birds present are recorded, but there is no long-term trend in this detection rate, then the long-term trend estimated from the counts is unbiased. Substantial measurement error - which is defined here as an index ratio <0.80 or >1.20 - means that a long-term trend in the index ratio, causing measurement bias, could occur. Thus, while measurement error alone does not cause any bias, it creates a situation in which measurement bias could occur. The description for each zone includes a heading for "Measurement error and measurement bias." When measurement error is negligible (<±20 percent), "Not applicable" is entered for measurement bias.

Selection bias is caused by (1) some parts of the zone being non-surveyable due to access problems, and (2) a long-term trend in the proportion of birds within these non-surveyable areas. Selection bias can also occur if a previously unsuitable area becomes suitable, for example through habitat management. More typically, an area becomes unsuitable for example due to encroachment by an invasive species, flooding, or development. The description for each zone contains a heading for "Access and selection bias." If all areas are accessible, then "not applicable" is entered for selection bias.

The potential for selection bias is also discussed at the regionwide level. Some entire zones might be in the non-surveyable category, which introduces a potential for bias not discussed within the individual zone descriptions. Furthermore, while there might be substantial potential for selection bias in some zones, it might be felt that spurious negative and positive trends would approximately balance each other at the regional level.

Preparation of the regional shorebird monitoring plans proceeds in up to three stages. Each stage may produce a separate document, and several drafts may be needed to produce the final draft. Each stage is described below.

Document One: Summary of Existing Information

This document contains background information and notes prepared for initial visits to each domain. It is a working document, continually revised and expanded as the investigation proceeds. It usually includes maps with preliminary delineation of areas to be examined, a description of each one, and issues to be investigated during field trips such as visibility, numbers of birds, and access. After initial visits have been made to a domain, a draft section describing the zones and needed pilot studies is prepared. This section may be revised several times as the work proceeds. Eventually, it is transferred to the second document ("Needed Pilot Studies"). Procedures for preparing the document are described below.

1. *Prepare regionwide analyses*

   a. Gather information on the distribution and abundance of staging, migrating, and wintering shorebirds throughout the region and year. Collect information from birders and biologists familiar with the areas as well as publications and reports such as regional shorebird conservation plans. Reviewing data may be helpful but detailed analyses are usually more time-consuming than is worthwhile. Plot major concentration sites (during the proposed survey period) on a map of the region.

   b. Make an initial choice for domain boundaries, trying to define domains so that major shorebird areas in each domain can be displayed on a single page. Domains are defined purely for presentation convenience. They have no statistical significance and their boundaries can be changed at any time.

   c. Make an initial choice for the survey period (e.g., July & August) and explain why the period was selected. Regional bird finding guides, reports, and local experts can be very helpful in this endeavor.

   d. Identify major landowners and other groups in or adjacent to the region who might wish to participate in development and implementation of the survey. Coordination with the Regional Shorebird Conservation Plan Working Group is recommended as they can provide information on shorebirds in the area and may know of the best individuals to contact when surveys are initiated.

2. *Prepare descriptions of each domain.*

   a. Review all shorebird, and other, information about the domain.

   b. Consider when during the day surveys should be conducted. In general, all surveys in a zone should be made during a single period particularly within tidal areas. Failure to do this raises the possibility that birds might tend to be double-counted or missed completely, and that the proportion of birds double-counted or missed might change through time causing (frame) bias. For example, if areas counted at low tide became unsuitable through time, birds might move to zones that were not surveyed thus causing a spurious trend in numbers counted. If the survey period is the same for all zones, then double-counting or missing birds does not cause any bias because, on average, these errors will balance each other and there will be no tendency for a long-term trend in such errors. Timing of surveys is especially important at tidal sites but may be important at other sites due to the sun or other factors. Note that if the number of shorebirds present varies rapidly, as is often the case with tidal areas, then the survey period should be brief. Otherwise, surveyors may gradually learn when surveys will yield the highest counts and may be tempted to visit at these times. This behavior would generate an increasing trend even if the mean number of birds present during the survey period did not change. For this reason, mean rather than peak counts will be used as an index to population. This method also preserves data elasticity, providing flexibility in timing with less emphasis on catching peak shorebird movements which may vary by year, weather, and other factors. In addition, mean counts make it possible to compare data gathered with different survey methodology (e.g. aerial vs. ground counts).

   c. Partition the domain into "zones" (i.e., every point within the domain is in exactly one zone). Try to describe the distribution of Type 1, 2, and 3 habitat within each zone. Begin to identify pilot studies needed to complete the delineation and description of zones. Summarize this information in writing (this helps insure wise use of field time) but without spending time on writing style or guesswork.

   d. Visit the domain, examining each zone and trying to improve the descriptions of where Type 1, 2, and 3 habitat occurs. Consider how to survey the Type 1 habitat in each zone. A first step is to decide whether sampling, rather than complete coverage, will be needed. If complete coverage is likely to be too time-consuming (the usual case) then consider different ways to sample the area. Stratification will often be useful as a first step, after which a wide variety of approaches should be considered. Studying completed plans for other regions and contact with PRISM personnel may be useful at this stage.

   e. Begin preparing the information for each zone that will be incorporated into the Needed Pilot Studies document and eventually into the sampling plan.

Document Two: Needed Pilot Studies

This document summarizes results from the initial work and identifies the pilot studies needed before a sampling plan can be prepared. It serves as a proposal to obtain the needed funding and other resources for carrying out the pilot studies. The format is flexible but might include the following sections.

1. A description of PRISM showing how the proposed work relates to achieving regional, national, and international goals. This material will be similar in each proposal.

2. Description of the region including outer boundaries, domains, major concentration sites, numbers of birds present, organizations with shorebird interests and/or responsibilities, etc.

3. Methods used to develop the proposal.

4. A list of the proposed pilot studies with descriptions of the needed work, budgets, schedule, and perhaps suggestions about parties to carry out the work including priorities for each.

5. In an appendix, a first draft of the "description" portion of the sampling plan for the region (see "Document Three" below). This material is included so that reviewers can examine how the information to be collected in the pilot studies will be used.

6. A "summary," prepared after all of the above sections have been completed, placed near the beginning of the document. The summary integrates the zone-specific studies. For example, aerial surveys may be needed in several zones, but it may be most efficient to carry them out at the same time. Ground surveys may be needed in several zones, but it may be most efficient to carry them out by hiring a single person.

Document Three: The Shorebird Sampling Plan

This report describes the sampling plan for each region. It cannot be completed until after the pilot studies have been completed but it is helpful to begin the report while preparing the "Needed Pilot Studies" document both to help identify and prioritize needed pilot studies and to demonstrate to reviewers how the pilot studies will permit completion of the sampling plan. The following information should be included.

1. Description of the region, probably taken directly from the "Needed Pilot Studies" document.

2. Description of the Type 1 habitat in each zone using the format in *table 1*.

3. Consideration of alternate sampling plans for each zone including a discussion of whether the zone is sampled or censused and, if sampled, how plots are selected (e.g., systematic, simple random, cluster sampling).

4. Description of how the weighting factors, used in combining the survey results with results from other zones, will be calculated. If the zone has no inaccessible areas (so either it is censused or all parts of it could be included in the sample of plots), then the weighting factor (for each species) is simply the estimated mean number of birds present in the zone from the surveys. If some areas cannot be surveyed, then a description must be provided of how weights will be calculated (e.g., by occasional aerial surveys of non-surveyable areas).

5. A description for surveyors of the zone, areas to be surveyed, survey protocols, etc., following the format used in the Western Shorebird Survey (http://wss.wr.usgs.gov). This material is transferred directly to the website and is distributed in printed form as appropriate.

6. An overview of the sampling plan, prepared after the zone descriptions have been written but usually included as an introduction to the zone-specific parts of the report.

Conclusion

The approach described above provides a rigorous conceptual basis for designing shorebird sampling plans for sites located throughout southern Canada and the United States. The approach needs to be extended gradually to all areas used by North American shorebirds during the survey period. Accomplishing this task would reduce frame bias dramatically because the study area - aside from areas that are non-surveyable due to access - would cover all locations occupied by shorebirds. This task should probably be the highest priority for the non-breeding surveys portion of PRISM. A second priority should be extending the regional analysis to all waterbirds. This task must be carried out largely by waterbird specialists under the auspices of the Waterbirds Initiative with additional assistance from the Waterfowl and Landbirds Initiatives.

Table 1— *Information provided for each zone.*

Category	Description
Description	Capsule description (e.g., a wide beach; a shallow lagoon) of the zone. Additional comments as appropriate on ownership, access, boundaries, and timing of surveys. Brief description of the species and numbers occurring during the survey period.
Classification	Describe where type 1, 2, and 3 habitats occur. These habitats are not normally mapped within zones so descriptions need to be clear.
Survey Methods	Brief discussion of what methods would probably work best; does not include final recommendations on methods or sample sizes.
Measurement Error and Measurement Bias	Discuss "measurement error," the expected difference between the number of birds present in the zone or surveyed parts of it and the number recorded, and "measurement bias," a long-term trend in the ratio, "number recorded"/"number present." Minimizing both quantities is important in the design. See "Introduction" above for a discussion of these terms.
Access and Selection Bias	Selection bias is a long-term trend in the proportion of birds present in areas that cannot be surveyed, usually due to access (including ownership) problems. It is "not applicable" if all areas can be accessed. See "Introduction" above for a discussion of these terms.
Pilot Studies	List separate studies describing goals and methods for each and including "priority" (high, medium, low).

Methods for Shorebird Surveys in the Arctic[1]

Jonathan Bart[2] and Susan L. Earnst[2]

Introduction

A substantial effort is being made to develop a long-term monitoring program for shorebirds in North American (Brown et al. 2000, Donaldson et al. 2001, Bart et al. this volume). The current program, PRISM (Program for Regional and International Shorebird Monitoring), has four segments: arctic and boreal breeding surveys, temperate breeding surveys, temperate non-breeding surveys, and neotropical surveys. The arctic breeding surveys are intended to provide estimates of population size for each of the species and subspecies breeding in the arctic, to improve our understanding of distribution and abundance of breeding shorebirds, and to provide baseline data for future surveys that will be used to estimate trends in population size. More information about PRISM and how the arctic surveys will help accomplish the PRISM goals may be found in Bart et al. (this volume). This report describes the approach being used to survey shorebirds in the arctic.

The arctic surveys use double sampling to estimate numbers present on a sample of plots and habitat-based regression models to extrapolate from the plots to large study areas. The methods were developed during 1994-1997. Operational work was carried out during 1998-2001 and is continuing.

Plot Selection

Several methods have been used for plot selection, the best approach depending to some extent on habitat configuration. On the Colville River Delta and the eastern portion of the National Petroleum Reserve, where the field methods were developed, most shorebirds occur in wetlands which cover only a small fraction of the landscape and are sharply delineated from the surrounding upland (tussock tundra). In this situation, it proved effective to use computer methods to eliminate from the habitat map wetlands less than 5 ha in size (due to the logistic costs of reaching such small areas), and to delineate the remaining wetlands, principally through repeated use of the Majority Filter command in ArcView, throughout the study area. We then selected one set of plots in the wetlands and one in the uplands. When a selected wetland exceeded 25 ha, it was subdivided into areas of 10-15 ha and one of these was randomly selected as the plot. Plots thus varied in size from 5-25 ha, and plot borders followed the very distinct borders between wetland and uplands. This approach was helpful because most birds were in the wetlands, but it was often hard to know where they were nesting. If a plot covered only a portion of the wetland, the surveyors would have had difficulty deciding whether birds they encountered should be recorded as within the plot or not. A small sample of plots in the uplands was selected by randomly choosing locations and regarding each one as the southwest corner of a 9-ha, square plot. Any portions of the plot that were in wetlands or unsuitable habitat (water, unvegetated areas) were excluded. This procedure sometimes resulted in very small plots being selected (e.g., because the selected point was just south of a large water body), and such plots were ignored. A better procedure would have been to work out computer procedures for combining such plots with an adjacent plot so that a true random selection of plots could have been made.

In other portions of the National Petroleum Reserve of Alaska, good areas are more extensive and less distinct. Many areas classified as uplands on the habitat map are flooded in June and may have as many shorebirds as the lower areas. The distinction between wetlands and uplands still seemed useful, because many upland areas had few birds. Delineating wetlands and selecting them as the plots, however, was not feasible because the wetland areas were much too extensive. Furthermore, it seemed wise to select equal-sized samples in the wetland and upland areas due to the higher density of shorebirds in areas classified as uplands. Another difference from the early work on the Colville River Delta was that we were using helicopters to access plots, and this limited our ability to have plot size – and therefore survey time – vary. The procedure we adopted involved an initial classification of the entire study area into wetlands, uplands, and unsuitable areas. A systematic sample of plots was then selected from throughout the study area, and a cluster of plots was selected at each point. The exact procedure for selecting the plots varied but in principle involved determining which habitat the initial point fell in and then, if the point was in

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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wetland or upland, expanding away from this plot following a pre-determined rule (e.g., move outward equally in all directions, but not crossing a habitat border, until the desired plot size was obtained). If the plot fell in unsuitable area, we selected another point. In the first year using this approach we needed a second plot, within walking distance. We did not want the plots closer than 1 km together to keep from sampling the same area, and they could not be more than 3 km apart to keep walking time reasonable. We accommodated these constraints by creating an annulus around the initial plot with a 1-km inner radius and 3-km outer radius and then randomly selecting points within this area until we obtained one in the desired habitat. The plot was then delineated by growing outwards from the point until we achieved the desired plot size. Variations of this approach were used in western Alaska, northeastern Alaska, and in Canada.

Rapid Surveys

In double sampling, a large sample of plots is surveyed with a rapid method and then a subset of these plots is surveyed intensively to determine actual numbers present. The detection rates on the rapid surveys of these plots are then used to adjust the results from rapid surveys. See Bart and Earnst (2002) for details of the general approach in bird surveys.

A first step in developing the method was defining the parameter at both the population and plot scale. For the population, our parameter was number of birds that occurred in the study area excluding young hatched that year. Various definitions of the number "present" on a given plot were considered. Assume that the study area is subdivided into plots in such a way that every point within suitable habitat falls in exactly one plot (i.e., suitable habitat is partitioned into plots). If the definition of "present" in a plot assigns every bird in the population to one plot, then the sum of the numbers present in all plots equals population size, and by selecting a random sample of plots we can estimate the mean number present per plot and thereby estimate population size, which was our primary goal. Other approaches to estimating population size might be imagined but we felt that assigning every bird to exactly one plot had substantial conceptual advantages so we considered definitions of "present on a plot" that met this requirement. An obvious approach would be to define present as meaning present at the time the survey started. This definition, however, was unsuitable because we could not conduct the intensive surveys to determine the "true" number present. Instead, we defined the number of birds on a plot as "the number of territorial males, and their mates, whose first nest of the season, or territory centroid for non-nesters, was within the plot". We used "territorial" broadly to include all males that had a well-bounded utilized area. The term, however, did not include floaters because we could not imagine any way to assign floaters to a particular plot that would also allow field workers on the intensive plots to determine the number of floaters present on their plots. When we developed this definition, we believed that floaters are rare in most if not all arctic shorebird species and were therefore not too concerned with excluding these birds. Robert Gill (pers. comm.) has recently commented, however, that Rock Sandpiper (*Calidris ptilocnemis*) populations may include a substantial floater population, so this whole issue may require more work.

The general goals in developing guidelines for the rapid surveys were (a) that results would be as consistent as possible between surveyors if they could somehow all survey the same plot at the same time; (b) that the ratio of number recorded to number present would be as consistent as possible among plots, weather conditions, times of season, times of day, and so on; and (c) that the ratio of number recorded to number present would be as close to 1.0 as possible. The reasons for these rules are fairly clear, but it may be worth noting that double sampling does require that detection rates are constant. We only need to estimate the overall ratio, number recorded/number present, on all plots surveyed, and we must believe that this is an essentially unbiased estimate of the ratio that would be obtained if all plots in the study area were surveyed. Achieving the three goals above, however, makes the overall detection rate easier to estimate, and facilitates comparisons among sub-populations which does require an assumption that the detection ratio is similar or that separate estimates of it are made for each sub-population.

We considered distance methods as a rapid method but found that the birds responded too strongly to the observer with the result that assigning distances would be highly arbitrary and would therefore vary substantially between observers. Weather conditions and time of season also seemed to have a strong effect on movement behavior. We therefore did not study this method in detail, though we tentatively plan to do so in the future, as some other observers have found it useful.

The rapid survey method we adopted was an area search in which surveyors covered about 10 ha per hour and recorded all evidence that might help them estimate the number of birds present on each plot. This information was recorded on plot maps using predetermined codes for nests, probable nests, pairs, males, females, unknown sex birds, and groups. Surveyors were encouraged to add arrows for flights and other notes that might help them decide how many birds were present on the plot according to the definition above. Immediately after each survey, a summary

Table 1*– Example of field form used in the rapid survey portion of the double-sampling approach. Total is the row total; the estimate is often less than the total because the surveyor believes that >1 observation was made of the same pair.*

Species	Nests	Probable nests	Pairs	Males	Females	Unk. sex	Total	Estimate
BBPL	1			1			2	1
AMGP		1	1				2	1
SESA	2		3			2	7	5
PESA		2			1		3	3
etc.								

was prepared (*table 1*), and an estimate of the number of birds present was made. We always assumed that single territorial birds had mates (at some time during the season even if not when the survey was conducted).

The final estimate prepared after completing the rapid survey was clearly subjective. Accordingly, we developed detailed guidelines, summarized below, in an effort to insure that different surveyors, detecting the same cues, would record the same final estimate for number present. A general guideline was that we were seeking unbiased estimates of the number present, not the number known by the surveyor to be present. Only recording numbers known to be present would sharply reduce the detection ratio and some species would almost never be recorded as present. We suggested several guidelines for surveyors to help them adopt the approach of making unbiased estimates:

(1) When uncertain whether to record a bird as within the plot, try to define the generalization being followed and then ask whether following that generalization would tend to over- or under-estimate the number present. For example, some species do not flush unless the observer almost steps on them, they do not display conspicuously near the nest, and they cover large areas. This might cause a surveyor to be uncomfortable in recording an individual of such a species as present on a plot unless its nest was found. But the species would then almost never be recorded. Another approach is to record the bird if it appeared to be present on the plot at the start of the survey. Assuming that one member of each pair is incubating and thus essentially undetectable (or that it occurs with its mate when off the nest), this procedure would lead to a detection rate of close to 1.0. Conversely, birds that cover large areas flying, or that approach observers from a great distance, should obviously not be recorded because doing so would lead to detection ratios greatly exceeding 1.0. In general, however, most birds found in the plot, on the ground, should be included in the estimated total.

(2) When birds appear to be on the edge of the plot, the best procedure is probably to make a quick estimate of how much of the probable territory is within the plot. On a rapid survey, these estimates are crude, but habitat configuration and behavior of the bird – especially territorial interactions with others – do often provide useful information. The final estimate for number present may then be computed as the sum of the proportions of territories within the plot. Thus, if three territories were felt to be largely, but not completely, outside the plot, then counting one as within the plot would be reasonable. Another approach is to make a judgment for each bird at the time it is recorded.

(3) Deciding which sightings represent distinct pairs is often difficult, especially when density is high. The best remedy for this problem seems to be keeping track of different birds, observing each one multiple times during the rapid survey. The rapid survey thus differs fundamentally from point counts in which a small area is surveyed for a short time and the observer then moves on. In the area search, when densities are high, the surveyor spends much time scanning ahead and looking backwards to work out territory boundaries and sort out how many individuals and pairs are present.

(4) In large patches of suitable habitat, substantial problems may be caused by birds that approach the observer from far away. These birds may follow the surveyor for long distances, and it may be impossible to tell during the survey whether they are nesting on the plot. The best way to avoid the problems these birds cause is by watching for them when approaching the plot and by watching them again when leaving the plot. Moving well away from the plot to a good vantage point and then waiting a few minutes for these birds to return to their territory is also often effective.

A particularly difficult problem arises when nesting and foraging habitat occurs in patches large enough that they tend to be in different plots. We have studied

this problem in western Alaska especially with respect to Western Sandpipers (*Calidris mauri*) which nest in the uplands but forage in the lowlands. The two habitats are sharply separated from one another (by 1 m in elevation) and in many areas the patch sizes are large so that a given plot occurs in only one area. The problem is that the sandpipers are often recorded in lowlands where they do not nest. If plots were always in one habitat or the other, the guideline could be "don't ever record Western Sandpipers as present in lowland plots because they don't nest there". This would minimize variation in detection ratios from plot to plot but would also depress the overall detection rate since many – perhaps most – of the individuals detected would not be included in the estimates. Furthermore, and perhaps of greater concern, we suspect that patch sizes will be smaller in some areas so that plots will include both habitats. Thus, the guidelines, "don't record western sandpipers as present in lowland plots" would not be practical. The best solution is probably to insure that surveyors are knowledgeable about nesting habits of the species and to rely on them to judge the likelihood that a bird seen foraging in wetlands is nesting within the plot. Information from following marked birds on how far from their nest they routinely travel to forage would also be most helpful. This issue, however, merits more thought and study.

Intensive Surveys

The purpose of the intensive surveys is to determine the number of nests, or number of territory centroids for those individuals whose nests were not found, present on the plot. Any other information gathered, e.g., habitat associations or nest success, is secondary to this goal.

Locating and Marking Plots

There are typically a total of four intensive plots (approx. 12-14 ha each) per camp with each intensive observer assigned two plots. It is important for the observer to become intimately familiar with a plot, thus better not to share plots among observers. It is convenient, with respect to travel logistics and safety, to locate intensive plots in sets of two, one for each observer in each location. The importance of choosing intensive plots randomly among all plots is discussed below. Once chosen, the borders of the intensive plot should be well marked. Wooden stakes, either plain or tipped with orange paint, or pin flags work well; the former may be less attractive to curious jaegers and ravens, and do not rip apart in high wind, but are more difficult to carry and install. If landmarks are lacking and the habitat is homogeneous, it may be necessary to create a center line of markers to facilitate mapping and re-locating territories and nests, but the number of markers should be minimized.

If an endangered species is discovered nesting, or is highly suspected of nesting on a plot, re-draw the plot borders to remain the approved distance (usually 200 m) from the likely nesting area or use an alternate plot.

Schedule

The short season places a premium on beginning as early as possible and working efficiently each day. For example, on the Colville River Delta, peak nest-searching was conducted from approximately 13-22 June, although during 8-12 June observers can become familiar with plots, and some nests can be found until hatch (roughly 1-4 July). Timing is optimal if one-fourth to one-half of nests found on the first day are 3-egg clutches. Given 10 days of peak nest-finding, each plot can be searched for a total of 5 full-day equivalents, with each plot covered every second day. Typically a full-day equivalent is approximately 8+ hrs on plot (travel time to and between plots is not counted). If travel time between plots is minimal, observers may wish to spend one-half day on each plot each day. Nest searching is efficient at all times of day, and can be conducted in all types of weather, except perhaps in extreme cold and rain which might cause egg cooling when incubating birds are disturbed. Nest finding is least efficient on windy days but worthwhile. On cold days, birds appear to flush closer to the observer, which increases the detectability of nests of species that typically flush at great distances, and makes the optimal nest-finding strategy one of intensive, systematic pacing rather than one of watching behavior.

Marking Nests

Nests should be marked with plain wooden pot markers (Forestry Suppliers sells a type that resembles a tongue depressor, pointed at one end), not a pin flag, at 1-2 m from the nest. A medium-point Sharpie can be used to write the species, nest number, distance, and an arrow indicating direction on the nest marker. We strongly suggest that each nest be plotted on a map and described on a nest card at the time it is found. Avoid leaving scent at the nest. Common mistakes include the following: touching vegetation around the nest with hands (use a stick or nest marker if necessary), standing at the nest while making the nest card or marker (move away a few meters where you can still see the nest), or placing a backpack or notebook on the ground near the nest. On the day preceding the first rapid survey of the intensive plot, all nest markers must be removed to avoid providing cues to rapid surveyors. Small, unobtrusive sticks placed flat on the ground, perhaps pointing in the direction of the nest, can be substituted for nest markers. It may be necessary to add

additional sticks as landmarks and further notes to nest cards.

Nest Cards

Nest cards are recommended for recording and re-locating nests even if nest monitoring is not an objective. We use a 4 x 6 inch custom-printed card with a large box on the front for a drawing of nest location; cells at the top of the card for observer's initials, species, nest number, and pair identity; and smaller cells near the bottom for optional nest and vegetation measurements of interest to the particular study. The back of the card contains one row for each visit to the nest, and columns for date, number of eggs, number of chicks, number of parents present on the plot, comments, and observer's initials. The essential part of the card is the drawing and description of nest location. The description should be written to allow a naive observer to find an empty scrape (i.e., in the case of predation). A common error is to write a less detailed description because a nest seemed easy to find due to the behavior of the flushing bird or the visibility of the eggs, neither of which may be present on subsequent visits. Use landmarks, number of paces, and cardinal directions to guide the observer from one landmark to another, then to the nest marker, and then to the nest. Keep the distance between landmarks short, especially if landmarks are small – it is much easier to consistently find a tongue depressor after 3 paces than after 50 paces. A crude drawing indicating the landmarks, paces and direction between landmarks, the nest marker, and the nest is very useful. In a landscape with many landmarks, such as on the Colville River Delta, we found that compass bearings were unnecessary and too time-consuming both while writing the card and re-locating the nest, but they may be useful in other habitats.

Numbering Nests

Each observer numbers his/her nests consecutively regardless of species or plot. The most common error is to use a number more than once; if separate runs were kept for plots or species, the potential for this error would multiply. At the beginning of the season, one observer is assigned the numbers 1-99 for his/her exclusive use, the second observer is assigned 101-199, etc. It is advisable for each observer to keep a list in a field notebook of nest number, species, plot, and day on which it was found. On maps and in notes, refer to nests by species and number (e.g., SESA 14).

Probable Nests

The definition of a probable nest (PN) is a location from which an individual flushes using a broken-wing, rodent-run or other distraction display. The location must be precise enough for the observer to be certain that the actual nest is on the plot. No other definitions of probable nests are acceptable. Probable nests should be numbered, mapped, recorded on nest cards, and mentioned on daily summary sheets. Refer to a probable nest as species-PN-#, for example, SESA-PN-15.

Scheduled Visits to Nests

It is important that intensive plots not have higher rates of nest loss than other plots, and thus important to visit nests as infrequently as possible. Curiosity leads observers to visit nests more often than necessary. We recommend the following scheduled visits: a) the day on which the nest marker is removed preceding the first rapid survey; and b) the day following the final rapid survey. If estimating nest success is a study objective, and if the final rapid survey is >3 days from estimated hatch, then each nest may be visited a final time approximately 3 days prior to hatch. There are several reasons not to visit near hatch: a) knowing nest outcome at hatch is not necessary for use of the Mayfield method; b) adults and newly hatched chicks easily become separated when disturbed; and c) it is usually not possible to tell whether an empty scrape was successful or not (except by a very detailed examination for shell fragments which can be done well after hatch). Note the results of each nest visit on the nest card; indicate that the visit was scheduled. Only scheduled visits should be used in estimating Mayfield daily survival rates.

Unscheduled Visits to Nests

During the course of nest-finding, a bird incubating a known nest may be visible from a distance or may be accidentally flushed. Record this information on the nest card as an unscheduled visit. Despite the risks of increased nest loss, it is important to continue intensive nest-searching in the vicinity of a known nest, even if the bird flushes as a result. On the Colville River Delta, it was not uncommon to find nests of other species within 1-2 m of a known nest, and Semipalmated Sandpipers (*Calidris pusilla*) sometimes nested within 1 m of a conspecific. Similarly, it may sometimes be necessary to flush a bird from a known nest to determine whether a nearby bird is associated with the known nest or is a member of a separate pair. It is also important to search for shorebird nests near the nests of charismatic species such as swans and geese; the increased risk of predation to these species is an unfortunate necessity of obtaining an accurate estimate of shorebird density on an intensive plot.

Plotting Nests and Territories

For use as a base map, scan the largest-scale aerial photo available, print black-and-white or color copies, and take several of each plot to the field. In the windy and

misty arctic environment, we find it best to place the map in a standard sheet protector, anchor it to a clip board with rubber bands, and write on the sheet protector with an ultra-fine tipped Sharpie (alcohol will remove ink for re-use of sheet protector). After each day in the field, transfer new nests and territory borders to permanent maps kept at camp. Also make a field copy of the permanent map and use it within a sheet protector for the next visit to the plot. Update both the field and camp copies after each visit. For plots with many nests and species, we find it useful to use fine-tipped permanent markers in 3-4 colors so that the three most common species can be mapped in one color and all other species in the fourth color on the paper copies of the maps. We use only black Sharpie on the sheet protector because other colors tend to rub or wash off easily.

The term "territory" is used in a broad sense to mean the area of primary use. For example, the area of use of a Semipalmated Sandpiper pair that is staying close to a nest may be drawn as a very small circle. The area of use of an American Golden-Plover (*Pluvialis dominica*) pair whose nest has not been found and who travels widely on and off the plot, may be indicated by a series of arrows denoting movements rather than by a well-bounded circle.

To provide correspondence between the map, field notes, and daily summaries, use consecutive letters within species to label pairs (or individuals) whose nests have not been found, e.g., SESA-A, SESA-B, PESA-A. Labeling is a matter of record-keeping and convenience. Label pairs (or individuals) that appear to be distinct from others; it is expected that several individuals will be labeled that are later determined to be outside the plot or determined to be the mate of another bird that has already been labeled or whose nest has been found. These extraneously labeled pairs do not affect data analysis or interpretation.

Estimating Number Present and Recording Effort

We use two forms to record daily records on number present and effort. The purpose of keeping daily records is two-fold: 1) final cumulative nests can be plotted against cumulative hours to illustrate the cumulative effort at which the number of nests asymptotes, i.e., after which few nests are found – if this effort is noticeably less than the total hours spent per plot, we can be more confident that all nests were found; 2) to keep track of the daily events that lead to changes in the estimated 'number present' and to the final end-of-season decision about whether a territory centroid is in or out of the plot. In the field, use a form similar to the "Birds Without Nests – Daily Summary" (*table 2*) to record whether each bird was observed on or off the plot and whether, based on all previous and current information, the territory centroid is estimated to be in or out of the plot at the end of each full-day equivalent of effort. Comments at the end of each line indicate the observations that led to your daily decision and eventually the final end-of-season decision. Once a bird's nest is found, it is no longer necessary to summarize its behavior on this form. After each visit, copy the list of birds without nests (first column) onto the next day's daily summary form (the identity of birds without nests should also be obvious from the field map). In addition, use the "Summary of Effort" form (*table 3*), which is kept in camp, to record hrs on plot, and number of new nests for each species. Comments at the bottom of the form explain cases in which number of cumulative territories for a species changed between visits, for example, "16 June, BBPL-A now clearly off plot" or "18 June, SESA-B is mate of bird at SESA 14 nest".

Nest Finding

During the first half-day or so on a plot, it is useful to walk through the plot finding as many nests as possible and noting the location of birds that likely have nests. Since nests found in this way are typically the easiest to find, this is referred to as 'high-grading'. By the end of the first full-day equivalent, all territories will have been plotted and the first estimate of number present made. On subsequent visits, the goal is to fill each territory with a nest, sort out the identity of territory owners, find nests of pairs on the edges of plots, and then search intensively for territories and nests that were not part of the first estimate. It is particularly important to find the nests of birds holding territories near the edges of plots so they can be conclusively ruled in or out of the plot. It is not a waste of time to spend hours looking for a nest that is eventually found off the plot.

A combination of several nest-finding strategies is necessary to find all nests on a plot. Within each strategy, nests may be found by following incubating birds back to the nest or by pinpointing the location from which a bird flushes. One strategy is to pick a territory or pair whose nest has not been found, walk the known area of use until you find a nest or a bird which can be followed back to a nest. Second, any suspicious bird, or bird that does not appear to be associated with a known nest, is worthy of an extended observation. In dimorphic species in which only one sex incubates, like Pectoral Sandpipers (*Calidris melanotos*), it is easier to decide which birds are worth watching. In monomorphic species (like Semipalmated Sandpipers) or those with dual incubation (like Dunlin [*Calidris alpine*]), it is more difficult. Incubating birds sometimes appear disheveled, and breast-preening is a classic tell-tale sign of a recently incubating bird. Third, walk preferred nesting habitats of key species (e.g., pond edges or marshes for phalaropes; dryas benches for American

Table 2– *Example of a Birds Without Nests form for use in recording daily observations and decisions regarding whether the territory centroid is in or out of the plot. Note that BBPL-A and BTGO-A are included here because they were included in the previous day's daily summary as birds without nests and their nests were found on the day in question (16 June).*

BIRDS WITHOUT NESTS – DAILY SUMMARY

Site: Colville Riv. Delta	Plot: S. Tam 2	Obs: SLE	Date: 16 June 02	Start Time: 8:15	End Time: 18:00

	OBSERVATIONS[A]		DECISIONS[B]		
Pair/Bird I.D.	M or Bird-1 ON/OFF /ND/NV	F or Bird-2 ON/OFF /ND/NV	Centroid ON/OFF	Nest #	Comments[C]
SESA – A	BOTH	ND	ON		primarily on; observed off once
BBPL – A	ON	ON	ON	PN-ON	PN near Dune 2
DUNL-A	ON	ON	ON		DUNL-A & B terr. encounter on ground 3m inside border
DUNL-B	BOTH	ND	OFF		DUNL-A & B parallel aerial displays inside plot
BTGO-A	BOTH	BOTH	ON	14	

[A] Record ON, OFF, BOTH, or ND if the area used by the bird was visited but the bird was not detected, or NV if the area used by the bird was not visited. Note that every section of the plot must be visited during every two days so that the Decisions column can be filled in.

[B] Record after each full-day equivalent. Record ON or OFF for territory centroid. Record Nest # once nest is found, otherwise leave blank. If a probable nest (PN) is located, write PN-ON or PN-OFF in the Nest # column.

[C] Record comments explaining Decisions or describing territorial encounters, etc.

Golden-Plovers). Fourth, for some habitats or sections of the plot with few landmarks, it may be necessary to search using a systematic grid to ensure complete coverage. The endpoints of parallel lines, approximately 3-5 m apart, can be temporarily indicated with pin flags. When the observer leaves the line to follow a bird, an additional pin flag can be placed at the point of departure until the observer returns. Fifth, nests of some species are more easily found by observing individuals at a distance before they are disturbed; this works well for Bar-tailed Godwits (*Limosa lapponica*), American Golden-Plovers and Black-bellied Plovers (*Pluvialis squatarola*). Species-specific hints for nest finding are beyond the scope of this document. However, here we give suggestions for two taxa because their behavior is particularly useful early in the season and might be missed if not given priority. Early in the season, attention should be given to phalaropes and other species in which one sex deserts early. Note the number of males and females, the location of pairs and their movements if possible. Pairs can often be followed to a prospective scrape, and it is not unusual to see the male or female sit in a newly formed cup. It is best to map the location and return in a few days rather than disturb her, but do not assume that this is the actual nest. Apparently cups are formed that are not used for egg-laying; this has also been observed in Dunlin and Semipalmated Sandpipers. Also, when a male phalarope suddenly appears in a pond near the observer, it is likely that he has come toward the observer from some distance away. He may make long flights to other ponds before returning to the pond nearest his nest, often leading the observer in a long circle back to the pond on which he was originally observed. Males sometimes land in the pond nearest their nest and walk discretely to the nest, or they fly to within a few meters of the nest and walk to it. Similarly, the behavior of male Pectoral Sandpipers early in the season is a useful indication of female and sometimes nest presence. During a male's aerial display, he often swoops low and "booms" directly over a female. Prior to incubation, he may perform this display over a foraging female or a group of females, but during incubation, he often displays over an incubating female.

Table 3– *Example of a Summary of Effort form for use in recording number of new nests, cumulative nests, cumulative territories, and new effort after each visit.*

SUMMARY OF EFFORT

Site: Colv Riv Delta	Year: 2002	Obs: SLE	Plot: S. Tam 2

	Vis 1 (date): 14 June			Vis 2 (date): 16 June			Vis 3 (date): 18 June		
Species	New Nests	Cum. Nests	Cum. Terr's	New Nests	Cum. Nests	Cum. Terr's	New Nests	Cum. Nests	Cum. Terr's
SESA	6	6	12	2	8	11	2	10	11
PESA	3	3	5	1	4	4	0	4	4
BBPL	1	1	2	1	2	3	0	2	3
etc									
Tot New Nests									
New Effort (hrs)	8.25			7.5			8.0		

Comments (Explain any changes between visits in number of cumulative territories):

Date	ID	Comments	Date	ID	Comments
16 Jun	SESA-A	same as SESA-B			
16 Jun	PESA-A	nest found; outside			
16 Jun	BBPL-C	not same as BBPL-B			

Habitat Data

Habitat data are useful in several ways in this study. They provide the regionwide GIS layers that are used to build the regression models and extrapolate findings from the surveyed plots to the entire study area. Observations made on the ground help us understand both the accuracy of the regionwide GIS layers and the relevance to shorebirds of the variables these layers contain. Observations made on the ground also help improve our knowledge of the shorebirds' habitat relationships which is one of the PRISM goals. Finally, in areas that have not been surveyed previously, observations made in this project may contribute useful information about other birds or other species.

On each plot, surveyors make brief notes of the general habitat (13 categories), ground cover including vegetation (13 categories), and moisture level (4 categories). Separate notes are made when more than one major habitat type is present within the plot. In addition, at the end of the field season, surveyors are asked to summarize their impressions of the major habitat relationships for each species. Where aerial photography is not available, photographs are often made as the helicopter is descending onto the plot.

Analytic Methods

The estimate, $\hat{X}$, of population size in a given study area is

$$\hat{X} \quad \frac{\hat{Y}}{\hat{P}}$$

where $\hat{Y}$ is an estimate of the number of birds that would have been recorded if surveyors had surveyed all plots in the study area and $\hat{P}$ is an estimate of the proportion of the population that would have been recorded on the surveys.

The numerator is obtained by developing regression models, from the rapid plots, and applying these models to every plot in the study area. Numbers of birds are converted to densities per km. Areas are converted to proportions. The dependent variable, for a given species, is the density of birds recorded. The independent variables are the proportions of the plot covered by each of the habitat variables in the GIS layers used for the study area. Other independent variables, such as distance to the coast or distance to the nearest wetland, may also be constructed. A conservative modeling approach has been adopted in which (1) only habitat variables with a positive relationship to density are allowed to enter the model, (2) only a few variables are used, and (3) every variable retained has a significant coefficient. The ideal model has an intercept of 0.0, meaning that if none of the explanatory variables is present the species is not present, and the variables believed to be of most

importance, based on impressions from the field, have the highest coefficients. For example, consider the following hypothetical model:

Pectoral Sandpipers/km^2 = 5 + 65(habitat 1)
+ 15(habitat 2)

This model would be interpreted in the following way. Habitats 1 and 2 appeared to be most important to Pectoral Sandpipers and the species was very rare (5/km^2) when neither of these habitats was present. Their density was substantially lower in habitat 2 (15 vs. 65). Different models are constructed for each species and with a large study area consideration is given to developing different models for different portions of the area if evidence of substantially different habitat relationships is present.

Different approaches have been used to compute $\hat{Y}$. In early work, the study area was actually partitioned into (ca. 12,000) plots. It was therefore straightforward to apply the models for each species to every plot, convert the estimated density to number present (using plot size) and sum the results. More recently (see above) only the plots actually surveyed have been delineated. If no spatial variables were included, the entire study area could be viewed as a single plot and the model could be applied to it. Distance to the coast, however, has been included for some species and it is anticipated that other spatial variables such as east-west and a north-south variables will be important. Furthermore, it has been interesting to compute densities for subdivisions of the study area. For both reasons, the study area has been partitioned into a few dozen sub-areas and estimates have been computed for each (*fig. 1*).

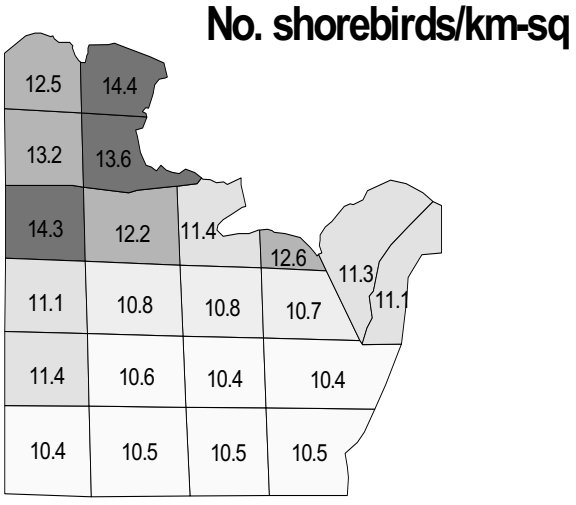

Figure 1— Density of breeding shorebirds in the eastern third of the National Petroleum Reserve of Alaska as determined during 1998-2000 using the double-sampling method.

In estimating $V(\hat{Y})$, we have treated the plots as a simple random sample and used standard regression methods. This approach, however, ignores the complex sampling plan used to select the plots which usually involves both stratification (based on habitat) and cluster sampling (for logistic reasons). It has recently been pointed out (Eric Reed, pers. comm.) that mixed effects regression models are available for grouped data. It appears likely that such models could be used to acknowledge clustering, and perhaps also the stratification. This approach warrants attention in the future. Another issue that should be studied is whether to use weighted or unweighted regression, with plot size being the weight. Theoretically, it seems more appropriate to use weighted regression since plots actually do vary in size. On the other hand, plot size is always evaluated as an independent variable, has never entered a model, and if it does not, then the accepted model assumes that plot size does not affect density. It might be thought that using a weighted regression approach would produce smaller standard errors but this was not the case in an early analysis we performed. Nonetheless, this issue also probably warrants further study.

Estimation of $\hat{P}$ is fairly straightforward although attention is needed to define the sampling plan correctly so that pseudoreplication is avoided. We are interested in making inferences about the overall detection rate that would be achieved by the surveyors we actually used in the study – not to some hypothetical population of surveyors. But any surveyor might survey any plot so we wish to estimate the overall detection rate if each surveyor could somehow survey each plot at every possible time of the season. The statistical population may thus be thought of as a two-dimensional array with plots as rows and "surveyor-times" as columns. The entries would be the number of birds recorded. The parameter we are trying to estimate could be represented as

$$P \quad \frac{\sum_i^N \bar{y}_i}{\sum_i^N X_i} \quad \frac{\bar{\bar{y}}}{\bar{\bar{X}}}$$

where $\bar{y}_i$ is the mean number that would be recorded on plot i by all surveyors recording at all times, and X_i is the number actually present on plot i. We estimate P with the following steps: (1) randomly select the intensive plot; (2) for every surveyor and plot (since all surveyors conduct at least 1 rapid survey on every intensive plot), randomly select one or more times to conduct rapid surveys; (3) compute the mean result for each surveyor and the mean of these means. The sampling plan for the numerator is thus three-stage: selection of plots, selection of surveyors (all surveyors

are selected), selection of 1 or more times. This being the case, the variance of the numerator is $V(\bar{y}_i)/n$ where n is the number of intensive plots selected (Cochran 1977, p. 298 with f_1, $f_2 = 0$). The variance of the denominator is just $V(X_i)/n$.

We use the standard formula for the variance of a ratio to estimate $V(\hat{X})$ (Cochran 1977, Section 6.4), assuming that $\hat{Y}$ and $\hat{P}$ are independent.

The description above, however, is incomplete in one important respect. It does not specify what random plan is used to select the intensive plots. This is an important issue because it is tempting to place the intensive plots in "good" or "typical" areas and doing so may result in variation between detection rates on them being less – in a worst case scenario much less – than in the suite of all plots in the study area. For example, there is no point in putting an intensive plot in an area with no birds so we have tried in the past to place them in locations with many birds. But it is possible that detection rates vary with density so this may not be appropriate. A more serious problem arises when species nest and forage in different habitats. It seems natural to put the plots in nesting habitat because the number nesting in foraging habitat may be low or even zero if there is no nesting habitat on the plot. But surveyors may record the species as being present in the foraging habitat if they do not fully understand the way habitat is used by the species. Under this scenario, detection rates would be over-estimated because we would exclude plots that would contribute positive numbers to the numerator and zeros for the denominator. More generally, if detection rates are similar, then failure to have a well-defined sampling plan to select intensive plots is not too serious and logistic considerations such as accessibility and number of birds on the plots are reasonable to include in deciding where to place the intensive plots. But if detection rates vary substantially, then – as with any estimation – following a well-defined sampling plan becomes much more important. In early years of this study we believed that detection rates did not vary much between plots (or species) and so we did not worry too much about how the intensive plots were selected. In the past few years, however, this issue has become more of a concern and we are now following a fully random plan in selecting the intensive plots around each camp.

One other issue is important to consider in selecting the intensive plots. We have had at least one case in which we felt a fox was attracted to a spike camp and, due to spending time near camp, may have seriously depressed nesting success on our intensive plots. It is possible that the fox also spent more time on the intensive plots than it would have otherwise due to the scent trails left by the observers, though we do not believe it was actually following these trails to nests (we avoid visiting nests after finding them for this reason). Nest loss probably reduces detection rates in at least some species due to the pair leaving the area. Thus, this form of visitor impact could cause a significant bias in our detection rates. Part of the solution is probably to locate intensive plots as far from camp as possible. Extreme care not to leave food scraps – even tiny ones – in the eating area may also reduce the extent to which predators are attracted to the camp area.

A final issue in defining the sampling plan for selecting the intensive plots is whether the plot, or the camp, should be considered the primary sampling unit. Concerns such as the one immediately above suggest that the detection rates might vary substantially from one camp to another. We will therefore probably consider the camp as the first stage in intensive plot selection. It is thus important to have as many camps – or sets of intensive plots – as possible.

An Example

The eastern portion of the National Petroleum Reserve of Alaska was surveyed during 1998-2000. Each year four plots were searched intensively to determine the number of birds present. About 20 percent of the survey effort was devoted to the intensive surveys. In 2000, a record was kept of new nests found per unit of effort (*table 4*). The results, and estimates of the total

Table 4– *Search effort and results obtained during each of three complete nest searches on intensive plots during 2000.*

	1st Search (15-20 June)	2nd Search (21-25 June)	3rd Search (26 June-1 July)
Search hr	62	65	72
Search hr/ha	1.2	1.2	1.4
New nests	44	31	4
New nests/hr	0.71	0.48	0.06
Estimated total	89	81	79

number present made periodically during the searching effort, both indicated that all or nearly all territorial males were located during the intensive surveys.

Surveyors not familiar with the intensive plots carried out 1-2 rapid surveys on each plot. The results showed that the average ratio (number estimated)/(number actually present) was 0.79 (*table 5*). All but one of the ratios was between 0.71 and 1.05, and the variation was not statistically significant. The outlier (Red Phalarope [*Phalaropus fulicaria*]) was probably caused by departure of the females well before the end of the season and, in most years, before the detection rates were measured (they were usually made late in the season for logistic reasons). Most operational surveys, however, were carried out before female Red Phalaropes left, and the investigators knew of no reason to believe that Red Phalaropes would have lower detection rates than other species. Thus a single correction factor of 0.79 was used for all species. As more data are accumulated, species-specific detection rates will probably be identified and they will then be used in place of the single rate.

More than 300 plots covering >100 km^2 were surveyed using the rapid method. The proportion of each plot covered by each of 17 habitat types (based on a map prepared by the Bureau of Land Management and Ducks Unlimited) was determined, and a few derived variables (e.g., distance to the coast) were also calculated from each plot. These data, and the numbers of birds recorded on each plot were used to construct regression models that predicted the density of birds on each plot (*table 6*).

The models were used to predict the number of birds that would be recorded if every plot (>12,000 plots) in the study area was surveyed. This total, or the total for any sub-region of interest, was divided by the estimated detection rate, 0.79, to obtain the estimated population total. The total population of all shorebirds in the eastern third of the National Petroleum Reserve of Alaska was estimated to be 356,000-455,000 (95 percent confidence interval). Application of the estimation procedure in each of 22 sub-regions showed that numbers were slightly higher closer to the coast (*fig. 1*).

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Table 5– *Index ratios on the rapid surveys for breeding shorebirds.*

Species	Number present	Average number recorded	Ratio
Semipalmated Sandpiper	101	72	0.71
Pectoral Sandpiper	45	46	1.02
Red Phalarope	27	13	0.49
Red-necked Phalarope[1]	36	29	0.80
Dunlin	14	15	1.05
Ruddy Turnstone[1]	7	7	0.93
Black-bellied Plover	6	6	1.00
Others	10	7	0.74

[1] Scientific names not reported in text: Red-necked Phalarope (*Phalropus lobatus*) and Ruddy Turnstone *(Arenaria interpres*).

Table 6– *Examples of models used to predict the density of shorebirds on plots on the North Slope of Alaska.*

Species	Model[1]
Black-bellied Plovers/km^2	0.5 + 2 (deep *Carex aquatilus*)
American Golden-Plovers/km^2	1.0 + 3.2 (upland sedge)
Bar-tailed Godwits/km^2	0.0 + 2.6 (shallow *Carex aquatilus*)
Red Phalaropes/km^2	3.3 + 13 (*Carex aquatilus*) – 0.2 (distance to coast)

[1]Habitat variables were defined as the proportion of the plot covered by the habitat; habitat types were from the land cover map prepared by the Bureau of Land Management and Ducks Unlimited.

Temperate Non-Breeding Surveys – A Key to Shorebird Conservation[1]

Sue Thomas[2]

Abstract

Completion of the United States and Canadian shorebird conservation plans recently identified and prioritized shorebird monitoring, management, and conservation needs in the Western Hemisphere. We present an emerging approach to monitor shorebird use of temperate non-breeding areas under the Program for Regional and International Shorebird Monitoring (PRISM). This program provides a single, comprehensive blueprint for implementing the monitoring component of both the U.S. and Canadian plans. The main goals of PRISM are to estimate the size of breeding populations, monitor population trends, evaluate the magnitude of use of stopover locations, and assist local managers with conservation goals. The primary goal of temperate non-breeding surveys is to produce an accurate estimate of the average number of shorebirds using stopover sites during the spring and fall migration in Canada and the United States. At a regional level, this effort will provide local or regional resource managers with quantitative information on shorebird use of key locations allowing them to more effectively manage and conserve shorebirds at the local and flyway scale. In coordination with the Biological Resources Division, US Geological Service, the Pacific Region of the US Fish and Wildlife Service is identifying and evaluating a network of monitoring sites along the Oregon Coast. This includes prioritizing focal species, evaluating potential biases in conducting surveys, defining survey methodology, and developing a strategy to coordinate volunteer efforts. This program seeks to build upon and advance citizen science initiatives such as the International Shorebird Survey, the Maritimes Shorebird Survey in the Atlantic Provinces of Canada, and the Western Shorebird Survey.

Key words: conservation, migration, monitoring, shorebird, surveys, temperate.

Monitoring Nonbreeding Shorebirds – A Multinational Priority

The U.S. and Canadian shorebird conservation plans acknowledge that data from long-term monitoring is the basis for establishing conservation goals, evaluating management activities, and identifying research needs. One of the highest priorities identified in the U.S. Shorebird Conservation Plan was the development of a comprehensive monitoring strategy with the following goals: (1) assures statistically valid monitoring of long-term species-specific population trends, (2) provides precise estimates of the size of species' populations, (3) monitors shorebird use of major staging, migration and wintering areas in the U.S. and Canada and, (4) ensures that shorebird population information is integrated into bird conservation planning and implementation.

The Program for Regional and International Shorebird Monitoring (PRISM) was developed by the Canada-U.S. Shorebird Monitoring and Assessment Committee, formed in 2001 by the Canadian Shorebird Working Group and the U.S. Shorebird Council, to meet these goals. It provides a single, comprehensive blueprint for implementing monitoring goals under both the Canadian and U.S. shorebird conservation plans. PRISM outlines a four-part approach to monitoring shorebirds throughout their annual cycle; this paper describes the rationale and procedure for implementing temperate non-breeding surveys. Further details on other components of PRISM are provided in this volume (see Bart et. al., this volume).

Temperate Non-Breeding Surveys

Temperate non-breeding surveys meet three of the five goals of PRISM including: (1) monitoring the use of stopover sites, (2) defining habitat relationships during the spring and fall migration, and (3) providing resource managers with quantitative population and habitat information to assist them in planning and implementing shorebird conservation measures. In addition, these surveys have the potential to provide an early warning signal of population declines that will prompt more intensive monitoring on the breeding grounds. The primary goal of temperate non-breeding surveys is to produce an accurate estimate of the average number of shorebirds using stopover sites during migration in Canada and the United States

At a regional level, this effort will provide local or regional resource managers with quantitative population and habitat information to assist them in the man-

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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agement and conservation of shorebirds. Of particular importance, is their ability to form comprehensive migratory bird management strategies with Joint Ventures, private land initiatives, and other bird conservation plans. For instance, habitat requirements for shorebirds during migration can be extrapolated from these data for use in building comprehensive habitat enhancement, protection, and acquisition plans. This survey could (1) provide a baseline for evaluation of management techniques, (2) monitor shorebird use of areas with invasive species issues and document the need for management, or (3) provide data on the use of stopover sites adjacent to populated coastal communities for purposes of mitigation.

Every effort is being made to develop and use statistically valid survey techniques that will accurately reflect population declines while minimizing bias and maximizing precision. The resulting data will be analyzed, at the species level, for accuracy before the data are used in trend analysis. At present, there are three sources of bias that could potentially produce erroneous trends: regional selection, site selection, and measurement bias (see definition provided by Bart, et. al. this volume). If the potential for bias exists within the study area, pilot studies are proposed to determine if the bias can be eliminated, minimized, or if the study area should be discontinued.

Survey dates for each study area will be determined from available scientific literature and local experts to ensure that each focal species is potentially represented in the survey. It is important to note that this effort will not use peak counts, but rather estimates of the mean number of birds present during the study period. This provides flexibility in the timing of surveys with less emphasis on catching peak shorebird concentrations that may vary by year, weather, conditions on the breeding grounds, and other potential factors.

Much like the Breeding Bird Survey, this initiative will be based on a volunteer, "Citizen Science" effort. It seeks to build and improve upon several successful shorebird migration monitoring programs such as the International Shorebird Survey (Howe et. al. 1989), the Maritimes Shorebird Survey in the Atlantic provinces of Canada, and the Western Shorebird Survey (Howe et. al. 2000). Each of these efforts will remain as separate initiatives, yet for purposes of statistical analysis, site selection and data collection will be standardized and a common database developed.

Regional Temperate Non-Breeding Surveys – A Case Study in Oregon

In coordination with US Geological Survey – Biological Resource Division, the US Fish and Wildlife Service, Pacific Region is identifying and prioritizing a network of migration monitoring sites on the Oregon coast, and prioritizing focal species and survey periods for monitoring the spring and fall migration. The initial tasks of site selection and focal species designation were recently completed. Site assessments are ongoing. Each regional assessment is a working document, continually revised as the process is refined. Below I outline methods for the development of bird monitoring regions and zones therein, selecting sites and focal species, survey methods, and potential measurement error and bias associated with each of these. I present particular examples encountered during my work on the Oregon assessment (S. Thomas, unpubl. data).

Bird Monitoring Regions

Canada and the United States were sub-divided into "Bird Monitoring Regions" by overlaying Bird Conservation Regions (BCR) with Provincial and State boundaries. Each Bird Monitoring Region (e.g. Northern Pacific Coast, BCR-5 in Oregon) was then geographically sub-divided into domains. Domains were delineated for ease of presentation and organizational purposes; their borders do not have any particular statistical significance or unique habitat representation. Domains were then sub-divided into zones that consist of one or two habitat types (e.g., rocky shorelines) that require a unique sampling plan.

Site Selection

Site selection relied heavily on areas identified in the *US National Shorebird Management Plan: Northern Pacific Coast Working Group Regional Management Plan* (Drut and Buchanan 2000) and the Western Shorebird Survey (*fig. 1*). Each site was then reviewed to determine if 80 percent of the shorebird days (equivalent to a shorebird spending 24 hours in the study area) for each focal species occur in that area. This analysis prioritizes survey effort so that migration monitoring will accurately reflect the importance of stopover sites within the Pacific Flyway.

Focal Species Designation

Focal species designation relied heavily on information provided by Paulson (1993), Nehls (1994), Drut and Buchanan (2000), and local expertise. Focal species were chosen based on the region's significance to the species in question [Regional Conservation Scores taken from http://shorebirdplan.fws.gov/U.S.Shorebird-/downloads/BCRSCORES3.xls and Drut and Buchanan (2000)], whether 80 percent of the flyway population moves through the BCR, abundance of adults, and whether the species was monitored by other survey programs, (*table 1*). Temperate breeding species were not included because they are best monitored during

the breeding season. Also, species that require special surveys (i.e., off shore migrants) were not included in this monitoring program.

Site specific information such as access and associated issues, period of use, and long-term change in use were collated from conversations with members of the Northern Pacific Coast Regional Shorebird Management Plan Working Group, local shorebird experts, and landowners.

After the initial tasks of selecting focal species, delineating the bird monitoring region into domains and identifying sites or "zones" of interest, a more detailed analysis of each zone was initiated to determine the level of effort necessary to effectively monitor shorebird use within the region. The following information was provided for each zone.

Zone Description

Each zone description included information on the boundaries of the zones, information regarding the best tidal conditions and time of day to survey, historical occurrence of species and specific concentration areas within the zone. Ownership, access, and safety issues were also described. A description of a rocky shoreline zone (*fig. 2*), might call for surveys on an evening high tide to take advantage of the sun low in the west, as the majority of rocky shoreline in this zone faces west.

Zone Classification

Zones were classified into three types (i.e., 1, 2 and 3) based on the number of shorebirds historically observed in the area. Historic use was based on available literature and confirmation by local experts. Type 1 zones are areas where shorebirds are present in substantial numbers and surveys are conducted annually. Type 2 zones are areas where shorebirds are present, but in small numbers and surveys are conducted periodically (e.g., every 5 years) to assure shorebird use of the zone has not changed. Type 3 zones are areas considered to have virtually no shorebirds and where surveys are not conducted unless warranted by changing shorebird use.

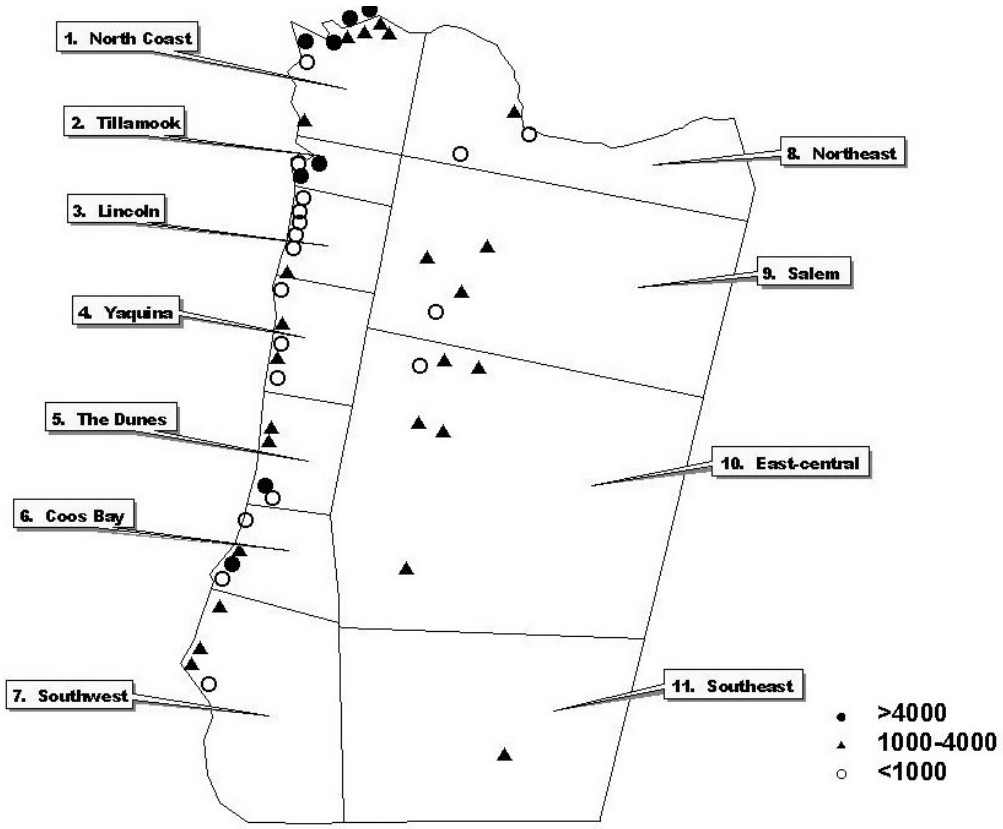

Figure 1—Shorebird concentration sites and domain boundaries in shorebird monitoring region Oregon-BCR5.

Table 1—*Preliminary Focal Species for temperate non-breeding surveys of shorebirds regularly occurring in shorebird monitoring region Oregon-BCR5 (Northwest Pacific Rainforest).*

Species	Regional Conservation Score[1]	National Conservation Score[2]
Black-bellied Plover	3	3
Semipalmated Plover	3	2
Black Oystercatcher	4	4
Greater Yellowlegs	4	3
Lesser Yellowlegs	2	3
Whimbrel	4	4
Ruddy Turnstone	3	3
Black Turnstone	4	4
Wandering Tattler	3	3
Surfbird	3	4
Rock Sandpiper	5	3
Red Knot	4	4
Sanderling	3	4
Dunlin	3	3
Western Sandpiper	3	4
Least Sandpiper	3	3
Short-billed Dowitcher	4	4
Long-billed Dowitcher	3	2

[1]Conservation Score – represents population status, trend and comparative importance of BCR5 to the species (5 – Highly Imperiled, 4 – Species of High Concern, 3 – Species of Moderate Concern, 2 – Species of Low Concern, 1 – Species Not at Risk). This score is considered along with the relative abundance of adults during migration and absence of other survey programs that adequately monitor the species. Taken from the U.S. National Shorebird Management Plan: Northern Pacific Coast Working Group Regional Management Plan.

[2]Taken from http://shorebirdplan.fws.gov.

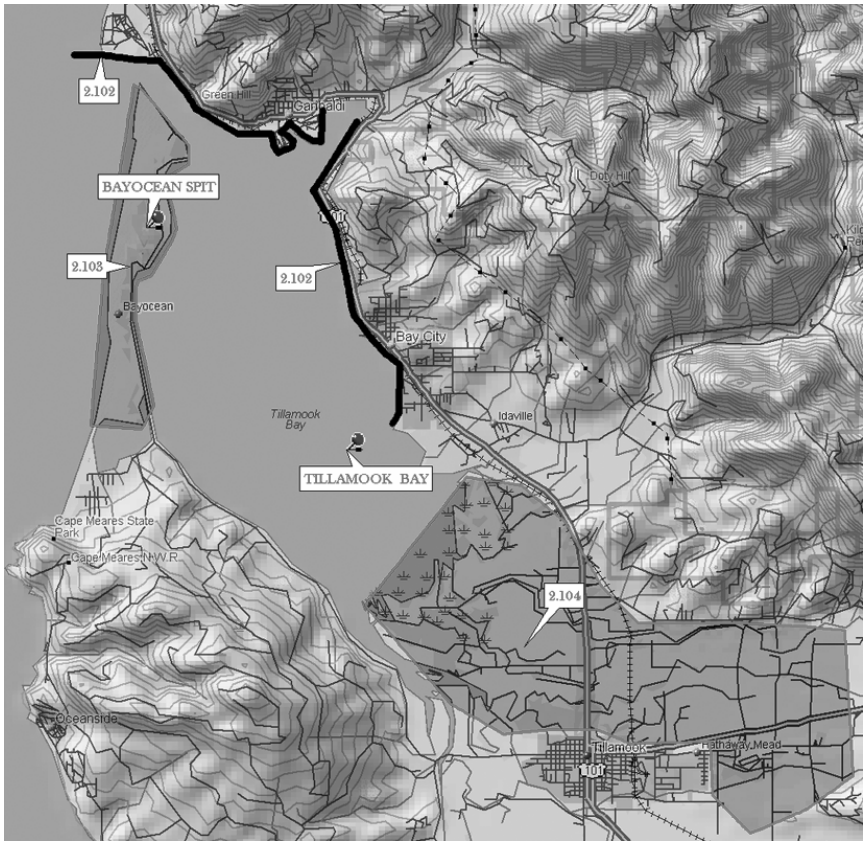

Figure 2—Rocky shoreline zone 2.102 in Domain 2, Tillamook Bay, shorebird monitoring region Oregon-BCR5**.**

The classification of zones into different types is an iterative process that can change as new information becomes available. For example, if a previously unsuitable zone, classified as Type 3, has become suitable, it can be included in the survey plan for reassessment at that time. Local shorebird experts or biologists are encouraged to identify Type 3 zones that should be reclassified based on change in use. The survey plan for the entire domain will be reassessed every five to ten years, by evaluating recent aerial surveys to assure changes in access or habitats have not caused previously unidentified biases or safety issues. This is particularly relevant in dynamic estuary environments and areas that are heavily managed. In the example above, rocky shorelines are considered a Type 1 zone.

Survey Methods

This section consists of initial suggestions on how and when to conduct surveys within each zone. We focus on conducting surveys during high tides to reduce the chance of double counting between zones. For example, Black-bellied Plovers (*Pluvialis squatarola*) often congregate along the outer shore during high tide and within the estuary during low tide. Surveys in these two zones without regard to tides could over-represent this species. The amount of time spent in each zone is also important in dynamic estuarine environments. In some areas with steep gradients, tidal heights can change considerably within 30 min. The rocky shoreline appears to be best surveyed using a shallow-bottomed boat such as a Zodiac to minimize hazards associated with walking on slippery, wave tossed jetties and access issues along the rocky shoreline. In addition, boats may cause fewer disturbances than ground-based surveys. Visibility would be particularly poor using aerial surveys in this habitat as cryptic sandpipers such as Surfbirds (*Aphriza virgata*), Rock Sandpipers (*Calidris ptilocnemis*), Wandering Tattlers (*Heteroscelus incanus*), and Black Turnstones (*Arenaria melanocephala*) could be significantly undercounted.

Measurement Error and Measurement Bias

Measurement error/bias could occur if some of the birds in the study area are not recorded. Some species are more prone to measurement error/bias than others. For example, because Least Sandpipers (*Calidris minutilla*), use the vegetated borders of mudflats to varying degrees; it is possible to record a different proportion of the birds during each survey and or year thereby producing a biased trend for this species over the long term. Certain areas are also prone to measurement error /bias. Disturbance issues from heavy human use of the zone could affect the survey one day and not the next. For example, humans use the south jetty of the Columbia River intensively during spring; this greatly influences the movement of shorebirds throughout the area with as many as 70 percent of the individuals flying past the survey areas (M. Patterson, pers. comm.). These situations are considered when designing surveys, delineating habitats, and classifying zones.

Access and Selection Bias

Access and selection bias are encountered if suitable areas within the zone cannot be surveyed because the site is inaccessible to an observer. This may occur if an area is privately owned or becomes available due to recent management actions (i.e., the site was not previously considered for monitoring). For example, an active management program designed to eradicate invasive species may significantly improve habitat for shorebirds in an area that had not been included in the original survey plan thereby inducing biased counts. Conversely, invasive species could render a previously important stopover site virtually unsuitable as is the case in Willapa Bay with *Spartina* encroachment. The availability of new areas and the use of old areas will be reevaluated every 5 to 10 years to assess the potential for bias due to changes in each zone.

Pilot Studies

If the potential for bias in survey counts exist, pilot studies are designed to determine if the bias can be eliminated, minimized, or if the study area should be discontinued. Pilot studies may include preliminary aerial surveys of each zone during the migration period. Aerial surveys may help to further delineate the boundaries of each zone; pinpoint concentration points and assist in defining the best time of day to monitor birds. Aerial surveys may also identify previously unknown high tide roosts such as sandy islands in the middle of a bay or suitable pastures adjacent to an estuary. As pilot studies, one advantage aerial surveys have over ground surveys is that adjacent zones can be assessed virtually simultaneously. This is particularly important when assessing the potential for double counting in a zone. Ground and water-based pilot studies may prove beneficial when assessing concentration points for smaller and cryptic shorebirds; determining the length of time necessary to fully cover a zone; and pinpointing absolute tide heights to cover the zone. A pilot study for the rocky shoreline zone might consist of boat surveys to confirm concentration sites along the shore; pinpoint absolute tide heights and time of day to cover the zone, determine the most appropriate method to count birds and whether the zone can be effectively sampled.

Future tasks necessary to complete regional evaluations on the Oregon coast include: (1) conducting a thorough GIS spatial analysis of each Type 1 zone to assess the

interaction of tidal heights, gradient, access, and habitat type, (2) conducting the necessary pilot studies to complete the description of each zone, and (3) assessing volunteer skills and coordination needs.

This is a multi-national effort that should be expanded throughout the Western Hemisphere in the near future. Coordinators are needed to develop regional assessments and monitoring networks in other bird monitoring regions.

Acknowledgments

I thank J. Buchanan, J. Gilligan, D. Jaques, N. Maine, H. Nehls, M. Patterson, D. Pitkin, and N. Seto for taking time out of their busy schedules to provide information regarding shorebird use of the bird monitoring region. This effort would not be possible without their years of experience observing shorebirds in the area. Also, I would like to thank B. Andres, J. Bart, R. Lanctot, M. Naughton, J. Solberg and T. Zimmerman for evaluating the manuscript and providing a broader scope to the project.

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Introduction – Regional Monitoring Programs[1]

Richard L. Hutto[2] and C. John Ralph[3]

Introduction

There is increasing interest in the initiation of regional or statewide monitoring programs that are less extensive than national efforts such as the Breeding Bird Survey. A number of regional programs have been in existence for a decade or more, so the papers in this section represented an effort to bring together the collective experience of the people who had developed these programs, and to hear about the benefits and drawbacks of their particular designs. Speakers reviewed why they felt there was a need for a regional monitoring effort, examined the designs and response variables associated with their regional monitoring program, presented the short- and longer-term results from the program, discussed the logistic and scientific successes and failures of each program, and presented recommendations for those who might be interested in starting their own regional monitoring program. Below, we provide a brief overview of some important points that emerged from this session, and how these regional efforts might be included as integral parts of broader national monitoring efforts that seem to be emerging.

Need for Regional Monitoring Efforts

The consensus among land managers seems to be that the sample sizes generated from Breeding Bird Survey (BBS) data include too few routes for meaningful use at the regional or more local level (perhaps at the level of a county or a Forest Service District). But does that mean we need to acquire population trend data from regions than are smaller than those effectively sampled by the BBS? An issue that managers need to be clear about is why they need trend data, and at precisely which spatial scale such data are needed. Would knowledge of a severe population decline of Townsend's Warbler (*Dendroica townsendi*) in one District be of concern? Given that we know almost nothing about the spatial scales at which the metapopulation dynamics of local extinctions and recoveries operate, we would not know whether declines at local scales are worrisome or not. For example, even though Linder and Buehler (this volume), Howe and Roberts (this volume), and Hanowski et al. (this volume) each show that reliable trend data can be obtained for smaller areas than can be addressed through the use of BBS data, are trends at these spatial scales worthy of management action? Moreover, local-scale trends are likely to differ from what BBS regional trends from the same area produce. This raises another important issue: what can one conclude if trend data do or do not correspond with BBS trend data from the same region? Differences could be due to subtle differences in the methodology used to generate data (e.g., roadside vs. off-road transects), in the locations sampled, in the sample area, or any of a number of other factors. All of the trend data are undoubtedly "correct," but they represent trends associated with different sets of birds (sets taken from different spatial scales). Without a better understanding of exactly what subsets of the landscape are being sampled, and how they differ, simple comparisons of BBS-generated trend data with trend data generated otherwise will be of limited value. However, at the very least, the fact that they do differ is an indication (if not a warning) to managers and conservationists that we need to think more about the spatial scales over which negative trend data would be indicative of a problem that needs management attention.

Perhaps our attempts to attain population trends at subregional scales for other than research purposes, or for the purpose of enhancing our understanding of spatial details associated with population trends of threatened or endangered species, are well meaning but misguided. For example, one would certainly expect population changes at the District or even National Forest level after the Forest experiences a stand-replacement fire (e.g., the Bitterroot National Forest after the fires of 2000), but that is not to say there is a problem that needs management attention. Trend data based on point count data are perhaps best left to the larger regional, multi-state scale that the BBS covers quite well. This is certainly more like the scale at which we wish to ensure persistence of a species. Additionally, we should at least encourage migration monitoring based on local, constant effort counting and netting operations that sample from substantial portions of migratory populations as they pass through restricted locations en route north or south. In general, perhaps more of our local monitoring efforts should be devoted to other

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than long-term population trend monitoring, as discussed further below.

Program Design

Multi-Agency Collaboration

Because virtually all public land management agencies want monitoring at relatively local scales in relation to land use practices, successful programs have capitalized on that common need, and have leveraged their resources to build larger collaborative efforts. Indeed, this is an opportunity to conduct coordinated monitoring in a way that produces collective information that far outweighs what each agency might be able to accomplish on its own. There are now several successful multi-agency cooperative monitoring efforts described in this section, and each can serve as a model of how one might undertake such an effort. Land managers from other regions interested in initiating monitoring programs may derive benefit from correspondence with the coordinators of these and other (e.g., Ontario, Colorado) monitoring programs that have persisted for more than a decade now.

Habitat Relationships "Monitoring"

Howe and Roberts (this volume) show that a relatively small volunteer effort can produce meaningful bird-habitat relationships information, which cannot be readily derived from current BBS data, but which is critical for management decision-making. Indeed, the Nicolet Forest monitoring program was not designed to produce trend data, but to focus on geographic occurrence and patterns of habitat use—kinds of information not well provided by existing monitoring programs. The Northern Region Landbird Monitoring Program (Hutto, this volume) also provides a strong focus on habitat relationships by including vegetation information with long-term monitoring points, and by devoting one of every two years to the gathering of targeted, short-term management effects information. This is exactly the kind of "monitoring" that provides a useful alternative to what seems to have become a fixation on population trend monitoring.

By permanently marking survey points, monitoring programs have also positioned themselves to be in a powerful statistical position to learn about the effects of natural disturbance events. For example, the Klamath Demographic Monitoring Program (Alexander et al. 2004), among many other applications, had located more than 100 stations in and near a fire that subsequently burned 125,000 acres within the Six Rivers and Shasta-Trinity National Forests in 1999. A simple after-the-fact comparison of bird occurrence between burned and unburned points shed light on fire effects that mirrored results from published studies specifically designed to extract such information. Similarly, the Northern Region Landbird Monitoring Program had run for a half-dozen years, more than 100 permanently marked points that were, coincidently, in the middle of the Bitterroot National Forest fires of 2000. Observers were then able to return to the same points after the disturbance event, and to nearby points on permanently marked transects that did not burn, to provide data that fit into one of the first-ever before-after/control-impact studies to investigate the effects of stand-replacement forest fire–a design that is otherwise impossible to achieve because managers will probably never be in a position to provide research biologists an experimentally ignited stand-replacement fire.

In summary, the acquisition of detailed habitat-based information associated with each survey point, the inclusion of managed lands, and the ability to conduct more local management effects studies or before-after/control-impact studies are not only possible, but highly prized data of immediate use to land managers and conservation biologists. Because one can anticipate long-term effects of alternative management scenarios using such monitoring data, habitat relationships monitoring data may actually be much more useful to a land manager than information derived from the typical long-term monitoring data, which allows only retrospective analysis. Thus, regional monitoring programs are revealing a kind of usefulness to decision-makers that cannot be attained from larger, national monitoring efforts. The critical part, as always, is to get decision-makers to listen to what the bird data have to offer. We feel that much progress has been made along these avenues in the last few years.

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MoSI (Monitoreo de Sobrevivencia Invernal): Assessing Habitat-Specific Overwintering Survival of Neotropical Migratory Landbirds[1]

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Abstract

Recent evidence suggests that population declines in many Neotropical-wintering migratory landbird species are caused by habitat loss and degradation on their wintering grounds. Such habitat loss and degradation can lower overwintering survival rates and cause surviving birds to leave their wintering grounds in poor physical condition, leading to high mortality during spring migration and low breeding productivity. Large-scale, long-term data on winter demographic parameters of these species and linkages between those parameters and winter habitat characteristics are urgently needed to understand the population dynamics of these migratory landbirds and guide management and conservation efforts for them. We established the MoSI (Monitoreo de Sobrevivencia Invernal) Program to fill this data gap. The objectives of MoSI are: (1) to assess habitat-, age-, and sex-specific overwintering survival rates and late winter physical condition for a suite of target species in a variety of winter habitats by applying state-of-the-art mark-recapture models to data collected from a network of standardized mist-netting and bird-banding stations throughout Mexico, Central America, and the Caribbean; (2) to use these data to formulate management plans for these species on their winter grounds; and (3) to use the MoSI network to facilitate feather collection for DNA and stable isotope analyses that aim to link breeding and wintering populations of these species. We have initiated a five-year pilot project aimed at evaluating, enhancing, and expanding the MoSI Program, and have created partnerships with 20 organizations and individuals in Mexico, Central America, and the Caribbean who operated 29 MoSI stations during the winter of 2002-03, the first year of this pilot project. We suggest that a successful MoSI Program can provide useful information on winter demographic parameters of resident, as well as migratory, Neotropical landbird species, and can be expanded northward into southern U.S. to address these same issues in temperate-wintering migratory species.

Introduction: Background and Extent of the Problem

Analyses of data from the North American Breeding Bird Survey (BBS) indicate that populations of many species of Neotropical-wintering migratory birds (hereafter, NTMBs) have declined over the past three decades (Robbins et al. 1989, Terborgh 1989, Peterjohn and Sauer 1993, Pardiek and Sauer 2000). In response to these declines, major conservation efforts such as the Neotropical Migratory Bird Conservation Initiative, Partners in Flight (PIF); the North American Bird Conservation Initiative (NABCI); and the Neotropical Migratory Bird Conservation Act (NMBCA) were established and funded. Nevertheless, these conservation efforts have been hindered by a lack of information concerning the causes of declines (DeSante 1992, 1995, Peterjohn et al. 1995, DeSante et al. 2001). For example, the BBS and similar monitoring programs provide indices of population abundance, yet the link between habitat quality and abundance can be misleading due to source-sink dynamics (Van Horne 1983, Pulliam 1988, Donovan et al. 1995).

In contrast to population abundance, vital rates (productivity, recruitment, survivorship, emigration, immigration) respond directly, and usually without substan-

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California**.

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tial time lags, to environmental stressors or management actions (Temple and Wiens 1989, DeSante and George 1994). Thus, estimation of avian vital rates provides critical information to population managers (DeSante and Rosenberg 1998) and should be an integral component of all avian monitoring and management efforts (DeSante et al. this volume). In the case of NTMBs, estimates of avian vital rates can be used to help determine whether population declines are related to low productivity on the breeding grounds, high mortality during migration or winter, or both (Sherry and Holmes 1995). More generally, these estimates can be incorporated into predictive population models to assess potential effects of various land use practices on population viability (Noon and Sauer 1992) or predict effects of global climate change on bird populations (Nott et al. 2002, Parmesan and Yohe 2003).

In order to complement the BBS and lend insight into causes of NTMB population changes, The Institute for Bird Populations (IBP) created the Monitoring Avian Productivity and Survivorship (MAPS) Program in 1989 (DeSante et al. 1995). MAPS is a cooperative effort among public agencies, private organizations, and individual bird banders in the U.S. and Canada to operate a network of over 500 standardized, constant-effort mist-netting and bird-banding stations during the breeding season. The principal goal of MAPS is to monitor the vital rates and population dynamics of over 120 species of resident and migratory landbirds (DeSante and O'Grady 2000). In addition to monitoring, MAPS is organized to address specific research and management goals. Research goals include the identification and description of: (1) temporal and spatial patterns in the vital rates of target species (DeSante 2000), (2) relationships between vital rates and population trends and ecological characteristics of target species (DeSante et al. 1999), and (3) relationships between vital rates and habitat and weather variables (Nott 2002). Management goals include: (1) the identification of proximate demographic cause(s) of population change (DeSante et al. 2001), (2) the formulation of management guidelines and conservation strategies to reverse population declines (Nott et al. 2003), and (3) the evaluation of the effectiveness of management actions through an adaptive management framework.

Recent analyses of MAPS data show that low adult survival appears to be the proximate demographic cause of population decline for a number of NTMBs (DeSante et al. 2001). In the Neotropics north of the equator (where the majority of these birds winter), high mortality may occur toward the end of the winter period when, due to the onset of the dry season, food resources are often scarce and intra- and inter-specific competition is high. Habitat loss or degradation in such a competitive environment could result in dramatically lowered survival rates. Alternatively, diminished late winter resources could increase mortality during the ensuing spring migration, when birds must cross hostile or unfavorable habitats, often under adverse weather conditions (Sillett and Holmes 2002). Either way, it is likely that low survival during the non-breeding season is an important factor affecting population declines of many NTMBs.

Another important result from the MAPS program suggests that conditions on the wintering grounds at the end of the overwintering period can play a major role in determining avian reproductive success on the breeding grounds (Nott et al. 2002). Again, the extent of this effect on productivity likely varies as a function of habitat quality on the wintering grounds. These findings agree with work that suggests winter habitat quality affects the physical condition and spring departure schedules of American Redstarts, resulting in variable arrival dates and physical condition on temperate breeding grounds (Marra et al. 1998). Both studies provide evidence of an important link between events affecting adult birds on the wintering grounds and subsequent life cycle events, and both suggest that winter habitat may limit populations.

Patterns of winter habitat use have been shown to differ between age- and sex-classes for many NTMB species (e.g., Conway et al. 1995, Wunderle 1995, Sherry and Holmes 1996, Marra et al. 1998, Murphy et al. 2001, Latta and Faaborg 2002). Such habitat segregation could translate into differences between the physical conditions and survival rates of different ages and sexes during the non-breeding season. This would be expected in cases where dominant males actively exclude first-year (i.e., sub-adults) and female birds from optimal habitats (Marra and Holmes 2001). Nevertheless, few data exist to shed light on this prediction. Understanding sex- and age-related differences in habitat use and survival is necessary before a complete picture of the factors affecting population dynamics can emerge. Recent advances in aging and sexing landbirds makes such a goal attainable for many NTMBs (Pyle 1997).

A growing body of evidence thus suggests that populations of many NTMBs may be limited by factors during the non-breeding season. Nevertheless, data on the overwintering ecology of most of these species is severely limited. A variety of local-scale studies have shown that many NTMBs use a wide array of habitats in the tropics; even species thought to prefer relatively mature or undisturbed primary forest can be found in substantial numbers in secondary forest, forest edge, and other disturbed habitats (e.g., Greenberg 1992). Patterns of winter abundance in different habitats, however, can be a misleading indicator of habitat quality (Marra and Holmes 2001). In order to determine the true value of different winter habitats, estimates of

sex-, age-, and habitat-specific overwintering survival rates and indices of late winter physical condition are needed. These parameters have been studied for a few species on a local scale. In order to draw inferences for a larger suite of species, and to determine how these parameters vary as a function of space and habitat, a standardized, spatially-extensive monitoring effort is required.

Solution to the Problem: The Establishment and Operation of the MoSI (Monitoreo de Sobrevivencia Invernal = Monitoring Overwintering Survival) Program

1. Overview of the MoSI Program

We suggest that the first step toward reversing population declines of NTMBs that are related to loss or degradation of winter habitat is to determine, for each species, the habitat characteristics that provide for adequate overwintering survival and good physical condition at the end of the winter season. This goal was identified by many presenters at the Third International Partners in Flight Conference in March 2002 (Ralph and Rich this volume), and at the 13th Annual Meeting of the Society for Caribbean Ornithology in July 2001 (Latta et al. 2003), as a critical need for the development of winter management strategies for NTMBs. We suggest that the optimal way to achieve this goal is to determine habitat-, age-, and sex-specific overwintering survival rates from mark-recapture data, and indices of late winter physical condition from data on body mass relative to wing length. We suggest further that this critical information can best be obtained by the establishment and operation of a network of standardized mist-netting and bird-banding stations throughout Mexico, Central America, and the Caribbean. With the initiation of the MoSI Program in 2002, we have begun to establish just such a network.

The MoSI program is patterned after the MAPS program in that it: (1) has clear monitoring goals based on firmly established needs, (2) provides direct links between monitoring data and research and management goals, (3) provides critical information at both regional and local spatial scales, (4) is comprised of a network of stations each utilizing the same standardized protocol, (5) provides the means for electronic data submission and verification by cooperators, (6) utilizes state-of-the-art analytical models for making inferences, (7) utilizes central data repositories and identifies individuals and organizations responsible for timely analyses of data and publication of results, (8) provides frequent and substantive feedback to cooperators, and (9) will undergo peer review after an appropriate five-year pilot period.

As with the MAPS program, MoSI addresses monitoring, research, and management objectives. The *monitoring goals of MoSI* are to provide estimates of habitat-, age-, and (when possible) sex-specific annual and seasonal (overwintering) survival rates, population sizes, and population trends for a suite of about 20 target species, as well as indices of late winter body condition. *Research goals of MoSI* include: (1) the statistical modeling of estimates of survival and indices of physical condition as functions of site-specific and landscape-level winter habitat characteristics and weather variables, (2) the linking of these winter population parameters with breeding season vital rates and population trends, and (3) the development of predictive population models to assess population viability of NTMB species under various scenarios of future habitat or climate change. The *management goals of MoSI* are to apply knowledge of the linkages between winter habitat and population parameters in such a manner as to (1) formulate generalized management strategies and specific management actions for the target species to reverse population declines and maintain stable or increasing populations, and (2) evaluate the effectiveness of any implemented management actions. The design of the MoSI program allows for many levels of data aggregation and analysis, and we anticipate the formulation of management strategies that will address issues at a variety of spatial scales, ranging from the regional (country, state, Bird Conservation Region, physiographic strata) to the local (park, preserve, or other local area) scale.

Accordingly, in partnership with 20 organizations and individuals in Mexico, Central America, and the Caribbean (*Appendix 1*), The Institute for Bird Populations has initiated a five-year pilot project to evaluate, enhance, and expand the MoSI Program. Primarily through the volunteer efforts of these 20 organizations and individuals, the first year of this pilot project has already been completed and 29 MoSI stations were established and operated during the winter of 2002-03. This number was limited by the lack of broad-scale funding, the lack of a MoSI coordinator for the Caribbean region prior to the 2002-03 winter field season, and the program's very recent establishment. We suggest that, given adequate funding, the MoSI network will grow rapidly over the next three winters to the point where about 150 stations will be operated during each of the last two years (2005-06 and 2006-07) of the five-year pilot project. We project that these 150 stations will be dispersed throughout six MoSI regions as follows: three in Mexico (Pacific lowlands, highlands, Atlantic lowlands), two in Central America (lowlands,

highlands), and one in the Caribbean, with about 25 stations in each MoSI region.

In order to provide focus to the MoSI pilot project, MoSI stations are currently sited to address a discrete list of target species (*Appendix 2*). These species were selected according to three criteria: (1) MAPS data have shown that they can be captured with ground-level mist nets in sufficient numbers to provide adequately precise estimates of annual survival rates; (2) they have been identified as priority species in one or more Bird Conservation Regions (and typically have declining 20-year BBS population trends), or they are non-declining species for which survival rates can be compared to those for the declining species; and (3) they provide for an adequate representation of declining and non-declining species over each of the six regions defined above.

Three coordinators, one each in Mexico, Central America, and the Caribbean, provide local coordination of the MoSI Program. Responsibilities of the three MoSI coordinators include: (1) helping to facilitate the recruitment and training of potential MoSI cooperators; (2) registering and maintaining the registry of MoSI stations within their region; (3) distributing MoSI materials, including manuals, data sheets, and electronic data entry, verification, editing, submission, and analysis programs; (4) receiving and archiving MoSI data from the cooperators; (5) disseminating regional annual reports on the results of the Program; and (6) sharing data with other researchers and organizations. Communication and sharing of information among cooperators is aided by an annual regional workshop and training session held in each of the three major areas. The Institute for Bird Populations provides assistance to the three coordinators in program development, program enhancement (creation of manuals and computer programs for data collection, verification, editing, and analysis), data analysis, and drafting of results.

2. The MoSI Field Protocol

The MoSI program is designed to be as inclusive as possible, and its overall goal – to maximize the numbers of captures of target species – is broad enough that it can accommodate several variations of the basic protocol. For all protocol variations, we suggest that every effort be made to run nets in a constant-effort manner and to apply the same protocol in all years of operation. Consistency of operation, although not required for mark-recapture analyses, can aid in mark-recapture modeling. We appreciate, however, that changes can often be necessary as funding levels or research objectives change.

The basic MoSI field protocol calls for five monthly ”pulses” of mist net operation on a 20-ha study area (the MoSI station) established in a habitat of interest where at least one MoSI target species can be captured in substantial numbers. Each pulse of mist netting consists of operating about 16 nets for two or (preferably) three consecutive (or near consecutive) days, yielding 10 or (preferably) 15 days of netting during the five-month (November through March) winter period. In general, pulses should be conducted as close as possible to the midpoints of each of the five monthly periods, and at least three weeks should elapse between successive pulses. This time gap should minimize net-avoidance resulting from more frequent net operation and better allow modeling of monthly survival rates.

MoSI cooperators that are unable to operate MoSI stations for five pulses should make every effort to run stations for at least three (preferably four) pulses. If three- or four-pulse protocols are followed, we suggest that nets be run for three days on each pulse (for a total of 9 or 12 netting days). If nets are run for four pulses, we recommend that the missing pulse be either December or February. If December is missed, we suggest that the November pulse be run after November 15. Likewise, if February is missed, we suggest that the March pulse be run before March 16. If nets are operated for only three pulses, we suggest that they be operated in November, January, and March. As for the four-pulse protocol, the November pulse should occur after November 15 and the March pulse before March 16.

Although less desirable, it may be possible to contribute to the MoSI program by running nets for only two pulses during the winter season. If only two pulses can be completed, we suggest that one of them be in March (before March 16). In addition, if only two pulses can be completed, we suggest that the size of the study area be increased to 40 ha, that it be divided into two 20-ha subplots, and that up to 16 nets be operated for two or (preferably) three days on each subplot in each pulse (to produce 8 or 12 netting days). In general, two days of operation on each subplot in each pulse would be preferable to three only if either (1) large numbers of birds are captured on the first day and capture rates drop so drastically on the second day that a third day of netting in the subplot would not be useful; or (2) logistic considerations limit the operation of the station.

Finally, it may be possible to include data in the MoSI Program from stations that operate even more frequently than one pulse per month (e.g., one pulse every two weeks or once every 10 days). In such cases, all data from the month would be pooled as if they were part of a single pulse. Before utilizing this approach, further investigation of possible biases that might be produced in the estimation of monthly survival and/or recapture rates will likely be necessary.

All mist nets used in the MoSI program should, if possible, be 12-m-long, 4-tier, tethered nets. Depending upon the local target species, these nets should have either a 30- or 36-mm mesh (36-mm if the major target species is *Catharus* thrush-sized or larger; otherwise 30-mm). One good strategy for placing the nets is to scatter them singly and relatively uniformly over the central 12 ha of the 20-ha station (or subplot) at locations where substantial numbers of birds can be captured. An alternate strategy is to place them along at least two lines that are at least 150 m apart and that traverse the station (or subplot). All nets on a given station (or subplot) should be operated during each day of operation of that station (or subplot). Although we recommend operating 16 nets per station (or subplot), the actual number of nets run should be the maximum that can be operated by available personnel without endangering the lives or welfare of the birds captured.

If possible, MoSI stations should be operated for all daylight hours on each day of operation. If high temperatures, lack of shade, or other logistic considerations prevent nets from being operated for all daylight hours, they should be operated for at least the first 4-6 morning hours. In general, the three (or two) days of operation should be as close to consecutive as possible, although we realize that inclement weather and unforeseen circumstances may make operation for three consecutive days problematic. For two-pulse stations that are divided into two 20-ha subplots, the three (or two) days of operation on the second subplot should follow immediately after the three (or two) days of operation on the first subplot.

Nets should be opened and closed and (if possible) checked in the same order on each day of operation and net check. Opening, closing, and net check times should be recorded to the nearest ten minutes. All birds captured should be identified to species, age (hatching-year/second-year vs. after-hatching-year/after-second-year, where '/' signifies the December 31/January 1 annual age change in all individuals), and (if possible) sex. Unmarked birds should be banded with a uniquely numbered leg band. The body mass of each bird captured should be determined to 0.1 g using a portable battery-operated electronic balance, and its unflattened wing chord should be measured to the nearest mm. Two tail feathers and 2-3 breast feathers should be plucked from each individual for DNA and stable isotope analyses, which are critical for linking breeding and wintering ranges of populations of NTMBs. Finally, all species seen or heard on the study plot during the course of the mist-netting effort each day (even if not captured) should be recorded in such a way as to determine the probable residency status of each species (e.g., using methods similar to those used in breeding bird atlas projects). A standardized protocol for assessing habitat structure and pattern is currently being created and will be available for the 2004-05 season.

Individual color banding and resighting, although labor intensive, can provide an excellent means for improving the precision of survival-rate estimates because, with sufficient effort, resighting probabilities can be substantially higher than recapture probabilities. We suggest that color banding/resighting effort be targeted on one or two (possibly three) focal species and be conducted in conjunction with, or immediately after, the operation of the stations during each pulse. Individuals of focal species should be banded with two or three plastic color bands and one numbered metal band. Resighting color-banded birds is best accomplished by: (a) creating a detailed map of the MoSI station, (b) systematically searching the MoSI station for individuals of the focal species, (c) closely observing all such individuals with binoculars and (if possible) following them for up to 15 minutes, and (d) recording, on species-specific daily station maps, the color-band combination, age and sex (if possible), and exact locations where each individual of the focal species was captured and subsequently re-sighted. A master summary map for each species can be created and updated at the end of each pulse and used in the next pulse to guide efforts to relocate individual birds.

We emphasize that the protocol presented here is in its pilot stage and we welcome suggestions for improvement. Data from the first pilot year of the program come primarily from stations operating only two pulses per winter and the revised protocol presented here arose from preliminary analysis of those data as well as five years of data from Cuba (Siegel et al. 2004). All field protocols will continue to be reviewed after data from each of the first three years of the pilot project have been received, will be modified as appropriate after each of these years, and will be disseminated in the MoSI Manual (DeSante et al. 2003), currently being translated into Spanish.

3. Analysis of MoSI data

All MoSI data are subjected to rigorous data verification procedures that identify and resolve both: (a) within-record discrepancies between age or sex determinations and supplemental data, such as degree of skull pneumatization, molt limits, and feather wear; and (b) between-record discrepancies in species, age, or sex determinations for a given band number. The means for cooperators to provide electronic verification, editing, and submission of their MoSI data is currently being developed through a modification of MAPSPROG, the MAPS data verification program.

Data collected within the suggested MoSI protocol guidelines will permit determination of seasonal

indices of body condition and estimation of both annual and overwintering survival rates, population sizes, and population trends. State-of-the-art methods are employed in the analysis of MoSI data. Modified Cormack-Jolly-Seber (CJS) mark recapture models (Pollock et al. 1990, Lebreton et al. 1992), that employ a between-pulse transient modification to account for the negative bias of transient individuals on estimates of survival rates (Pradel et al. 1997), are used to estimate survival and recapture probabilities. Initial estimates of overwintering survival rates (i.e., monthly survival raised to the fourth power, constrained to be constant over all months) will be available after the winter of 2003-04.

At the end of the five-year pilot project, estimates of overwintering survival, oversummering survival (i.e., survival from March to November, which includes mortality during both the spring and fall migration periods), and annual survival (estimated either from March to March or from November to November), as well as recapture (or resighting) probabilities will be modeled as functions of time (year), geographic location, habitat characteristics, age, and (when possible) sex using Program MARK (White and Burnham 1999). Model selection methods based on Akaike's Information Criteria (AIC) (Burnham and Anderson 1998) will be used to assess evidence for sex-, age-, year-, location-, and habitat-related differences in survival and recapture probabilities. Models in each candidate set will be ranked by second-order AIC differences and adjusted by the ĉ obtained from bootstrap goodness-of-fit tests to ensure conservative model selection (Cooch and White 2002). The relative likelihood of each model in each candidate set will be estimated with $QAIC_C$ weights, and model-averaging procedures will be used to provide the best estimates of survival and recapture (or resighting) probabilities from all models in a candidate set. This method of multi-model inference will enable us to use the entire set of candidate models to judge the importance of a parameter to survival rate, rather than basing conclusions on a single best-fit model (Burnham and Anderson 1998).

Discussion

The most important goal of the MoSI program over the next two years is to recruit local ornithologists to establish and operate new MoSI stations. To this end, we have identified regional coordinators in Mexico and Central America to organize regional workshops and training programs, recruit and coordinate the activities of MoSI cooperators, distribute MoSI materials to them, and provide, through their sponsoring organizations, regional repositories for MoSI data. These regional coordinators are *Claudia Romo de Vivar Alvarez*, Laboratorio de Ornitologia de CIB, Universidad Autonoma del Estado de Morelos, Cuernavaca, for Mexico; and *Salvadora Morales*, Alianza para las Areas Silvestres (ALAS), Masaya, Nicaragua, for Central America, who was aided by *Alexis Cerezo*, Fundación para el Ecodesarrollo y la Conservacio (FUNDAECO), Ciudad de Guatemala, Guatemala. Discussions are currently underway to identify a regional coordinator for the Caribbean. The existence and efforts of these regional coordinators have been critical for the initial success of MoSI. Indeed, they were responsible for organizing and facilitating the MoSI workshops and training programs held in Mexico and Nicaragua during October 2002, and for recruiting the 19 cooperating organizations and individuals that established and operated 26 MoSI stations in Mexico and Central America during the winter of 2002-03. Moreover, the regional coordinators serve to ensure that control of the program resides in the hands of the people of each region, and that researchers throughout the region will have access to the data.

The five-year MoSI pilot project will generate substantial capacity-building among partners in Mexico, Central America, and the Caribbean, by providing them with: (1) access to critical equipment (e.g., mist nets); (2) USGS/BRD subpermits and bands for migratory birds provided through the Master Station banding permit of The Institute for Bird Populations; (3) training in advanced ageing and sexing techniques and in the MoSI mist-netting protocol; (4) information and tools (e.g., manuals and computer programs) for collecting, verifying, editing, and analyzing mist-netting and mark-recapture data; (5) a means for obtaining and sharing critical data on demographic parameters of migratory landbirds that can only be obtained from a large-scale program; and (6) a network of cooperators and an established program that adds a measure of legitimacy to individual small-scale efforts. In addition, MoSI station operators are encouraged to invite the participation of local residents interested in birds. The information gained from MoSI stations can be used to help educate local residents (including children and school groups) on the importance of conserving quality habitat for Neotropical migrant and resident birds. The presence of MoSI stations and of ornithologists interested in conserving Neotropical birds will contribute to promoting a conservation ethic among area residents.

The MoSI Program will contribute greatly toward creation of a major network of ornithological stations throughout the Neotropics to promote the conservation of both migratory and resident birds. Indeed, a result of the October 2002 Mexico MoSI workshop was the formal creation "El Grupo de MoSI de Mexico." Two of the first goals it identified were to promote the establishment of a repository for survival data on resident bird species in Mexico and the establishment of a

national Mexican bird banding program to distribute uniquely numbered bands for resident species in Mexico. Sustainability of the MoSI Program (in Mexico at least) is being enhanced by efforts to include the program as a critical monitoring, research, and management tool in the bird conservation plans and demonstration projects being developed by NABCI for select Important Bird Areas in Mexico. To this end, the establishment of MoSI stations along important habitat gradients is currently being considered as an integral part of the bird conservation efforts at both the El Triunfo Biosphere Reserve (through a NABCI workshop held in Chiapas in January 2003) and the El Cielo Biosphere Reserve (through the efforts of the Texas Parks and Wildlife Department). Sustainability of the program elsewhere in Central America is being enhanced by efforts to include MoSI as an important aspect of the monitoring programs that are being developed for use in national parks and protected areas in Middle America through Park Flight, a consortium between the National Park Service, National Park Foundation, National Fish and Wildlife Foundation, USAID, and American Airlines. In addition, discussions are underway between IBP and the American Bird Conservancy to include MoSI stations as a means for monitoring the effectiveness of the GEF Silvipasture Project being led by CATIE in Costa Rica.

The MoSI program also provides a means for promoting further cooperation between United States and Canadian bird banders and Latin America ornithologists. For example, a project could be envisioned whereby banders from the United States cooperate with ornithologists from Mexico and Central America to operate MoSI stations along gradients of managed habitat (e.g., cover and species composition of shade trees for coffee growing) to document the effect of these practices on overwintering survival of NTMBs. The existence of the MoSI Program will facilitate the establishment of such cooperative ventures. Indeed, over 20 individual bird banders or prospective bird banders have contacted IBP and enquired about the possibility of helping at on-going MoSI stations in the Neotropics. In addition, the MoSI protocol may well turn out to be useful for assessing overwintering survival and late-winter physical condition of temperate-wintering, as well as Neotropical-wintering, migratory landbirds. If this proves to be the case, the MoSI Program should be expanded northward with new MoSI stations targeting the many declining species of sparrows wintering throughout the southern United States.

In conclusion, the MoSI Program promises to forge major partnerships among researchers, ornithologists, and institutions in Mexico, Central America, the Caribbean, and United States, and provides opportunities for sharing crucial data on overwintering survival of NTMBs (as well as permanent resident species). These data will be used to guide and evaluate management plans for modifying and preserving critical habitat in an effort to positively affect vital rates (e.g., survivorship) of these species so as to reverse their population declines. Finally, MoSI provides a means to collect a spatially extensive sample of feathers from target species on their Neotropical wintering grounds for DNA, stable isotope, and trace element analyses. Such samples are critically needed to link breeding and wintering ranges for populations of NTMBs. As of this writing, IBP and both the MAPS and MoSI Programs have developed cooperative agreements with the UCLA Neotropical Migrant Conservation Genetics Project, headed by Dr. Thomas E. Smith, for the analysis and archiving of feather samples collected from these cooperative mist-netting efforts.

Acknowledgments

We are extremely grateful to the 20 organizations and individuals who have established 29 MoSI stations in Mexico, Central America, and the Caribbean (*Appendix 1*), along with the many volunteers who helped operate those stations during the winter of 2002-03. We thank P. Pyle for his helpful comments on an earlier draft of this manuscript. We thank an anonymous donor to The Institute for Bird Populations for seed money to initiate the MoSI Program, and the U.S. Department of Defense Legacy Resource Management Program for funding to investigate overwintering survival of resident and migratory Neotropical landbirds on Naval Station Guantanamo Bay, a project that paved the way for the creation of the MoSI Program. This is Contribution No. 205 of The Institute for Bird Populations.

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Appendix 1— *Twenty partners that have established 28 MoSI stations during 2002-03 (or 2001-02). Unless stated differently, all stations began operation in November or December, 2002.*

A. Mexico

1. *Manuel Grosselet - Independent researcher*
   Stations:
   101 - "Parque Nacional Huatulco, Cacaluta" Oaxaca, Mexico (started November 2001)
   201 - "Llano Grande," Oaxaca, Mexico (started November, 2001)
   210 - "Etla Viguera," Oaxaca, Mexico
2. *Jardín Botánico de Santo Domingo*
   Station:
   202 - "Jardín Botánico de Santo Domingo," Oaxaca, Mexico (started November, 2001)
3. *Ornitorrinco*
   Stations:
   102 - "Bosque de Maple," Jalisco, Mexico
   103 - "Meso," Jalisco, Mexico
4. *University of Michigan*
   Station:
   104 - "Finca Irlanda," Chiapas, Mexico
5. *Pronatura Noroeste Mar de Cortes*
   Stations:
   105 - "Patolandia," Sinaloa, Mexico
   106 - "Pichiuila," Sinaloa, Mexico
6. *Laboratorio de Zoología, Fez-Iztacala-UNAM, Mexico*
   Station:
   203 - "Parque Estatal Sierra de Nanchititla," Mexico, Mexico
7. *Parque Ecología de la Ciudad de Mexico*
   Station:
   204 - "Cortafuegos de Corena," D.F., Mexico
8. *Centro de Investigaciones Biológicas, Universidad Autónoma del Estado de Molelos*
   Station:
   205 - "San Andres de la Cal," Morelos, Mexico
9. *Ramiro Aragon - Independent researcher*
   Station:
   206 - "El Capamento," Oaxaca, Mexico
10. *Instituto de Biología, UNAM, Ciudad Universitaria, D.F.*
    Station:
    207 - "Carricitos," D.F., Mexico
11. *Instituto de Biología, UNAM Departamento de Zoología, Colección de Nacional de Aves*
    Station:
    208 - "Jardín Botánico, UNAM," Morelos, Mexico
12. *Universidad Autonoma de Guerrero*
    Station:
    209 - "Parque Ecologico Estatal Omiltemi," Guerrero, Mexico (started February, 2002)

B. Central America

Guatemala

13. *Fundación para el Ecodesarrollo y la Conservacion (FUNDAECO)*
    Stations:
    405 - "Las Torres," Izabal, Guatemala
    406 - "Navajoa," Izabal, Guatemala (started February, 2002)
    407 - "Punta de Manabique," Izabal, Guatemala (started February, 2002)

Honduras

14. *Universidad Nacional Autónoma de Honduras*
    Station:
    408 - "Panacam," Cortes, Honduras (started February, 2002)

Nicaragua

15. *FUNDACIÓN COCIBOLCA*
    Stations:
    401 - "Reserva Natural Volcán Mombacho - Cafetál de Sombra," Nicaragua
    402 - "Reserva Natural Volcán Mombacho - Bosque Nuboso," Nicaragua
16. *Fundación Amigos del Río San Juan (FUNDAR)*
    Station:
    403 - "Refugio de vida silvestre los Guatuzos," Rio San Juan, Nicaragua
17. *Centro de Acción y Apoyo al Desarrollo Rural (CENADE)*
    Station:
    404 - "Chocoyero - El Brujo," Managua, Nicaragua
18. *FUNDENIC - Fundación Nicaraguense para el Desarrollo Sostenible SOS*
    Stations:
    501 - "Bosque Jaguar," Nicaragua
    502 - "Coffee Plantations Jaguar," Nicaragua

Panama

19. *Sociedad Audubon de Panama (SAP)*
    Station:
    409 - "Campo Chagres, Parque Nacional Chagres," Panama (to start November, 2003)

C. Caribbean

20. *Environmental Protection in the Caribbean (EPIC)*
    Stations:
    601 - "St. Martin Dry Forest," Netherlands Antilles (started January, 2001)
    602 - "St. Martin Thorn Scrub," Netherlands Antilles
    603 - "St. Martin Mangroves," Netherlands Antilles

Appendix 2— *Target species for the first two years (2002-03 and 2003-04) of the five-year MoSI Pilot Project*.

Species [1]		20-year BBS population trend [2]		Mexico			Central America		
				Pacific Lowland	Highland	Atlantic Lowland	Lowland	Highland	Caribbean
Willow Flycatcher	*Empidonax traillii*	Neg.**		✓			✓		
Least Flycatcher	*E. minimus*	Neg.**		✓	✘	✓	✓	✘	
White-eyed Vireo	*Vireo griseus*		Pos.			✓	✓		
Warbling Vireo	*V. gilvus*		Pos.**	✓	✓	✘	✓	✓	
Swainson's Thrush	*Catharus ustulatus*	Neg.**		✓	✓	✓	✓	✓	
Wood Thrush	*Hylocichla mustelina*	Neg.**				✓	✓		
Gray Catbird	*Dumetella carolinensis*		Pos.			✓	✓		✘
Orange-crowned Warbler	*Vermivora celata*	Neg.*		✓	✓	✘			
Magnolia Warbler	*Dendroica magnolia*		Pos.	✘		✓	✓		
Cape May Warbler	*D. tigrina*	Neg.							✓
Black-throated Blue Warbler	*D. caerulescens*		Pos.**						✓
Prairie Warbler	*D. discolor*	Neg.**							✓
American Redstart	*Setophaga ruticilla*	Neg.		✓		✓	✓		✓
Ovenbird	*Seiurus aurocapilla*		Pos.	✓		✓	✓		✓
Kentucky Warbler	*Oporornis formosus*	Neg.**				✓	✓		
Mourning Warbler	*O. philadelphia*	Neg.**					✓	✓	
MacGillivray's Warbler	*O. tolmiei*	Neg.			✓			✓	
Hooded Warbler	*Wilsonia citrina*		Pos.*			✓	✓		
Wilson's Warbler	*W. pusilla*	Neg.**		✓	✓	✘	✓	✓	
Indigo Bunting	*Passerina cyanea*	Neg.**		✓		✓	✓		✓
Painted Bunting	*Passerina ciris*	Neg.		✓		✓	✓		✘

[1]Additional potential target species of a fully realized MoSI Program: Yellow-bellied Flycatcher (*E. flaviventris*), Dusky Flycatcher (*E. oberholseri*), "Western" Flycatcher (*E. difficilis/ occidentalis)*, Bell's Vireo (*V. bellii)*, House Wren (*Troglodytes aedon)*, Ruby-crowned Kinglet (*Regulus calendula)*, Blue-gray Gnatcatcher (*Polioptila caerulea)*, Tennessee Warbler (*V. peregrine)*, Nashville Warbler (*V. ruficapilla)*, Yellow Warbler (*D. petechia)*, Chestnut-sided Warbler (*D. pennsylvanica)*, Yellow-rumped Warbler (*D. coronata)* , Palm Warbler (*D. palmarum)*, Black-and-white Warbler (*Mniotilta varia)*, Prothonotary Warbler (*Protonotaria citrea)*, Worm-eating Warbler (*Helmitheros vermivorus)*, Northern Waterthrush (*Seiurus noveboracensis)*, Common Yellowthroat (*Geothlypis trichis)*, Yellow-breasted Chat (*Icteria virens)*, Brewer's Sparrow (*Spizella breweri)*

[2] Trends and their significance from Pardiek and Sauer (2000).

* $0.05 \leq P < 0.10$

** $P < 0.05$

✓ regular and relatively common

✘ irregular or uncommon

Monitoring Puerto Rican Avifauna Using Roadside Surveys[1]

Keith L. Pardieck[2] and Bruce G. Peterjohn[2]

Abstract

In 1997 we began investigating the use of roadside point counts to monitor the long-term status and trends of Puerto Rican bird populations. If such a methodology proves feasible it may provide the empirical data needed for the development of sound conservation plans for the island's avifauna in much the same way that North American Breeding Bird Survey data are used by the avian conservation prioritization process of Partners in Flight, the U.S. Fish and Wildlife Service, and the Canadian Wildlife Service. By the end of the 2003 field season, we will have the data needed to quantitatively evaluate the utility of the program for tracking the population trends of Puerto Rican avifauna. Here we present data from the 2001 and 2002 field seasons to demonstrate the potential utility of these data for quantifying and portraying avian distributions, abundances, and population trend estimates. In 2001, 27 of the 44 available 5-mile roadside routes (11 stops/route) were sampled between 15 April and 15 May. At each stop a 5-minute point count was conducted. The surveys detected 5,471 individuals representing 70 species. Distribution and abundance maps are depicted for seven endemic species. In 2002, 29 routes were sampled. A total of 6,252 individuals was detected representing 79 species. Significantly fewer species and individuals were detected on wet zone routes as compared to moist and dry zone routes.

Introduction

Island bird communities are particularly susceptible to catastrophic declines due to their small population sizes and the fact that the species are often narrowly adapted to the conditions of their limited range (Temple 1985). Since the 1600s, 93 percent of extinct species were from islands (King 1980). Moreover, Collar and Andrew (1988) estimated that approximately 46 percent of all threatened bird species are island inhabitants. For these reasons, the International Council for Bird Preservation identified the long-term monitoring of endemic island species as a conservation priority (Johnson 1988). However, over a decade later few such programs exist for the avian species endemic to the Caribbean basin.

Puerto Rico, in particular, harbors numerous endemic avian species whose populations are not being monitored on an island-wide scale. Out of 141 breeding bird species (Raffaele 1989), 16 species are Puerto Rican endemics, while another 15 are endemic to the Caribbean basin (AOU 1998). Yet only about 13 percent of all species found in Puerto Rico benefit from any type of long-term island-wide monitoring program. For example, species being monitored consist primarily of game birds (Rivera-Milan 1993) and threatened or endangered species (D. Ramos, Puerto Rico Department of Natural and Environmental Resources, pers. comm.), leaving the majority of the avian species, including two-thirds of the endemics, outside of an existing monitoring framework. Thus in cooperation with the Puerto Rico Department of Natural and Environmental Resources, we are investigating the feasibility of using roadside avian surveys to monitor the long-term status and trends of the island's bird populations. If feasible, this information will allow bird population changes to be identified, and declines reversed through further research and management actions, before populations reach critically low levels.

Methods

We used 44, 8-kilometer (5-mile) roadside routes that were randomly established throughout the island by the Puerto Rico Department of Natural and Environmental Resources (*fig. 1*). The routes were originally developed to monitor columbid populations at 1.6-kilometer (1-mile) intervals (Rivera-Milan 1993). For the purposes of our study, stops were added at 0.8-kilometer (0.5-mile) intervals for a total of 11 stops per route. At each stop, a skilled observer conducts a 5-minute point count recording every bird seen within a 400-meter (0.25-mile) radius or heard. Surveys begin at local sunrise and take approximately 2 hours to complete. Routes are run once per year between 15 April and 15 May.

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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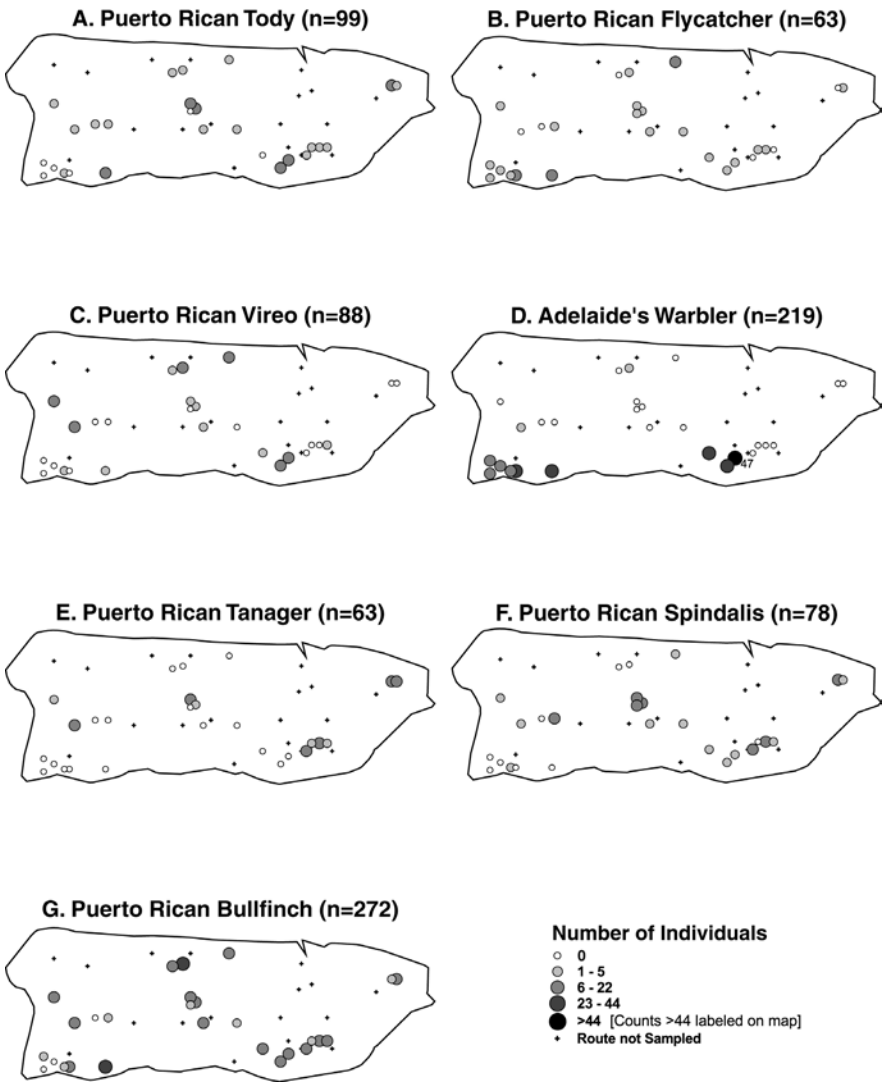

Figure 1— Locations of the 44 sample routes in Puerto Rico and the number of individuals of seven island-endemic species detected on 27 routes sampled in 2001.

Routes were classified into ecological life zones by overlaying maps depicting route locations and life zone boundaries (Ewel and Whitmore 1973). Routes crossing a life zone boundary were assigned to the boundary with the majority of the route path. Although six life zones are present in Puerto Rico, no effort was made to distinguish between the four wettest life zones. Thus, routes in this study were assigned to one of the following life zone groups: dry – Subtropical Dry Forest (17.6 percent of the island's area); moist – Subtropical Moist Forest (58.4 percent); and, wet – which includes, Subtropical Wet Forest (22.6 percent), Subtropical Rain Forest (0.1 percent), Lower Montane Wet Forest (1.2 percent) and Lower Montane Rain Forest (0.1 percent; Ewel and Whitmore 1973). No attempt was made to further classify habitats along routes.

All statistical analyses were conducted using Minitab™ Statistical Software (2000) (Use of trademark or brand name does not constitute government endorsement). Kolmogorov-Smirnov normality tests were conducted on life zone samples within years and pooled between years. Means of normally distributed data were compared between years using two-sample, two-tailed t-tests, while medians of non-normally distributed data were compared using the non-parametric Mann-Whitney test. Means of normally distributed life zone data pooled over the two-year sample period were compared between life zones using one-tailed, t-tests. All tests were considered significant when $P < 0.05$.

Mean species richness (MSR) was significantly lower on wet zone routes than on moist zone routes ($t = 4.82$, $P < 0.001$), or dry zone routes ($t = 3.89$, $P = 0.001$; see *table 1* for mean values). No difference in mean species richness was found between the moist and dry zone routes ($t = -0.13$, $P = 0.552$). Similar to species

Table 1— *Species detected along Puerto Rico Breeding Bird Survey routes in 2001 and 2002. Status codes: BR = breeding resident, E = endangered, ES = endangered species, N = island endemic, R = resident, RN = regional endemic, X = exotic.*

		Ecological Life Zone							
		Wet		Moist		Dry		Totals	
	Status	2001 (N = 15)	2002 (N = 15)	2001 (N = 5)	2002 (N = 9)	2001 (N = 7)	2002 (N = 5)	2001 (N = 27)	2002 (N = 29)
Brown Pelican (*Pelecanus occidentalis*)	R	0	0	0	1	1	4	1	5
Magnificent Frigatebird (*Fregata magnificens*)	R	0	0	0	0	2	2	2	2
Great Blue Heron (*Ardea herodias*)	R	0	0	0	1	2	0	2	1
Great Egret (*Ardea alba*)	R	3	8	6	14	15	16	24	38
Snowy Egret (*Egretta thula*)	R	2	0	5	11	1	0	8	11
Little Blue Heron (*Egretta caerulea*)	R	0	0	0	0	3	4	3	4
Tricolored Heron (*Egretta tricolor*)	R	0	0	0	0	0	1	0	1
Cattle Egret (*Bubulcus ibis*)	R	18	1	36	68	102	307	156	376
Green Heron (*Butorides virescens*)	R	1	2	7	8	0	2	8	12
Black-crowned Night-Heron (*Nycticorax nycticorax*)	R	0	0	0	2	0	0	0	2
Yellow-crowned Night-Heron (*Nyctanassa violacea*)	R	0	0	0	1	0	0	0	1
Turkey Vulture (*Cathartes aura*)	R	0	0	0	0	10	8	10	8
Osprey (*Pandion haliaetus*)	M	0	0	0	2	0	0	0	2
Sharp-shinned Hawk (*Accipiter striatus*)	ES	0	1	0	0	0	0	0	1
Broad-winged Hawk (*Buteo platypterus*)	ES	1	2	0	0	0	0	1	2
Red-tailed Hawk (*Buteo jamaicensis*)	R	23	17	4	12	7	3	34	32
American Kestrel (*Falco sparverius*)	R	10	6	1	9	20	9	31	24
Clapper Rail (*Rallus longirostris*)	R	0	0	0	0	0	2	0	2
Common Moorhen (*Gallinula chloropus*)	R	0	0	4	4	0	0	4	4
Wilson's Plover (*Charadrius wilsonia*)	R	0	0	0	0	1	2	1	2
Killdeer (*Charadrius vociferus*)	R	0	0	3	3	14	14	17	17
Black-necked Stilt (*Himantopus mexicanus*)	R	0	0	2	0	9	9	11	9
Least Tern (*Sterna antillarum*)	R	0	0	0	0	12	22	12	22
Rock Pigeon (*Columba livia*)	X	25	85	14	33	13	20	52	138
Scaly-naped Pigeon (*Patagioenas squamosa*)	RN	239	189	31	73	0	0	270	262
White-crowned Pigeon (*Patagioenas leucocephala*)	R	0	1	12	3	0	0	12	4
Plain Pigeon (*Patagioenas inornata*)	ES	0	0	0	4	0	0	0	4
Ringed Turtle-Dove (*Streptopelia risoria*)	X	0	0	0	0	0	6	0	6
Eurasian Collared-Dove (*Streptopelia decaocto*)	X	0	0	0	0	9	4	9	4
White-winged Dove (*Zenaida asiatica*)	R	45	153	26	80	102	87	173	320
Zenaida Dove (*Zenaida aurita*)	R	51	21	77	119	50	13	178	153
Mourning Dove (*Zenaida macroura*)	R	1	6	5	4	24	9	30	19
Common Ground-Dove (*Columbina passerina*)	R	3	5	48	84	136	84	187	173

Table 1— *contd.*

		Ecological Life Zone							
		Wet		Moist		Dry		Totals	
	Status	2001 (N = 15)	2002 (N = 15)	2001 (N = 5)	2002 (N = 9)	2001 (N = 7)	2002 (N = 5)	2001 (N = 27)	2002 (N = 29)
Key West Quail-Dove (*Geotrygon chrysia*)	RN	0	0	0	1	2	0	2	1
Ruddy Quail-Dove (*Geotrygon montana*)	R	3	0	4	7	0	0	7	7
Yellow-billed Cuckoo (*Coccyzus americanus*)	R	0	0	0	0	2	2	2	2
Mangrove Cuckoo (*Coccyzus minor*)	R	8	4	19	19	11	7	38	30
Puerto Rican Lizard-Cuckoo (*Saurothera vieilloti*)	N	6	5	7	15	9	0	22	20
Smooth-billed Ani (*Crotophaga ani*)	R	2	6	10	17	42	44	54	67
Puerto Rican Screech-Owl (*Megascops nudipes*)	N	2	3	2	4	2	0	6	7
Antillean Nighthawk (*Chordeiles gundlachii*)	BR	0	1	0	0	21	4	21	5
Black Swift (*Cypseloides niger*)	BR	12	2	0	0	0	0	12	2
Antillean Mango (*Anthracothorax dominicus*)	RN	2	0	7	6	2	4	11	10
Green Mango (*Anthracothorax viridis*)	N	11	12	1	5	0	0	12	17
Puerto Rican Emerald (*Chlorostilbon maugaeus*)	N	20	17	2	3	1	0	23	20
unidentified hummingbird	--	1	0	0	0	0	0	1*	0
Puerto Rican Tody (*Todus mexicanus*)	N	53	94	23	33	23	6	99	133
Puerto Rican Woodpecker (*Melanerpes portoricensis*)	N	76	79	28	51	27	4	131	134
Caribbean Elaenia (*Elaenia martinica*)	RN	0	0	0	0	5	5	5	5
Lesser Antillean Pewee (*Contopus latirostris*)	RN	2	3	1	4	2	3	5	10
Puerto Rican Flycatcher (*Myiarchus antillarum*)	N	15	15	19	29	29	13	63	57
Gray Kingbird (*Tyrannus dominicensis*)	R	202	198	106	195	195	160	503	553
Loggerhead Kingbird (*Tyrannus caudifasciatus*)	RN	5	17	11	13	2	2	18	32
Puerto Rican Vireo (*Vireo latimeri*)	N	26	56	52	40	10	5	88	101
Black-whiskered Vireo (*Vireo altiloquus*)	BR	317	265	149	203	38	38	504	506
Caribbean Martin (*Progne dominicensis*)	BR	0	0	5	20	5	6	10	26
Cave Swallow (*Petrochelidon fulva*)	R	20	18	17	34	4	9	41	61
Barn Swallow (*Hirundo rustica*)	R	0	0	0	0	2	0	2	0
Red-legged Thrush (*Turdus plumbeus*)	RN	22	28	27	38	4	1	53	67
Northern Mockingbird (*Mimus polyglottos*)	R	13	25	24	39	66	51	103	115
Pearly-eyed Thrasher (*Margarops fuscatus*)	RN	101	75	20	70	3	3	124	148
Yellow Warbler (*Dendroica petechia*)	R	0	0	0	0	22	19	22	19
Adelaide's Warbler (*Dendroica adelaidae*)	N	1	0	80	94	138	94	219	188
Elfin-woods Warbler (*Dendroica angelae*)	E, N	3	0	0	0	0	0	3	0
Bananaquit (*Coereba flaveola*)	R	514	583	118	219	95	66	727	868
Puerto Rican Tanager (*Nesospingus speculiferus*)	N	63	41	0	0	0	0	63	41
Puerto Rican Spindalis (*Spindalis portoricensis*)	N	67	114	7	14	4	2	78	130
Yellow-faced Grassquit (*Tiaris olivacea*)	R	37	63	3	21	20	11	60	95

Table 1— *contd.*

		Ecological Life Zone							
		Wet		Moist		Dry		Totals	
	Status	2001 (N = 15)	2002 (N = 15)	2001 (N = 5)	2002 (N = 9)	2001 (N = 7)	2002 (N = 5)	2001 (N = 27)	2002 (N = 29)
Black-faced Grassquit (*Tiaris bicolor*)	R	98	100	45	38	66	63	209	201
Puerto Rican Bullfinch (*Loxigilla portoricensis*)	N	147	136	83	122	42	19	272	277
Grasshopper Sparrow (*Ammodramus savannarum*)	R	0	0	0	0	0	4	0	4
Greater Antillean Grackle (*Quiscalus niger*)	RN	7	12	61	101	446	339	514	452
Shiny Cowbird (*Molothrus bonariensis*)	R	15	22	11	17	2	1	28	40
Greater Antillean Oriole (*Icterus dominicensis*)	RN	20	19	3	11	3	19	26	49
Troupial (*Icterus icterus*)	X	0	0	0	0	7	2	7	2
Antillean Euphonia (*Euphonia musica*)	RN	10	9	0	1	0	0	10	10
House Sparrow (*Passer domesticus*)	X	1	0	1	5	8	17	10	22
Orange-cheeked Waxbill (*Estrilda melpoda*)	X	2	12	5	10	4	0	11	22
Bronze Mannikin (*Lonchura cucullata*)	X	0	0	0	2	0	0	0	2
Nutmeg Mannikin (*Lonchura punctulata*)	X	2	0	5	9	4	0	11	9
Unidentified munia (*Lonchura malacca* / *L. atricapilla*)	X	0	0	0	3	0	20	0	23
Pin-tailed Whydah (*Vidua macroura*)	X	0	0	0	1	6	0	6	1
Total individuals		2328	2531	1237	2050	1907	1671	5471	6252
Species richness		50	45	49	60	59	55	70	79
Average species richness per route		20.8	21.9	28.4	29.7	28.1	30.0		
Average number of individuals per route		155	169	247	228	272	334		

Not included in total individuals or species richness.

richness, mean abundance (MA) was significantly lower on wet zone routes than on moist ($t = 3.99$, $P < 0.001$), or dry zone routes ($t = 4.97$, $P < 0.001$). Dry zone routes also had greater mean abundance than moist zone routes ($t = 2.07$, $P = 0.027$). See *table 2* for the ten most abundant species by life zone.

Discussion

For 38 years the North American Breeding Bird Survey (BBS) program has provided the United States and Canadian avian conservation communities with critical population data needed to manage North American bird populations. The U.S. Fish and Wildlife Service, Canadian Wildlife Service, Partners in Flight, and state agencies all use BBS data along with other indicators to set avian conservation priorities at various scales (Peterjohn 1994, Carter et al. 2000). Similar to the BBS, an island-wide avian monitoring program like that described here could provide Puerto Rican natural resource managers with the population information needed to plan and implement effective avian conservation strategies for species not currently being monitored. In its current form, this pilot Puerto Rican monitoring program is relatively inexpensive, relying on skilled volunteers to gather data, and appears to be an effective means of collecting population data on a large portion of Puerto Rican avifauna, including approximately 75 percent of the locally and regionally endemic species (*table 1*).

Figure 1 depicts sample distribution and range maps for seven island-endemic species based on 2001 data. The maps demonstrate the potential utility of these data for quantifying and portraying avian distributions, abundances, and population trend estimates for Puerto Rican avifauna. Future maps could demonstrate temporary range shifts induced by hurricane events, population declines due to habitat loss, or the spread of exotic species.

The potential utility of this program is further demonstrated by our results that mean species richness and abundance were significantly greater on dry zone routes (MSR = 28.9 species, MA = 298.2 individuals)

Table 2— *Relative abundance of species per life zone per year in descending rank order. The four-letter species codes are defined in* table 3.

Wet Life Zone		Moist Life Zone		Dry Life Zone	
2001	**2002**	**2001**	**2002**	**2001**	**2002**
BANA	BANA	BWVI	BANA	GAGR	GAGR
BWVI	BWVI	BANA	BWVI	GRKI	CAEG
SNPI	GRKI	GRKI	GRKI	ADWA	GRKI
GRKI	SNPI	PRBU	PRBU	CGDO	ADWA
PRBU	WWDO	ADWA	ZEDO	WWDO	WWDO
PETH	PRBU	ZEDO	GAGR	CAEG	CGDO
BFGR	PRSP	GAGR	ADWA	BANA	BANA
PRWO	BFGR	PRVI	CGDO	BFGR	BFGR
PRSP	PRTO	CGDO	WWDO	NOMO	NOMO
PRTA	ROPI	BFGR	SNPI	ZEDO	SBAN

Table 3— *Definitions of species codes found in* table 2.

Common Name	Four-Letter Code
Adelaide's Warbler	ADWA
Bananaquit	BANA
Black-faced Grassquit	BFGR
Black-whiskered Vireo	BWVI
Cattle Egret	CAEG
Common Ground-Dove	CGCO
Gray Kingbird	GRKI
Great Egret	GREG
Greater Antillean Grackle	GAGR
Northern Mockingbird	NOMO
Pearly-eyed Thrasher	PETH
Puerto Rican Bullfinch	PRBU
Puerto Rican Spindalis	PRSP
Puerto Rican Tanager	PRTA
Puerto Rican Tody	PRTO
Puerto Rican Vireo	PRVI
Puerto Rican Woodpecker	PRWO
Rock Pigeon	ROPI
Smooth-billed Ani	SBAN
Scaly-naped Pigeon	SNPI
White-winged Dove	WWDO
Zenaida Dove	ZEDO

than on wet zone routes (MSR = 21.3 species, MA = 162.0 individuals). Kepler and Kepler (1970) found similar differences in bird species richness and abundance between the El Yunque Rain Forest and Guanica Forest in Puerto Rico. Our data indicate that island habitats (coastal and low-elevation sites) under the heaviest development pressure (Lopez et al. 2001) also harbor the most bird species and individuals, suggesting that continued urban development in those areas should follow sound conservation practices in order to preserve Puerto Rico's unique natural habitats and associated avifauna.

These data are taken from a pilot Puerto Rican avian monitoring program initiated in 1997. Upon completion of the 2003 season the entire data set will be quantitatively evaluated to determine the utility of the program for tracking population trends of island species.

Acknowledgments

We thank E. Hernandez Prieto and J. Colon for coordinating sampling activities on the island, as well as, the 2001 and 2002 participants: S. Birch, J. Colon, S. Colon Lopez, and A. Tossas. We also are indebted to A. Hedin for entering the data, K. Boone and A. Hedin for developing the figures, and C. J. Ralph, M. Howe, and M. Wimer for providing comments on earlier versions of this manuscript.

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Making Management Recommendations from Annual Bird Point Count Data[1]

Gary M. Peters[2]

Abstract

In the past decade, more than one hundred thousand breeding bird occurrences have been recorded on Southern National Forests in the United Sates. The majority of these occurrences have been geo-referenced using global positioning satellite (GPS) technology. This spatial information is available for use as a coverage in several geographic information system (GIS) applications. ArcView GIS software was used to overlay selected occurrence records with other habitat coverages (e.g., soils, hydrology, vegetation, elevation, and land use). Multiple years of accumulated bird point count data has made analysis possible at a local district and forest level. This revealed clues to understanding habitat preference, landscape distribution, and frequency of occurrence for breeding birds on the Francis Marion and Sumter National Forests in South Carolina. The comparison of ecological data with occurrence information is incorporated in project planning and analysis on the Francis Marion and Sumter National Forests. Interpretations of bird point count data influence field projects by providing insight into habitat parameters, management actions and potential project outcomes that promote conservation of avian habitats. One interesting outcome was the trend in frequency of occurrence for some species differed from statewide and regional trends derived from the North American Breeding Bird Survey.

Key words: breeding birds, Francis Marion and Sumter National Forests, frequency of occurrence, GIS, monitoring, point counts, spatial coverages.

Introduction

Interest in declining numbers of neotropical migratory birds in the latter part of the 20th century focused attention on monitoring efforts for these and associated species (Harris 1984; Soule 1986; Verner et al. 1986; Cooperrider et al. 1986; Wilson 1988; Hunter et al. 1993). In response, National Forests in the Southern Region of the United States initiated a pilot study during 1992 to develop a methodology for monitoring breeding birds across all forested habitats on the Chattahoochee National Forest in Georgia. By 1994, two thousand eight hundred sixty-five bird point counts were grouped by physiographic area (Robbins 1986), and distributed over one hundred five Ranger Districts on sixteen National Forests in the South. This effort implemented the Southern National Forest's Migratory and Resident Landbird Conservation Strategy (Gaines and Morris 1996). One of the objectives of this strategy is: "to develop and implement a standardized forest bird monitoring program that will measure the success in achieving population and habitat objectives at the district, forest, and regional level…" The Francis Marion and Sumter National Forests (FMS) augmented this regional strategy by installing additional bird points in all forest habitats on the FMS.

On the FMS, point count data are geo-referenced and entered into a Microsoft Access database developed specifically to manage bird point count data for spatial display and analysis, which we refer to as "Sumter BIRDBASE." In 2002, the Forest Service Southern Region developed a similar database (Access R8Bird) for region-wide application. Access R8Bird will facilitate data analysis at several spatial scales and enhance compatibility with Fauna, the national Forest Service terrestrial species database. Reports generated from Sumter BIRDBASE, and Access R8Bird enable users to identify habitat preference (*fig. 1*), and variations by physiographic area (*fig. 2*) for breeding birds. Information contained in Sumter BIRDBASE and Access R8Bird is also compatible with the National Bird Point Count Database (currently under beta-testing) maintained at Patuxent Wildlife Research Center (U.S. Department of the Interior, Geological Survey 2001).

Compiling multiple years of data permits investigation into possible indices describing temporal population trends at landscape scales (*fig. 3*).

Linking these results to a spatial display of habitat variables provides valuable information on species distribution (*fig. 4*), as well as habitat quality and distribution at both local and larger landscape scales.

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California**

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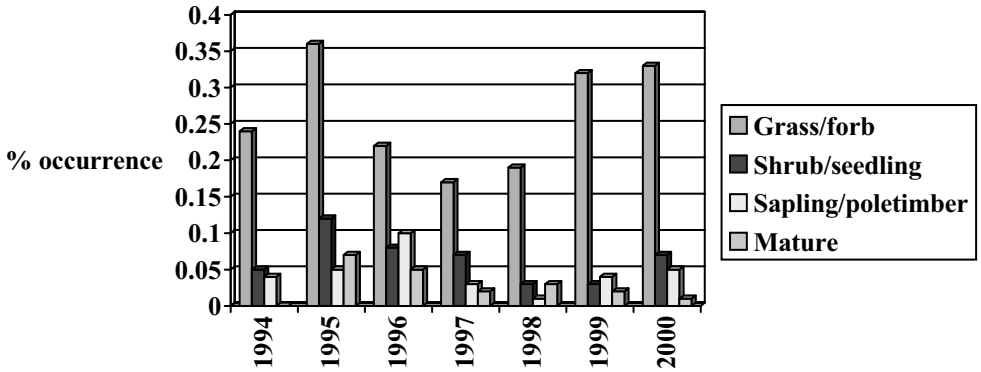

Figure 1— Frequency of annual observations of Eastern Bluebird (*Sialia sialis*) by successional sere on the Francis Marion and Sumter National Forests.

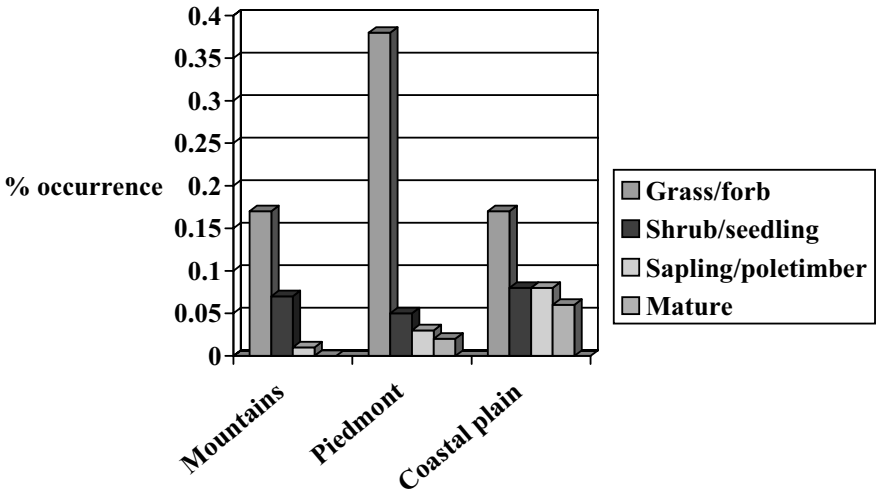

Figure 2— Eastern Bluebird (*Sialia sialis*) observation frequency by successional sere, by physiographic area on the Francis Marion and Sumter National Forests.

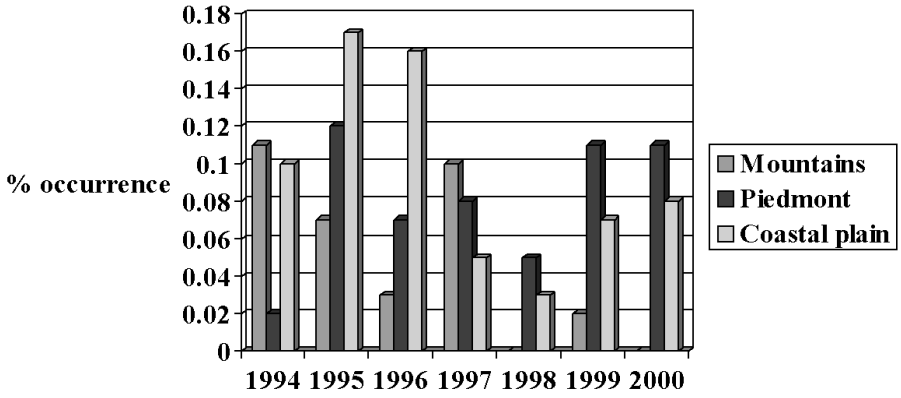

Figure 3— Frequency of observations of Eastern Bluebird *(Sialia sialis*) by physiographic area on the Francis Marion and Sumter National Forests (1994–2000).

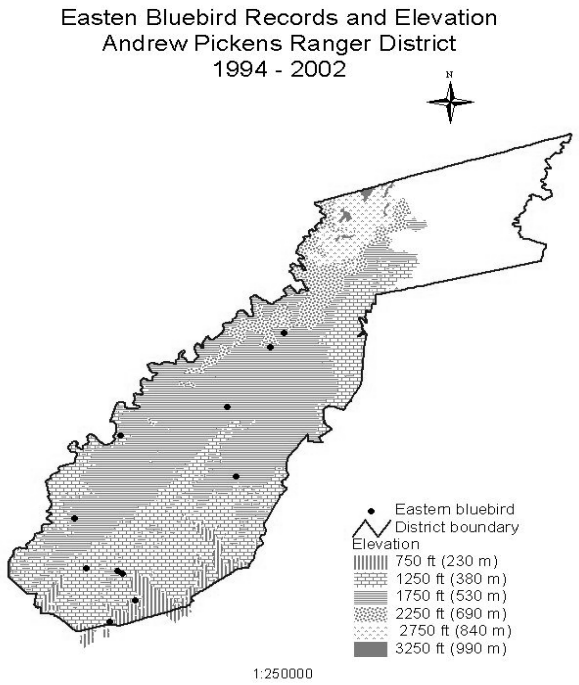

Figure 4— Eastern Bluebird (*Sialia sialis*) occurrence in relation to elevation. Occurrence of a selected species compared to elevation.

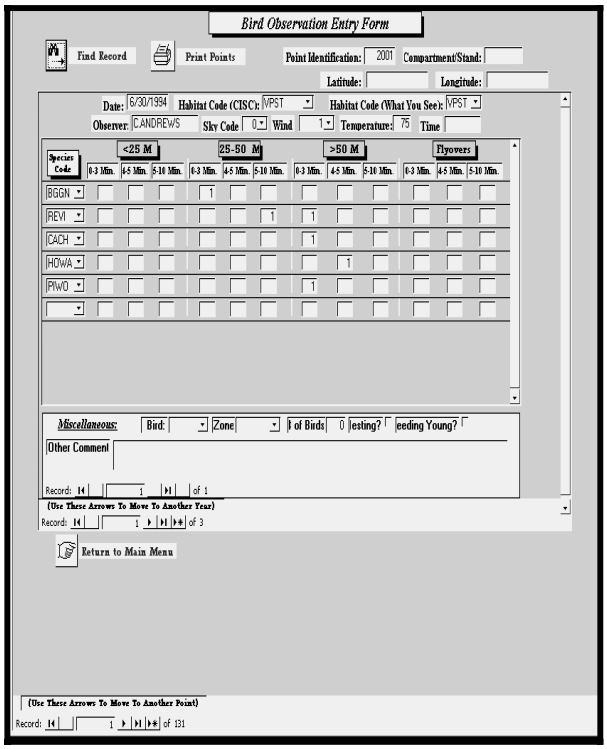

Figure 5— Sumter BIRDBASE bird observation data entry form.

Methods

Standard 10-minute point counts (Hamel et al. 1996) are used to collect bird point count data. Visual and auditory observations are recorded at three time intervals (0-3 min., 4-5 min., 6-10 min.) and at three distance bands (<25m, 25-50m, >50m) from the point center. Points were established in four habitat conditions (grass/forb, shrub/seedling, sapling/pole, mature forest), in several forest "habitat groups" (e.g., southern yellow pine, bottomland hardwood, upland hardwood, mixed pine hardwood, white pine/hemlock, cove hardwoods) to represent the full range of available forest types and structural conditions found on the Francis Marion and Sumter National Forests. Permanent point locations within forest stands are randomly selected within each habitat group. A minimum of five points was established for each condition in all habitat groups, and placed at least 50m within a stand boundary. A subset of total bird point locations are selected each year and monitored once per season, which extends from May 5 to June 15. All bird points on the FMS have been monitored between three to nine times during the nine-year period 1994–2002. In addition to bird observations, weather, date, time, and observed habitat conditions are recorded each time a point is sampled (*fig. 5*).

After a point location was determined, latitude, longitude, and vegetation parameters describing midstory and groundcover conditions are collected (*fig. 6*).

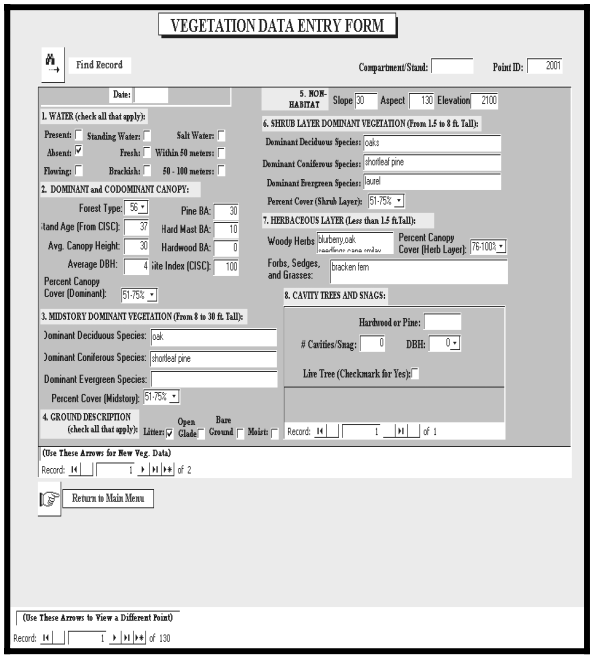

Figure 6— Sumter BIRDBASE vegetation data entry form.

Data entered into Sumter BIRDBASE is linked to a spatial coverage created with spatial coordinates from each point (*fig. 7*).

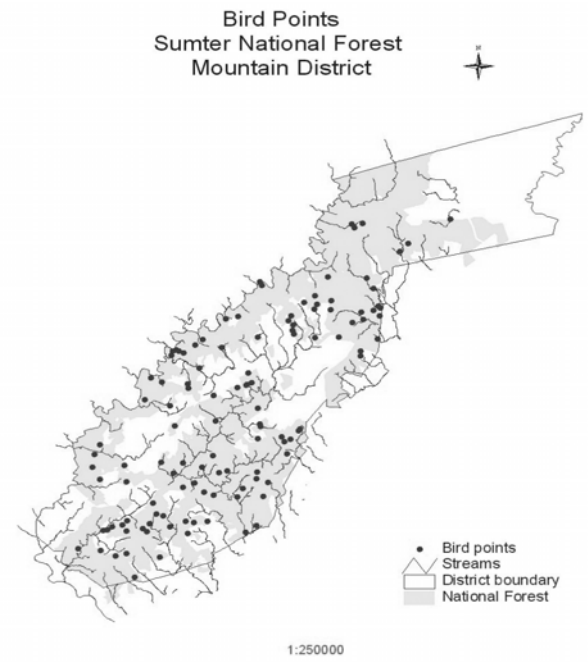

Figure 7— Distribution of bird points on the Andrew Pickens Ranger District, Sumter National Forest in South Carolina (USA).

Results

Nine years of data collection on the Francis Marion and Sumter National Forests has provided a foundation to partially accomplish several objectives: (1) acquire baseline information on habitat relationships of breeding birds on the Forests; (2) gather data on frequency of occurrence, and the ability to monitor neotropical migrants and other birds on a National Forest by physiographic area (Keys et al. 1995); (3) gather information to assess habitat quality for inventory, maintenance, and restoration proposals; (4) accumulate data for eventual development of habitat capability models (Linder 2001; Buehler et al., this volume); (5) accumulate data to facilitate large and small scale comparisons with modeled population changes from the North American Breeding Bird Survey (Sauer et al. 2001), or the Monitoring Avian Productivity and Survivorship (MAPS) Program (DeSante 2001); and (6) develop management recommendations to affect change in avian reproductive success (Nott 2000).

In addition, this stratified random sample of habitats often suggested population trends different than those referenced in published literature (e.g., North American Breeding Bird Survey [Sauer et al. 2001]). Differences were most apparent for species dependent upon short-lived (<10 – 20 years old) habitats such as open woodland/savannas, shrubland, and grasslands. For example, Eastern Bluebird (*Sialia sialis*) population change in South Carolina is summarized as slightly increasing, trend estimate 0.5; P = 0.74 in the BBS from 1980–2000 (Sauer et al. 2001), whereas detections on the FMS indicate population trends are decreasing in the mountains and coastal plain (*fig. 3*). Northern Bobwhite Quail (*Colinus virginianus*) in South Carolina are shown to be in decline from 1980-2000, BBS trend estimate –5.6; P = 0.0, however FMS detections indicate increasing populations in the coastal plain, and stable populations in the piedmont (*fig. 8*). Likewise, Yellow-breasted Chat (*Icteria virens*) population change in South Carolina for 1980–2000 is reported by BBS as stable, trend estimate 0.0; P = 0.97, however FMS detections indicate a decline in all physiographic areas (*fig. 9*).

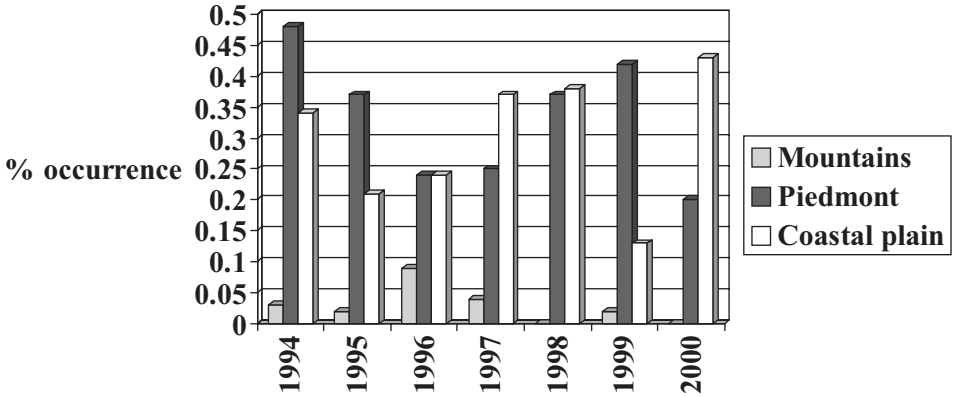

Figure 8— Frequency of annual observations of Northern Bobwhite Quail (*Colinus virginianus*) by physiographic area on the Francis Marion and Sumter National Forests (1994–2000).

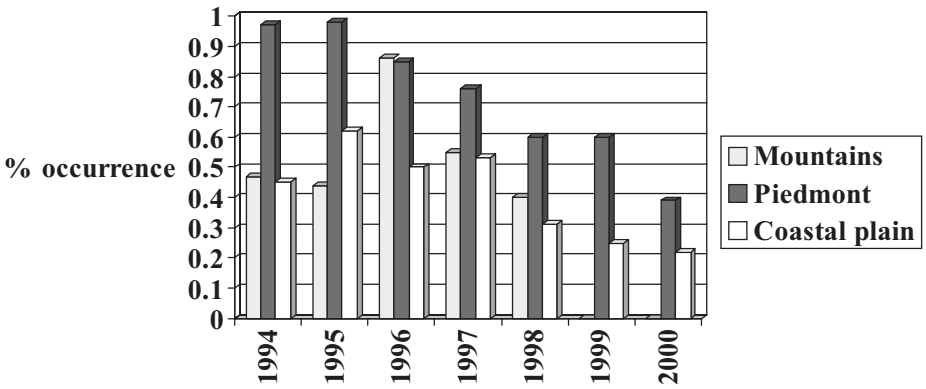

Figure 9— Frequency of annual observations of Yellow-breasted Chat (*Icteria virens*) by physiographic area on the Francis Marion and Sumter National Forests (1994–2000).

These differences can largely be attributed to two factors: 1) contrasting forest management regimes on relatively small (<5 percent of the State) National Forests, and 2) over a decade of deferred forest management activities due to policy direction arising from administrative appeal procedures on the Sumter and, except for prescribed burning and Red-cockaded Woodpecker (*Picoides borealis*) management, effects of Hurricane Hugo on the Francis Marion. When it is possible to implement, management of the FMS emphasizes a diversity of habitat conditions, extended harvest rotations (60+ years for pine types, 100+ years for hardwood types), increased basal area in mast producing hardwoods, and restoration of pyrophitic communities such as Table Mountain pine (*Pinus pungens*), longleaf pine (*Pinus palustris*) and shortleaf pine (*Pinus taeda*)/bluestem (*Andropogon* spp.).

Analysis of bird point data provides species-specific information used at project level analyses in describing effects and developing mitigation measures for improving wildlife habitat. Interpretation of data collected through bird point monitoring also supports projects that implement new strategies in forest silviculture such as low-density management (LDM) (*fig. 10*). While traditional forest management maintains high productivity levels of wood products per unit area, LDM maintains forestland at 40 – 60 ft^2 (12 – 18 m^2) or lower basal area, and develops groundcover dominated by herbaceous plants and grasses (*fig. 11*).

Discussion

It has become increasingly evident that the power of geographically based habitat relationship and species occurrence information can begin to answer questions related to population trends and management effects for many species of birds. Observations from a companion monitoring effort in the Northern Rocky Mountains recognize similar possibilities at local, landscape, and regional scales (Hutto and Young 2002). Overall, the value of monitoring landbirds on the Francis Marion and Sumter National Forests has been greatly increased by implementing strategies that are similar in design, comparable in results, and complimentary to other regional or national efforts such as Access R8Bird, MAPS, and the National Bird Point Count Database.

Figure 10— Herbaceous understory response to LDM strategy from initial treatments of a combination of thinning and burning.

Figure 11— A heavily reduced basal area loblolly pine (*Pinus taeda*)/bluestem (*Andropogon* spp.) stand under LDM. These open woodland/savanna conditions are established through sequential thinnings and harvests, and maintained with periodic fire.

Acknowledgments

First and foremost, my heartfelt thanks goes to the district biologists, technicians, and volunteers who faithfully and reliably collected bird point count data over the past nine years on the Forests; to the District Rangers, Forest Supervisors, and the Southern Region of the USDA Forest Service for support of this project; and to D. Forsythe and F. J. Alsop III for their expertise in training our cadre of birders. A special thanks goes to Mr. E. Morris whose idea for a graduate thesis was the catalyst for starting landbird monitoring in the Southern Region, and to A. Marshall and D. B. Ray for creating Sumter BIRDBASE. I am especially grateful to M. Trani-Griep, M. S. Garner, and C. Hardy for their thoughtful review of this manuscript, to Joyce, my wife, for proof reading and editing, and finally to T. Ott for her assistance in developing the poster display at Asilomar, and for managing our Sumter BIRDBASE.

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Analysis of U. S. Forest Service Bird Point-Count Monitoring Database – Implications for Designing and Implementing Avian Monitoring[1]

Eric T. Linder[2] and David A. Buehler[3]

Abstract

In 1996, Region 8 of the U. S. Forest Service implemented a program to monitor landbirds on southeastern U.S. national forests. The goal was to develop a monitoring system that could document population trends and bird-habitat relationships. Using power analysis, we examined the ability of the monitoring program to detect population trends (3 percent annual change) at three spatial scales: ranger district, national forest, and physiographic province. The monitoring program did not detect trends adequately at the district scale and success at the forest level varied on the intensity of sampling, but was generally low (6 – 50 years). At the physiographic province the monitoring program was relatively powerful in detecting population trends. It appears the population trend information derived from this monitoring program is distinct from other monitoring programs. The merits and shortcomings of this monitoring program are also addressed.

Key words: avian, monitoring, point count, power analysis, Southeast, U.S. Forest Service.

Introduction

The long-term decline of many neotropical migratory birds has been noted by scientists (Robbins et al. 1989, Hagan and Johnston 1992, Martin and Finch 1995). In response to these declines, Partners in Flight was created by the National Fish and Wildlife Foundation in 1990. The strength of Partners in Flight is the diverse parties that have come together to form partnerships. Participants in Partners in Flight include federal agencies, state agencies, and non-governmental organizations. Among these groups, the U.S. Forest Service has played a leading role in Partners in Flight since its inception.

In recognition of the importance in monitoring bird populations and meeting legal requirements under the National Forest Management Act of 1976, Region 8 (hereafter; Region) of the U.S. Forest Service developed a program to monitor neotropical migratory birds, as well as temperate migrants and resident species (Gaines and Morris 1996). The goal of the program is to monitor landbird populations in the southeastern United States occurring within 23 national forests, which are comprised of 105 ranger districts, and reside within 10 physiographic provinces (Gaines and Morris 1996). The physiographic units considered are the same physiographic areas used in the Breeding Breed Survey (Robbins 1989).

When analyzing data collected as part of a monitoring program, it is important to note that errors can be made in different ways. When evaluating the null hypothesis that a population has not changed (i.e., no net increase or decrease over some time period), there are two types of errors that can be made. A null hypothesis that is actually true may be rejected (Type I error) or a null hypothesis may be accepted when it is actually false (Type II error). The probability of a Type II error is equal to β and the statistical power is equal to $1-\beta$. Thus, power can be defined as the probability of correctly rejecting a null hypothesis (Sokal and Rohlf 1995). To calculate power, we must estimate the following parameters: sample size, α-level, sampling variance, and effect size (difference between the null and alternative hypothesis). Although many measures of effect size can be used, 0.8 is relatively common threshold for biological studies (Cohen 1988). Other factors can influence power and include count variability, within year effort, and survey length (Gerrodette 1987, Gibbs and Melvin 1997).

When establishing a monitoring program, the benefit of conducting power analysis to aid in determining how to best sample is widely acknowledged (prospective power analysis; Steidl et al. 1997). Since parameters are not known at the outset, however, they must be estimated. This allows researchers to examine the relationships between parameters and to aid in deciding which values best represent the biological intent of the

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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monitoring program. Conversely, retrospective power analysis can be used after the data are collected and analyzed to aid in the interpretation of results, especially when we fail to reject the null hypothesis (Gerrodette 1987). For example, if the monitoring failed to detect the designated intensity of trend, power analysis can be used to determine what intensity of trend can be reliably detected.

There are several approaches to retrospective power analysis, which can lead to very different conclusions (for issues see Thomas 1997, Gerard et al. 1998). In this study, we calculate power using a pre-specified effect size (population change) and the observed variance, but vary the duration of the study and sampling effort. Unlike many retrospective power analyses, we are not interested in interpreting why a particular hypothesis was rejected, but rather evaluate the existing monitoring program to accurately detect population trends.

In this paper we examine whether the current sampling design for the Region allows one to detect trends of common species at three spatial scales. The spatial scales we consider are ranger district, national forest, and physiographic region. Although one of the stated goals of this monitoring program is to monitor populations at the physiographic scale (Gaines and Morris 1996), many issues of biological, managerial, and/or legal importance are frequently addressed at the scale of an individual forest. The second issue we attempt to address is whether the monitoring program produces information that cannot be derived from other avian monitoring programs such as the Breeding Bird Survey (which is conducted on private, state, and federal land).

Methods

One of the goals of this study was to assess the Region monitoring program at multiple spatial scales. Consequently, we analyzed data at three spatial scales; ranger district, national forest, and physiographic province. At the level of ranger district, we used point count data from all districts that resided within national forests in the Southern Blue Ridge and Mid Atlantic Ridge and Valley physiographic provinces. At a larger spatial scale, we aggregated point count data by national forest and then again we aggregated all point count data for a single analysis of the entire province. National forests with the Southern Blue Ridge physiographic province included in our analyses include Chattahoochee (Georgia), Cherokee (Tennessee), and Francis-Marion Sumpter (South Carolina). Although Pisgah and Nantahala National Forests (North Carolina) also resided within the Southern Blue Ridge province, data from these forests were unavailable at the time of this analysis. Since the Jefferson/George Washington National Forest (Virginia) is the only national forest in the Mid Atlantic Ridge and Valley physiographic province, results based on this data are applicable at both the national forest and physiographic province scale.

Avian censuses were conducted during the breeding seasons (mid-May to early July) from 1992 to 2000 by various observers on each national forest. The number of years monitored varied by national forest and depended upon when the monitoring program was implemented. All national forests in this study had their full contingent of census points established by 1996. Point counts were conducted between 0600 and 1000 EST and limited to 10 min in duration. All birds detected by sight or sound within a 50-m radius were recorded. Point count stations were visited once per breeding season (Hamel et al. 1996). Point count stations were evenly stratified across forest type and forest age class and located within the middle of stands, except in the Jefferson/George Washington National Forest, where points were clustered along transects (n = 10). For this analysis, abundance was estimated at the scale of transect in the Jefferson/George Washington National Forest and at the individual point in the other national forests. Only census points where the target species occurred in ≥ 1 season were included in our estimate of abundance. Census points were distributed as follows: 225 on the Chattahoochee National Forest, 120 on the Cherokee National Forest, 80 on the Francis-Marion Sumpter National Forest (Andrew Pickens District only), and 782 on the Jefferson/George Washington National Forest.

To assess the ability of the Region's monitoring program to detect population trends, we focused on the Ovenbird (*Seiurus aurocapillus*) and the Pileated Woodpecker (*Dryocopus pileatus*), both Management Indicator Species for several national forests in the southeast. Both species were relatively abundant (occurred from 18 – 46 percent of all census points/national forest) and relatively easy to detect, thereby minimizing some, but not all, of the criticisms surrounding the use of point counts to estimate abundance (Rosenstock et al. 2002).

Several parameters were determined by the monitoring program itself (e.g., sample size), by the data itself (e.g., mean and variance); we fixed other parameters (e.g., percent annual change to be detected). We were interested in assessing the ability of the Region monitoring program to detect a 3 percent annual change with a power of 0.8, based upon on the observed sampling variance. In this analysis, a power >0.8 indicates the sampling methodology has an acceptable chance of detecting a 3 percent annual change. Our decision to use 3 percent was consistent with the rate of decline for some priority species of management interest based on Breeding Bird Survey

data and was held consistent across tests for comparisons. Power of 0.8 is considered adequate for ecological trend analysis (Cohen 1988). To assess the power of the Region monitoring program, we used the program MONITOR 7.0 (Gibbs 1995). MONITOR allows examination of the power of a monitoring program to detect population trends by manipulating several of the input variables, including sampling effort and time span. To simulate an increase in sampling effort, we randomly selected the desired number of additional census points from our pool of actual data. For example, to simulate an increase in sampling effort of 50 percent for the Cherokee National Forest (n = 120 points), we randomly selected 60 points and added their mean and variances to the original 120 points and input the 180 'new' values into MONITOR.

To determine if the monitoring program is obtaining unique information, we first compared the population trends of our two focal species using Region and Breeding Bird Survey data and restricted to only points in Virginia and Tennessee (and the corresponding national forests) within the Southern Blue Ridge and Mid Atlantic Ridge and Valley provinces, respectively. We also compared the population trends of 10 species derived from aggregated Region data and Breeding Bird Survey data for the Southern Blue Ridge province. We restrict our analysis to the period 1992-2000 when reliable Region data is available province-wide. Breeding Bird Survey trends were estimated using route regression (Sauer et al. 2001) while Region trends were estimated using linear regression.

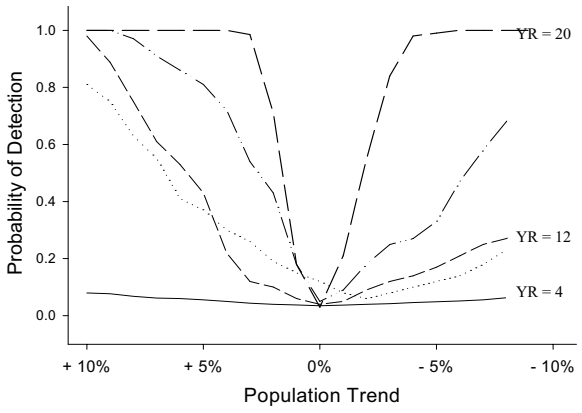

Figure 1— The power (0.8) to detect a 3 percent annual population trend of the Ovenbird on a typical ranger district in the Southern Blue Ridge physiographic province was low, failing even after 20 years of monitoring.

Results

At the scale of an individual district, current monitoring strategies appear to be inadequate to detect a 3 percent/yr change in Ovenbird abundance, even after 20 years (*fig. 1*; although a positive change was detected, a negative change was not). Only on the Deerfield Ranger District of the Jefferson/George Washington National Forest, which had the greatest number of point stations, did the current monitoring effort identify a 3 percent annual change, and that required 16 years of monitoring *(fig. 2*). Results of the monitoring program at the national forest were mixed with Ovenbird population trends being detected on the Jefferson/George Washington National Forest in 8 years. Contrast this with trends on other national forests such as the Chattahoochee (20 years), Francis-Marion Sumpter (26 years), and with only 120 census points, our results suggest it would take more than 50 years to detect an annual population change of 3 percent (*fig. 3*) on the Cherokee National Forest. At the scale of the physiographic region, population trends of Ovenbirds were detectable after 6 years in the Southern Blue Ridge and 8 years in the Mid Atlantic Ridge and Valley. The power to detect changes for Pileated Woodpeckers was less than that of Ovenbirds with no district and only the Jefferson/George Washington National Forest having the ability to detect a 3 percent change (10 yrs for increase and 12 yrs for decrease) in <20 yrs.

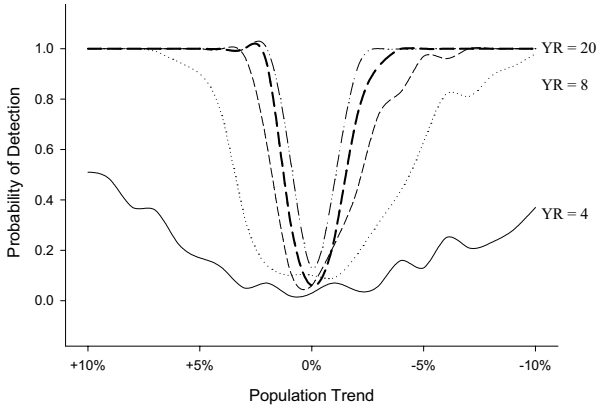

Figure 2— The power (0.8) to detect a 3 percent annual population trend of the Ovenbird on the Deerfield Ranger District (JGW NF) should occur after 16 years of monitoring.

We were also interested in the effect of increasing sampling effort on the monitoring program's ability to detect trends. We increased the number of census points where Ovenbirds were detected on the Chattahoochee National Forest by 50 percent which resulted in detecting a 3 percent annual trend only two years earlier (18 years). Increasing the sampling effort by 100 percent or 200 percent resulted in shorting the detection time from 20 years to 15 and 13 years, respectively. In contrast, on the Cherokee National Forest where relative few (120 vs. 225 for the Chattahoochee), increasing sampling effort by 100 percent reduced the time needed to detect a 3 percent

trend from >50 years to 20 years (*fig. 4*). Similar changes were noted for Pileated Woodpecker trends, although exact changes varied by forest.

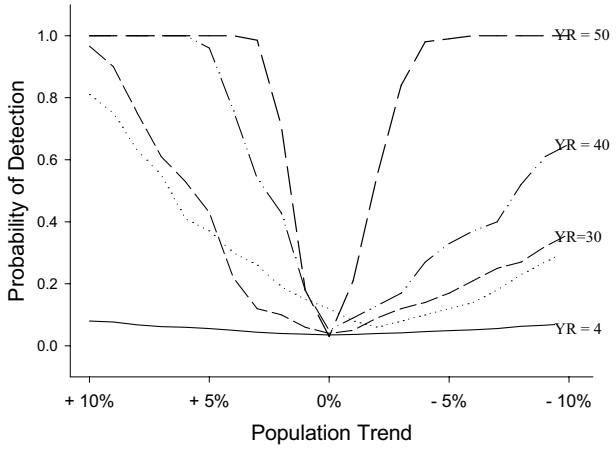

Figure 3— The failure to detect a 3 percent annual population trend of the Ovenbird on the Cherokee National Forest with current sampling effort.

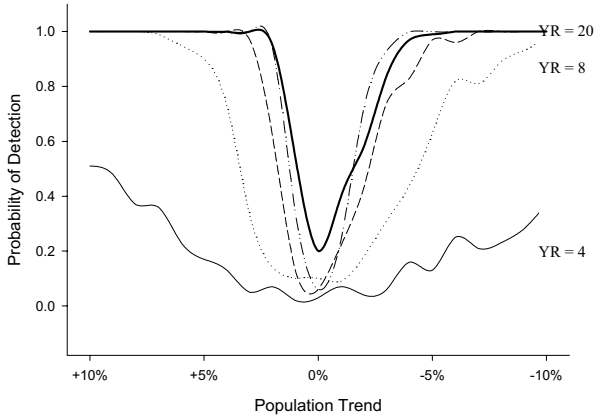

Figure 4— Increasing sampling effort by 100 percent (on the Cherokee NF) is expected to reduce the time needed to detect a 3 percent annual population trend from >50 years to 20 years.

Our results suggest population trends, as determined by Region monitoring data and Breeding Bird Survey data, were not consistent within the physiographic province. For example, comparing population trends of our two focal species in Virginia demonstrated how populations may be changing with varying intensities (*fig. 5a*). Results from Tennessee suggest even the direction of the trend may differ within the same geographic area (*fig. 5b*). When we examined 10 species across the entire province, populations on national forest land were trending in the opposite direction of those monitored the Breeding Bird Survey routes (*table 1*). This suggests that at least for a subset of the avifauna in the Southern Blue Ridge province, Region and Breeding Bird Survey monitoring programs are tracking actual differences in population trends.

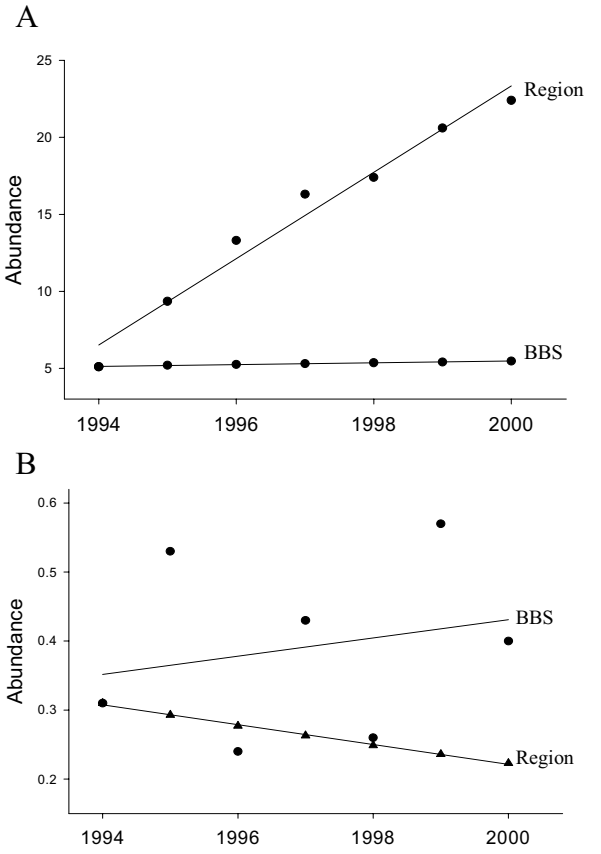

Figure 5— a) Population trends of the Ovenbird on Jefferson/George Washington National Forest and BBS routes located in Virginia. b) Population trends of the Ovenbird on Cherokee National Forest and BBS routes located in Tennessee.

Discussion

The goal of this study was to assess the relative effectiveness of the Region monitoring program to detect population trends. We were particularly interested which spatial scale can be utilized to detect trends, what time interval is required to document such a trend, and if this program gathered unique data. Our results suggest the current monitoring effort will not provide adequate data to detect modest population trends at the district level, although that was never a goal of the monitoring program. On the Jefferson/ George Washington National Forest sampling was 3x more intensive than any other national forest considered in this study and not surprisingly, their monitoring program also has the greatest ability (in terms of fewest years to detect an actual decline) to detect population changes compared to other national forests. Manipulating the number of census points offered some insight

Table 1— *Comparison of population trends (percent change per year) for species in the Southern Blue Ridge physiographic province using Region and BBS data spanning 1992-2000. BBS data were analyzed using route regression while Region data were analyzed using linear regression.*

	Region		BBS	
Species	**Trend**	***P***	**Trend**	***P***
Acadian Flycatcher*	6.34	0.001	-6.85	0.092
Black-and-white Warbler	-0.04	0.553	-2.11	0.624
Eastern Wood-pewee*	2.23	0.007	-7.81	0.013
Indigo Bunting*	1.28	0.008	-1.25	0.168
Ovenbird	4.29	0.001	3.25	0.065
Pileated Woodpecker	0.62	0.278	1.44	0.390
Pine Warbler*	-4.12	0.001	7.80	0.062
Red-eyed Vireo	2.13	0.001	0.43	0.537
Scarlet Tanager*	3.35	0.014	-3.72	0.109
Veery	1.40	0.506	5.69	0.537

* Species for which analyses indicated different directions (positive vs. negative) of population trend.

into the expected resolution gained by increasing the monitoring effort. For the focal species in this study, doubling the number of census points on the Cherokee National Forest resulted in decreasing the time expected to detect a trend by over 30 years. Unfortunately, a 3 percent annual trend could still only be detected after 20 years, but it illustrates the potential effectiveness of increasing sampling effort. This is likely due, in part, to the relatively small annual population change (3 percent) in this analysis. Other studies utilizing power analysis have frequently considered a 5 percent annual change to be important, but the actual amount of change should be biologically relevant to the population of interest (Lougheed et al. 1999, Wilson et al. 1999).

The ability to detect population trends in a reasonable amount of time is paramount to conserving species. Our results suggest that on some national forests, it may take >50 years to detect a 3 percent annual decline. This would result in 78 percent total decline of initial population. In a 15-year study in Australia, all uncommon bird species (<100 observations/yr), power was less than 0.8, failing to detect populations that had declined by >70 percent (Williams et al. 2001). Monitoring programs that fail to detect such large declines or take too long, fail to meet most reasonable goals of trying to detect biologically significant population declines.

One of the stated goals of the Region program is to monitor Partners in Flight priority species (Gaines and Morris 1996). Some of the Partners in Flight species of concern that occur in the Southern Blue Ridge province include Bewick's Wren (*Thryothorus bewickii*), Cerulean Warbler (*Dendroica cerulea*), and the Golden-winged Warbler (*Vermivora chrysoptera*). However, both the Region and Breeding Bird Survey monitoring programs are inadequate to address population trends for many of these species, even at the scale of the physiographic province (Sauer et al. 2001, Linder and Buehler unpubl. data). For species that are narrowly distributed or uncommon, targeted monitoring may be necessary to adequately address population trends.

It appears the Region monitoring program does provide unique information independent of the Breeding Bird Survey. Although different analyses were used to determine rates of change for Region trends and Breeding Bird Survey trends (linear regression and route-regression, respectively) and therefore are not directly comparable, the fact that trend directions for half of species considered were in opposite directions suggests the two monitoring programs are providing unique information. Differences between the monitoring programs may be attributable to such factors as, but not limited to, observer bias, sampling design, statistical analysis, and actual differences in trends. For example, some forests have used few observers over the years while other forests have utilized a large number of novice (for that particular forest) observers both within and between years. Most national forests have stratified individual points by habitat whereas Breeding Bird Survey routes consist of 50 points on a single transect. Consequently, the two distinct sampling designs also necessitate different statistical treatments. Finally, it may be the monitoring programs are actually accurately monitoring different populations (or portions of a larger, single population). Breeding Bird Survey routes are located on roads on public and private lands whereas the Region program typically establishes points within forested settings (>50 m from a road) and only in national forests. There are likely other sources of variation that influence one or both monitoring

programs, but it appears that the programs do indeed track different populations.

While the Region monitoring program is early in its development, an analysis of this type is useful in determining if a program will meet its desired goals (Gibbs and Melvin 1997). If not, alterations should be considered by managers and the relative costs and benefits can be weighed to determine if changes such as adding census points, is necessary. We recommend the Cherokee National Forest increase the number of census points it currently conducts, by at least a factor of two, if a desired goal of the program is to monitor at the scale of each individual national forest. As a region, the monitoring program is adequate to detect modest trends in species that are relatively common. It remains to be determined if the monitoring program is adequate for most species of management concern. Further analysis is warranted on a larger sample of the avifauna of the region.

Acknowledgments

We would like to thank M. T. Griep, T. Mersmann, and D. Belcher (all of U.S. Forest Service) for pulling together the Region data set. K. Stodola provided assistance in conducting power and trend analyses. We would all like to thank the many observers their time to collecting these point-count data. Funding was provided by the U.S. Forest Service, University of Tennessee, Institute of Agriculture and Mississippi State University. This manuscript was improved by comments from M. Husak and C. Johansson.

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Northern Region Landbird Monitoring Program: A Program Designed to Monitor More than Long-term Population Trends[1]

Richard L. Hutto[2]

Abstract

The Northern Region Landbird Monitoring Program (NRLMP) has been in place for nearly a decade and is designed to allow us to track population trends of numerous landbird species, while at the same time allowing us to investigate the effects of various kinds of land use activity on the occurrence, abundance, or demographics of numerous landbird species. We conduct point-count bird surveys biennially at about 350 permanently marked 10-point roadside transects that have been positioned in a geographically stratified fashion throughout USFS lands in northern Idaho and Montana. On alternate years we conduct more focused land-use effects studies entailing the use of replicated treatment and control plots. Habitat relationships derived from the combination of bird and vegetation information surrounding the permanently marked points and from the short-term, management-oriented monitoring protocol have generated the most support for the monitoring program within the USFS. Generating financial support from potential partners has been the most difficult obstacle to expansion beyond USFS lands, but many of those who were resistant early on are beginning to realize the power of birds as monitoring tools, and are starting to join forces to develop a more comprehensive statewide monitoring plan.

Introduction

The primary goal of land management agencies is to maintain ecological integrity of the lands they manage. It, therefore, follows necessarily that monitoring is an essential part of land management. How, other than through monitoring, can agencies determine if they are doing a good job? Given that monitoring is necessary, what should be monitored? Most of us would probably argue that we should monitor indicators of ecological integrity, and in practice, the approach adopted by the USFS and other agencies has been to use a few indicator species as monitoring tools. This has evolved into the use of "flagship," "umbrella," and "keystone" species approaches as well (e.g., Wilcox 1984, Mills et al. 1993, Simberloff 1998). The problems with indicator approaches are numerous, however (Hutto et al. 1987, Landres et al. 1988), with the main concerns being that (1) the numbers of species traditionally used in such schemes are too few to assure that we are maintaining the ecological conditions needed for the maintenance of all species (some forests in the USFS Northern Region list as few as five Management Indicator Species, for example); and (2) few of those species designated as management indicators are actually monitored effectively, if at all. One way to deal with the primary limitation of using so few, difficult-to-monitor indicator, umbrella, or keystone species is to broaden the species list to include large groups of species that can be monitored by way of a single field method (Hutto 1998). Landbirds are one such group.

Landbird species are ideal monitoring tools because (1) they are easy to monitor (no other vertebrate group is as detectable or consists of species as readily identified with little or no equipment); (2) a single monitoring method can produce information on numerous species (a trained field crew can collect information on patterns of bird occurrence for more than 100 species using a single, inexpensive, point-based survey method); and (3) attending to the needs of many rather than few species forces managers to abandon efforts to provide for all species on each project area (it cannot be done). Instead, by having to deal with information from a large number of species simultaneously, managers are forced to plan at the landscape scale in order to ensure that conditions for all species are maintained. This is true because it is only at large spatial scales that all species can be maintained in the face of negative effects of activities on some species at more local scales. Thus, land managers who attempt to meet the needs of a large number of landbird species are effectively forced toward landscape management to achieve sustainability.

Selling these potential strengths of using birds as a monitoring tool, we initiated the Northern Region Landbird Monitoring Program (NRLMP) in about 1990. The program is a cooperative effort involving

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California**.

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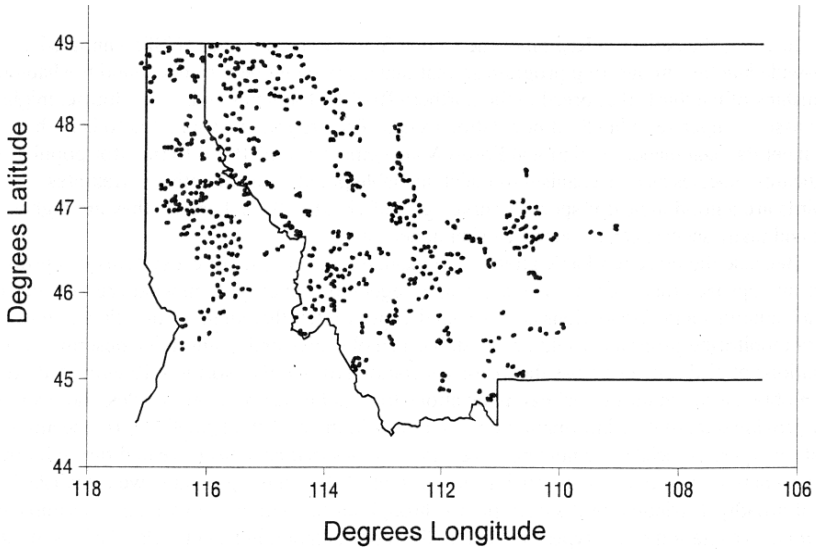

Figure 1— Map depicting the locations of permanent landbird monitoring transects in northern Idaho and western Montana.

numerous partners (Bureau of Land Management; Confederated Salish and Kootenai Tribes; Idaho Fish and Game; Montana Department of Fish, Wildlife and Parks; National Bison Range; National Park Service; Potlatch Corporation; Plum Creek Timber Company; and the U.S. Forest Service[USFS]), although the bulk of funding for the program has come from the USFS.

Since a national Breeding Bird Survey already exists, why was it necessary to start a smaller, regional monitoring program? There are two reasons: (1) land managers want data that are more regional than national in scope; and (2) there is a need for developing an understanding of bird-habitat relationships so that we can anticipate the effects of habitat change, instead of reacting to change after discovering the presence of a worrisome long-term population trend.

Monitoring Program Design

The NRLMP consists of three elements: (1) long-term population trend monitoring, (2) habitat-relationships monitoring, and (3) management effects monitoring. Here, I provide an overview of the methods and goals associated with each element, and wish to emphasize that the monitoring program involves much more than the tracking of long-term population trends (often the only element that people associate with the word "monitoring"); elsewhere (Hutto and Young 2002) we include additional detail associated with the monitoring program design.

Long-Term Population Trend Monitoring

Long-term population trend monitoring is essential because, while local activities may not be affecting organisms negatively, it may very well be that activities outside the jurisdiction of a given agency cause declines in the organisms that reside therein. For example, land-use patterns in Mexico could affect populations of bird species that breed in Montana. Thus, a coarse-filter approach, whereby an agency maintains the proper amount, distribution, and quality of vegetation types on its land, will never be a satisfactory way to assure that they are maintaining the species that they are legally obligated to maintain. Coarse-filter approaches fail to consider that the effects of human activity outside the management area may affect species that reside part-time within the management area.

Therefore, in northern Idaho and western Montana, we have distributed about 350 permanently marked 10-point transects across the region (*fig. 1*), which serve as the framework for long-term population monitoring. We have yet to generate meaningful long-term results from this element of the program, of course, because it takes decades to generate such data, but the format for extracting and reporting population trend data has been developed in cooperation with the Cornell Laboratory of Ornithology (see example output in at http://www.birdsource.org/LBMP/). The CLO houses a computer server that is linked to an interactive web page (web), which directs the server to compute trend information for any subset of data that the user (a biologist, manager, or private citizen) defines.

Even though long-term trend monitoring is an essential component of any well-designed monitoring program, a program that relies entirely on the monitoring of long-term population trends will always be reactive. Therefore, long-term trend monitoring takes a back seat to two more proactive kinds of monitoring in our program–habitat relationships, and comparative or ex-

perimental studies of the effects of specific management activities.

Habitat-Relationships Monitoring

Habitat-relationships data can help us move beyond the limits associated with monitoring programs that are devoted entirely to long-term population trend monitoring in the absence of habitat data. Perhaps most importantly, if various categories of managed lands are included within the vegetation type or habitat type scheme as part of the monitoring program design, habitat association data can be used to anticipate problems, and can thereby allow an agency to modify its activities as a result of anticipated effects, instead of waiting to react to a long-term trend that looks bad. As a hypothetical example, habitat association data might tell us that a particular species is negatively affected by forest harvest method A. If harvest method A is becoming more common on the landscape, then that should be adequate warning that conditions are deteriorating for the species of concern. We generate habitat relationships by simply recording the vegetation cover type at each sample point and then use data from those points (about half of our sample) that are surrounded within 100 m by a single vegetation type. For any species, the probability of occurrence in each of a number of vegetation cover types can then be calculated as the proportion of points in each vegetation type that had the species present. We have defined some 250 vegetation types or categories, but we generally aggregate the data into 18 types for most analyses, because that level of aggregation provides at least 50 broadly distributed points in each vegetation type-a sample size deemed to be sufficient to build reliable habitat relationships models (Ralph et al. 1995).

Within a matter of three years, we were able to generate information on habitat relationships for about 80 species (Hutto and Young 1999). Our habitat relationships are based on the assumption, of course, that the probability of occurrence within a fixed radius is an accurate index of bird abundance, but the data are perfectly amenable to adjustments based on distance sampling (Thomas et al. 2002), should one be more comfortable with that approach to deal with potential detectability bias related to vegetation type. Whichever method one chooses to develop an index of bird abundance, the relationships are much more refined than information available from field guides, and relationships that include categories of heavily managed lands can be used to uncover land use effects amazingly rapidly. By coupling habitat data with bird occurrence data, we have moved beyond a monitoring program (like BBS) built entirely around the generation of long-term trend data (which can only lead to a reactive form of wildlife management), to one that includes habitat relationships (which allows for more proactive, adaptive management whereby one can anticipate problems before they actually become such).

As a single dramatic example of what simple distributional information can do to inform management, consider the distribution of the Black-backed Woodpecker (*Picoides arcticus*), which appears to be nearly restricted to early post-fire forests in the USFS Northern Region (*fig. 2*). The relatively restricted distribution

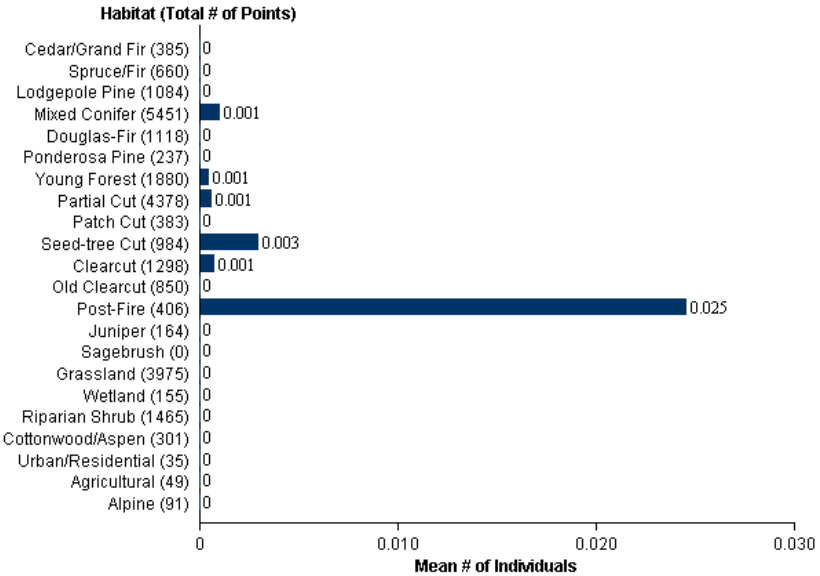

Figure 2— Data from the Northern Region Landbird Monitoring Program suggest that the Black-backed Woodpecker is relatively restricted in distribution among vegetation types in the Northern Region. The pattern agrees with other independently derived information based on a comprehensive literature review (Hutto 1995).

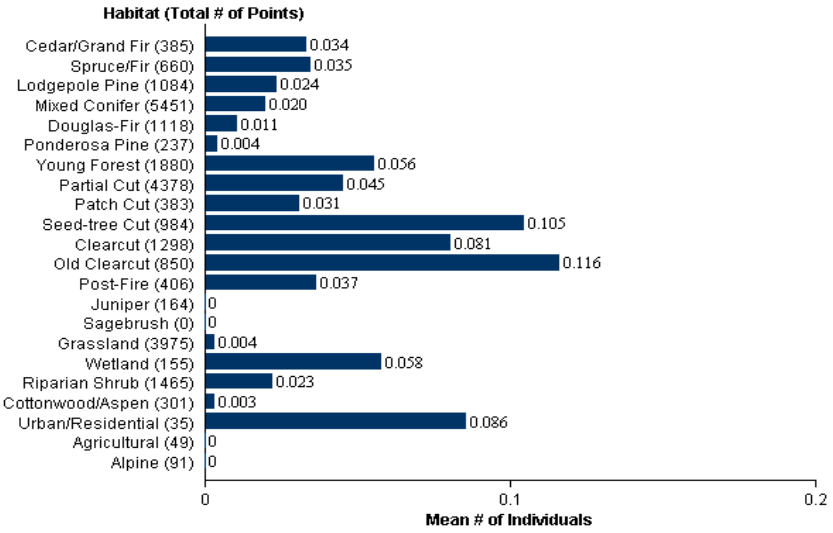

Figure 3— The mean number of Olive-sided Flycatchers detected in points distributed as shown among each of 22 vegetation types.

pattern of this and several other species (e.g., Mountain Bluebird [*Sialia currucoides*], Three-toed Woodpecker [*Picoides tridactylus*]) results from the fact that those bird species depend to a great extent on standing dead trees in burned forests for feeding and/or nesting purposes. Not only do we have much less of this cover type than we had historically because of an overly aggressive fire suppression policy during the past half-century (Agee 1993, Arno and Allison-Bunnell 2002), but because we have also salvage logged much of what little did manage to burn, the data suggest that we will exacerbate even further the negative effects of fire suppression on species that are either restricted to, or relatively restricted to, these early post-fire conditions. There have been changes in post-fire salvage-logging policy in the USFS Northern Region. These changes are in part a consequence of habitat relationship information on Black-backed Woodpeckers and other species that are relatively restricted to early post-fire habitats.

Other animal and plant species (morel mushrooms, geraniums, bark beetles, etc.) are also relatively restricted to recently burned forests, supporting the idea that landbirds are, indeed, a useful management indicator tool; the birds are exposing some important management issues that affect other kinds of organisms as well.

Another surprising result was the fact that some species (e.g., Williamson's Sapsucker [*Sphyrapicus thyroideus*], Olive-sided Flycatcher [*Contopus cooperi*], and MacGillivray's Warbler [*Oporornis tolmiei*]) are relatively abundant in the more heavily managed lands (e.g., *fig. 3*). On the surface, this looks encouraging, but the potential problem is that heavily managed lands are always somewhat "unnatural." Widely and evenly spaced live trees that result from some forms of timber harvesting, for example, simply do not exist in natural successional seres. Nonetheless, these unnatural cover types may elicit settling responses by species that are "programmed" to respond to superficially similar, but fundamentally different, early successional forest types. Thus, harvested forests could be acting as "ecological traps" (areas that attract species that subsequently have relatively poor reproductive or survival success). The latter example serves to illustrate the power of this program to expose and highlight real management issues that need to be examined more closely. In fact, these results have served as the stimulus for a number of follow-up studies of nest success in naturally vs. artificially disturbed forests throughout the West (e.g., unpublished reports by Bob Altman, Natasha Kotliar, and Bruce Robertson).

In addition to building simple habitat-relationships models based on bird occurrence patterns across major vegetation types, we can also build more sophisticated models by looking at patterns of variation in occurrence within any one vegetation type and linking this information to additional local-scale vegetation information. We now know, for example, not only that Swainson's Thrush (*Catharus ustulatus*) is broadly distributed across all kinds of conifer forests (*fig. 4a*), but that they occur only in those forests that have more than about 40 *percent* shrub cover (*fig. 4b*). The Brown Creeper (*Certhia americana*) occurs not only in relatively uncut conifer forests (*fig. 5a*), but also occurs most commonly in older uncut forests (*fig. 5b*), perhaps because of strict nesting requirements.

In addition, because all points are geo-referenced, we can look at the landscape context within a fixed area around each survey point to assess whether landscape

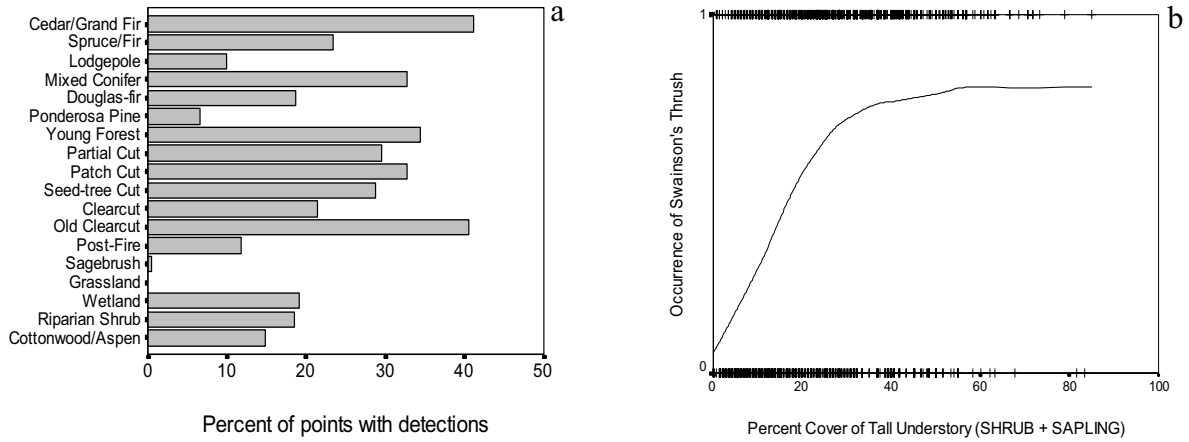

Figure 4— (a) The percentage of 7,500 points in which Swainson's Thrush was detected in each of 18 vegetation types. (b) The probability of occurrence as a function of percent shrub cover within 30 m surrounding a count point.

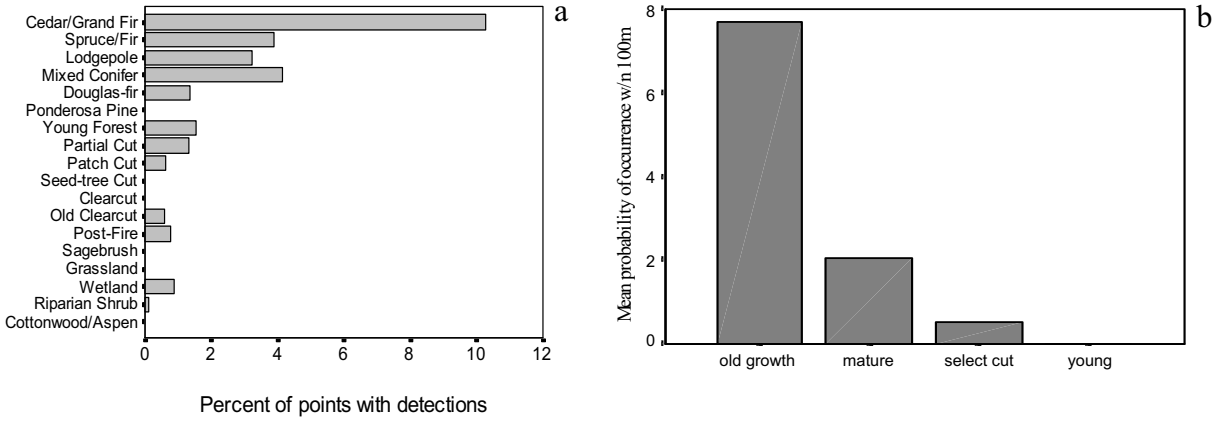

Figure 5— (a) The percentage of 7,500 points in which Brown Creeper was detected in each of 18 vegetation types. (b) The probability of occurrence of Brown Creeper in conifer forest habitat, broken down by age/ structural class.

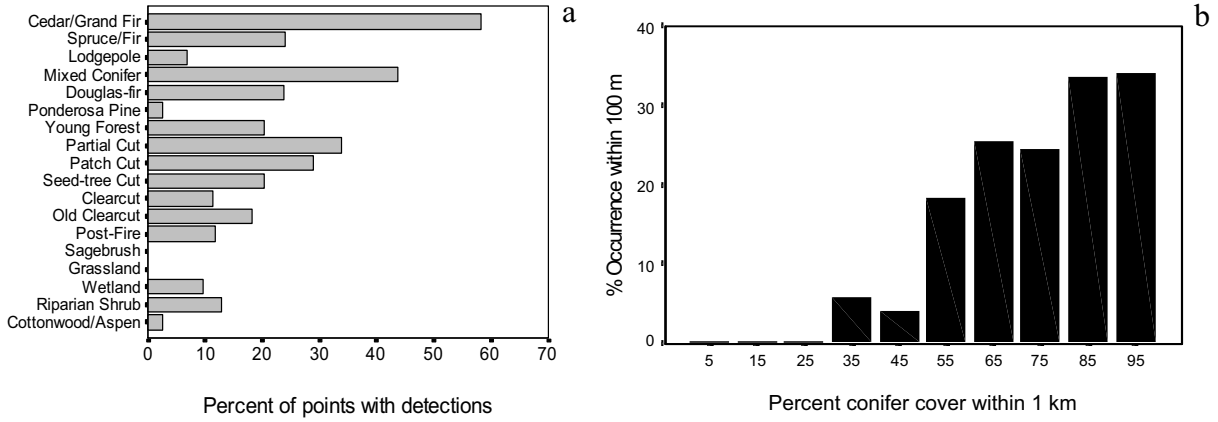

Figure 6— (a) The percentage of 7,500 points in which Townsend's Warbler was detected in each of 18 vegetation types. (b) The probability of occurrence of Townsend's Warbler in conifer forest habitat, broken down by percentage of conifer cover within a km around the count point.

conditions contribute above and beyond what vegetation type alone can contribute to an understanding of the occurrence patterns of birds. For example, Townsend's Warbler (*Dendroica townsendi*) occurs not only in conifer forests (*fig. 6a*), but most often in those with greater forest area surrounding the point (*fig. 6b*). In the case of the Brown-headed Cowbird (*Molothrus ater*), we have found that it is most abundant in open

forest, grassland, agricultural, and riparian habitats, but the distance to agriculture is the most powerful predictor of presence at a point (Young and Hutto 1999). Cowbirds can, in fact, serve as a textbook example of the importance of landscape context in the distribution of a bird species.

Experimental and Comparative Monitoring Studies

By design, we survey permanently marked long-term monitoring points every other year, and conduct studies of specific land-use effects in the alternate years. This allows for a more refined study of issues of immediate management concern during the alternate years when we are not collecting data from the permanently marked points. The number of true replicate plots associated with a typical alternate-year study is also noteworthy. Even with each National Forest hiring only a single seasonal field worker, the entire monitoring crew is large enough to allow us to work with numbers of replicate sites that exceed the levels of true replication in 95 percent of the studies published in various ecological, ornithological and conservation journals over the past 25 years (Sallabanks et al. 2000). Thus, the power of this program to generate statistically meaningful data is directly linked with the commitment to maintain a large field crew during the alternate years.

The long-term monitoring points also avail themselves to before-after/control-impact studies, which are generally assumed to be the most powerful and rapid way to gain knowledge. For example, we have begun studying the effects of a natural event (the extensive fires of 2000) whose effects would be impossible to study in a truly experimental arena. Vegetation surrounding nearly 100 of our long-term monitoring points burned in 2000, leaving us with before and after data for points that did and did not experience a kind of natural disturbance event that is of a scale and magnitude that simply does not avail itself to true experimentation.

Caveat

The single-most glaring weakness in this and other monitoring programs is that there does not appear to be a formal mechanism built in to use the resulting information. Findings from this program that have helped to change policy have done so because the information filtered informally into management circles. Monitoring efforts must become incorporated more formally into forest plans. Adaptive management is a grand concept whereby management practices change in response to results of monitoring, but the concept would be even better in practice. The integration of monitoring and management is the essence of adaptive management, but we have to arrange for a more formal adaptive management process. Long-term trend monitoring and habitat-relationships monitoring (both of which accumulate data over time) allow us to bring findings at any time to planning meetings so that management plans can be based, at least in part, on the patterns that we expose. A decision-maker's desire to use results from monitoring efforts still appears to be the limiting factor in bird conservation.

Acknowledgments

I thank J. Young and C. J. Ralph for offering comments to improve the manuscript.

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Sixteen Years of Habitat-based Bird Monitoring in the Nicolet National Forest[1]

Robert W. Howe[2] and Lance J. Roberts[2]

Abstract

The 16-year-old Nicolet National Forest Bird Survey is the longest-running volunteer monitoring program on any U.S. national forest. Every year, teams of volunteer observers led by at least one expert with proven field experience sample more than 250 permanent points during the second weekend in June. Altogether 512 points are monitored, approximately half during a given year. Observers use a standard 10-minute point count, separated into three time intervals (0-3 min, 3-5 min, 5-10 min) and three bird-to-observer distance categories (<50 m, 50-100 m, >100m). Since 1989, 75-100 volunteers have participated annually. The initial objective was to quantify the relative abundances, patterns of habitat use, and geographic distributions of breeding birds in the 661,400-acre national forest. The longevity of the survey now permits analyses of regional population trends and more detailed modeling of bird-habitat associations. Results are used with GIS data to predict bird distributions across the region. Data from the survey are available at http://www.uwgb.edu/birds/nnf/. Important findings include: 1) species assemblages sampled by the Nicolet National Forest Bird Survey are different from those monitored by the North American Breeding Bird Survey; 2) an alarmingly large number of species (45) have shown significant declines, compared with only seven species that have shown significant increases; 3) data from the point counts can be used to identify species-specific habitat associations and geographic distribution patterns; and 4) GIS tools can be used to effectively model the distribution of many species across the entire forest. Production of a custom CD of local bird songs has provided an incentive for participation and has helped cultivate a sustained base of expertise among volunteer observers in this regional bird monitoring program.

Key words: bird habitat associations, Breeding Bird Survey, GIS landscape analysis, Nicolet National Forest, population trends, Wisconsin.

Introduction

The North American Breeding Bird Survey (BBS) provides a foundation for large scale analyses of bird population trends in the United States, but the program is not designed to answer spatially explicit questions about local bird distributions or bird-habitat associations (Robbins et al. 1986). Maps presented on the U.S.G.S. Breeding Bird Survey web site (Sauer et al. 2001) and maps derived by Price et al. (1995) provide a coarse image of bird distributions in North America, with little meaningful information at scales of 100 km^2 or perhaps even 10,000 km^2. Nevertheless, bird distributions at these local scales are of great interest to land managers who must determine the impacts of resource extraction, habitat management and other human activities.

In this paper we describe a local bird monitoring program consisting of annual counts at more than 500 permanent points in the eastern unit of the Chequamegon-Nicolet National Forest. Our objectives are 1) to determine how such a program differs from the larger scale BBS, and 2) to illustrate some applied research that can be derived from the results.

Study Area

The Nicolet National Forest is the eastern administrative unit of the Chequamegon-Nicolet National Forest, covering nearly 661,400 acres in Florence, Forest, Langlade, Oconto, Oneida, and Vilas Counties of northeastern Wisconsin. The landscape consists of a complex, glacially-derived mosaic of moraines, drumlins, outwash plains, depressions, and scoured bedrock ridges (Albert 1995). More than 1100 lakes, 400 spring-fed ponds, and extensive lowlands add significant diversity to the predominantly forested uplands. Because of its value as breeding habitat for neotropical migratory birds, the forest is recognized as an Important Bird Area by the American Bird Conservancy (http://www.abcbirds.org/iba/aboutiba.htm).

The presettlement vegetation of the Nicolet National Forest consisted mainly of old growth northern hardwoods forest dominated by sugar maple (*Acer saccharum*), eastern hemlock (*Tsuga canadensis*), basswood (*Tilia americana*), yellow birch (*Betula alleghaniensis*), and white pine (*Pinus strobus*), dissected by several other important vegetation types including lowland conifer forests dominated by black spruce (*Picea mar-*

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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iana), balsam fir (*Abies balsamea*), tamarack (*Larix laricina*), or northern white cedar (*Thuja occidentalis*); lowland hardwoods of black ash (*Fraxinus nigra*) and American elm (*Ulmus americana*); dry upland forests with oaks (*Quercus* spp.), jack pine (*Pinus banksiana*), and red pine (*Pinus resinosa*); and successional forests with aspen (*Populus* spp.) and white birch (*Betula papyrifera*). Aspen and birch forests cover a much larger area today (approximately 25 percent of the forest) than they did prior to logging in the 1800's and early 1900's (Frelich 1995); today, only northern hardwoods and mixed northern hardwoods/conifers (approximately 39 percent of the forest area) are more extensive than aspen/ birch forest. Lowland conifers cover an additional 18 percent of the forest area (Great Lakes Ecological Assessment 1997). Like other national forests in the western Great Lakes region, a significant amount of land within the proclamation boundary of the Nicolet National Forest is privately owned, much of it consisting of non-forested agricultural uplands.

Nicolet National Forest Bird Survey

In June 1987, U.S. Forest Service biologists, scientists from the University of Wisconsin-Green Bay, and members of the Northeastern Wisconsin Audubon Society established 65 points in the southern two districts (Lakewood and Laona) of the Nicolet National Forest, and the following year 116 points were established in the northern districts (Eagle River and Florence). Additional points were added during 1989 and 1990, yielding the current array of 151 points in the southern half of the forest and 161 points in the northern half. These "habitat-based points" represent 19 major vegetation or landform types that are prominent in the forest and recognized by the U.S. Forest Service land classification database (*fig. 1*). Points were selected according to two critera: 1) continuous area of the target habitat and 2) accessibility (Howe et al. 1994). Large continuous areas that could be reached within about 200 m from a road were selected whenever possible. The selection process also took into account sampling logistics; points were clustered into groups of 5-7 to minimize travel time. In all cases points were located at least 500 m from any other point. Although the selection process was not random, it provides a reasonably extensive distribution of sites across the forest. These "habitat points" are located off roads, typically 100 - 200 m within the target habitat. A permanent marker (wooden post) was established at each point and at the road access point from which explicit directions are given. Global positioning system (GPS) coordinates have been documented for all of these points.

Beginning in 1992, additional survey points were selected from randomly determined locations across the forest. A straight line was projected from randomly selected coordinates to the nearest road. This constrained random selection process yielded 200 "roadside points," 100 in the southern half of the forest and 100 in the northern half.

Between 1992 and 2001 the 512 points (312 “habitat-based” points and 200 roadside points) were visited during alternate years; approximately half were sampled in the southern half of the forest during one year, while the other half were sampled in the northern half of the forest during the following year.

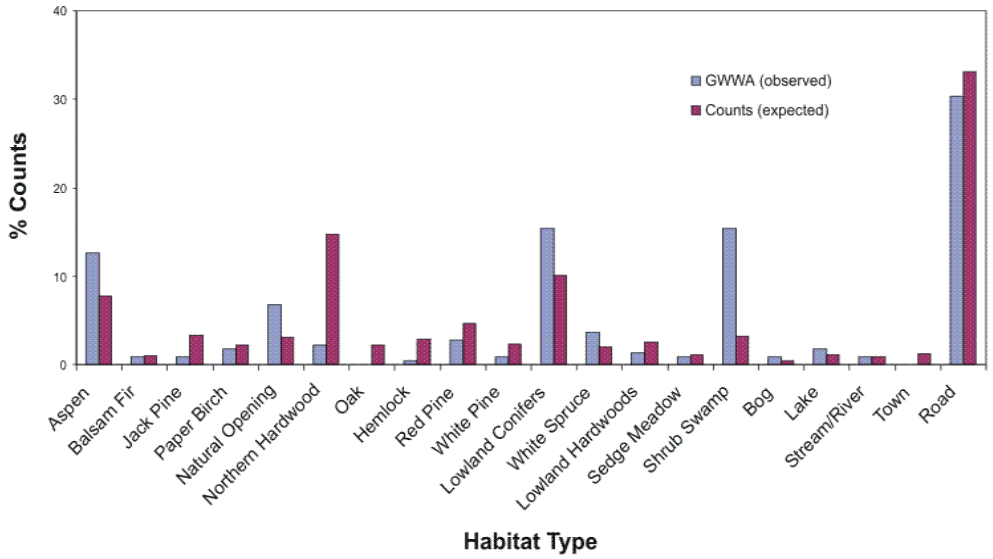

Figure 1— Habitat associations of Golden-winged Warbler from 1987-2001 in the Nicolet National Forest using 19 habitat categories, in addition to random road points. Dark bars represent expected frequency of occurrence based on the number of points sampled in each category (i.e., assuming random distribution among habitats). Light bars represent observed frequency of Golden-winged Warbler in that category.

Six North American Breeding Bird Survey (BBS) routes are located in or near the boundaries of the Nicolet National Forest (Sauer et al. 2001): Amberg, Crandon, Eagle River, Hollister, LandOLakes, and Popple River. Each route consists of 50 roadside points located ½ mi apart. In all but one case at least some part of the 24.5 mi route falls within the boundary of the Nicolet National Forest.

Methods

The Nicolet National Forest Bird Survey (NNFBS) is conducted during a single weekend in early June. Standard, 10-minute point counts (Ralph et al. 1995, Howe et al. 1997) are conducted at each point by teams of observers led by at least one "expert" who is experienced in the auditory identification of birds in northern Wisconsin forests. The bird survey has attracted many of Wisconsin's most skilled birders, and the team approach helps ensure high quality field data and, at the same time, helps groom expertise among less skilled participants. A custom CD with recordings of Nicolet National Forest bird species was prepared by the Cornell Laboratory of Ornithology (funded by the U.S. Forest Service) to help participants learn and practice bird identifications.

Point counts are conducted between sunrise and 9:00 a.m. All birds seen or heard are recorded on standardized forms, with separate fields for distance from observer (0-50 m, 50-100 m, >100 m) and for time intervals when the bird was first observed (0-3 min, 3-5 min, 5-10 min). Birds flying over the habitat but not landing are distinguished by a standard code. In contrast, BBS routes are sampled with 3-min point counts at each of the 50 stops. For both the NNFBS and the BBS, all birds seen or heard at each stop are recorded on standardized forms. In order to compare the species composition of BBS samples with the species composition from the NNFBS, we transformed the count data to relative abundance among all species in the respective samples. BBS data included all available counts between 1966 and 2001 (*table 1*).

Ten groups of bird samples (northern NNFBS habitat-based sites, northern roadside points, southern habitat-based points, southern roadside points, and data from the six BBS routes) were compared using a nonparametric ordination technique known as nonmetric multidimensional scaling (McCune and Grace 2002). This iterative procedure maps the groups of samples in two or three dimensional shape based on their similarity in bird species composition. The algorithm optimizes the configuration so that groups with the most similar bird species compositions are located nearest one another. The software package PC-Ord was used to perform the calculations (McCune and Mefford 1999).

We used another nonparametric technique, Spearman rank correlation (Conover 1999), to test for significance of species abundance trends in the NNFBS between 1989 and 2001. Like nonmetric multidimensional scaling, this test requires fewer assumptions than standard methods (i.e., linear regression analyses and their analogs) and the results are simpler to understand. The trend analyses based on rank correlation are presumably more conservative than the route regression method used to identify trends in the BBS data (Sauer et al. 2001). Systat Version 10 was used for the statistical calculations.

Predictive models for mapping expected bird distributions in the Nicolet National Forest are described in detail by Roberts (2001). He used logistic regression (Systat, Version 10) to predict species presence/absence given two sets of independent variables: local variables measured directly at the point (e.g., mean canopy height, shrub density, etc.); and landscape variables derived from the U.S. Forest Service GIS data-

Table 1— *Number of counts (3-minute unlimited-radius point counts for BBS, 10-minute unlimited-radius counts for NNF) and number of geographic points used in comparison of bird surveys from the North American Breeding Bird Survey (BBS) and Nicolet National Forest Bird Survey (NNF).*

Dataset	No. years*	No. points (max.)**	Total no. counts
NNF Habitat Sites North	7	164	1096
NNF Habitat Sites South	8	152	1125
NNF Road Sites North	5	100	586
NNF Road Sites South	5	100	507
BBS (Amberg)	22	50	1100
BBS (Crandon)	28	50	1400
BBS (Eagle River)	34	50	1700
BBS (Hollister)	31	50	1550
BBS (LandOLakes)	29	50	1450
BBS (Popple River)	33	50	1650

*NNF points are sampled every other year; some road sites were sampled annually during the 1990's.
**several sites were dropped due to access problems or presence of Northern Goshawk nest.

base of the Nicolet National Forest, augmented by published land cover data from non-federal lands (WISCLAND 1998). "Presence" of a species was defined as the occurrence of at least one individual in two or more years during the five point counts at each site between 1992 and 2001. The local variables were further divided into a structure subset (e.g., average basal area of canopy trees, total shrub cover, etc.), and a species composition subset (percent cover of each tree species in the canopy and four subcanopy layers), and finally all variables were combined to examine the relative utility of the different scales of habitat characterization.

Results

Observers have recorded 178 bird species during the first 15 years of the NNFBS, compared with 142 species on the six nearby BBS routes over a much longer time period (1966-2001). The BBS data include a larger number of point counts, but the total observation time (26,250 min) is somewhat less than in the NNF Bird Survey (33,140 min) because the duration of BBS counts (3 minutes per stop) is shorter than the 10-min counts in the NNF.

The greater number of species in the NNF Bird Survey can be traced to the broader geographic and ecological coverage. Of the 36 species observed in the NNFBS but not on the BBS routes, 19 (e.g., American Black Duck, *Anas rubripes*; American Coot, *Fulica atra*; Marsh Wren, *Cistothorus palustris*; Ring-necked Duck, *Aythya collaris*; Virginia Rail, *Rallus limicola*; and Willow Flycatcher, *Empidonax traillii*) are associated with lakes and wetlands, habitats that are not well represented along roads. The NNF Bird Survey includes six sites in or along lakes, plus six in sedge meadows and 16 in shrub swamps. Other species recorded in the NNF Bird Survey but not on the BBS routes include several species of owls (e.g., Eastern Screech-Owl, *Otus asio*; Northern Saw-whet Owl, *Aegolius acadicus*) and species that typically occur in remote habitats such as conifer bogs (e.g., Black-backed Woodpecker, *Picoides arcticus*; Golden-crowned Kinglet, *Regulus satrapa*) and forest interior (e.g., Northern Goshawk, *Accipiter gentilis*). No species was observed on the BBS routes that was not also recorded in the NNF Bird Survey counts between 1987-2001.

The ordination (nonmetric multidimensional scaling) of bird samples from the BBS routes and NNF Bird Survey reveals comprehensive differences in species composition between these two projects and illustrates year-to-year variation in the NNF Bird Survey results (*fig. 2*). Note that the ordination gives results for groups of censuses (habitat-based sites vs. random roadside sites) for each year of the NNF Bird Survey, but combined species assemblages over all years for the BBS routes. The independent variables were relative abundances of each species in all counts combined (i.e., proportions of all individuals belonging to each bird species), thereby standardizing the results among data sets that included different numbers of point counts.

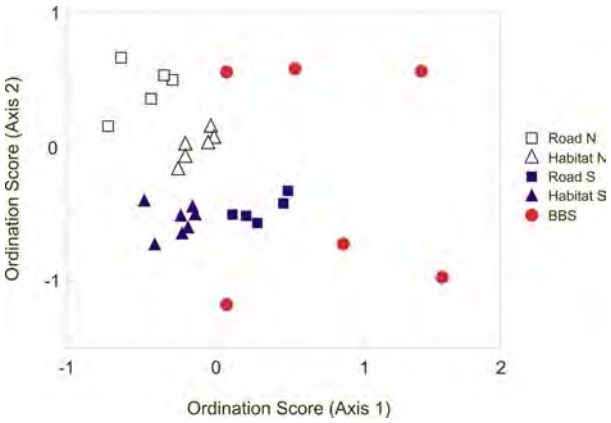

Figure 2— Ordination of bird survey data sets from the Nicolet National Forest and nearby Breeding Bird Survey (BBS) routes. Nicolet National Forest Bird Survey data sets include habitat-based sites in the northern half (Habitat N) and southern half (Habitat S) of the forest and random roadside points in the northern half (Road N) and southern half (Road S). In these cases, cumulative data for all points in a given year were plotted: 1990, 1992, 1994, 1996, 1998, and 2000 for the northern half and 1989, 1991, 1993, 1995, 1997, 1999, and 2001 for the southern half. BBS data sets (see *Table 1*) include all bird records between 1966-2001. For each data set, abundances were relativized as percentages of all birds counted. Ordination was calculated with the method of nonmetric multidimensional scaling using Sorensen's Index as the multivariate distance measure (McCune 2001).

Not only are bird assemblages in the NNF Bird Survey consistently different from those documented by the BBS, but geographic subsets within the NNF Bird Survey (road sites vs. habitat-based sites and northern half of the forest vs. southern half) also are distinct from one another (*fig. 2*). Ovenbird (*Seiurus aurocapillus*) was the most abundant species in all of the NNF data sets, followed in all cases by Red-eyed Vireo (*Vireo olivaceus*). This relationship was reversed in two of the six BBS routes, and in one (Eagle River) Ovenbird was the third most abundant species, after Red-eyed Vireo and American Crow (*Corvus brachyrhynchos*) (*table 2a*).

Table 2a— *Species that were most abundant in the Nicolet National Forest Bird Survey (NNF) between 1987-2001 compared with their relative abundances in six nearby North American Breeding Bird Survey (BBS) routes between 1966-2000. Numbers indicate relative abundance, the proportion of all individuals that belonged to that species.*

Common name	Scientific name	NNF	BBS	Difference
Ovenbird	*Seiurus aurocapillus*	0.108	0.094	0.014
Black-throated Green Warbler	*Dendroica virens*	0.031	0.020	0.011
Great Crested Flycatcher	*Myiarchus crinitus*	0.010	0.0006	0.009
Blue Jay	*Cyanocitta cristata*	0.030	0.021	0.009
Cedar Waxwing	*Bombycilla cedrorum*	0.023	0.015	0.008
Rose-breasted Grosbeak	*Pheucticus ludovicianus*	0.028	0.021	0.007
Nashville Warbler	*Vermivora ruficapilla*	0.033	0.026	0.006
Hermit Thrush	*Catharus guttatus*	0.028	0.023	0.005
Canada Goose	*Branta canadensis*	0.007	0.002	0.005
Common Raven	*Corvus corax*	0.015	0.010	0.005
Red-winged Blackbird	*Agelaius phoeniceus*	0.017	0.013	0.004
Northern Parula	*Parula americana*	0.006	0.002	0.004
Blackburnian Warbler	*Dendroica fusca*	0.007	0.004	0.004
Scarlet Tanager	*Piranga olivacea*	0.009	0.006	0.004
Golden-crowned Kinglet	*Regulus satrapa*	0.004	0.000	0.004
Common Yellowthroat	*Geothlypis trichas*	0.014	0.011	0.003
Brown Creeper	*Certhia americana*	0.005	0.001	0.003
Eastern Wood Pewee	*Contopus virens*	0.013	0.010	0.003
Least Flycatcher	*Empidonax minimus*	0.025	0.022	0.003
Winter Wren	*Troglodytes troglodytes*	0.013	0.010	0.003

Table 2b— *Species that were most abundant in the North American Breeding Bird Survey (BBS) routes between 1966-2000 compared with their relative abundances in the Nicolet National Forest Bird Survey (NNF) between 1987-2001. Numbers indicate relative abundance, the proportion of all individuals that belonged to that species.*

Common name	Scientific name	NNF	BBS	Difference
Chipping Sparrow	*Spizella passerina*	0.015	0.033	-0.018
American Robin	*Turdus migratorius*	0.043	0.058	-0.015
European Starling	*Sturnus vulgaris*	0.004	0.017	-0.013
Red-eyed Vireo	*Vireo olivaceus*	0.081	0.093	-0.012
American Crow	*Corvus brachyrhynchos*	0.031	0.042	-0.011
Cliff Swallow	*Hirundo pyrrhonota*	0.002	0.012	-0.010
Chestnut-sided Warbler	*Dendroica pensylvanica*	0.028	0.037	-0.008
Song Sparrow	*Melospiza melodia*	0.018	0.025	-0.007
Common Grackle	*Quiscalus quiscula*	0.005	0.010	-0.006
Barn Swallow	*Hirundo rustica*	0.001	0.006	-0.005
Brewer's Blackbird	*Euphagus cyanocephalus*	0.0003	0.005	-0.005
Indigo Bunting	*Passerina cyanea*	0.014	0.018	-0.004
Yellow-rumped Warbler	*Dendroica coronata*	0.011	0.014	-0.003
Brown-headed Cowbird	*Molothrus ater*	0.006	0.009	-0.003
House Sparrow	*Passer domesticus*	0.001	0.004	-0.003
Savanna Sparrow	*Passerculus sandwichensis*	0.001	0.004	-0.003
Bobolink	*Dolichonyx oryzivorus*	0.001	0.004	-0.003
Veery	*Catharus fuscescens*	0.012	0.015	-0.003
Pine Warbler	*Dendroica pinus*	0.004	0.006	-0.003
Eastern Phoebe	*Sayornis phoebe*	0.003	0.005	-0.003

Birds of open country and disturbed habitats tend to be more common in the BBS than in the NNF Bird Survey (*table 2b*). Chipping Sparrow, American Robin, European Starling, American Crow, and Common Grackle are among the species that are relatively more abundant in the BBS than in the NNF Bird Survey. Species with the opposite relationship (i.e., relatively more common in the NNF Bird Survey) include Ovenbird, Black-throated Green Warbler, Great Crested Flycatcher, Rose-breasted Grosbeak, Hermit Thrush, Blackburnian Warbler, Scarlet Tanager and other species that are characteristically found in extensive or mature forests. Within the NNFBS, north-south differences were caused by known geographic gradients in species abundances (e.g., Great Crested Flycatcher, House Wren, Baltimore Oriole, and others more common in south; Golden-crowned Kinglet, Black-throated Green Warbler, Black-throated Blue Warbler, and others more common in north). Roadside vs. habitat-based points were distinguished by differences in abundances of Chestnut-sided Warbler, American Crow, Mourning Warbler, and Indigo Bunting (more common at road points) and Brown Creeper (more common at habitat-based sites), among others.

Besides providing a broader coverage of habitat types, the NNF Bird Survey creates opportunities for geographically explicit analyses of bird-habitat associations. In most cases, these analyses are not possible or not as easily derived from BBS data. Observed species' frequencies in different habitat types can be compared with the expected frequencies (based on a neutral hypothesis of random habitat use) to help identify habitat associations (*fig. 1*). If site descriptions are elaborated to include management histories, stand ages, etc., the NNFBS results can help predict the impacts of future land management activities on bird populations.

Davis et al. (2000) used the spatially explicit point data to identify geographic patterns of distribution for many species in the Nicolet National Forest. The majority of species showed patterns of aggregation (clumping), implying that conservation efforts might be targeted effectively toward specific areas. A more detailed analysis of bird-habitat associations is possible by evaluating the habitat characteristics at the geo-referenced NNFBS points. Roberts (2001) acquired local vegetation data (e.g., tree density, canopy species composition, shrub density, etc.) at each habitat-based point and more extensive landscape scale data through analysis of the U.S. Forest Service GIS (geographic information system) data layers. He concluded that both datasets are effective in predicting species occurrences, and the combination of landscape and local variables is most effective. Although local variables performed better than landscape variables, the success of landscape variables is particularly significant because GIS data are available for the entire forest. Predictive models can be used to map the expected distributions of species that show significant landscape associations. We calculated landscape variables for a grid of overlapping 500m circles covering the forest area. Expected probabilities of occurrence based on logistic regression models can be superimposed on this grid. A model for the Black-and-white Warbler (*fig. 3*) predicts a pattern of distribution that is consistent with known habitat associations of this species. Regions of extensive mixed lowland deciduous-conifer forest, known to be a favored habitat of this species (Kricher 1995), are predicted to have the highest numbers of Black-and-white Warblers. Similar maps can be drawn for all species that yield acceptably significant logistic regression models of occurrence.

The NNFBS was not designed to provide information about population trends because that role is well served by the BBS. Nevertheless, the program has been in existence long enough for at least preliminary analyses of changes in species' abundances. We used Spearman rank correlation to identify changes in the average number of individuals per count between 1989-2002. (The 1987 and 1988 survey years were excluded because they did not include the full complements of sites.) Northern and southern halves of the forest and habitat-based and roadside points were treated separately.

Rank correlations of the NNF Bird Survey results yield an alarming result. Among 147 species for which sufficient numbers are available for at least one portion of the forest (northern habitat-based sites, northern road sites, etc.) 45 species declined significantly during this period, compared with only seven species that increased significantly (*table 3*). Of these 52 species, 24 showed similarly significant ($P < 0.05$) or marginally significant ($0.05 < P < 0.10$) BBS trends in Wisconsin over the same period (1989-200), while only one species (House Wren) showed the opposite trend (Sauer et al. 2001). In addition to species showing significant change at the $P < 0.05$ level, six species showed marginally significant increases ($0.05 < P < 0.10$ or similar change in all four sets of data, *table 3*) and 18 species showed marginally significant decreases (*table 4*).

BBS data identify another 15 species that showed significant or marginally significant increases and 10 species that showed significant or marginally significant decreases in Wisconsin between 1989-2000 (*table 5*). None of these 25 species showed significant change in the NNFBS, but in most cases the direction of change was consistent with the BBS trend.

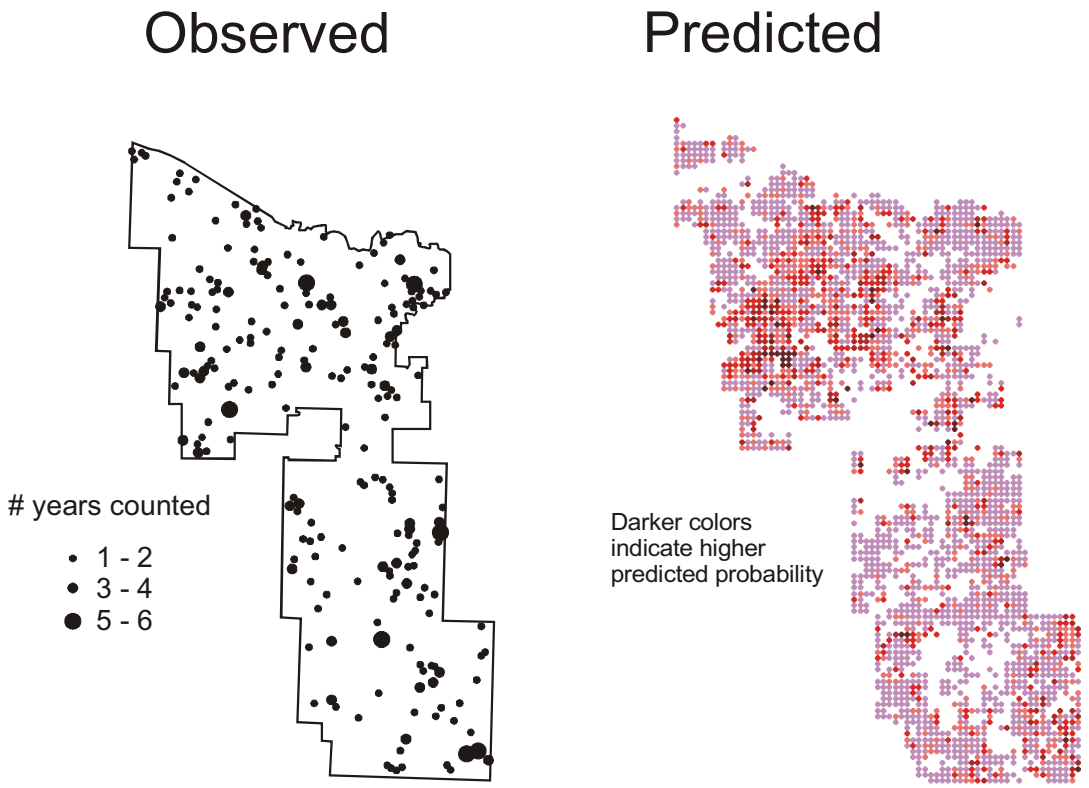

Figure 3— Observed distribution of Black-and-white Warblers in the Nicolet National Forest Bird Survey (on left) and predicted distribution (on right) based on a logistic regression model of local and landscape level habitat variables. Model details are given in Roberts (2001).

Table 3— *Species that showed statistically significant (P < 0.05) or marginally significant (0.05 < P < 0.10) population increases between 1989 – 2002 according to Spearman Rank Correlation of average abundance per point count in the Nicolet National Forest (NNF) Bird Survey and North American Breeding Bird Survey (BBS). NNF Bird Survey points are grouped into 4 categories: habitat-based sites in the northern half (NH) and southern half (SH) of the forest; and roadside sites in the northern half (NR) and southern half (SR) of the forest. Data in the table indicate whether the observed numbers were increasing (+) or decreasing (-) between 1989-2002 for the NNF Bird Survey and 1989-2000 for the BBS.*

Species	Scientific name	NH	NR	SH	SR	BBS
Mourning Dove	*Zenaida macroura*	+**	-	+*	+**	-
American Goldfinch	*Carduelis tristis*	-	+**	+	+**	+**
Wild Turkey	*Meleagris gallopavo*			+	+**	+**
Bald Eagle	*Haliaeetus leucocephalus*	-	+*	-	+**	+**
Chipping Sparrow	*Spizella passerina*	-	+**	-	+	+**
Common Grackle	*Quiscalus quiscula*	+	-	+**	-	-**
Common Loon	*Gavia immer*	-	-	-	+**	+**
American Crow	*Corvus brachyrhynchos*	+	0	+	+*	+**
Palm Warbler	*Dendroica palmarum*	+	+*			+
Northern Parula	*Parula americana*	-	+*	-	-	+*
Cape May Warbler	*Dendroica tigrina*	+	+	+	+	+*
Ovenbird	*Seiurus aurocapillus*	+	+	+	+	-
Red-eyed Vireo	*Vireo olivaceus*	+	+	+	+	+**

*0.05 < P < 0.10
**P < 0.05

Table 4— *Species that showed statistically significant (P < 0.05) or marginally significant (0.05 < P < 0.10) population decreases between 1989 – 2002 according to Spearman Rank Correlation of average abundance per point count in the Nicolet National Forest (NNF) Bird Survey and North American Breeding Bird Survey (BBS). NNF Bird Survey points are grouped into the same categories as in table 3. Data in the table indicate whether the observed numbers were increasing (+) or decreasing (-) between 1989-2002 for the NNF Bird Survey and 1989-2000 for the BBS.*

Species	Scientific name	NH	NR	SH	SR	BBS
Barn Swallow	*Hirundo rustica*	-**	-	-**	-	-
Mourning Warbler	*Oporornis philadelphia*	-**	-	-**	-	-*
White-throated Sparrow	*Zonotrichia albicollis*	-**	-	-**	-	+
Song Sparrow	*Melospiza melodia*	-**	-	-**	-	-
Osprey	*Pandion haliaetus*	-	-**	-**	+	+
Great Crested Flycatcher	*Myiarchus crinitus*	-**	+	-**	-	-**
Eastern Kingbird	*Tyrannus tyrannus*	-**	-	-*	-	-**
Golden-winged Warbler	*Vermivora chrysoptera*	-*	-	-**	-	-*
Baltimore Oriole	*Icterus galbula*	-**	-	-*	-*	-**
Gray Jay	*Perisoreus canadensis*	-*	-	-**		+
Great Blue Heron	*Ardea herodias*	-**	-	-	-	-**
Olive-sided Flycatcher	*Contopus cooperi*	-**	-	-	-	-
Tree Swallow	*Tachycineta bicolor*	-**	-**	+	+	+
Gray Catbird	*Dumetella carolinensis*	-**	-	-	-	-
Eastern Bluebird	*Sialia sialis*	-	-	-**	-	-*
Field Sparrow	*Spizella pusilla*	-	-	-**	-	-**
Eastern Towhee	*Pipilo erythrophthalmus*	-	-	-**	-	+
Brown-headed Cowbird	*Molothrus ater*	-	-	-**	-	-
Northern Flicker	*Colaptes auratus*	-**	+	-*	-	-**
Eastern Wood Pewee	*Contopus virens*	-**	+	-*	-	-
Chestnut-sided Warbler	*Dendroica pensylvanica*	-**	-*	-	+	+
Black-throated Blue Warbler	*Dendroica caerulescens*	-**	-*	-	+	+
Common Nighthawk	*Chordeiles minor*	-	0	-**	-	-
White-breasted Nuthatch	*Sitta carolinensis*	-*	-	-*	-	+**
Pied-billed Grebe	*Podilymbus podiceps*	-**		-		-**
Turkey Vulture	*Cathartes aura*			-**	-	+
Blue-winged Teal	*Anas discors*	-**		-		-**
American Woodcock	*Scolopax minor*	-**		-		ns
Barred Owl	*Strix varia*	-**	-	+	-	-*
Downy Woodpecker	*Picoides pubescens*	-**	-	-	+	+
Yellow-billed Cuckoo	*Coccyzus americanus*	-		-**		-
Black-and-white Warbler	*Mniotilta varia*	-	-	-**	+	-
Connecticut Warbler	*Oporornis agilis*	-**		-		-**
Yellow-throated Vireo	*Vireo flavifrons*	-	-	-**	+	+
Scarlet Tanager	*Piranga olivacea*	-	-	-**	+	+
House Sparrow	*Passer domesticus*	-		-**		-**
Veery	*Catharus fuscescens*	-**	+	-*	+	-
Magnolia Warbler	*Dendroica magnolia*	+	+	-**	-*	+
Killdeer	*Charadrius vociferous*	-		-**	+	-**
Northern Rough-winged Swallow	*Stelgidopteryx serripennis*	-**				+
Vesper Sparrow	*Pooecetes gramineus*			-**		-**
American Bittern	*Botaurus lentiginosus*	-	-	+*	-**	-**
European Starling	*Sturnus vulgaris*	-*	-	-	0	-
Hairy Woodpecker	*Picoides villosus*	+	+	-**	-	-
Cliff Swallow	*Riparia riparia*	+	-	+	-**	+
Cedar Waxwing	*Bombycilla cedrorum*	-	+	-**	+	-*
House Wren	*Troglodytes aedon*	-**	+	0	+	+**
Black-capped Chickadee	*Poecile atricapilla*	-	+	-*	-	+**
Brown Creeper	*Certhia Americana*	-	+	-*	-	+

Table 4 *(continued).*

Species	Scientific name	NH	NR	SH	SR	BBS
Golden-crowned Kinglet	*Regulus satrapa*	-	+	-*	-	+
Yellow Warbler	*Dendroica petechia*	-*	-	-	+	+
Brewer's Blackbird	*Euphagus cyanocephalus*	-			-*	-*
Indigo Bunting	*Passerina cyanea*	-	-	-*	+	-**
Blue-headed Vireo	*Vireo solitarius*	-	0	-*	+	+
Common Yellowthroat	*Geothlypis trichas*	-*	+	-	+	+
Blue-winged Warbler	*Vermivora pinus*	+	+	-*	+	+
Broad-winged Hawk	*Buteo platypterus*	-	-	-	-	-
Least Flycatcher	*Empidonax minimus*	-	-	-	-	-
Swainson's Thrush	*Catharus ustulatus*	-	-	-	-	+
Brown Thrasher	*Toxostoma rufum*	-	-	-	-	-**
Northern Waterthrush	*Seiurus noveboracensis*	-	-	-	-	+**
Bobolink	*Dolichonyx oryzivorus*	-	-	-	-	-
Rose-breasted Grosbeak	*Pheucticus ludovicianus*	-	-	-	-	+

*0.05 < P < 0.10
**P < 0.05

Table 5— *Species that showed statistically significant (P < 0.05) or marginally significant (0.05 < P < 0.10) population increases or decreases between 1989 – 2000 in all Wisconsin Breeding Bird Survey routes but not in the Nicolet National Forest (NNF) Bird Survey. NNF Bird Survey points are grouped into the same 4 categories as in table 3. Data in the table indicate whether the observed numbers were increasing (+) or decreasing (-) between 1989-2002 for the NNF Bird Survey and 1989-2000 for the BBS.*

Species	Scientific name	NH	NR	SH	SR	BBS
Canada Goose	*Branta canadensis*	+		+	+	+**
Red-tailed Hawk	*Buteo jamaicensis*	-		-	+	+**
Sandhill Crane	*Grus canadensis*					+**
Ruby-throated Hummingbird	*Archilochus colubris*	-	+	+	+	+**
Eastern Phoebe	*Sayornis phoebe*	-	+	-	+	+**
Warbling Vireo	*Vireo gilvus*	+	+	+	-	+*
Common Raven	*Corvus corax*	-	+	+	+	+**
Red-breasted Nuthatch	*Sitta canadensis*	-	+	-	+	+**
Yellow-rumped Warbler	*Dendroica coronata*	-	-	+	+	+**
Black-throated Green Warbler	*Dendroica virens*	-	+	+	+	+**
Blackburnian Warbler	*Dendroica fusca*	+	-	-	+	+**
Pine Warbler	*Dendroica pinus*	-	+	+	+	+**
American Redstart	*Setophaga ruticilla*	-	-	+	-	+**
Swamp Sparrow	*Melospiza Georgiana*	-	0	-	+	+*
House Finch	*Carpodacus mexicanus*	-		-		+**
American Kestrel	*Falco sparverius*	-				-**
Sora	*Porzana Carolina*					-**
Wilson's Snipe	*Gallinago delicata*					-**
Black Tern	*Chlidonias niger*	-		+		-*
Black-billed Cuckoo	*Coccyzus erythropthalmus*	-	-	-	+	-**
Red-headed Woodpecker	*Melanerpes erythrocephalus*	+		-	+	-**
Purple Martin	*Progne subis*	-		-		-**
Savannah Sparrow	*Passerculus sandwichensis*	0			+	-**
Red-winged Blackbird	*Agelaius phoeniceus*	-	+	-	+	-**
Eastern Meadowlark	*Sturnella magna*			-	-	-**

*0.05 < P < 0.10
**P < 0.05

Discussion

Both the Nicolet National Forest Bird Survey (NNFBS) and North American Breeding Bird Survey (BBS) provide snapshot views of bird species assemblages in northeastern Wisconsin. Considerable variation characterizes the results at any individual census point, but when combined with other points a meaningful picture of the regional avifauna emerges. The BBS data are important because they can be compared with results from across North America as early as 1966. Our analysis, however, shows that local, habitat-based programs like the NNFBS can provide complementary information and opportunities to understand bird populations in specific management areas. Because each habitat-based point is geo-referenced and classified according to widely recognized vegetation/ physiographic types, results can be used to quantify bird-habitat associations at finer scales. These relationships, in turn, can be used to predict species occurrences across areas that have not been sampled for birds. Although still in the early stages, GIS-based models of bird populations (e.g., Flather and Sauer 1996, Pearson and Niemi 2000, Gutzwiller and Barrow 2001, Gustafson et al. 2002) hold considerable promise for conservation planning.

Land managers can use these predictive models to identify critical areas, anticipate the consequences of habitat modifications, and prescribe changes that might benefit priority species. As current models are tested with field observations, new iterations of the predictive models may provide increasingly reliable guidance for management activities. Habitat-based point counts are particularly valuable for developing these predictive models.

Our comparisons of bird assemblages suggest that the habitat-based point counts of the NNFBS assess qualitatively different aspects of the avifauna than does the BBS. In general, the NNF Bird Survey yields higher relative abundances of wetland/aquatic species and species that occur largely in extensive forest. Birds of open country are better represented in BBS database. These differences are not surprising given the differences in site selection; BBS routes were established randomly along roadsides (Robbins et al. 1986), whereas habitat-based points from the NNF Bird Survey were selected to represent specific vegetation types, including wetlands and interior forest.

Trends in species abundances derived from the NNF Bird Survey do not always mirror trends reported from Wisconsin's BBS routes, although results from the two monitoring programs are similar more often than they are different. Differences should not be surprising, however, given the geographically variable population trends that have long been documented by the North American Breeding Bird Survey (Robbins et al. 1986, Sauer et al. 2001). Even widely declining species like Red-headed Woodpecker (*Melanerpes erythrocephalus*) are increasing in parts of their ranges, in marked contrast to the precipitous decline that has occurred elsewhere (Sauer et. al. 1997, 2001). Nevertheless, the fact that so many species (45) in the Nicolet National Forest are declining significantly (compared with only seven species that are increasing significantly) is cause for genuine concern. Declining species include neotropical migrants, short-distance migrants, permanent residents, forest interior species, wetland species, early successional species, old-growth forest species, and birds of open country, so a single explanation for the declines is unlikely. Especially troubling are species like Eastern Kingbird, Golden-winged Warbler, Baltimore Oriole, and several others that have shown consistent declines in all parts of the Nicolet National Forest as well as in the Breeding Bird Survey. Continued monitoring will help determine whether these trends reflect temporary declines in bird numbers or whether they represent widespread and ongoing deterioration of environmental conditions. The possibility certainly exists that Terborgh's (1990) controversial warning about the decline of North American birds is correct and deserves increasing attention by land managers and conservationists.

In summary, regional surveys like the NNFBS provide information that complements the more comprehensive North American Breeding Bird Survey. Results of geo-referenced surveys can be used for analysis of bird-habitat associations and GIS models can be derived from the spatially explicit point counts. In addition, bird species that are not well represented in the BBS database (e.g., wetland birds, species of remote habitats) can be specifically targeted, providing a more complete representation of the regional avifauna.

Like the BBS, the NNFBS relies on volunteer observers for all of the field work. Quality control is improved by using teams of observers and by providing these teams with reference tools like a custom CD of bird songs. Reliability of the data can be evaluated by implementing a rigorous observer certification program, an initiative that is currently being explored. Other measures that might improve the quality and applicability of the results include expanded coverage of habitats, better coordination with management activities on the forest, and estimation of variance associated with the point counts. Despite the shortcomings of the point count method (Dettmers et al. 1999, Drapeau et al. 1999, Nichols et al. 2000, Bart and Earnst 2002, Thompson 2002), databases generated by the NNFBS provide meaningful results that will grow in importance as these consistent annual surveys are continued.

Acknowledgments

We acknowledge the work of hundreds of volunteer observers in the NNF Bird Survey and BBS and institutional support from the U.S. Forest Service, Northeastern Wisconsin Audubon Society, Wisconsin Society for Ornithology, University of Wisconsin-Green Bay, and U.S. Fish and Wildlife Service/U.S. Geological Survey. We are particularly grateful for contributions to the Bird Survey or this paper by T. Rinaldi, L. Parker, G. Zimmer, M. Peczynski, T. Matthiae, J. Kastenholz, B. Reardon, S. Anderson, J. Nieland, M. Grimm, A. Wolf, J. Davis, A. Paulios, and R. Hutto.

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Regional Breeding Bird Monitoring in Western Great Lakes National Forests[1]

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Abstract

We established breeding bird monitoring programs in three National Forests in northern Minnesota (Superior and Chippewa in 1991) and northern Wisconsin (Chequamegon in 1992). A total of 134, 169, and 132 stands (1,272 survey points) have been surveyed annually in these forests through 2002. We examined trends in relative abundance for 53 species in the Chequamegon, 51 species in the Chippewa, and 41 species in the Superior. Thirty-six species were also tested for regional trends by combining data from the three forests. Twenty-four species increased significantly ($P < 0.05$) in at least one forest and 23 species decreased. Six species had significant increasing regional trends and ten had significant decreasing trends. The most convincing increasing regional trends ($P < 0.01$) were Least Flycatcher (*Empidonax minimus*) and American Redstart (*Setophaga ruticilla*). The most convincing regional decreasing trends were Eastern Wood-Pewee (*Contopus virens*), Winter Wren (*Troglodytes troglodytes*), Hermit Thrush (*Catharus guttatus*), and Song Sparrow (*Melospiza melodius*). Species with increasing trends were early- to mid-successional, deciduous forest species that nest in the shrub or subcanopy layers, whereas species with decreasing trends were mature forest species, many of which nest on the ground. Nest predation may be having negative effects on declining ground-nesters. In a comparison of 35 species, our trends and BBS trends from strata 20 and 28 were the same for 10 species. Inconsistencies in trends were likely due to differences in area included to calculate trends and sampling methods. Our monitoring data have been used extensively by the Forest Service and Minnesota and Wisconsin for a variety of activities related to bird conservation in this region. In addition, bird/habitat data have been used to develop forest management planning software applications.

Key words: breeding birds, monitoring, Great Lakes, forests, population trends.

Introduction

In response to the need for National Forests to monitor management indicator species, we established long-term forest breeding bird monitoring programs in 1991 on the Chippewa and Superior National Forests in northern Minnesota and in 1992 on the Chequamegon National Forest in northern Wisconsin. Although large-scale population monitoring programs such as the U.S. Geological Survey's Breeding Bird Survey (BBS) provide important information on trends at a continental scale, limited coverage in specific regions like a National Forest can make it difficult to use BBS data to characterize population trends locally (Peterjohn et al. 1995). For example, there are only five BBS routes in the Superior, four routes in the Chippewa, and three routes in the Chequamegon. Our objectives for monitoring were to: (1) establish off-road and habitat specific monitoring programs in each forest, (2) create bird-habitat relationships relevant to the Forest Service cover classification system, (3) establish potential links between population trends and habitat or landscape changes, and (4) develop bird species linkages with forest models used in forest management (Hanowski and Niemi 1995).

In addition to providing population trend information for each National Forest, we leveraged their investment (about $600,000 over 12 years) with over three million dollars in state and other funding sources to accomplish the third and fourth objectives. In this paper we briefly describe our monitoring program and report on: 1) current population trends detected over the past 12 years; 2) how these trends compare to BBS trends from the same physiographic region; and 3) how these data have contributed to bird conservation efforts in this region.

Methods

Sampling Design

Sampling design and point count methods used in our program follow national and regional standards (Ralph et al. 1993, 1995; Howe et al. 1997). The monitoring program was designed to integrate with each National Forest's method of describing forest cover types (Hanowski and Niemi 1995). The sampling unit in our design is a forest stand that is ≥16 ha (40 acres), which

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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is the minimum size needed for three non-overlapping 100 m-radius point counts. Stands within each of the Forests are stratified and proportionately sampled by forest cover type, so that our sample of stands is representative of the area available in each Forest. Four to five stands (12 to 15 points) are the maximum number that can be sampled by one person in a single morning. Thus, stands were selected in a random manner but in a way to accommodate access and travel time between stands. A total of 134, 169, and 132 stands (1,272 survey points) were established in the Chippewa, Superior, and Chequamegon National Forests, respectively (*Figure 1*).

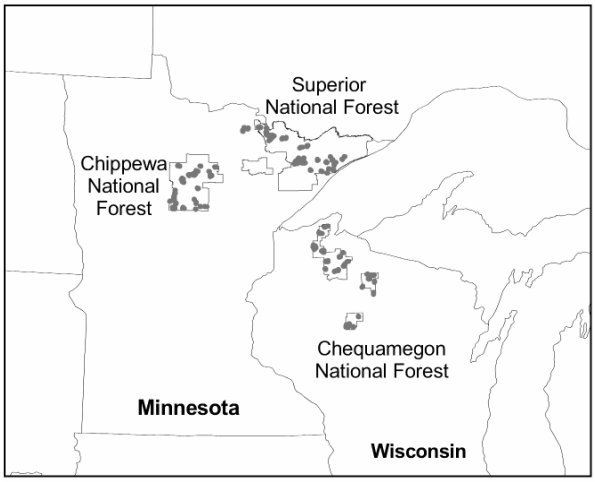

Figure 1— General locations of breeding bird points in the Chippewa, Superior and Chequamegon National Forests.

Bird Sampling

Ten-minute point counts were conducted at each point between June and early July (Reynolds et al. 1980). Point counts are appropriate for characterizing relative abundance of most singing passerine species, but are inadequate for waterfowl, grouse, and most raptors. In addition, because our surveys are conducted during the summer months, we may underestimate the relative abundance of early nesting species (e.g., permanent residents such as woodpeckers and chickadees).

Point counts were conducted by experienced and trained observers from approximately 0.5 hour before, to four hours after, sunrise on days with little wind (< 15 km/hr) and little or no precipitation. All birds heard or seen from the point were recorded with estimates of their distance from that point. We used number of birds observed within 100 m of the point count center in data analyses, primarily based on results from training observers over the past 20 years. In training sessions, we have found that it is difficult to standardize distance estimates among observers for 150 plus bird species that we encounter in our surveys. We have found that it is much easier and more realistic to train observers to consistently identify birds within and outside the 100 m radius circle. In addition, because our main objective is to calculate population trends with our point count data, and data are collected identically from year to year, counts within the 100 m radius circle are suited for this objective.

The number of individuals observed for each species can also be summed for 3-, 5-, and 10-minute periods so that regional comparisons are possible with data gathered using 3- or 5-minute point counts. To minimize bias due to observer differences in sampling different forest cover types, each observer sampled a similar number of stands of each forest cover type. Weather data (cloud cover, temperature, and wind speed) and time of day were recorded before each count.

Prior to the field season, tapes of 120+ bird songs were provided as a learning tool, and all observers were required to pass an identification test of 75 bird songs made by Cornell University's Laboratory of Ornithology. A standard for number of correct responses was established by giving the test to observers who were trained in identifying birds by sound, and who had four to five years of field experience. This was done to identify songs on the tape that were not good representations of songs heard in northern Minnesota and Wisconsin. Based on results of trained observers, the standard for passing was set at 85 percent correct responses. Songs on the tape were grouped by habitat (e.g. upland deciduous, lowland coniferous) to simulate field cues that would aid in song identification.

Observer field training was conducted during the last week of May in the Superior National Forest. Observers conducted simultaneous practice counts at several points used in the monitoring program. Data were compiled for each observer, and species lists and numbers of individuals recorded on the count by each observer were compared to that of experienced observers. Deviations from the average or species missed were noted on the field sheets and returned. In addition to field training and testing, all observers were required to have a hearing test to ensure that their hearing was within normal ranges, as established by audiologists, for all frequencies (125 to 8000 hertz).

Table 1— *Trends for five study areas and regional analysis (three National Forests (NF) combined) based on LOESS-regression. I = significantly increasing, D = significantly decreasing, * P ≤ 0.05, ** P ≤ 0.01.*

Species	Scientific name	Chequamegon NF	Chippewa NF	Superior NF	Regional
Yellow-bellied Sapsucker	*Sphyrapicus varius*	ns	D**	ns	ns
Downy Woodpecker	*Picoides pubescens*		ns		
Hairy Woodpecker	*Picoides villosus*	ns	ns		
Olive-sided Flycatcher	*Contopus borealis*		ns		
Eastern Wood-Pewee	*Contopus virens*	D**	D**	D**	D**
Yellow-bellied Flycatcher	*Empidonax flaviventris*	I*	ns	I**	I**
Alder Flycatcher	*Empidonax alnorum*	ns	ns	ns	I*
Least Flycatcher	*Empidonax minimus*	ns	I**	ns	I**
Great Crested Flycatcher	*Myiarchus crinitus*	ns	D*		
Eastern Kingbird	*Tyrannus tyrannus*	I*			
Yellow-throated Vireo	*Vireo flavifrons*		ns		
Blue-headed Vireo	*Vireo solitarius*	ns	I**	ns	ns
Red-eyed Vireo	*Vireo olivaceus*	I**	ns	I*	I*
Blue Jay	*Cyanocitta cristata*	ns	ns	ns	ns
Black-capped Chickadee	*Poecile atricapillus*	ns	I**	I**	ns
Red-breasted Nuthatch	*Sitta canadensis*	ns	I*	ns	ns
White-breasted Nuthatch	*Sitta carolinensis*	ns	ns		
Brown Creeper	*Certhia americana*	ns	ns	ns	D**
House Wren	*Troglodytes aedon*	ns			
Winter Wren	*Troglodytes troglodytes*	D**	D**	D**	D**
Golden-crowned Kinglet	*Regulus satrapa*	ns	ns	ns	ns
Ruby-crowned Kinglet	*Regulus calendula*			D**	
Veery	*Catharus fuscescens*	D*	ns	D*	D*
Swainson's Thrush	*Catharus ustulatus*			I*	
Hermit Thrush	*Catharus guttatus*	D**	D**	ns	D**
Wood Thrush	*Hylocichla mustelina*	I**			
American Robin	*Turdus migratorius*	ns	ns	ns	ns
Gray Catbird	*Dumetella carolinensis*		I**		
Brown Thrasher	*Toxostoma rufum*	ns			
Cedar Waxwing	*Bombycilla cedrorum*		I**		
Golden-winged Warbler	*Vermivora chrysoptera*	ns	ns	ns	ns
Tennessee Warbler	*Vermivora peregrina*			ns	
Nashville Warbler	*Vermivora ruficapilla*	D**	ns	ns	ns
Northern Parula	*Parula americana*	ns	ns	I**	I**
Yellow Warbler	*Dendroica petechia*		D**		
Chestnut-sided Warbler	*Dendroica pensylvanica*	I**	I**	ns	ns
Magnolia Warbler	*Dendroica magnolia*		ns	I**	
Yellow-rumped Warbler	*Dendroica coronata*	ns	ns	ns	ns
Black-throated Green Warbler	*Dendroica virens*	ns	ns	D**	ns
Blackburnian Warbler	*Dendroica fusca*	I**	ns	ns	ns
Pine Warbler	*Dendroica pinus*	ns	ns	I**	ns
Palm Warbler	*Dendroica palmarum*		ns		
Black-and-white Warbler	*Mniotilta varia*	D**	I**	ns	ns
American Redstart	*Setophaga ruticilla*	I**	I**	ns	I**

Table 1. (continued)

Species	Scientific name	Chequamegon NF	Chippewa NF	Superior NF	Regional
Ovenbird	*Seiurus aurocapillus*	D*	D**	ns	D*
Northern Waterthrush	*Seiurus noveboracensis*	I*		ns	
Connecticut Warbler	*Oporornis agilis*		D**		
Mourning Warbler	*Oporornis philadelphia*	ns	D**	ns	ns
Common Yellowthroat	*Geothlypis trichas*	D**	D*	D**	D**
Canada Warbler	*Wilsonia canadensis*	ns	ns	ns	ns
Scarlet Tanager	*Piranga olivacea*	ns	D**	ns	D**
Eastern Towhee	*Pipilo erythrophthalmus*	I*			
Chipping Sparrow	*Spizella passerina*	ns	ns	D**	ns
Clay-colored Sparrow	*Spizella pallida*	ns			
Vesper Sparrow	*Pooecetes gramineus*	I*			
Song Sparrow	*Melospiza melodia*	D**	D**	ns	D**
Swamp Sparrow	*Melospiza georgiana*	ns	ns	I**	ns
White-throated Sparrow	*Zonotrichia albicollis*	ns	D**	D*	D**
Rose-breasted Grosbeak	*Pheucticus ludovicianus*	ns	ns	D**	ns
Indigo Bunting	*Passerina cyanea*	ns	I**		
Red-winged Blackbird	*Agelaius phoeniceus*	D**			
Brewer's Blackbird	*Euphagus cyanocephalus*	ns			
Brown-headed Cowbird	*Molothrus ater*	ns	D**		
Purple Finch	*Carpodacus purpureus*		ns		
American Goldfinch	*Carduelis tristis*	ns			
Evening Grosbeak	*Coccothraustes vespertinus*	D*			

Data Analysis

The aim of our work was to describe the status of bird populations in each National Forest. We accomplished this using a two-fold approach: 1) by describing the trajectory of the population path of each species through time, and 2) by evaluating whether the trend of the population path represented a significant increase or decrease since the study began (Link and Sauer 1997). To describe both of these components, we built statistical models of species relative abundance as a function of time.

For each species, yearly relative abundance was calculated using birds detected within 100 m of each point by summing the number of individuals of each species across two points per stand. In order to avoid double-counting of individuals, data from the two farthest separated points within a stand were analyzed. Stands were included in the analysis only if they had been sampled in at least six years. Data were included for a species if it was observed on a minimum of five stands per study area and in at least three years on each stand. For species that were observed on a minimum of five stands in each of the three National Forests, we pooled all stands and carried out an additional regional analysis (three National Forests combined). Although this regional analysis does not include lands in non-federal ownership, it should give an indication of population trends at a larger scale than the individual National Forest.

We used a non-parametric route regression procedure similar to that described by James et al. (1996) to characterize population trajectories. This method allowed us to use relative abundance from the sampling unit to describe populations across entire study regions, without assuming a specific pattern of population change (e.g., a linear population trajectory). For each sampling unit, a non-linear estimate of trajectory was calculated for each species by using locally-weighted regression (LOESS) to model species abundance as a smooth function of year. In LOESS-regression, fitted values (points along the curve) for years are calculated by giving a small amount of weight to neighboring years. For example, a year with high raw abundance for a species would tend to bring up the fitted values for the year before and the year after. Overall mean relative abundance for each species in each study area was then calculated by averaging the smoothed (fitted) relative

abundance across all stands in each year. The individual fitted values were used in a bootstrap procedure to estimate a 95 percent confidence interval around each year's mean. By plotting the mean fitted values and confidence intervals in a time series, we get a graphic depiction of the population trajectory (see web site www.nrri.umn.edu/mnbirds/).

When we characterized population trajectories, we did not assume that the paths were linear. Changes in relative abundance over a specific time interval (population trends), however, can be viewed as linear, or directional changes (Urquhart and Kincaid 1999). Therefore, we used linear methods to detect trends, without ever asserting that the population trajectory was linear. To assess whether populations have increased or decreased, we modeled the relationship between mean fitted values (i.e. relative abundance) and time using simple linear regression. We used the slope coefficient to characterize magnitude and direction of the trend and change in mean relative abundance per year. Trends were considered significant at the $P< 0.05$ level. All statistical analyses were conducted in S-Plus (MathSoft, Inc. 1999).

We used BBS trends from 1990-2000 in the combined strata 20 and 28 (Sauer et al. 2001) and compared these trends to our trends over the same time period. We used trends created by the BBS web site (Sauer et al. 2001). These two strata include all the area where our points are located but extend beyond Minnesota and Wisconsin primarily to the east (Sauer et al. 2001). Note that trends reported in *table 1* are from 1991 or 1992 through 2002. The comparison of our trends with BBS are from the time period up to 2000 and may not be the same as those reported in *table 1* (see Lind et al. 2000).

Results

Sixty-six species were tested for trends in at least one forest, including 53 in the Chequamegon, 51 in the Chippewa, and 41 in the Superior (*table 1*). Additionally, 36 species were tested for a "regional" (three National Forests combined) trend.

Of the 53 species tested for trends in the Chequamegon, 10 species (19 percent) increased significantly and 11 (21 percent) decreased (*table 1*). The most convincing increases ($P < 0.01$) were those of the Red-eyed Vireo (*Vireo olivaceus*) and American Redstart (*Setophaga ruticilla*). The most convincing declines were those of the Eastern Wood-Pewee (*Contopus virens*), Winter Wren (*Troglodytes troglodytes*), Hermit Thrush (*Catharus guttatus*), and Common Yellowthroat (*Geothlypis trichas*).

Of the 51 species tested in the Chippewa National Forest, ten species (20 percent) increased significantly and 14 (27 percent) decreased (*table 1*). The largest increases were those of the Least Flycatcher (*Empidonax minimus*), Cedar Waxwing (*Bombycilla cedrorum*), Chestnut-sided Warbler (*Dendroica pensylvanica*), and American Redstart. The Eastern Wood-Pewee, Winter Wren, Hermit Thrush, Ovenbird (*Seiurus aurocapillus*), Connecticut Warbler (*Oporornis agilis*) Mourning Warbler (*Oporornis philadelphia*), Song Sparrow (*Melospiza melodia*), and Brown-headed Cowbird (*Molothrus ater*) each had decreasing trends.

Of the 41 species tested in the Superior National Forest, eight species (20 percent) increased, and nine (22 percent) decreased (*table 1*). The most significant increases were those of the Black-capped Chickadee (*Poecile atricapillus*) and Magnolia Warbler (*Dendroica magnolia*). The most convincing decreasing trends were those of the Eastern Wood-Pewee and Winter Wren.

Of the 36 species tested for a regional trend, six species (17 percent) increased significantly and ten (28 percent) decreased (*table 1*). The most significant increases were those of the Least Flycatcher and American Redstart. The most convincing declines were those of the Eastern Wood-Pewee, Winter Wren, Hermit Thrush, and Song Sparrow.

In a comparison of 35 species, our regional trends and BBS agreed on trends for ten species (*table 2*). Overall, our regional trend data detected 11 decreases, four increases and 20 non-significant trends. In contrast, BBS trends found nine decreases, 11 increases and 15 non-significant trends. Opposite trends were found for Winter Wren and Hermit Thrush and for 23 species, either our trend or BBS were non-significant while the other trend was either increasing or decreasing.

Discussion

Most of the species we monitor exhibit large annual fluctuations in abundance, a phenomenon that has been documented on several other long-term studies (Virkkala 1991, Blake et al. 1994, Wesolowski and Tomialojc 1997, Holmes and Sherry 2001). Long-term monitoring studies are important for differentiating between these short-term fluctuations and actual long-term trends. The majority of species tested had non-significant trends. Species such as the Least Flycatcher, Red-eyed Vireo, American Redstart, and Chestnut-sided Warbler have increased in multiple study areas since the early 1990's and may be benefiting from current and past management practices, including the creation of early- to mid-successional deciduous forest types. All of these species nest above the ground and

Table 2— *Comparison of Natural Resources Research Institute (NRRI) regional trends (1991-2000) with Breeding Bird Survey (BBS) trends from the northern spruce/hardwoods (strata 28) and the Great Lakes transition (strata 20) physiographic strata combined.*

	NRRI Trends		
BBS Trends	**Increase**	**Decrease**	**Not significant**
Increase	Northern Parula	Winter Wren Hermit Thrush	Alder Flycatcher Blue-headed Vireo Red-eyed Vireo Blue Jay Black-capped Chickadee Yellow-rumped Warbler Black-throated Green Warbler Swamp Sparrow
Decrease		Eastern Wood-Pewee Ovenbird Song Sparrow	Least Flycatcher Veery Golden-winged Warbler Mourning Warbler Rose-breasted Grosbeak Chestnut-sided Warbler
Not significant	Yellow-bellied Flycatcher Red-breasted Nuthatch American Redstart	Brown Creeper Black-and-white Warbler Common Yellowthroat Canada Warbler Scarlet Tanager White-throated Sparrow	Golden-crowned Kinglet American Robin Nashville Warbler Blackburnian Warbler Pine Warbler Chipping Sparrow

are habitat generalists in this region. Some of the increasing species have relatively high conservation value (e.g. Least Flycatcher, Chestnut-sided Warbler), according to the Partners in Flight (PIF) prioritization scheme (Carter et al. 2000). This status is partly due to their declines based on BBS surveys (Least Flycatcher and Chestnut-sided Warbler).

There are, however, a number of species whose declining population trends warrant concern. Species such as the Eastern Wood-Pewee, Winter Wren, Hermit Thrush, and Connecticut Warbler have shown consistent declines and may need special management consideration. Many of the declining species breed in mature forests, and many are ground-nesters. Some of these population declines may be linked to recent changes in the landscape, especially in light of regional studies showing high nest predation on ground-nests near forest edges. Several of these declining species also have high PIF conservation values (e.g. Eastern Wood-Pewee, Connecticut Warbler), and the extensive forests of northern Minnesota and Wisconsin may represent an opportunity to provide source populations for many species.

The landscapes surrounding our study areas are primarily forested, but there are indications that the landscape has shown signs of increased fragmentation in recent years. Wolter and White (2002) used satellite data from northeastern Minnesota between 1990 and 1995 and demonstrated a substantial decrease in patch size and interior forest area and a significant increase in edge density in early successional forest types. Some studies have shown that nesting success is reduced in fragmented landscapes, probably due to an increase in generalist nest predators (Robinson et al. 1995, Donovan et al. 1997). In the forested landscapes of the upper Midwest, recent studies have found higher predation rates on ground nests near forest/clearcut edges than in interior areas (Fenske-Crawford and Niemi 1997, Manolis et al. 2000, Flaspohler et al. 2001). Data from the Minnesota Department of Natural Resources winter track survey (Berg 2001) between 1991 and 2000 indicate a peak in track indices in 1995 for potential ground nest predators such as fisher (*Martes pennati*) and pine marten (*Martes martes*), which loosely follows the declines between 1994 and 1996 in many of the species we monitor. Nonetheless, the effects of nest predation on population trends in this study are unknown. It is also possible that more than one factor may be causing the observed pattern, or that ground nesting may be a surrogate for some unknown factor(s).

It is not surprising that our trends and BBS trends agree for only a third of the species compared. Differences in methods (on versus off-road) and sizes of

regions used to characterize trends probably contribute to these discrepancies. The BBS stratum covers a much larger area and extends to the east coast. This result reinforces the need for regional monitoring programs that more clearly identify species of conservation concern for smaller geographic areas such as a National Forest or State.

Our habitat specific monitoring program has provided valuable information to the National Forests, and several other State (Minnesota Department of Natural Resources, Forest Resources Council) and Federal (Environmental Protection Agency) agencies. We have made this information easily available to Forest Service personnel that are involved with forest management activities via a web site where information can be queried and downloaded. Several types of queries can be conducted on our web site that provide information on species distributions (maps), life history information (species accounts), and habitat specific relative abundance information. These data have also been used to evaluate the proposed Chippewa and Superior National Forest plan revisions. For example, we linked our bird data to forest cover data that were modeled for seven alternatives that have been proposed for managing the Forests for the next 15 years. We evaluated the relative impacts that the different alternatives would have on breeding birds and recommended which alternative would best address breeding bird conservation in these Forests.

Our habitat specific monitoring program also has provided data for forest planning software applications (see www.nrri.umn.edu/SUSTAIN and www.nrri.umn.edu/mnbirds/), for regional species specific conservation assessments (Hanowski 2002), for an extensive environmental impact statement (Jaako Pöyry Consulting 1993), and for regional bird conservation planning (http://www.uwgb.edu/birds/great lakes/).

Acknowledgments

Financial assistance was provided by the United States Forest Service and Minnesota State legislature from the Environmental Trust Fund as recommended by the Legislative Commission for Minnesota Resources. This is contribution number 334 from the Center for Water and the Environment of the Natural Resources Research Institute.

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The Need for a North American Coordinated Bird Monitoring Program[1]

Jonathan Bart[2] and C. John Ralph[3]

Introduction

Bird monitoring is at a crossroads. While monitoring programs have existed in North America for nearly a century, recent political, biological, sociological, and economic changes necessitate a new and more efficient approach. Fortunately we now have tools available to meet the demands, including powerful coalitions of the willing within agencies, organizations, and universities. Further, rapid advances in several areas auger well for the process: specifically advances in monitoring methods, data archiving, and extremely powerful computer tools that allow retrieval and analysis, all have reached unprecedented levels of sophistication.

The waterbird, shorebird, and landbird initiatives have all begun work on taxa-specific monitoring programs (e.g., Brown et al. 2001, Donaldson et al. 2001, Kushlan et al. 2002, Rich et al. 2004). Their plans identify species that warrant monitoring, important habitat relationships, declare goals for long-term estimates of trend in population size, and – to varying degrees – describe how the goals can best be achieved. Coordinated Bird Monitoring (CBM) is an attempt by the initiatives, working with many agencies, non-government organizations, and individuals, to forge a comprehensive approach to monitoring that will provide information on all nongame birds. Here, we briefly describe the CBM approach, how it can help implement the initiatives' proposals, and suggest which aspects of the general approach should be emphasized during the next several years.

Vision, Goals, and General Approach

The vision of CBM is that monitoring should be, at one level, issue-driven, science-based, scale-dependent, and implemented through partnerships. It should also be opportunistic, encompassing methods or metrics that give warning of unanticipated environmental changes. The broad goal of CBM is to increase the efficiency and utility of bird monitoring through improved coordination. Two pervasive principles that affect all aspects of CBM are (1) that design of monitoring programs depends on the management issues that the monitoring will help address, and (2) that coordination should occur at the scale of the management issue.

Identifying the management issues that long-term, multi-species monitoring programs will address is difficult because many of the specific issues that will use these monitoring data arose long after initiation of the program. For example, a substantial effort has been made recently to estimate landbird population sizes using historic Breeding Bird Survey (BBS) data (Rich et al. 2004). This particular use of the BBS, however, was certainly not one of the envisioned applications when the BBS was started. Only with computer and analytical technology in the last few years, has it become feasible. As another example, recent efforts to identify portions of northern Alaska, in the National Petroleum Reserve, that are most important to preserve, in view of imminent oil exploration activities there, have been based largely on long-term, multi-species aerial surveys, begun in the mid-1980s. These surveys were not initially designed to gather information for this specific purpose, but the surveys have proved highly effective in this regard.

We feel that long-term, multi-species surveys should be designed at the national or continental scale. This is because the changing needs, and the difficulty in predicting these needs, require surveys to be designed to provide information on broad management efforts (*table 1*) that are likely to be relevant in the future. Since, as stated in the second principle above, coordination should occur at the scale of the management issues, it would follow that in order to avoid duplication, the surveys should generally be on a national or continental scale. One of the major uses of these surveys is to obtain rangewide estimates (e.g., of population size, trend, habitat relationships). Designing at a smaller scale may meet more local objectives, such as estimating trends within a state, but usually hinders development of the larger-scale programs because regional and local groups become attached to methods that are hard to coordinate and may be incompatible with one another. Thus, state and federal agencies, and non-government organizations need to work together,

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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not independently, in designing the needed new continental programs to monitor bird abundance.

Table 1—*Management issues that monitoring can help address.*

1. Setting harvest limits.
2. Setting population or habitat conservation targets.
3. Deciding whether to give a species special protection.
4. Designing a strategy to reverse undesirable trends.
5. Deciding which habitats to protect.
6. Evaluating and improving existing projects.

A Super-Abundance of Abundance Surveys, and What to Do about It

The development of monitoring programs has resulted in a healthy diversity of methods, objectives, and programs. While having many programs helps ensure that no species is left behind, the choice may instead be between avoiding redundancy, and allowing replication. The issue of just how many independent programs are needed does warrant careful study. One part of the CBM project has been to identify programs whose intent is to be collecting long-term information on bird abundance and habitat. Most state programs have not yet been included in this effort, yet we already know of 251 separate survey programs (e.g., the Breeding Bird Survey is a single program). With state and other programs, the total number surely exceeds 1000 survey programs. This fact clearly demonstrates the need for a coordinated effort to consolidate the long-term surveys into a smaller number of coordinated surveys. We do not need 1000 independent bird abundance surveys. We do need several thousand interconnecting efforts that utilize common and interacting methods. The CBM project is attempting to help consolidate surveys by: (1) defining a relatively small number (*table 2*) of survey methods and programs; (2) reaching agreement on methods, including data management procedures, for each one; and (3) convincing the federal agencies and national organizations to take leadership roles in coordinating and conducting these surveys. This is not to say that a few, broadly overlapping programs or methods would not be a good thing: replication, rather than redundancy. In fact, some national programs that began with broad mandates and enthusiastic backers have become the victims of the selective process of inattention or imagination of agencies or organizations.

Methods do not need to be totally standardized as long as results are reliable, include a common core set of variables (e.g., location, effort, date, species, and numbers), and as long as data management does not become too complex. A general approach to data management has been developed that involves consolidation of databases to as small a number as practical, such as the Avian Knowledge Network and its eBird program of the Laboratory of Ornithology at Cornell University (Kelling and Stewart this volume), but while still recognizing that many groups will need to maintain their own databases. A web-searching approach is being developed at the Laboratory so that cooperating data providers can make their data available to others, while retaining control of the data and responsibility for data entry and error checking. This approach has the considerable advantage of providing at least one permanent repository that any participant can use, while also allowing others to maintain their own databases and still participate in the program.

The Future of Bird Monitoring

A coordinated approach for monitoring of nongame, and ultimately all birds, is clearly required to insure that monitoring resources are used efficiently. Thus, implementing CBM, or an approach like it, should be a primary goal for all initiatives, organizations, and agencies involved with bird conservation during the next several years. At present, several states are working on State CBM plans that summarize existing work on bird monitoring within the state's borders, and identify the highest priority surveys for the coming few years. The initial version of the state CBM plans also provides detailed descriptions of aquatic areas within the state and how to survey them. A detailed format has been developed for these descriptions (see http://map.wr.usgs.gov). Other CBM efforts include carrying out detailed power analyses to estimate the accuracy of different comprehensive bird monitoring programs, developing recommendations for the infrastructure needed to support bird monitoring in Canada and the

Table 2—*Initial list of broad bird abundance surveys to be organized at the continental level.*

Survey	Season	Region
1. Breeding landbirds	Breeding	Temperate
2. Migration surveys	Migration	Temperate region
3. Aquatic bird surveys	Year round	Temperate region
4. Northern surveys	Breeding	Boreal and arctic regions
5. Winter surveys	Winter	Temperate region

United States, and developing guidelines for the design of short-term, management-oriented bird monitoring projects. An analysis was recently completed of the BBS (Bart et al. 2004), with a recommended accuracy target, with estimates of the number of BBS routes in each province and state, and suggestions for bias-reduction methods needed to achieve the accuracy target. Thus, while much remains to be done, there is ample reason for optimism that much progress will be made in bird monitoring during the next few years, particularly through creation of a North American Coordinated Bird Monitoring Program.

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Guidelines for Designing Short-Term Bird Monitoring Projects[1]

Jonathan Bart[2]

Introduction

The Coordinated Bird Monitoring Program (Bart and Ralph, this volume) program is helping biologists around the country design short-term monitoring projects for birds. We have found that addressing a series of questions (*table 1*), in a systematic way, helps insure that projects are well planned. The process is being used by several States and organizations in the U.S. Here I describe it in general terms with examples.

Overview of the Process

Guidelines for preparing each component of the project description (*table 1*) are described below. The identified elements are intended as suggestions only. Real examples, as indicated later in this report, usually differ in content and sequence.

Table 1— *Outline used to describe short-term bird monitoring projects.*

Outline
A. Description of the management issue
B. Survey Objectives
1. Biological population
2. Information needed
3. Quantitative objectives
C. Methods
1. Brief description
2. Statistical population
3. Sampling plan
4. Training and field methods
5. Sample size requirements
6. Analytic methods
7. Data management
8. Reports
D. Roles and Responsibilities

A. Description of the Management Issue

Describe the management issue to be addressed or, preferably, the management decision that the monitoring will help managers make. Examples include what treatment to apply, what land to purchase, what direct intervention method to use, and whether to grant a species increased or decreased protection. Explain the spatial and administrative level at which the project is being organized and why this is the right level. The section should end with a clear, albeit qualitative, description of the product needed to address the management issue. If this section is clear, and especially if only one or a few management decisions are the focus of the work, then the rest of the survey description is relatively easy to complete. If the management issue is not clear, then all the rest of the sections are much harder to write.

B. Objectives

1. Biological population

Describe the birds to be studied, e.g., migrating shorebirds, breeding waterfowl, etc. Specify which individuals are included (e.g., all birds, only breeders, only residents?).

2. Information needed

Provide a more detailed description of the information to be obtained in the project's survey. Species, cohorts, times of year, and habitats of greatest interest should be identified, as should auxiliary information such as level of disturbance, evidence of breeding, and habitat relationships. This section should include identification of the parameters to be estimated, expressed in quantitative terms, e.g., density of pairs, trend in abundance, or habitat relationships expressed as regression coefficients. We have found that often one of three products is needed: a regional model, a site-specific model, and project evaluation. These products are described in the next section.

3. Quantitative objectives

Specify the accuracy target, expressed as power or as precision (SEs, CIs, CVs) for each parameter, and discuss how it was chosen. This is frequently a difficult section to write, especially in the early phase of a project, and the target may change as work progresses. Having an accuracy target is important, however, because it provides the basis for calculating sample sizes and, in some projects, for choice of field methods.

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California**.

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C. Methods

1. Brief description

Provide one or two sentences giving an overview of the methods. This helps readers put the next few sections in context.

2. Statistical population

Identify the population unit and the statistical population. Population units are usually either individuals (birds in our case), capture devices exposed for a given amount of time (e.g., a "mist net-hour"), or, most common of all, a location for a specified period (e.g., as in a 3-minute point count or a 30-minute area search). The statistical population is the set of population units about which we wish to make inferences (the population of interest), or from which we sample (the sampled population); these two should be distinguished if they are different. For example, in a point count project, the spatial dimension of the statistical population might be all forested locations in a National Wildlife Refuge, and the temporal dimension might be mornings without high winds or heavy rain. The population of interest would probably be all possible location-times in the population, and the spatial dimension in the sampled population might be locations along roads and trails.

3. Sampling plan

Define the sampling plan using standard survey sampling terminology, as in the following example. "Two-stage sampling will be employed, with stage one preceded by stratification by habitat. Three strata (probably woodlands, fields, other) will be delineated. Primary units will be locations (i.e., the set of possible survey times at a location), and secondary units will be survey times (at a given location). We anticipate that primary and secondary units will both be selected systematically." Assistance from a statistician familiar with survey sampling may be needed in this phase.

4. Training and field methods

Provide a detailed description of training and field methods. Try to foresee practical problems, how they can be addressed, and how seriously the sampling plan or data collection might be compromised by the problems.

5. Sample size requirements

Use formulas for sample size estimation and allocation of effort, with multi-stage designs, to estimate the sample size needed to achieve the accuracy target for each parameter. Needed sample sizes will differ between parameters (e.g., number of pairs of a species) so the final design will usually be a compromise between costs and meeting most of the accuracy targets.

6. Analytic methods

Describe the methods to be used identifying any possibly problematic issues and how they are being addressed – to the extent possible – in the project design. Extremely detailed accounts are not needed, but demonstrate that careful thought has been given to where the analyses may lead and insuring, insofar as possible, that the data collection will support the most useful analyses.

7. Data management

Describe how the data will be organized; how they will be entered, stored, and retrieved; and whether data will be contributed to regional, national, or continental repositories (and if not, why not).

8. Reports

Describe when reports will be prepared and what they will contain.

D. Roles and Responsibilities

Describe who will have responsibility for detailed design, field work, data management, analysis, and communication. Also describe who will support the project and how (e.g., contracts, in-house support).

Kinds of Information Needed

Short-term monitoring or assessment projects are sometimes undertaken to characterize the birds of an area using simple field and analytic methods. More commonly, however, these projects are undertaken to produce what can be termed regional models, site-based models, or project evaluations (*table 2*). This section describes each product and provides guidelines for producing them.

All three products involve one or more independent (predictor) variables and a dependent (response) variable. In most applications, predictor variables will be habitat descriptors, such as cover type or elevation for regional models or more specific habitat descriptors (e.g., stand density, understory condition, forb cover) for site-based analyses. In project evaluations, the independent variable may be as simple as presence/absence of a habitat implementation project, but can also include habitat characteristics that are a result of the project (e.g., tree densities after revegetation).

The response variable is typically a measure of bird abundance during a specified time of year or a fitness

Table 2— *Summary of typical products of short-term Coordinated Bird Monitoring projects.*

Regional model	Description	A model that expresses the parameter[1] of interest (e.g., focal species abundance) as a function of independent variables (e.g., habitat type) whose values are known throughout a region
	Uses	Understand large-scale patterns in abundance Estimate statewide population Identify low- and high-quality areas throughout the region
	Methods	Maps showing distribution of the focal habitat are obtained Regionwide bird surveys in the habitat, perhaps using stratification to insure samples are obtained from a variety of conditions Independent variables suspected to be correlated with bird abundance (or other dependent variables) are obtained (usually from GIS layers) throughout the region Models are developed using standard regression methods
Site-based model	Description	Similar to the regional model but includes independent variables known only for the surveyed areas (e.g., understory type, tree density, burn history, etc.).
	Uses	Better understand determinants of habitat quality by including specific habitat variables not measurable statewide Estimate effects of proposed projects (e.g., habitat conversion, protection, or restoration)
	Methods	Same methods as for the regional model In addition, stand-specific variables are collected by field work, examination of aerial photos, or other sources
Project evaluation	Description	Estimated value of the parameter[1] (e.g., focal species abundance), within a habitat implementation project area, measured before, during, and after the project.
	Uses	Help evaluate habitat implementation projects, and perhaps revise project plans Document effects of the project on birds
	Methods	Surveys on the project area before, during and after the project

[1]The parameter of interest may be bird abundance during any period of the year or a fitness indicator such as productivity or nutritional status.

indicator, such as productivity or nutritional status. Focal species may include a single species, species of special concern (e.g., habitat obligates) in the area, or all species present. The response variable must often be defined as the total abundance of all focal species to obtain sufficient sample size to achieve the accuracy target.

Regional Models

Regional models express the parameter of interest as a function of independent (usually habitat) variables whose values are known throughout a region. The model is applied to the entire region or, more typically, to all of a regional habitat type (e.g., aspen or Mojave lowland riparian). The model may predict the abundance of a group of focal species, or it may be species-specific. The results of these analyses provide an estimate of regionwide species abundance, help managers understand large-scale patterns in abundance, and identify high- and low-quality habitats throughout the region. The models are constructed by obtaining field data from a substantial sample of randomly-selected sites (usually using stratified sampling). Broadly defined habitat variables are then identified that are thought to be correlated with bird populations and which are available in regionwide Geographic Information Systems (GIS) layers.

Site-based Models

Site-specific models also express the bird population parameters as a function of independent (usually habitat) variables. But, in addition to variables whose values are known throughout the region, site-based models may also include variables that were measured for each surveyed site and that are not available regionwide. These variables are usually habitat measurements that are obtained in the field or from detailed vegetation maps, aerial photos, or other supporting data. Results from these models usually make better predictions of bird population parameters

Table 3— *Estimation of sample size to detect a stated change.*

Step 1: Select power and Z_β

Power (1- β)	β	Z_β
0.6	0.4	0.25
0.8	0.2	0.84
0.9	0.1	1.28

Step 2: select the significance level and $Z_{\alpha/2}$ (assuming a two-tailed test and large sample size.)

Significance (α)	α	$Z_{\alpha/2}$
0.05	0.025	1.96
0.10	0.05	1.65
0.15	0.075	1.44

Step 3: Read the corresponding value of G

	Power		
Significance	0.6	0.8	0.9
0.05	5.8482	2.5088	0.9248
0.10	3.92	1.3122	0.2738
0.15	2.8322	0.72	0.0512

Step 4. Estimate the CV (see text) and read the sample size.

		R		
G	CV	1.5	2	3
5	0.5	11	5	3
5	1.0	45	20	11
5	1.5	101	45	25
5	2.0	180	80	45
10	0.5	23	10	6
10	1.0	90	40	23
10	1.5	203	90	51
10	2.0	360	160	90
15	0.5	34	15	8
15	1.0	135	60	34
15	1.5	304	135	76
15	2.0	540	240	135

for specific sites, and may reveal more about which habitat variables are correlated with bird population data than the regionwide models can reveal. Site models cannot be extrapolated statistically to the entire region because, by definition, they include variables whose values are not known regionwide. However, basic habitat management guidelines derived from site-based models can be applied throughout the region in which the habitat characteristics used in the model apply. As a hypothetical example, if a site-based model for aspen were to predict a higher abundance of aspen-associated focal species with increased shrub coverage, then this insight could be applied to aspen management throughout the region in which aspen-associated birds were believed to respond to this effect.

Project Evaluations

Project evaluations involve surveys on a habitat implementation project site before, during, and after the project. These surveys help evaluate and perhaps revise the project and they document effects of the project on birds.

Sample Size Needed to Detect a Specified Change

Suppose we wish to detect a ratio change (R) in abundance or some other parameter, $R = Y_2/Y_1$, where Y_1 and Y_2 are the values at two times, for example, before and after a project. R will be estimated as $r = y_2/y_1$ where y_1 and y_2 are the estimates of Y_1 and Y_2. Estimating the needed sample size requires that we specify the value of R to be detected, the significance level, the power, and the CV(r), which depends on the CVs of y_1 and y_2 and on their correlation. A convenient way to make the calculations is presented in *table 3*. The CV(r) must be estimated from a pilot study (ideally), from other similar studies, or using professional judgment. Tentative values for R, the level of significance, and power may then be selected and the required sample size to achieve the stated power may be read from *table 3*. This process may be repeated until a satisfactory compromise is reached between the desire for high power and the resources available for the study. The example, presented in the next section, provides an illustration of calculating the CV and using it to choose the sample size.

A Sample Project Description: Effects of Altering Riparian Habitats on Birds

A description for a short-term assessment project is presented below. It is modified from the Nevada CBM Plan (Ammon et al. 2003). Species lists and other tabular material have been omitted, and the format is slightly different from the description above.

Description of the Management Issue

Riparian habitats are here defined to include rivers, lowland springs and streams, and montane streams. Major rivers include the Truckee, Carson, Walker, Mary's, Reese, Virgin, Muddy, Colorado, White and

the entire Humboldt River system. Lowland springs and streams occur mainly in southern Nevada, for example at Meadow Valley Wash, Ash Meadows, and Warm Springs. Montane streams are widely distributed in northern Nevada but in southern Nevada occur mainly on the Spring and Sheep Mountains.

Riparian areas in Nevada are used by a total of 136 bird species, including 66 focal species for this objective. (The original description included the entire list and the list of 66 focal species.) Riparian areas are among the most heavily impacted environments in the state. During the past 150 years, riparian habitats have been converted, rivers have been channelized, and substantial amounts of water have been withdrawn for agricultural or municipal uses. Nevada is one of the fastest-growing regions in the country so the pressure to develop riparian bottomlands, remove ground water, and develop other water projects is likely to increase during the coming decades. Concerns about impacts on riparian areas have led to many riparian restoration efforts. In 2002, Nevada passed a $200 million bond issue for acquisition and preservation of open space and wildlife habitats around the state, and much of this money is intended for the protection of riparian resources.

Numerous lowland riparian habitat implementation projects have been undertaken, or are being considered, in Nevada. For example, restoration is planned or underway on McCarran, Ferretto, and Mustang Ranches on the Truckee River; on River Fork Ranch on the Carson River; on Rosaci Ranch on the Walker River; and on Torrance and Parker Ranches on the Amargosa River. In each of these projects, studies are needed (and in many cases are in progress) of effects on birds of planned or occurring activities.

Montane streams of particular interest in Nevada include Mahogany Creek (a proposed Important Bird Area); streams in the Montana Range, where restoration work is planned; streams in the Selenite Range and other ranges in Bureau of Land Management's (BLM) Winnemucca District, where effects on birds of a recent change in grazing management are being evaluated; and streams in the Santa Rosa Range, in the Mountain City area, and the Spring Mountains which support focal species that are otherwise rare in Nevada. Other sites of importance may include Porter Springs in the Seven Troughs Range and streams of the Snowstorm Range that have been studied by Nevada Division of Wildlife (NDOW) and others.

Managers working in riparian areas primarily need two kinds of information: predicted effects of proposed habitat implementation projects on birds, and actual effects of implemented projects. A site-based model is needed to provide the first kind of information; project evaluations are needed to produce the second kind of information.

Survey Objectives

Needed information

Project evaluations should, at a minimum, document breeding abundance of focal species, but focal species abundance throughout the year and measures of fitness, including productivity during the breeding season and foraging success during migration, would also be highly desirable especially in large projects.

A site-based model should predict the abundance of focal species relative to a continuum in habitat conditions influenced by fire, grazing, and restoration treatments. The models should be generated for both breeding and migration, but this draft of the Nevada Plan only discusses abundance during the breeding season. Later revisions will address other needed information. Short-term trends in abundance, as projects are implemented, may also be of interest particularly in large projects.

Quantitative objectives

Species-specific estimates of abundance are desirable but often cannot be obtained with sufficient precision to be useful. As an alternative, we define the primary parameter of interest as the mean number of individuals of all riparian focal species that would be recorded with a large sample.

The desired accuracy of models to predict abundance, should a proposed project be implemented, must be established independently of specific projects. More experience is needed in developing these models for riparian habitats in Nevada, but we believe that a reasonable initial target is that the CV of the predicted abundance for a single project area should be 0.25.

Projects affecting riparian habitat often cause major changes in habitat, and thus bird abundance, so surveys can be designed to detect large, rather than small, changes. As an approximate guideline, it seems reasonable that power to detect a 2- to 3-fold change should be at least 80 percent. The lower precision goal (detecting a 3-fold change) might be appropriate for smaller projects. The higher precision goal might be appropriate for larger projects.

Methods

Bird survey methods

Abundance of landbirds during the breeding season is usually determined using point counts in programs

like the Nevada Bird Count, a transect-based point count program.

Sample size requirements

Sample sizes for project evaluations were estimated from data collected in the Nevada Bird Count. We used individual points as the primary sampling unit, assuming that points would be distributed evenly across the project area. The Nevada Bird Count uses two-stage sampling (selection of transects, selection of points within transects) so we calculated means and SDs within transects and then estimated CVs as (mean of the SDs/mean of the means). The number of surveys per year varied from 1 to 3. Our sample included 50 transects surveyed during 2001-2003. There was little variation in CVs with number of surveys, indicating that most variation results from change in place, rather than change in time. The grand CV was 1.36 (*table 4*). If the level of significance is 0.05 and power is 0.8, then G, from *table 3*, is 16 and, using CV = 1.5 to be conservative, the needed sample is 135 if the change is R = 2 and is 76 if the change is R = 3. If surveys are conducted for three years prior to a project and three years after a project, then 25-50 points should be surveyed each year, depending on whether a two-fold or three-fold change is expected. Note, however, that the parameter is number of individuals of all riparian species of special concern. Much larger sample sizes would be needed for species-specific estimates, and the sample size requirement would vary enormously depending on abundance of the focal species in the project area.

Table 4— *CVs ($SD(y_i)/\bar{y}$) for 10-minute point counts in riparian habitat conducted during the Nevada Bird Count*[1].

	Number of surveys			
	1	2	3	All
N transects	28	8	14	50
N points	275	82	139	496
Average SD	1.0	0.5	0.8	0.8
Mean no. birds	0.7	0.4	0.6	0.6
CV(means)	1.37	1.41	1.31	1.36

[1] y_i is the mean number of birds recorded at the i^{th} station; the calculations (see text) exclude two counts >80; the remaining counts were <10 except for two counts of 11 and 21.

Sample sizes required to construct the site-based model are hard to estimate, in part because the number of different models must be specified. At present, we suspect that separate models will be needed for (a) northern rivers, (b) southern rivers and springs, and (c) montane streams. An initial estimate is that the accuracy target for each of these models (CVs of 0.50) can be met if data are available from 200 points (20 ten-point transects in the Nevada Bird Count). Three counts per season from each point would be useful (and are being collected at some stations) but a single count might suffice. The sample size target is thus 200 points in each of the three regions: northern rivers, southern rivers and springs, and montane streams.

Habitat survey methods

Habitat data already exist for several projects (e.g., the Bureau of Reclamation's lower Colorado River surveys, and Truckee and Carson River surveys) and may be supplemented with data from additional sites to increase our knowledge of habitat associations. This information is essential in developing the predictive model, since the predictions are based on habitat variables (defined broadly). Habitat variables may include predictors such as width of riparian woodland corridor, total woodland cover, cover by exotic shrubs and trees, measures of foliage height diversity, cover by native understory species, cover by floodplain wetlands, and emergent vegetation cover.

Sampling plans

Project evaluation surveys should probably employ one-stage systematic sampling, perhaps preceded by stratification, when project areas are small enough for this to be feasible, and should use multi-stage sampling (e.g., clusters of ten stations as in the Nevada Bird Count) when the strata are too large for this approach. Precision will generally be higher, for a fixed number of stations, with the first approach.

The same general approach will probably work to gather the data for development of the site-based predictive model, although in most cases strata will be large enough that clusters of point count stations will be used. Strata should be delineated to insure that a wide range of habitat types is included. Analysis should acknowledge the stratification and multi-stage nature of the sampling plan.

Finding high-quality sites may be especially difficult. Mary's River may provide the best site for developing the model for northern rivers. Warm Springs may be most useful in developing the model for southern rivers and springs, although better reference sites for Mojave riparian areas may be found outside of Nevada. For montane streams, several exclosure sites could be used as reference sites, for example in Sheldon National Wildlife Refuge, at Mahogany Creek, and several BLM exclosures in Humboldt County. However, other areas may also provide useful information on reference conditions.

Table 5— *Projects that will affect riparian birds in Nevada and information about them.*

Name	Location	Size	Status	Monitoring?
McCarran Ranch	Truckee River	5 river miles	Currently being implemented	Yes
Ferretto Ranch	Truckee River	2 river miles	In planning stage	Yes, but needs to be combined with McCarran for evaluation
Mustang Ranch	Truckee River	5 river miles	In planning stage	Some, but probably not enough for evaluation
River Fork Ranch	Carson River	3 river miles	In planning stage	Some, but probably not enough for evaluation
Rosaci Ranch	Walker River	2 river miles	In planning stage	Yes (enough for evaluation?)
Humboldt County streams	About 40 streams	About 100 stream miles total	Change in grazing management implemented in late 90's	Yes
Torrance Ranch	Amargosa River	2 river miles	Partially implemented	Some, but long-term uncertain
Parker Ranch	Amargosa River	2 river miles	Partially implemented	None currently
Las Vegas Valley Wash			In planning stage	
Meadow Valley Wash		60 river miles	In planning stage	Some, but no long-term plans
Virgin River		About 25 river miles	likely projects in the future	some, but coordination needed
Muddy River, Warm Springs		about 6 miles of river	in planning stage	some, but no long-term plans
Ash Meadows spring restoration projects	Ash Meadows NWR	several springs	several have been completed	none currently
Corn Creek	Desert Wildlife Range	1 mile of stream	partially completed	some, but not enough for evaluation

Roles and Responsibilities

Project monitoring surveys

Information about existing projects that will affect riparian birds is summarized in *table 5*.

Predictive (site-based) model

Many riparian surveys have been conducted in Nevada. For example, surveys made during the Nevada Bird Count included nine 10-point transects on the middle and lower Truckee River (three visits during each of two breeding seasons); seven 10-point transects along the Carson River (two or four visits during each of two breeding seasons); and 20 or more, 10-point transects located elsewhere in the State surveyed once per season. Other surveys, conducted by NDOW and BLM, covered stretches of the Humboldt River and numerous tributaries of the King, Quinn, Reese, and Humboldt rivers. Habitat information has been recorded in some, but not all, of these surveys, and methods have varied. The next steps in developing predictive models are to consolidate this information, record additional habitat data as needed, and develop draft models. This work will clarify what additional field work, if any, is needed.

Project management

A number of funding partners (Clark County, BLM, U.S. Forest Service, NDOW, and U.S. Geological Survey) are providing support for the Nevada Bird Count, which is providing much of the currently available data. As part of the Nevada Bird Count program, the Great Basin Bird Observatory (GBBO) takes responsibility for data management, analysis and reporting. Coordination with other monitoring efforts is also actively pursued as part of the mission of GBBO's Nevada Bird Count. Information resulting from analyses for this management issue will be made available online, through reports to funding partners, and through peer-reviewed publications.

Conclusions

While each plan will differ in details, the topics above, if all covered clearly and in approximately the order above, provide a logical and complete description of the project's goals, objectives, and methods, including an action plan for implementation. While none of the topics is difficult to cover, finding all of this material for a monitoring project has been rare in the past. Hopefully this situation will change in the next few years.

Literature Cited

Ammon, E., L. Neel, and J. Bart. 2003. **Coordinated bird monitoring in Nevada.** Unpublished report available from Nevada Division of Wildlife, 1100 Valley Road, Reno, Nevada, 89512.

Bart, J., and C. J. Ralph. this volume. **The need for a North American coordinated bird monitoring program.**

Appendix: Derivation of *Table 3*

Let the estimated ratio of population size, y_2/y_1 be r, and let the ratio of actual sizes be R. The value of R under the null hypothesis is 1.0 so we will declare the sample estimate significant if $|r\text{-}1|/\mathrm{SE}(r) < Z_{\alpha/2}$. We initially assume a large sample and $\alpha = 0.05$ so $Z_{\alpha/2} = 1.96$. Since R is >1, we assume $r > 1$ and use r-1 in place of $|r\text{-}1|$. For power to be 0.80, we thus want

$$P\left[\frac{r-1}{\mathrm{SE}(r)} \geq Z_{\alpha/2}\right] = 1-\beta \qquad (1)$$

We convert the right side of the inequality to a standard normal,

$$P\left[\frac{r}{\mathrm{SE}(r)} - \frac{1}{\mathrm{SE}(r)} - \frac{R}{\mathrm{SE}(r)} \geq Z_{\alpha/2} - \frac{R}{\mathrm{SE}(r)}\right] = 1-\beta \qquad (2)$$

$$P\left[\frac{r-R}{\mathrm{SE}(r)} \geq Z_{\alpha/2} - \frac{R-1}{\mathrm{SE}(r)}\right] = 1-\beta \qquad (3)$$

and thus

$$P\left[N(0,1) \geq Z_{\alpha/2} - \frac{R-1}{\mathrm{SE}(r)}\right] = 1-\beta \qquad (4)$$

By the definition of a standard normal variable, the right side of the inequality must equal $Z_{1-\beta}$ for power to be 1-β,

$$Z_{\alpha/2} - \frac{R-1}{\mathrm{SE}(r)} = Z_{1-\beta}. \qquad (5)$$

Solving for SE(r) yields

$$\mathrm{SE}(r) = \frac{R-1}{Z_{\alpha/2} - Z_{1-\beta}} \qquad (6)$$

or, since $-Z_{1-\beta} = Z_{\beta}$,

$$\mathrm{SE}(r) = \frac{R-1}{Z_{\mathrm{df},\alpha/2} - Z_{1-\beta}} \qquad (7)$$

and so

$$V(r) = \frac{(R-1)^2}{(Z_{\alpha/2} + Z_{\beta})^2}. \qquad (8)$$

If we assume (a) the sample sizes, n, are equal, (b) the two estimates are independent (which is conservative), and (c) that the CVs, are equal, then variance of r may be expressed as

$$V(r) = \frac{R^2}{n}(\mathrm{CV}(y_{1i})^2 + \mathrm{CV}(y_{2i})^2) = \frac{2R^2\mathrm{CV}(y_i)^2}{n} \qquad (9)$$

where the CVs are SD/mean, not SE/mean. Setting expressions (8) and (9) equal to each other and solving for n yields

$$n = 2(Z_{\alpha/2} + Z_{\beta})^2 \mathrm{CV}(y_i)^2 \left(\frac{R}{R-1}\right)^2$$

or, with $G = 2(Z_{\alpha/2}+Z_{\beta})^2$,

$$n = G\mathrm{CV}(y_i)^2 \left(\frac{R}{R-1}\right)^2.$$

This is the sample size assuming the SE is known. Snedecor and Cochran recommend multiplying n by (df+3)/(df+1) which in our case equals 1+2/n and increases the sample size by <10 percent if n > 20, which is almost always the case. This correction is therefore ignored in *table 3*.

Small-Scale Monitoring – Can It be Integrated with Large-scale Programs?[1]

C. M. Downes,[2] J. Bart,[3] B. T. Collins,[2] B. Craig,[4] B. Dale,[5] E. H. Dunn,[2] C. M. Francis,[2] S. Woodley,[6] and P. Zorn[7]

Introduction

There are dozens of programs and methodologies for monitoring and inventory of bird populations, differing in geographic scope, species focus, field methods and purpose. However, most of the emphasis has been placed on large-scale monitoring programs. People interested in assessing bird numbers and long-term trends in small geographic areas such as a local birding area, or in management units such as parks or regional forests often find it hard to get guidance on which methods would be best for them while also providing useful results. To help meet this need, we have developed a set of recommendations aimed both at land managers and ornithologists who want to conduct detailed and rigorous inventory, population monitoring or comparison of sites, as well as at individuals or groups who simply want to participate in bird monitoring and contribute to cooperative programs or to involve the public in a useful manner. Wherever possible, emphasis is placed on methods that are useful for site-specific monitoring but could also contribute to national programs.

The guidelines for small-scale monitoring outlined in this paper are based on the results of a workshop, held in November 2001, sponsored by the Canadian Wildlife Service and the Environmental Monitoring and Assessment Network, Environment Canada. Because a more detailed paper is planned for publication in the near future, we provide only a short overview of the guidelines we have been developing for monitoring and surveying birds at small geographic scales. For details on techniques, we refer to a variety of publications that provide detailed information and background on the monitoring techniques mentioned in this paper (e.g. Baillie 1990; Ralph et al. 1993, 1995; Bibby 2000; Downes et al. 2000).

For the purposes of this paper, we loosely define the term "small scale" as any area too small for national programs to provide meaningful results; these programs are usually designed to cover an area the size of a province or an entire physiographic region. Our recommendations are suitable for use at sites ranging in size from a few hectares to a large national park (e.g. 10,000 hectares). Our recommendations complement those developed for U.S. National Parks (http://www.nature.nps.gov/im/monitor/birds.htm), but cover a broader range of monitoring goals and participation levels.

Differences Between Small-Scale and Large-Scale Monitoring

We monitor birds to get information about population changes that can help to guide effective bird conservation strategies. The primary role of monitoring is usually to determine what changes are occurring in bird populations. A secondary, but important, role is to get clues as to why population change is occurring. Both large- and small-scale monitoring programs are needed to address these questions. Large-scale monitoring programs, which collect information at the scale of a biogeographic region, country or continent, are usually designed to address the first role. However, large-scale programs are usually too coarse to provide information on changes at specific sites or to provide direct information on the causes of population change. Directed studies are needed to pinpoint why population change is occurring. Small-scale monitoring programs, which are site-specific, give information on local status of bird populations. However, because these sites are not necessarily representative of the broader landscape, changes in the local bird numbers cannot be extrapolated to the population level. Data from small-scale programs are useful for site management but need to be put in the context of population-level change to determine if changes at a particular site are due to local or external factors. In cases where the survey site is protected from development, the data from a small-scale

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[1] A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

[2] National Wildlife Research Centre, Canadian Wildlife Service, Ottawa, Ontario, K1A 0H3.
[3] U.S. Geological Service, Forest and Rangeland Ecosystem Science Centre, Boise, Idaho, 83706.
[4] Ecological Monitoring and Network, Environment Canada, Burlington, Ontario, L7R 4A6.
[5] Canadian Wildlife Service, Environment Canada, Edmonton, Alberta, T6B 2X3.
[6] Parks Canada, National Parks Branch, Gatineau, Quebec, K1A 0M5.
[7] Parks Canada, Ontario Service Centre, Ottawa, Quebec, K1B 3V7.

monitoring program can also be useful as a benchmark for landscape level change.

The different contributions of small- and large-scale monitoring programs emphasize the value of integrating approaches. The value of small-scale monitoring is greatly increased when the results can be interpreted relative to changes at the population level. Large-scale programs need information across large geographic areas and large sample sizes, but can benefit from comparison with benchmark sites. If carefully designed, small scale programs can contribute to the large-scale programs, and/or provide in-depth information at specific sites. By using compatible techniques, to the extent possible, the usefulness of both large- and small-scale monitoring programs can be maximized. As an additional benefit, managers of small-scale programs can make use of data-management systems, routine analytical programs, and other logistics developed by established programs that they may not have the expertise or facilities to develop on their own. *table 1* shows some examples of established programs that have been developed for large-scale monitoring but that can be used at the single site. However, it must be understood that results from a single sample point in a large-scale program are not adequate for monitoring populations at a local site.

Before Starting

The importance of carefully thinking through the study objectives, logistics and data management procedures before starting a monitoring program cannot be over emphasized. The reasons for wanting to establish a monitoring program should be carefully considered and the goals clearly established. Available resources and logistics should be considered, including the lifespan of the project, availability of participants and their skill level, data management and analytical capabilities, and reporting needs. It is important to consider not only the initial resources available, but the level of commitment that can be sustained into the future, if the objectives involve longer term goals such as population monitoring. The types of auxiliary data to be collected should be identified, such as weather, habitat descriptions, observer names and so on. Deciding on the best techniques will depend on the goals of the monitoring program, the species being monitored and the season of monitoring.

Monitoring Goals and Suggested Methods

For individuals or groups not previously involved in bird monitoring it is sometimes difficult to develop an appropriate and useful goal for a monitoring program. Here we discuss the three main types of data that are collected in monitoring programs and suggest useful questions that can be addressed by these data, depending on the techniques used. For each type of data we divide our recommendations on the most appropriate technique into one or more of three categories and give examples of questions that can be addressed in each category: "basic" monitoring techniques where objectives require less statistical rigor, and "intermediate" and "advanced" methods that should be used when results must meet targets of increasing statistical reliability (*table 2*). Uses of monitoring data that require statistically reliable results include assessing effectiveness of management, comparing quality of sites, or examining population trends within a site as compared to trends in a broader area.

Table 1-- *Examples of large-scale programs to which participants in small-scale monitoring may usefully contribute. Note that some of these surveys, such as the Breeding Bird Survey, involve random route selection and, even if they intersect a particular site of interest, may go beyond its borders. The website http://www.americanbirding.org/opps/voldiindex.htm gives a list of volunteer ornithological projects (including most of the surveys listed below) with details on survey goals, skill level and time commitment required, as well as contacts and links to project-specific websites. For surveys in table 1 not listed in this website (indicated by *) a reference is included in the list of references at the end of this paper.*

Purpose	Example of established project
Inventory	Project FeederWatch
	Christmas Bird Count
	*Checklist surveys
	Atlases
Abundance	Breeding Bird Survey
	Project FeederWatch
	Christmas Bird Count
	Owl monitoring
	Marsh monitoring
	Ontario Forest Bird Monitoring Program (Cadman et al. 1998)
Demography	Productivity: Nest Record Schemes (with repeated visits to nests)
	*BBird, MAPS

Species Inventory

A basic inventory program consists simply of a list of the presence or absence of species in a particular site. Provided that dates and locations of observations are recorded, such data can be used to compare species composition among sites or seasons, or to document critical sites based on presence of particular species or

a high diversity of species. A simple species inventory program can be a useful educational tool because the techniques are relatively simple and can include a wide range of skills from beginners to experts; unlike many other programs, checklists do not require that the same person take observations each year. A visiting school group, for example, can usefully participate in a simple species list in a park. We recommend the "Checklist technique" for basic species inventory, emphasizing that the value of the results will increase by using a standardized and organized approach. Guidelines on the development of a standardized checklist program that will fit into existing national checklist programs are available (Dunn 1995; see also the Ebird project website at http://www.ebird.org/content/). An Area Search approach is the best method for species inventory; it is essentially a "checklist" (sensu Dunn 1995) approach recording all species in a designated area that is searched in a standardized, systematic way.

Abundance Monitoring

Monitoring for abundance is the most common form of bird monitoring. It involves obtaining an estimate of the population size and/or an index of population abundance. In the short term, such data can be used to compare bird abundance among sites or habitat, and to evaluate the effect of management practices on a site. If counts are repeated over time, long-term population change or trends can be monitored. Long-term monitoring can be used to assess species status, determine conservation priorities, and detect whether species are responding to management activities. All these goals require a monitoring program that will give results that are statistically reliable.

Our recommendation for the "basic" technique is the standardized Checklist approach described in the above section. Checklists can detect large changes in abundance. However, for more detailed and reliable data some combination of index or density estimators should be used (Ralph et al. 1993, 1995; Bibby et al. 2000; Thompson 2002). Density estimators, which allow for adjustment of counts for birds that are present but not detected, are more robust but require greater effort. All methods require a well-designed plan to ensure results are not biased. Target species may need to be selected, spatial and temporal sampling should be non-biased, and appropriate auxiliary data should be collected.

Demographic Monitoring

Demographic monitoring refers to the measurement of survivorship and productivity. These data can provide clues as to why bird populations are changing, thus addressing the secondary goal of monitoring programs. Productivity estimates can be used to compare specific study plots in order to detect differences in habitat quality or to evaluate treatments. Over the long term these data can be used to detect changes related to habitat quality, predator levels and weather. Basic data on productivity can be obtained by observing behavioral indicators of success. Nest finding and monitoring are probably the best techniques for monitoring productivity at a specific site. Nest monitoring requires intensive effort and in many cases it will be best to concentrate efforts on selected focal species. For details on nest monitoring techniques see Martin and Geupel (1993) and the Breeding Biology Research and Monitoring Database (BBird) program protocol http://pica.wru.umt.edu/BBIRD/info.htm). Constant effort mist-netting may be used to obtain productivity information at the regional level. This method is also time intensive and requires the participation of trained bird banders. The Monitoring Avian Productivity and Survivorship (MAPS) program (http://www.birdpop.org/maps.htm) provides an example protocol of constant effort mist-netting.

Because survivorship of birds is strongly influenced by factors external to the study site, it is difficult to determine the extent to which site-related effects influence survivorship. Nevertheless, site-specific studies can make important contributions to national programs designed to monitor survivorship, such as MAPS. Again, such projects require intensive effort as well as skilled workers (e.g. experienced, licensed banders) and will only be feasible in some projects and areas.

Conclusions

Monitoring can address a wide variety of questions related to the occurrence of species in space and time, how populations are changing, and clues to the causes of such change. Results can be used to assess the effectiveness of management activities and to establish future conservation priorities. Monitoring programs also provide an excellent opportunity for public education and participation. The choice of monitoring techniques and study design will depend on the questions being asked and will vary, among other reasons, depending on whether results have to be statistically robust. If the main goal at a site is to provide opportunities for public education and participation it may be more effective to establish a sampling site for an established project (e.g. Christmas Bird Count, Ontario Forest Bird Monitoring Program [see Cadman et al. 1998], MAPS) rather than to design a separate monitoring program. While this will not generate data sufficient for monitoring populations at a particular site, it will provide ways for participants to contribute useful data to larger programs while conducting work at a favorite site.

Table 2—*Recommended methods for monitoring at small geographic scales.*

Purpose	Basic	Intermediate	Advanced
Inventory	Checklist technique with repeated visits in target season(s)	1) Checklist with repeated visits; good spatial sampling 2) Atlas project	As for "intermediate," but with evidence (e.g. from statistical analysis of multiple checklists) that coverage meets targets
Abundance	Checklist with standards for counts and good spatial sampling and repeated visits	Standardized index counts with good sampling design	Density estimators with good sampling design
Demography	Behavioral indicators of success	Behavioral indicators of success with good sampling design	Intensive nest search with good sampling design

Small- and large-scale monitoring programs can be mutually beneficial. Interpreting the results of a site-specific monitoring program requires knowledge of what is happening in the surrounding region. The smaller the site the less likely that on-site trends will reflect those at a large scale and trends from small sites should not be used to infer status of species beyond the borders of the study area. However, if standardized and established techniques are used, the results can be comparable among sites and can contribute to established large-scale programs. Site managers need such large-scale data in order to put their own site-specific results in context. Similarly, if sites participate in established programs it will help increase sample sizes and the geographic range of large-scale monitoring programs. Observers trained at small-scale monitoring programs will increase the pool of skilled observers for both small- and large-scale monitoring. We emphasize the importance of contributing to both, and hope site managers will see the value of contributing to large-scale monitoring programs even if those are outside their jurisdiction. Once the manuscript on the recommendations for small-scale monitoring are finalized, we hope they will be widely adopted and thus help to ensure the results of both small-and large-scale monitoring efforts are maximized.

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Progress Toward Developing Field Protocols for a North American Marshbird Monitoring Program[1]

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Abstract

Populations of many marsh-dependent birds appear to be declining, but we currently lack a continental program that provides estimates of population trends for most secretive marshbirds. The survey protocol outlined here is a standardized survey methodology being used on a pilot basis at National Wildlife Refuges and other protected wetland areas across North America and will ultimately be refined and proposed for use in a continental marshbird monitoring program. These protocols: (1) provide flexibility so that data from ongoing local and regional monitoring efforts may be pooled to the extent possible, (2) summarize the full description of proposed survey protocols contained in Conway (2003), and (3) include details on, and rationale for, point spacing, survey duration, seasonal and daily survey windows, and structure of call-broadcast sequences. Attempts to validate abundance indices based on call-broadcast surveys for primary marshbird species will be included in the survey effort by incorporating three methods for estimating different components of detection probability into the field protocols. Implementation of these protocols at a continental scale awaits delineation of a sampling frame and will occur after several years of field testing and review/revision of these draft field protocols. Field testing is currently being conducted at ~80 National Wildlife Refuges in a variety of freshwater and saltwater marshlands distributed across North America.

Introduction

The amount of emergent wetland habitat in North America has declined drastically during the past century (Tiner 1984). Locally, regionally, and even continentally, populations of some secretive marsh-dependent bird species appear to be declining (Tate 1986, Eddleman et al. 1988, Conway et al. 1994, Timmermans and Craigie 2002). Secretive marsh birds of primary concern include all species of rails, bitterns, coots, moorhens, gallinules, Limpkins, and solitary-nesting grebes. Because rails and bitterns consume a wide variety of aquatic invertebrates, populations may be affected by accumulation of environmental contaminants in wetland substrates (Odom 1975, Klaas et al. 1980, Eddleman et al. 1988, Gibbs et al. 1992, Conway 1995). Marshbirds are also vulnerable to invasion of wetlands by purple loosestrife (*Lythrum salicaria*) (Gibbs et al. 1992, Meanley 1992), and may be vulnerable to anthropogenic disturbances to marsh habitats (Adamus et al. 2001). Hence, marshbirds may represent indicator species for assessing wetland ecosystem quality, and their presence might be one way to measure the success of wetland restoration efforts. Marshbirds also have high recreational value; many species are highly sought-after by recreational birders. Finally, several rails are game species in many portions of North America, yet we lack population surveys on which to base harvest limits.

The U.S. Fish and Wildlife Service has identified Black Rails (*Laterallus jamaicensis*), Yellow Rails (*Coturnicops noveboracensis*), Limpkins (*Aramus guarauna*), and American Bitterns (*Botaurus lentiginosus*) as "Birds of Conservation Concern" because they are relatively rare and we lack basic information on status and trends in most areas (U.S. Fish and Wildlife Service 2002). Many U.S. states consider these species threatened (or species of special concern) for similar reasons and several species are on the Audubon Society Watchlist. King Rails (*Rallus elegans*) are federally endangered in Canada, Least Bitterns (*Ixobrychus exilis*) are federally threatened in Canada, and Black Rails are federally endangered in Mexico.

Because of their vulnerabilities, value, and largely unknown status, state/provincial and federal management agencies have a high level of interest in monitoring marshbird populations in North America to estimate population trends and to measure health of their supporting wetland habitats. Any management action that alters water levels, reduces mudflat/open-water areas, alters invertebrate communities, or reduces the amount of emergent plant cover within marsh habitats could potentially affect habitat quality for marshbirds (Griese et al. 1980, Eddleman et al. 1988, Eddleman

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California**.

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and Conway 1994, Conway 1995). Long-term monitoring of marshbirds will allow resource managers to evaluate whether management actions or activities adversely impact wetland ecosystems.

Some regional programs have been implemented to monitor marshbird populations, but lack of standardized methods limits our ability to estimate population trends of secretive marshbird species across North America. Given this, a North American marshbird monitoring program that integrates and standardizes these regional efforts to the extent possible would be advantageous and desirable. A workshop in 1998 was held to synthesize information and to suggest the best approach for developing and implementing a continental marshbird monitoring program. Attendees at that 1998 workshop suggested a two-tier sampling approach. One tier would target National Wildlife Refuges and other publicly-managed wetlands, and the other tier would include all North American wetlands as the scope of inference. Tier 2 would provide the information needed to set harvest limits and to determine conservation status of each species, and tier 1 would provide management agencies with information on species status on lands that are (or can be) actively managed to increase abundance. Both tiers would use the same survey methods. In this paper, we discuss progress made toward developing tier 1 of this program and a pilot effort to evaluate the survey methods that are currently being proposed for use in both tier 1 and tier 2.

Possible goals of a North American marshbird monitoring program include estimation of population trends, abundance, and density of numerous species of marshbirds at various spatial scales. However, surveys rarely count all individuals present in the sampling area because detection probability is typically less than 100 percent. Number of birds responding during standardized surveys can be used as an index of abundance that allows comparisons among wetland basins and vegetative communities. The value of such an index depends on the correlation between number of individuals detected during the survey and number of individuals actually present in the area sampled (i.e., the amount of spatial and temporal variation in detection probability). Unfortunately, a strong positive correlation between number counted on a survey and actual number present cannot be assumed and few reliable estimates of detection probabilities from marshbird surveys are available (but see Conway et al. 1993, Legare et al. 1999, Bogner and Baldassarre 2002, Conway et al. 2004). Incorporating methods to estimate components of detection probability into the large-scale monitoring effort will allow analysts to evaluate the assumption that trends in count data are not caused by temporal changes in detection probability. So, attempts to validate indices based on surveys for primary marshbird species will be included in the survey effort by incorporating three methods for estimating different components of detection probability into the field protocols. The three potential methods for estimating components of detection probability include distance sampling (Buckland et al. 2001), double-observer surveys (Nichols et al. 2000) at a subset of points, and a removal model approach (Farnsworth et al. 2002). Each method has implicit assumptions and only estimates component parameters that contribute to overall detection probability (see Nichols et al. 2000, Buckland et al. 2001, Farnsworth et al. 2002, Conway et al. 2004). For example, the double-observer approach provides estimates of observer bias whereas the removal model approach ignores observer bias and estimates the probability that a bird that has vocalized during one time interval will vocalize during another time interval. A monitoring program that incorporates all three methods offers the best approach for validating the usefulness of count data.

Few estimates of marshbird population trends currently exist, and reliable estimates of population trends will probably require >5 years (and perhaps as much as 15-20 years) of survey data. After 2-3 years of pilot data collection at a variety of sites across the continent we will be able to conduct power analyses to determine the percent annual change detectable with a specific number of survey points, and the number of survey points required to detect a desired annual rate of change over a specified time period. Currently, a power analysis is not warranted because we do not have reliable estimates of temporal variation in numbers counted using standardized surveys across North America.

A continental marshbird monitoring strategy should also include attempts to estimate change in wetland habitat characteristics at each site. Information about vegetation change over time will allow data analysts to: (1) estimate density of marshbirds in each of several vegetative communities within a local area, (2) correlate changes in marshbird numbers with changes in wetland vegetation to identify potential causes of observed population changes (Gibbs and Melvin 1993), (3) identify vegetative communities that need protection or control, and (4) manage wetlands in ways that benefit marsh-dependent birds.

The survey protocol described below is a standardized survey methodology being used on National Wildlife Refuges and other protected wetland areas across North America (i.e., tier 1). With some modification and flexibility, it could be used to monitor secretive marshbirds on all lands where suitable wetlands occur. These protocols have been modified through feedback from participants during the initial pilot years of survey efforts. Although these surveys were designed to target a subset of secretive marshbirds, observers are

encouraged to record detections of other species that are also under-sampled by existing monitoring programs, e.g., colonial grebes, herons, egrets, Forster's and Black terns (*Sterna forsteri* and *Chlidonias niger*), Common Snipes (*Gallinago gallinago*), Sandhill Cranes (*Grus canadensis*), Northern Harriers (*Circus cyaneus*), Belted Kingfishers (*Ceryle alcyon*), and numerous marsh-dependent passerines too extensive to list here. Each cooperator should decide which secondary species to include in their surveys in advance and list these species on their datasheet so that all participants in future years will know the list of species recorded in prior years.

Recommended Standardized Marshbird Monitoring Protocols

Standardized survey methods are based partly on recommendations and discussion resulting from the 1998 workshop designed to begin development of standardized marshbird monitoring strategies (Ribic et al. 1999). Recommendations from Conway and Gibbs (2001) and recent methodological advances in estimating components of detection probability and observer bias were also considered in developing these protocols. Because many marshbirds are secretive, seldom observed, and vocalize infrequently, the protocol to be evaluated in our pilot efforts employs broadcast of calls to elicit vocalizations during vocal surveys (Gibbs and Melvin 1993). However, we also hope to: (1) estimate components of marshbird detection probability; (2) estimate density of marshbirds within several common vegetative communities; (3) evaluate usefulness of call broadcast for future survey efforts, and; (4) monitor marshbird species not included in the broadcast sequence. Hence, the protocol includes a passive listening period that occurs prior to broadcasting calls when all birds detected will be recorded. An initial passive period will provide comparable data to pool among survey areas despite differences in length and composition of call-broadcasts used during the second half of each survey. Data from an initial passive period will also permit estimates of detection probability components for certain species following Farnsworth et al. (2002), resulting in national and continental monitoring standardization.

Wetland Basins to be Included in Tier 1 Surveys

The target 'survey areas' for pilot surveys included in tier 1 are National Wildlife Refuges, National Wildlife Areas, and other managed and/or protected wetland areas. Surveys are to be conducted in all emergent marshes (freshwater, brackish, and salt marshes) >0.5 ha in total area within each survey area. Location and extent of emergent vegetation within a wetland basin often changes over time. Hence, we advocate an area-based rather than a marsh-based sampling scheme.

Location of Survey Points

Fixed, permanent survey points are to be selected and marked with inconspicuous markers in the field. Locations of each survey point should also be plotted on maps, and UTM locations of each point should be recorded using a GPS receiver. This protocol requires a minimum distance between adjacent survey points of 400 m to avoid the risk of double-counting individual birds and to increase the total area covered by the monitoring effort in a local area. Participants who desire closer minimum inter-point spacing (i.e., to meet local management or monitoring needs) are to ensure that there is a minimum distance of 200 m between survey points, and record that this preference was chosen.

Once the survey area is selected, participants should choose their initial survey point randomly based on all possible locations for a survey point (all possible marsh-upland interfaces and all possible marsh-open water interfaces). Many local volunteer marshbird survey efforts place survey points at the interface between emergent marsh and upland. This approach provides easy access to survey points, minimizes travel time between adjacent points, reduces trampling of vegetation within the marsh, and may increase the distance at which observers can hear vocalizing birds due to increased elevation relative to the marsh vegetation.

Number of Survey Points

Surveys are to include as many survey points as possible (with the constraint that no two points are closer than 400 m apart) within the 'survey area'. Hence, the number of survey points in each survey area should be roughly correlated with amount of emergent marsh patches within that survey area. Observers are directed to add survey points (while ensuring not to drop any existing survey points) as emergent marsh vegetation increases or shifts within their defined 'survey area.' Number of survey points to include within a local refuge or management area (or the size of the survey area selected) will depend on personnel time available and other logistical constraints. Points within a 'survey area' are to be organized into ≥ 1 survey routes. Number of points to include on a particular survey route can vary among routes and the number of points on a particular survey route should correspond to the number that a surveyor can reasonably complete during a morning or evening survey window. Participants who survey fewer total points per morning (rather than fewer survey routes with lots of points per route) will typically detect more marshbirds. One observer should

expect to survey approximately 5-20 survey points each morning, depending on travel times between survey points and length of their broadcast sequence. Once the survey route direction is selected, all subsequent survey visits for the route are to be consistently conducted in this same fashion (e.g., route 'x' is always surveyed during the morning from north to south commencing at the same time).

Timing of Surveys

Marshbirds are typically most vocal during the two hours surrounding sunrise and sunset, so surveys can be conducted during either early morning (dawn) or early evening (dusk). Once a route is assigned to be surveyed during morning or evening, the route must be consistently surveyed during that period (i.e., always morning or always evening) each year. Time windows for both morning and evening surveys are described by Conway (2003). Allowing both morning and evening surveys in a standardized monitoring protocol provides added flexibility and more potential survey hours for participants.

Number of Replicate Surveys at Each Point

The protocol requires that at least three survey visits be completed at each survey point annually. Each of these three replicate surveys must be conducted during a ten-day window and the three ten-day windows must be separated by seven days. Seasonal timing of these three survey windows will vary regionally depending on migration and breeding phenology of focal marshbirds breeding in an area. The first survey window should be when migratory passage is over, but prior to breeding, and the second and third survey windows should occur during the breeding season. Our intent is to estimate trends over time in number of breeding adults, so it is essential that the three annual survey windows occur prior to initiation of juvenile vocalizations.

Three or more surveys are needed to confirm seasonal presence/absence of some marshbird species in a wetland with 90 percent certainty (Gibbs and Melvin 1993, Conway et al. 2004). Including ≥3 replicate surveys annually at each point will provide data on temporal variation in numbers counted (a key parameter needed to conduct reliable power analyses once enough preliminary data are available) and will also allow us to estimate proportions of sites occupied by each species (MacKenzie et al. 2002).

Survey Methods

At each survey point, observers should record the number of individuals of all primary species (see list in *Appendix 1*) detected during both a 5-minute passive period prior to broadcasting recorded calls as well as during the subsequent call-broadcast period in which pre-recorded vocalizations are broadcast into the marsh. The broadcast sequence at a particular location includes calls of those species from *Appendix 1* that are expected to occur in that area. Calls should be broadcast at 80-90 decibels (measured 1 m in front of the speaker) using a portable CD player or MP3 player attached to amplified speakers. Recorded calls of each species will be made available by the program coordinator. Additional details describing specifications of call-broadcast equipment and protocols describing how call-broadcast surveys are designed can be found in Conway (2003).

Observers are to record the time interval(s) within the survey period when each individual bird was detected. Observers should also estimate the distance from each individual focal bird to the survey point. This should be done by estimating distance to each bird when the bird is first detected because some birds will approach the call broadcast (Legare et al. 1999, Erwin et al. 2002). Such distance sampling will enable estimations of density for each species in each vegetative community. Habitat-specific density estimates are useful because they allow managers to extrapolate survey data to estimate a minimum number of each marshbird species on their entire management area.

Observers have the option of recording species of birds that are not included in their broadcast sequence (*Appendix 2*). The suite of species recorded by a particular observer will depend on the marshbirds of interest or occurrence at a given wetland or region. For example, participants may want to include species that are thought to be declining or that are not sampled well by other survey efforts in their region.

Surveys should be conducted only when wind speed is <20 km/hr and not during periods of sustained rain or heavy fog; even winds <10 km/hr (12 mph) can affect the detection probability of marshbirds (C. Conway, pers. obs.). Participants should postpone surveys if winds are affecting calling frequency of marshbirds or the ability to hear calls. Surveyors who will be conducting surveys in constantly windy locations should determine the time(s) of day when detection probability of primary marshbirds is highest (given temporal variation in both wind velocity and calling frequency). Participants who include an initial settling period (e.g., one minute between arrival and initiation of survey) prior to each survey should consistently do so for each survey point and during each visit and should record the duration of the settling period on each survey form. See Conway (2003) for sample survey forms.

Some survey points within a survey area will have too many focal birds calling to permit observers to record each temporal sub-segment during which each individual bird is detected and/or to estimate distance to each calling bird. For example, an observer may detect >20 American Coots (*Fulica americana*) at one survey point. In these situations, participants are asked to estimate the total number of individuals detected for that particular species during the entire survey period on one line of the data sheet (e.g., "23 AMCO" on one line of the data sheet) instead of recording each bird on a separate line.

Habitat Descriptions and Measurements

Natural changes in water level and management activities (e.g., dredging, wetland restoration efforts, prescribed burning) can lead to dramatic changes in marsh vegetation composition and structure. Patterns of distribution and local population trends of marshbirds might best be explained by local changes in wetland vegetation. Consequently, quantifying the relative proportions of major vegetation types surrounding each survey point can help identify causes of observed changes in marshbird populations.

Vegetation should be quantified at two spatial scales: (1) observers should visually estimate the relative proportions of open water, mudflats, and each major vegetation type within a 50-m radius circle around each survey point, and; (2) aerial photographs should be used by an analyst to periodically determine amount of each major vegetation type on each management area. To control for the seasonal progression of annual growth in emergent plants, observers should quantify vegetation types within the 50-m radius of each point during their final survey each year. However, vegetation data need not be collected while bird surveys are being conducted. An example of visual estimates of proportions of each vegetation type at a survey point might be: 15 percent water, 10 percent California bulrush, 20 percent three-square bulrush, 5 percent cattail, 20 percent seep willow, 10 percent mudflat, 20 percent upland shrub community. Observers are encouraged to estimate proportion of each plant species present, because some marshbirds preferentially use habitats dominated by only one species of emergent plant. If necessary, participants should enlist the help of a botanist or other qualified assistance to conduct vegetation surveys (or bring samples to a herbarium for later identification). Upon request, program coordinators will provide survey participants with standard instructions for describing marsh vegetation at their survey points.

Personnel and Training

Each observer should be able to identify all common calls of marshbird species in their local area. Regularly listening to the recorded calls used for surveys can help observers learn calls, but observers should also practice call identification at marshes where species of interest are frequently heard calling. All observers should also be trained to determine distance to calling marshbirds and have a hearing test (audiogram) at a qualified hearing or medical clinic before, during, or immediately after the survey season each year. See Conway (2003) for recommended methods for training participants.

Integration with Other Monitoring Protocols

These protocols were designed to allow maximum flexibility for integration with existing regional marshbird survey efforts. The authors are aware of at least five existing regional marshbird survey efforts and 11 more localized or discontinued survey efforts (Conway and Gibbs 2001) which all use different survey methodologies (*table 1*). In particular, survey efforts vary in the duration of each survey and in the sequence of species' calls included in the call-broadcast periods. Some of these survey efforts do not include an initial passive listening period prior to broadcasting calls. Survey protocols described in this paper and detailed in Conway (2003) will allow at least a portion of data produced from all of these survey efforts to be comparable by allowing participants to conduct either morning or evening surveys, and by having participants record numbers of marshbirds detected during each 1-min segment of the survey. Finally, some investigators and resource managers have interest in monitoring marshbirds without the use of call-broadcast (particularly for salt marsh passerines; Ribic et al. 1999; S. Droege, unpubl. ms.). The survey program outlined here allows such individuals to participate in this program because participants need only conduct the five-minute passive observation period (i.e., skip the call-broadcast portion of the survey) at each survey point. Data produced from such surveys will still be compatible with survey protocols outlined herein because birds detected during these initial 5-min passive periods can be analyzed separately from those detected during the call-broadcast segment.

Regional Context

Estimates of change in marshbird populations in one survey area will be compared to local population changes in other parts of the region and to other regions. These data will allow comparisons among management areas in a particular region so that local managers can determine the relative importance of

specific wetlands to the regional population health of specific species. Several U.S. Fish and Wildlife Service National Wildlife Refuges began using these marshbird survey methods in 1999 and participation has increased each year. In 2002 and 2003, over 111 participants conducted marshbird surveys using these protocols (85 in the United States, 25 in Mexico, and 2 in Canada) at over 2800 survey points. For assistance initiating survey routes, obtaining appropriate CDs or the most recent survey protocols, or questions regarding standardized marshbird survey methods, please contact the program coordinator: Dr. Courtney J. Conway, Arizona Coop. Fish and Wildlife Research Unit, 104 Biological Sciences East, University of Arizona, Tucson, AZ 85721, ph: 520-626-8535, FAX: 520-621-8801, email: cconway@ag.arizona.edu.

Additional Optional Components to Survey Protocol

Recording Water Depth at Each Point (or Each Management Unit)

Water level is thought to influence abundance and distribution of marshbirds. Water levels vary annually and even daily in some marshes and these fluctuations can explain spatial and temporal changes in marshbird abundance (Craigie et al. 2002). Some National Wildlife Refuges and National Wildlife Areas control water levels in some of their management units and have the ability to directly benefit marshbirds via hydrologic management. Participants are encouraged to place gauges for measuring water level change in permanent locations at numerous points within their survey area(s). Water level should be recorded before or after each marshbird survey. If water levels vary annually (or seasonally) within survey areas, we recommend that this component become incorporated into the participant's marshbird survey effort.

Recording Noise Level at Each Point

Recording the level of background noise during the survey at each survey point is useful for trend analysis. This information can be used as a covariate in future trend analyses because level of background noise varies spatially and temporally and influences detection probability. If noise levels are periodically high enough to reduce an observers' ability to detect calling marshbirds, this optional component should be considered mandatory. Record background noise on a scale from 0 (no background noise) to 4 (cannot hear birds beyond 25 m; see Conway 2003).

Table 1— *Summary of methods associated with other marshbird survey efforts.*

Survey coordinator	Location	Num. of species in broadcast sequence	Years	Minutes per point[1]	Number of points	Point spacing (m)	Number of surveys	Number of surveys per point	Time of day[2]	Season
Paine	Illinois	4-11	1996-1998	8/8/3	142	175	1094	1-8	m	Apr-Aug
Pentfila	Wisconsin	7	1983-2000[3]	2/3-6/2	58	800	1632	1-10	m	Apr-Jun
Fitzpatrick	Arizona/California	1	1979-2003	0/5-6/0	1066	180	3222	1-3	m,e	Apr-Jun
Timmermans	Great Lakes	5	1997-2003	0/5/5	900	250	1450	1-8	e	May-Jul
Shieldcastle	Ohio	5	1991-2003	0/5/0	525	unk	3660	1	m	May-Jun

[1]minutes initial passive period/minutes during call broadcast/minutes final passive period.
[2]m=morning, e=evening, n=nighttime.
[3]1987-89 not surveyed; converted to survey methods described in this document in 2001.

Two-Observer Surveys

The extent to which trends in count data represent the underlying trend in true abundance depends on variation in detection probability and observer bias associated with the particular survey method. Two observers conducting a subset of surveys simultaneously but without sharing information will allow analysts to estimate observer bias associated with their survey efforts using the double-observer method (Nichols et al. 2000). Hence, whenever possible, surveys should be conducted by two observers simultaneously (Conway 2003).

Summary

This paper is a summary of progress made to develop standardized survey methods that could be used as part of a continental marshbird monitoring program. The information here summarizes draft field protocols in Conway (2003). Those interested in participating in this initiative and/or in developing localized or regional standardized marshbird monitoring initiatives following the protocols described herein are encouraged to contact Courtney Conway (at the address given above) to obtain a copy of the technical documentation that describes these protocols in greater detail. This paper is meant to generate discussion and debate of methods that should or should not be included in a continental marshbird monitoring program. These protocols are being implemented on many National Wildlife Refuges and other protected areas across North America. This initial effort will allow these draft field protocols to be field-tested and improved prior to implementation of a continental marshbird monitoring program in which the data generated will provide inference to status and trends of continental populations of marshbirds.

Acknowledgments

J. Bart, S. Badzinski, V. Garcia, and C. Kirkpatrick provided helpful comments on earlier drafts of the paper.

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Appendix 1—*Proposed list of marshbirds that would be the focus of a North American marshbird monitoring program, and the most common calls for each species.*

Species	Call
Least Grebe (*Tachybaptus dominicus*)	loud, high-pitched *gamp* (advertising call), *trill* (often paired duet), *nye-nye-nye-nye* (rushing call)
Pied-billed Grebe (*Podilymbus podiceps*)	3-part gurgling song, *quaa-aaa-aaa* (wavering, guttural copulation call), *kwah* (alarm call), *ek-ek-ek* (rapid, staccato greeting call), *tshick-tshick*
Least Bittern	*coo-coo* (male advertisement), *kak-kak-kak*, *gack-gack* (given from nest), *ank-ank* (given when flushed)
American Bittern	*pump-er-lunk* (territorial/advertisement call), *chu-peep* (given during copulation ceremony), *kok-kok-kok* (given when flushed)
Black Rail	*kickee-doo* (primary breeding call), *grr-grr-grr, churt, ticuck*
Yellow Rail	*click-click*, *wheese* (female call), *descending cackle* (pair maintenance), *squeak* (given by retreating bird)
Sora (*Porzana carolina*)	*whinny* (territorial defense and mate contact), *per-weep*, *kee* (may be given to attract mates)
Virginia Rail (*Rallus limicola*)	*grunt* (pair contact, territorial call), *tick-it* (male advertisement call), *kicker* (female advertisement call), *kiu* (sharp, piercing call)
King Rail	*chac-chac* (pair communication), *kik-kik-kik* (mating call)
Clapper Rail (*Rallus longirostris*)	*clatter* (pair contact, territorial call), *kek* (male advertisement call), *kek-burr* (female advertisement call), *kek-hurrah ,hoo, squawk* (chase squeal), *purr*
Common Moorhen (*Gallinula chloropus*)	*cackle* (primary advertising call), *squawk, yelp, cluck*, *purr*
Purple Gallinule (*Porphyrula martinica*)	*cackle* (primary advertising call), *squawk*, *grunt*
American Coot	*pow-ur* (crowing for territorial defense), *puhk-ut* (warning), *puhk-kuh-kuk* (crowing for territorial challenge), *puhlk*, *tack-tack* (cackling), *kerk* (sharp cough)
Limpkin	*krr-oww*

Appendix 2— *Examples of 'secondary' species that would be part of the proposed North American marshbird monitoring program, but participants would not include their calls in the call-broadcast sequence.*

Species
Green Heron (*Butorides virescens*)
Great Blue Heron (*Ardea herodias*)
Glossy Ibis (*Plegadis falcinellus*)
White-faced Ibis (*Plegadis chihi*)
White Ibis (*Eudocimus albus*)
Northern Harrier
Sandhill Crane
Willet (*Catoptrophorus semipalmatus*)
Common Snipe
Forster's Tern
Black Tern
Belted Kingfisher
Alder Flycatcher (*Empidonax alnorum*)
Sedge Wren (*Cistothorus platensis*)
Marsh Wren (*Cistothorus palustris*)
Common Yellowthroat (*Geothylpis trichas*)
Yellow Warbler (*Dendroica petechia*)
Saltmarsh Sharp-tailed Sparrow (*Ammodramus caudacutus*)
Nelson's Sharp-tailed Sparrow (*Ammodramus nelsoni*)
LeConte's Sparrow (*Ammodramus leconteii*)
Swamp Sparrow (*Melospiza georgiana*)
Savannah Sparrow (*Passerculus sandwichensis*)
Seaside Sparrow (*Ammodramus maritimus*)
Red-winged Blackbird (*Agelaius phoeniceus*)
Yellow-headed Blackbird (*Xanthocephalus xanthocephalus*)
Boat-tailed Grackle (*Quiscalus major*)

The Challenges of Standardizing Colonial Waterbird Survey Protocols – What is Working? What is Not?[1]

Melanie Steinkamp,[2] Peter Frederick,[3] Katharine Parsons,[4] Harry Carter,[5] and Mike Parker[6]

Our ability to manage and conserve colonial waterbird species throughout Mexico, Meso-America, Canada, the Caribbean nations, and the United States is presently hampered by a lack of reliable information on the status and trends of their populations, information that can only be obtained by collecting comparable data using standardized data collection techniques that estimate bias. The U.S. Geological Survey, Patuxent Wildlife Research Center is working in concert with the North American Waterbird Monitoring Partnership (Kushlan et al. 2002) to coordinate waterbird monitoring efforts and to develop an agreed-upon set of survey methods that incorporate bias estimation. To determine the practicality of implementing methods that require measures of detection probability and to test the error associated with specific survey methods prior to their adoption as standards, several tests have been conducted the field.

The U.S. Geological Survey and U.S. Fish and Wildlife Service conducted a study to measure the detection probability associated with aerial photographs of colonies of breeding Common Murres (*Uria aalge*) and Brandt's Cormorants (*Phalacrocorax penicillatus)*. Aerial photographs have been used to estimate the number of Common Murres and Brandt's Cormorants along the California coast for many years and the ability to detect birds has been assumed to be within a few percentage points. For Brandt's Cormorants, the use of aerial photographs as a reliable method for estimating numbers was validated, with a mean detection probability (p) of 103.6 percent (95 percent CI, 101.8-105.5 percent) for birds and a mean p of 96.1 percent (95 percent CI, 94.1-98.1 percent) for nests. For Common Murres however, the mean detection probability was only 89.7 percent (95 percent CI, 88.0-91.5 percent). These results suggest the need to implement additional measures to reduce estimation error and to incorporate detection probability into analyses of population trends.

Monomoy National Wildlife Refuge in Massachusetts used a dependent double observer approach to measure the detection probability associated with ground counts of Black-crowned Night Herons (*Nycticorax nycticorax)* and Snowy Egrets (*Egretta tula)* at a breeding colony. The average detection probability measured for Black-crowned Night Herons was 94 percent (95 percent CI and SE of 1.65), validating the use of ground counts to estimate populations on the refuge. The number of Snowy Egret observations was too small to determine detection probabilities.

Observer-related factors also contribute significantly to the reliability of population estimates (Erwin 1982, Verner 1985). Researchers at the University of Florida used a controlled simulation to look at the inter-observer variation and accuracy associated with estimating large numbers of densely aggregated birds in vegetation via aerial surveys and aerial photographic counts. A large model was constructed of plywood and other materials to mimic everglades wetlands as seen from the air by observers during aerial surveys. Rice grains were painted white and were used to represent large white egrets or storks that are easily seen from the air and were distributed in varying densities within the model everglades system. Observers walked around the model and conducted counts at varying altitudes by changing their heights above the model. For aerial surveys, the absolute value of the mean total error for observers was approximately 50 percent; for photographic counts the absolute value of the mean error was approximately 21 percent. These results suggest extreme caution be used when interpreting data collected using aerial surveys to estimate population sizes or trends.

Researchers at the University of Florida also looked at the effects of nesting asynchrony on our ability to estimate numbers using "snapshot" counts. Comparisons were made between snapshot counts and repeated visits to a colony during the breeding cycle. Results showed that very early and late survey dates picked up

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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almost no nests. Furthermore, counts conducted during "peak" periods of activity were poor estimators of the total numbers of nests initiated, sometimes undercounting the total breeding population by greater than 50 percent.

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New Opportunities for Bird Conservation Research[1]

Ellen Paul[1] and Robert J. Cooper[2]

Abstract

It is accepted and acknowledged that effective conservation requires a scientific basis, and it is accepted and acknowledged that scientific research benefits conservation. However, there has been little effort to bring together the resources of the research communities—both academic and government-based—with the conservation planning and implementation programs. Most scientific research is driven by either the investigator's own research interests or, on the government side, by the relatively short-term, relatively local management needs of natural resource managers. Also lacking is a comprehensive system to bring new or existing science to the conservation programs and resource managers. Developing a system to help planners and managers find and apply existing data is a critical need. And finally, there is a need to find funding for each of these components—setting the research agenda, conducting the research, and making it available to planners and managers. This session reviewed several promising opportunities to knit together ornithological research and bird conservation work.

Introduction

In the United States, most ornithological research is conducted with federal funds appropriated by Congress to one of the federal research agencies such as the U.S. Geological Survey (USGS), U.S. Forest Service, and the Smithsonian Institutions, or to the National Science Foundation for competitive grants programs for researchers at universities and other research centers. It is particularly difficult to persuade the government to fund research for non-biomedical biology, or as it might be better described, "the biology of the natural world."

The bird conservation community and the ornithological research community can and should take measures that will help persuade those who control the federal purse strings to provide more funding for ornithological research.

Making better use of existing funding is a critical first step. Despite efforts by Partners in Flight, the National Park Service, and others, there is no cohesive, prioritized bird conservation research agenda at any scale. Efforts to date have resulted in incomplete, duplicative lists using different organizational levels for taxa, geographical and temporal scopes, and information needs.

In 2003, the U.S. Geological Survey was spending about $25 million on bird research—without a cogent, well-thought out program of bird research. As a research agency whose primary mission is to undertake the research needed by the land and natural resource managers in the Department of the Interior—park superintendents, refuge managers, and others who manage hundreds of millions of acres of land in every kind of ecosystem and habitat—the agency stretched these dollars across a very large number of management-oriented research projects that tend to be very localized and short-to-medium term. This research is important, but it doesn't add up to a comprehensive package of research designed to provide a solid underpinning for bird conservation planning, implementation, and evaluation. There aren't enough biologists and research dollars to do enough of either the near-term management research or the long-term, large-scale research that is required to understand biological systems. The dollars are further stretched by the need to provide information transfer and technical assistance to the natural resource managers.

Gaps in our knowledge go unfilled. Ornithologist J. M. Scott (pers. comm.) estimates that of the 800 or so bird species in North America there are fully 100 species about which we have little or no literature, other than a few field notes dating back 80 years. Incredible though that may seem, it was only recently that the breeding habitat of the Marbled Murrelet was discovered. Just a few years ago the migratory pathway of the Blackpoll became known. And after years of trying to limit the cowbird populations in Michigan, biologists learned that Kirtland's Warbler needs young jackpine forest for

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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nesting, and a little fire would go a long way to the recovery of this species.

If for no other reason than that dollars are limited, a rigorous research priority list is critical; that it could make it easier to obtain more federal funding is another compelling reason. Government budget officials within agencies and in the Congress place higher value on programs that are well-designed to meet identified needs and that are coordinated across agencies.

It cannot be said enough: a list is not a list of priorities. The tendency of bird conservation efforts and other conservation planners is to make lists. Everything on the list is a priority of equal weight. Limited funding, however, forces hard choices. Something has to be first, something else has to wait. Criteria for priority-setting would be helpful. For instance, a project that has applications for a wide region might take priority over a very small-scale project. The extent to which the research is needed to design and assess specific bird conservation projects should be considered. Research that meets the needs of the projects implemented by the Joint Ventures or the states (through the North American Waterfowl Conservation Act grants or the State Wildlife Grants, respectively), is another possible consideration for determining priorities.

Data sharing will also increase the value of existing research. While scientists have a legitimate interest in safeguarding the results of their research efforts in order to make use of the data for publications, there should be a means for scientists to make their data publicly available and fully accessible when they choose to do so. The availability of such data could make it possible to identify trends, obtain baseline or historical data, generate or eliminate research questions, and compare results of studies.

Another way to maximize the use of existing funding requires the involvement of the academic research community. These researchers rely primarily on competitive grants from agencies such as the National Science Foundation (NSF). The research is investigator-driven. Researchers can and do submit proposals for research on subjects of interest to them, within fairly-loosely defined categories and priorities established by panels of experts convened by the NSF for this purpose, and by NSF program officers. Some of this research, which tends to be basic in nature, provides exactly the right kind of information for the development and implementation of bird conservation plans. However, the research conducted with NSF funding is not driven by, focused on, or even informed by bird conservation plans. So, for instance, while Partners in Flight is developing conservation plans based on assumptions about viable population sizes and trying to assess outcomes of the plans. However, the plans are developed despite gaps in data on life history and population dynamics, untested assumptions about habitat relationships, and a dearth of understanding of characteristics of source and sink habitats for most species. Meanwhile, NSF-funded biologists are out there doing some of this and some of that.

The will on the part of the academic research community to serve bird conservation exists. The challenge is to find a way to knit together these independent researchers and the bird conservation initiatives at all levels - from the specific projects funded by Joint Ventures to the broad scale development of population objectives.

Even with a list, with clearly-identified priorities, and even with the full involvement of the academic research community, there won't be enough money. This current administration is implementing “performance-based” budgeting. Some of the performance measures are managerial in nature, but what really counts is how the program succeeds in reaching clear and well-reasoned goals. This doesn't mean how many papers were produced or published or how many talks were given in scientific meetings. What budget officials want to know is how the money spent for bird research has helped to reach the goal of conserving bird populations. The stated intent is to reward the programs that do well by giving those programs more money.

There is one more critical ingredient in the recipe for more funding. The administration proposes a budget to Congress and Congress decides how much to actually provide for each agency and program. Conservation organizations and other groups such as the Ornithological Council spend considerable time working to persuade the administration and Congress to provide more funding for all aspects of bird conservation programs, including research. However, the help of the entire bird conservation community is needed. It is important to meet with elected officials, either in Washington or when legislators are in their home districts, to show them what bird conservation is about and to explain why research is such an integral part of conservation. Ornithologists should write to their congressional representatives, explaining what they do, why it is important, and thanking those members for NSF or NRI funding—or wherever their federal funding comes from. Ornithologists should invite their elected officials to visit labs or research sites to show them what the federal research dollars fund and why it matters. Bird conservation organizations should organize bird walks for their elected officials and explain what we need to know and why we need to know it. Nothing is more effective than showing people who control the purse strings why bird conservation is so important and why research is such an integral part of conservation.

The sections that follow summarize talks focused on programs with promise for filling research needs for bird conservation. The first, by Janet Ruth, an ecologist with the U.S. Geological Survey, described an exciting effort to develop a cohesive framework for bird conservation research. The next three look at ways to bring together the research and conservation sectors. Session co-convenor Robert Cooper described an effort to form a research cooperative to integrate research into regional bird conservation work through funding from what was then the hoped-for funding from the Conservation and Reinvestment Act or other sources. Three existing but underappreciated resources—the U.S. Geological Survey Cooperative Research Units, the newer but rapidly-developing Cooperative Ecosystem Studies Units, and the Breeding Bird Biology and Monitoring Database (BBIRD) were described by Ken Williams, Larry Norris, and Penn Lloyd, respectively. The importance of making data available cannot be underestimated. Elizabeth Martin explained how the National Biological Information Infrastructure (NBII) and the Bird Conservation Node of the NBII will meet that need.

Science for Avian Conservation: A USGS Workshop To Identify Research Priorities

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In October 2000, the U.S. Geological Survey (USGS) convened a planning workshop entitled "Science for Avian Conservation: Understanding, Modeling, and Applying Ecological Relationships." Although the effort, one in series of workshops called "Integration and Collaboration for Emerging Biological Issues and Research Goals" was sponsored and organized by the USGS, and was intended to help the USGS define its own role in conducting research to support bird conservation, the larger goal was to assist bird conservation initiatives in defining goals and developing new approaches for research. The workshop participants thus included many scientists from USGS, as well as some from other federal agencies, academia, and non-governmental organizations. The workshop and its outcomes are more fully described in Ruth et al. (2003).

Ornithological research was historically small-scale, species-specific, and not keyed to the needs of conservation and management activities. As bird conservation efforts grew rapidly in the 1980s and 1990s, some researchers and some research programs recognized the need to take an integrative, interdisciplinary approach and to work at larger temporal, spatial, and organizational scales. Nevertheless, a deliberate program of avian conservation research has not developed. As bird conservation has coalesced and reached a level of organization that encompasses all birds in all landscapes—in the form of the North American Bird Conservation Initiative (NABCI)—there is a need to identify an approach to research that provides information to support "the full spectrum of bird conservation through regionally-based, biologically-drive, landscape-oriented partnerships" as U.S. NABCI Committee (2000). The workshop participants were asked to identify science that should be conducted and science approaches that could be used to address this very large and very complex need.

After a series of talks and break-out discussions, the workshop participants concluded that the research needed could be categorized into five priority research areas:

Avian Life History, Populations, and Ecology

Through a mix of project types, we can fill gaps in detailed ecological information for many species. Specific research focuses identified were: the factors affecting population dynamics throughout the annual cycle and across the migratory range of a species; understanding metapopulations; and gaps in our knowledge of life history and distribution, with an emphasis on high-priority species (as defined by the specific initiatives). The role of well-designed monitoring plans, tied to management objectives and conducted at the appropriate geographic scales, was stressed. A consensus developed that monitoring programs have limited use in determining causes of population changes unless the monitoring is linked to research programs. Responses to changes in land management and other changes in habitat also need to be studied.

Habitat and Environment

The effects of habitat quantity, quality, and distribution on bird populations were deemed to be priority research areas. There is a need for monitoring of key environmental factors affecting birds, such as hydrology, climate, habitat, food, and disease agents. Better capabilities for remote sensing and collection of field data are needed. Application of scientific information to guide habitat management is needed and could take place in the context of an adaptive management pro-

gram that relies on models to guide management activities and on monitoring to assess the results.

Integration of Ecological Information

Modeling was considered to be a critical predictive tool that would guide management choices. Population models for priority bird species are needed; research is particularly needed to improve the ability of models to address density-dependent growth, bird-habitat associations at different spatial scales, and situations where estimates of vital rates are not available. Using models that link environmental factors such as water quality or climate to bird population dynamics can also aid in conservation planning and operations.

Bird Conservation Planning

The bird conservation plans were necessarily developed without complete information about and understanding of the reasons for changes in bird populations. Assumptions were made, and these assumptions need to be tested with research. The plans should be revised if research shows that the assumptions are incorrect.

Scientific guidance will be required to integrate the different priorities and goals of the various bird conservation plans (and other species and habitat plans for that matter) into multispecies strategies.

Communication of Ecological Information

Synthesizing and integrating scientific information and making it available to managers and policy makers is important. Better data management, display, and analyses are needed. Ways to link existing data sets, modeling and application tools, and information products are a high priority and should be available to scientists, managers, policy makers, and the public. The systems should be developed in collaboration between the scientist and the users and provide direct linkages from science to management questions.

Adaptive resource management (ARM) was cited as a means for integrating scientific information with conservation and management processes. The process is iterative, linking monitoring and assessment, science-based decision making through models and other information, evaluation of the results of management decisions, and refinement of management through incorporation of the results into refined modeling. These ARM concepts describe the components required for accomplishing the bird conservation goals identified by the North American Bird Conservation Initiative.

Approaches to Cooperative Research on Conservation and Management of Migratory Birds

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Introduction

Although we have made impressive gains in our knowledge of the ecology of migrant landbirds, the state of knowledge regarding effective management practices for these and other nongame species is far from adequate. How do we gain this knowledge as quickly, reliably, and efficiently as possible? In the Southeast United States, we have addressed this question by taking preliminary steps towards establishing a Southeastern Migratory Bird Research Cooperative. The main objective of the Cooperative would be to address priority management questions by selecting and funding large-scale manipulative experiments over multiple study sites (states) using identical methods across sites, and to facilitate the dissemination of results and recommendations to Southeastern land managers. Initially, we hoped that the funding base for the Cooperative would come from the Conservation and Reinvestment Act (CARA). Although CARA has not happened as originally envisioned, the need for cooperative approaches to research on management is still there. This paper describes the original ideas regarding the purpose, structure and activities of the Cooperative, and to briefly describe the cooperative approaches now taking place in the Southeast in the absence of adequate funding for the Cooperative.

Research Priorities

Recently, the Southeastern Working Group of Partners in Flight developed a list of research needs for Southeastern species. While the nature of such a list is hierarchical, with specific needs within more general categories, the priority needs were summarized into the following general categories:

(1) Ascertain the abundance and distribution of priority species and their habitats, and quantify the relationships between those species and their habitats;

(2) Ascertain the effects of alternative management practices, as well as options within types of management, on vital rates of populations of priority species;

(3) Ascertain the compatibility of single species (e.g., game or endangered species) management with management of priority species;

(4) Ascertain the relationships between the vital rates of populations of priority species and landscape features;

(5) Ascertain the most effective ways to restore habitats of priority species; and

(6) Ascertain the extent to which, by meeting habitat needs of priority species, the habitat needs of other nongame species are being met as well.

It is recognized that these needs are pertinent for migrating and wintering populations as well as breeding populations.

In developing this list, a number of questions were raised. For example, if we have all these uncertainties about managing this resource, how do we apply management practices in the face of this uncertainty? Further, how do we monitor the success or failure of our management options? How do we gain the knowledge needed as quickly, reliably, and efficiently as possible? How can we meaningfully compare the results of studies or management actions done in similar habitats but in different parts of the Southeast? And how do we deal with the fact that birds are just a part of the resource we are ultimately charged with managing? It was becoming apparent quickly that a new approach was needed.

Goals and Objectives of the Cooperative

The goal of the Cooperative was to gain knowledge about the ecology and management of Southeastern migratory birds as quickly, reliably, and efficiently as possible using appropriate funding sources. Specific objectives of the Cooperative were: (1) to identify priority research needs involving migratory birds in the Southeast, and specific projects of greatest need; (2) to identify professionals to conduct research to address those needs; (3) to design large scale manipulative experiments involving alternative management options to be conducted at a number of replicate sites throughout the Southeast; (4) to develop standardized procedures for collecting data in those experiments so as to maximize comparability among replicate sites; (5) to report results in a timely manner by publishing a series of land manager's guides and peer-reviewed publications in scientific journals; (6) to enlist the moral and fiscal support and cooperation of each of the southeastern states, identify additional funding sources, and obtain funding; and (7) implement studies developed through the Cooperative.

Structure and Functioning of the Cooperative

First, a Research Oversight Committee was to be formed that would identify major research needs, investigators to meet those needs, and assure accountability for how funding is spent and for high-quality information obtained from that funding. The Committee would be comprised of Partners in Flight coordinators from the 12 cooperating states and representatives from federal agencies, non-government organizations, industry, and academia. Proposals for particular projects would be solicited via a formal call for proposals. The competing proposals would be from different teams of investigators, and would be reviewed by the Committee. We envisioned that each project would be awarded to a lead institution (and a project leader), with collaborating principal investigators from cooperating institutions to be funded via subcontract from the lead institution.

Projects would usually take the form of large-scale manipulative experiments and would feature the characteristics of good experimental design such as replication, controls, and randomization (Hurlbert 1984). Many would feature a before-after, control-intervention design, so that several years of pretreatment data could be collected before the management alternatives (treatments) would be applied, followed by several years of post-treatment data collection. A key feature is that each experiment would be replicated in several locations (i.e., states), which would be treated as blocks in the design. Each site would be a stand-alone experiment, but by replicating the study in several states we would get an estimate of spatial variability of results across sites, and conclusions would be more applicable to the southeast as a whole, instead of to just one or two sites.

Several projects would be active at any particular time, but not every state would be a site for every project. However, this situation is desirable because each state would benefit from the results obtained from every study. In other words, the results would be applicable to the Southeast as a whole, and all partners benefit.

In addition to the experimental design, field methods would be identical across sites, often following standardized protocols such as those for the Breeding Bird Inventory and Research Database (BBIRD), which includes protocols for nest monitoring, point counts, and vegetation sampling (Martin et al. 1997).

The actual Cooperative was to be housed at a location such as a university. All data collected on all projects would be housed in electronic form. By combining data from multiple projects, additional important questions involving migratory bird management could be

addressed. For example, each of the field sites would be located in a habitat patch within a landscape with certain features (patch size and insularity, percentage of different land cover types surrounding the patch, fractal dimension, connectivity, etc.). Therefore, in addition to investigating the specific questions of interest on a number of sites, plus analyzing those data among sites, we often would be able to combine many of the sites from several projects to answer questions at a landscape scale. Furthermore, we could and should be able to direct some effort to answering some questions pertaining to parts of the life cycle of these birds previously overlooked—migrating and wintering ecology. Thus, in several ways the whole of this approach is greater than the sum of the parts.

For the Cooperative to succeed, it must provide results to land managers in a timely fashion so that they can implement desired alternatives. We anticipated that these findings would be published as a series of land managers guides, written at the same level and in the same spirit as *A Land Manager's Guide to Point Counts of Birds in the Southeast*, by Hamel et al. (1996), and targeting a more general audience. Because the work will be scientifically rigorous, cooperators also would be encouraged and expected to publish results in peer-reviewed scientific journals, which would serve to give the program greater prestige and notoriety within the scientific community.

Funding the Cooperative and Some Alternatives

This was obviously a very ambitious and expensive endeavor; we had originally envisioned approaching the states to contribute some of the funds they were to receive from CARA each year as base funding for the Cooperative. These funds would then be used as leverage to obtain additional funds from federal agencies, NGOs, industry, and the like. We presented this idea to the Southeastern state directors of Fish and Wildlife Agencies in 1998 and they unanimously agreed to the concept in principle. However, they made it clear that they did not have that funding available then, and would not unless something like CARA became enacted.

Unfortunately, because CARA was not enacted, the anticipated source of funding for cooperative research on migratory birds in the Southeast has not materialized. Instead, cooperative approaches to investigating management questions involving priority species have been initiated on an opportunistic basis. Three examples of this new, species-based approach are the Painted Bunting Initiative, the Swallow-tailed Kite Initiative, and the Cerulean Warbler Technical Group. The first two involve the lower Atlantic Coast states (Florida, Georgia, and South Carolina) and do not include any manipulative experiments at this time. The objectives of those efforts are to share data, use similar approaches when feasible, and pool resources to find adequate funding. The Cerulean Warbler Cooperative is a new effort that involves most Southeastern states included in the range of the Cerulean Warbler, and features a manipulative experiment in forest management similar to that described above. Efforts will be made to use identical field methods and experimental designs in multiple states to understand more about how to create forest habitat for this species.

The advantages to cooperative approaches such as those outlined above are obvious; reliable information is obtained quickly, efficiently, and rigorously, for a minimal cost. The alternative to cooperative approaches is to proceed as before, letting each state administer its own migratory landbird research and management program rather than participate in a cooperative effort. However, I believe that very little usable information for managing the migratory bird system on regional/landscape scales is likely to be produced if the cooperative approach is not used. Given enough time, we can learn using the old approach, as evidenced by what we have learned about managing game species. However, time is something we do not have. If we are not careful, we may find that what we have learned will allow us to state with certainty why a large number of these species went extinct before we acted.

U.S. Geological Survey Cooperative Research Units

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Introduction

Dating back to 1934, when Jay Norwood "Ding" Darling, served as Chief of the Bureau of the Biological Survey and created the Cooperative Wildlife Research Units, this research program marries federal funding for university faculty at state universities to state funding for research. Darling, as Iowa State Fish and Game Commissioner, started a single cooperative research program at Iowa State College to train wildlife biologists. When, in 1939, the Bureau of the Biological Survey was transferred from the Department of Agriculture to the Department of the Interior, the cooperative research units went along. Managed by the U.S. Fish and Wildlife Service until 1993, when the Department of the Interior biologists were transferred from the management agencies into the National

Biological Survey (later renamed the National Biological Service, and ultimately transferred to the U.S. Geological Survey where it is now known as the Biological Discipline), the units continue as cooperatives among the U.S. Geological Survey, host universities, state natural resource agencies, the Wildlife Management Institute, and the U.S. Fish and Wildlife Service. After more than 40 years of operation, the program was officially born in 1960, when the Cooperative Units Act (16 U.S.C. 753a-753b, 74 Stat. 733), as amended, Public Law 86-686, September 2, 1960, was enacted. The statute authorized the Secretary of the Interior to enter into cooperative agreements with colleges and universities, state fish and game agencies, and nonprofit organizations for the purpose of developing adequate, coordinated, cooperative research and training programs for fish and wildlife resources.

Over the years, the program grew from the initial eight units to 39 Cooperative Research Units (CRUs) in 36 states. Supporting 119 researchers, three field supervisors, and 10 headquarters staff, the CRUs have trained countless graduate students who go on to become natural resource professionals. The training has another purpose, however. The graduate student conduct research needed by the state or federal agencies that provide funding for the research. The Wildlife Management Institute, a private, nonprofit organization, provides some financial support as well as coordination at a national level. The premise of the CRUs is that all cooperating parties contribute resources, all benefit from the leveraging of resources, the cooperators jointly direct CRU activities, and state or federal agencies procure research needed for wildlife management. Research areas covered by the CRUs is wide-ranging. Landscape ecology, biological modeling and analysis, natural resource monitoring, and all manner of wildlife and fisheries investigations, are mainstays. Specific problems such as invasive species and contaminants are also addressed.

Among the many examples of conservation-oriented bird research completed by CRUs in 2002 are projects that used spatially-explicit models to project Bachman's Sparrow (*Aimophila aestivalis*) populations in longleaf pine forests and to determine the effect of fire management regimens on the species' population; developing a means to integrate recapture data into the U.S. Bird Banding Laboratory's bird banding database; and numerous studies of habitat availability for and use by shorebirds and waterbirds.

Perhaps because CRUs are a long-established part of the landscape, they are overlooked as a resource for bird conservation research. However, a quick look at the productivity of the CRUs demonstrates the substantial contribution made by this program: in 2002, the CRUs accounted for 1200 ongoing research projects, 400 publications, 300 technical reports, and 750 presentations. The importance of the CRUs for bird conservation research should be obvious. The CRUs are a proven way for states to procure much-needed research for bird conservation. Should they choose to use State Wildlife Grant funding, for instance, the CRUs are already available to address the research needs identified in state Comprehensive Wildlife Conservation Plans.

The CRUs also provide an important part of the research resource for federal agencies. For instance, in 2002, the CRUs completed 26 projects for the Bureau of Land Management, 57 for the National Park Service, 175 for the U.S. Fish and Wildlife Service, 46 for the U.S. Forest Service, and numerous others for federal agencies and tribes. Private organizations, such as conservation organizations, contracted for another 41 research projects.

The CRUs also provide technical assistance to cooperators. According to the 2002 Cooperative Research Units Annual Report, technical assistance "consists of numerous, diverse tasks ranging from participation on a task force or a recovery team to conducting workshops or symposia to writing newspaper articles." Again, the importance of the CRUs for bird conservation is obvious. Research for bird conservation requires effective application. Resource managers need to call on researchers to participate in processes to address specific management issues. The CRUs make this important work an integral part of the program.

Cooperative Ecosystem Studies Units

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Partnerships are the basis of the recently-developed Cooperative Ecosystem Studies Units (CESUs) which arose from a 1999 interagency agreement to work together to obtain high-quality science for natural resource management in a cost effective way. The basic premise of the CESU program is that meeting the challenges of providing science to manage natural resources requires the skills and capacities of the nation's universities. In a nutshell, the various federal agencies may purchase research from the universities, through a framework of regional cooperatives, each guided by a formal agreement, mission statement, and self-governing structure. Although the concept emanated from discussions between the National Park

Service and the Biological Discipline of the U.S. Geological Survey, the original memorandum of agreement included the Departments of Interior, Agriculture, and Energy. The CESU Network is multi-agency and interdepartmental. Any one or more of the 16 CESUs, biogeographically-organized units that now cover the entire nation, could include the National Aeronautics and Space Administration, the Forest Service, Department of Defense, National Park Service, National Marine Fisheries Service, U.S. Fish and Wildlife Service, Bureau of Land Management, or other federal agencies.

Each CESU is based at a host university that provides space and basic administrative services but other institutions, such as museums or bird observatories, and organizations such as conservation groups may also join these partnerships. Partners can include state agencies, tribes, nonprofit organizations and others. Each CESU is guided by a mission statement that identifies research, technical assistance, education, and other services that it is especially qualified to provide. The CESU network now comprises 120 universities and 34 states, territories, and tribes.

This partnership has obvious benefits to federal research agencies, which gain significant research expertise and other research resources without having to expand their own programs and facilities—something that cannot be achieved with limited federal funding. The universities and their graduate students also benefit because they have increased opportunities for research. Natural resource management agencies, which require more research than the federal research agencies can provide, also benefit because academic researchers receive funding to conduct research of interest to the agency. Managers can procure a wide range of research, from archeology to zoology. Custom-designing research projects also allows agencies to obtain interdisciplinary research, which is often needed for problem-solving.

For individual scientists who want to contribute directly to natural resource management and conservation, the benefit is clear. They now have the opportunity to conduct the research and provide the technical assistance that is needed by natural resource managers. Thus, the CESUs provide opportunities for bird conservation oriented research that should be explored. For instance, a joint venture management board could become a partner of a CESU. State agencies—many already CESU partners—can look to CESUs to help conduct the research needs identified in the Comprehensive Wildlife Conservation Plans that must be submitted to obtain State Wildlife Grants. If the appropriations for the State Wildlife Grants increase, as is hoped, to $350 million per year, there should be a substantial need for research and the states may want to take advantage of the CESUs to purchase some of this research.

The value of the CESUs can be measured partly by the achievements reported at the end of Fiscal Year 2001. After only two full years, with some CESUs still forming and others not yet underway, the CESUs had completed 508 projects totaling $27,038,000 in support funds. Almost half were research projects and 41 percent of the projects involved the biological sciences, while 24 percent were interdisciplinary. The National Park Service was by far the largest funder, purchasing some $19 million worth of research and technical assistance. The Bureau of Land Management followed with $6.3 million in funding. This demonstrated ability to provide the research needed for natural resource conservation and management suggests that the CESUs are a good vehicle for bird conservation research.

Breeding Bird Biology and Monitoring Database

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The Breeding Bird Biology and Monitoring Database (BBIRD), initiated in 1992 and run by the U.S. Geological Survey Cooperative Research Unit at the University of Montana, has the attributes of a model research program for bird conservation. The research addresses a key question for bird conservation: nesting success and habitat requirements of breeding birds. Conservation of bird populations and of biodiversity in general depends on identification and conservation of habitat conditions that support self-sustaining populations of coexisting species. Yet, the necessary breeding biology and habitat information is lacking for most species. BBIRD is comprised of independent investigators from throughout North America who work with, and make their results available to local managers, disseminate results through articles in peer-reviewed journals, and who meet annually to discuss results and issues. With a standardized protocol for data collection and a database that permits data sharing, BBIRD allows examination of large-scale patterns and trends.

Standard protocols for monitoring nesting success and habitat of nongame birds by finding and monitoring nests at replicate plots across North America are available on the BBIRD website at http://pica.wru.umt-.edu/BBIRD/protocol/protocol.htm. Studies at each local site generally include plots within large blocks of relatively unfragmented habitat and plots within an-

other treatment to examine land use issues, such as fragmentation, habitat loss, or silvicultural treatments. Resulting data can allow identification of source (self-sustaining) and sink (non-self-sustaining) populations and the habitat conditions that produce such populations. In addition, local results can be put in the context of larger regional patterns through comparisons of nesting success in different geographic locations. BBIRD also includes point counts to index population size at plots and possible changes across years. Standardized vegetation sampling is conducted at nest sites, non-use plots, and point counts to allow detailed analysis of microhabitat requirements for successful nesting.

By 2002, BBIRD had accumulated more than data on more than 60,000 nests and associated vegetation. Metadata descriptors include nest fate, nest measurement, vegetation and tree measurement, species counts, and weather. These metadata make BBIRD suitable for inclusion in the National Biological Information Infrastructure (see Martin below). Although the NBII Bird Node already includes a link to BBIRD, when the NBII provides the capacity to access and search across multiple databases, BBIRD will provide a very sizeable collection of data critical for bird conservation decisions, such as selection of priority sites for conservation and appropriate habitat management regimens. For instance, BBIRD researchers recently used BBIRD data on Ovenbirds from 15 sites across the United States to determine the relationship between forest fragmentation and nest parasitism, nest predation, and the finite rate of population increase. They demonstrated how the effect of landscape scale from 1km to 100 km affected nesting parameters. BBIRD has also developed a Management Handbook for the U.S. Forest Service to demonstrate the management applications of the scaling approach (see http://pica.wru.umt-.edu/BBIRD/handbook.htm).

Analytical tools to allow land managers to assess data - that can be accessed through a publicly-accessible website have been provided. Recently, BBIRD was linked to the National Biological Information Infrastructure Bird Conservation Node, making it more widely available even to land managers who would not otherwise know of its existence. Other tools that are provided include standard protocols, manuals, and data entry instructions and software.

The Second Generation National Biological Information Infrastructure: Vision and Implementation

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The National Biological Information Infrastructure (NBII) is a broad, collaborative program to provide access to data and information on our nation's biological resources. It is designed as a distributed electronic gateway to biodiversity and ecosystem information maintained by a broad federation of partners including government agencies and private sector institutions, including conservation organizations and museums. Currently, NBII—which can be accessed through the internet at http://www.nbii.gov—consists of a set of links and a metadata clearinghouse that direct the user to potential sources of information on our nation's biological resources. In the 1990s, when NBII was first conceived of and developed by the U.S. Geological Survey's Biological Discipline, the first task was to catalogue existing web resources. The key to a useful catalogue—a metadata standard—was an essential first step. Metadata are "data about data." They are descriptors of the content, quality, condition, and other characteristics of data. Examples include geospatial, temporal, and taxonomic information. The NBII created a biological extension to the existing Federal Geographic Data Committee (FGDC) metadata standard. Training programs in metadata and the biological standards were created and are regularly offered. Using these standards, organizations and individuals can submit metadata about their data to the NBII Metadata Clearinghouse (http://www.nbii.gov/datainfo/metadata-/clearinghouse/submitting.html) or search for data that meet the searcher's information needs.

A critical element of biological metadata is a standard for taxonomic nomenclature and classification. If this is lacking, retrieving biological data can be difficult if not impossible. The NBII staff are leading in the development of taxonomic naming standards for North America through the Integrated Taxonomic Information System (http://www.itis.usda.gov). The goal of ITIS is to create an easily accessible database with reliable information on species names and their hierarchical classification. The database will be reviewed periodically to ensure high quality with valid classifications, revisions, and additions of newly described species. The ITIS includes documented taxonomic information of flora and fauna from both aquatic and terrestrial habitats.

However, a second generation NBII is needed in order to provide to natural resource managers, researches, and policymakers the kind of data, information, and analyses needed for decision-making. Instead of simply retrieving information about existing data, the user would be able to actually access the data. A 1998 report issued by the President's Committee of Advisors on Science and Technology (PCAST) entitled Teaming with Life recommended the development of a Next Generation NBII, saying that, "Potentially useful and critically important information abounds, but it is virtually impossible to use it in practical ways. The sheer quantity and diversity of information require an organizing framework on a national scale." What PCAST envisioned was a fully digital, distributed, and interactive system that would allow users access to the nation's holdings of biological and natural resource data. It would include analytical tools and new information technologies. In short, it would allow users to access and analyze all data available on a given subject, across multiple datasets, wherever located. Through a series of regional and thematic nodes, the information would be stored and made available to a wide range of users. The National Research Council of the National Academies of Science endorsed PCAST's recommendation in 2001. By that time, nodes for bird conservation and fisheries and aquatic resources were online. Regional nodes now online include Central Southwest and Gulf Coast, Northern Rockies, Pacific Basin, Pacific Northwest, and Southwest.

Node products and services include: resource catalogues, on-line searchable databases, interactive mapping applications for population, habitat, and climate data, 3-D visualization applications, citizen science training, and support for regional planning activities. The bird conservation node (http://www.nbii.gov/-about/pubs/factsheet/pdf/birdcons.pdf) is intended to provide access to bird population and habitat data, for use in bird conservation planning. As of late 2003, links to bird census and survey databases such as the Breeding Bird Survey and MAPS, along with information about and links to the various North American bird conservation initiatives, were available.

The ability to share and retrieve data across many decades, across geographical regions, ecosystems and habitat types, and among many sources of information at one time promises to be a significant resource for bird conservation planning and assessment. In only a few years, NBII will likely be a central tool for bird conservation.

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Integrated Bird Conservation Web Site in the United States[1]

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Abstract

In working towards a vision of integrated bird conservation, scientists, conservationists, land managers, and administrators are faced with a variety of scientific, managerial, administrative, and logistical challenges and complexities. The broad scope of integrated bird conservation requires organizations to work together to conserve birds across taxonomic groups, across landscapes, across geopolitical boundaries, and across social, economic, and political groups. This is no small task. While the benefits of achieving such an integrated approach are numerous and far-reaching, the effort requires considerable coordination and communication among numerous individuals at all levels of organizational structure. Communications tools, such as the internet, are key to enhancing the ability of people to coordinate and exchange information and ideas. A partnership of organizations involved in the North American Bird Conservation Initiative (NABCI) developed an integrated bird conservation web site in the United States that is helping to facilitate coordination and collaboration among users. The site contains linkages to all the major bird conservation planning initiatives, and provides information on progress being made in the field towards integrated bird conservation, information on NABCI as a forum for integrated bird conservation, and a variety of state-of-the-art tools and resources. The web address is http://www.nabci-us.org.

Key words: bird conservation, NABCI, North American Bird Conservation Initiative, web site.

Introduction

In working towards a vision of integrated bird conservation, scientists, conservationists, land managers, and administrators are faced with a variety of complex scientific, managerial, political, administrative, and logistical challenges. The broad scope of integrated bird conservation requires that organizations and individuals work together across taxonomic groups, across landscapes, across geopolitical boundaries, and across social, political, and cultural groups. This is no small nor simple task. While the benefits of achieving such an integrated approach are numerous and far-reaching, the effort requires considerable coordination and collaboration among individuals working at the local, state, regional, national, and international levels. In today's world, the internet is rapidly becoming the principal mechanism for sharing information and providing access to documents, especially in efforts where participants are widely spread geographically, such as the various bird conservation initiatives in North America.

The North American Bird Conservation Initiative

During the last two decades of the 20th century, a surge of interest in conserving birds and their habitats spurred the development of several proactive, partnership-based bird conservation initiatives, including the North American Waterfowl Management Plan, Partners in Flight, the United States Shorebird Conservation Plan, and the North American Waterbird Conservation Plan. Each of these initiatives has produced landscape-oriented conservation plans for birds that lay out population goals and habitat objectives. By the end of the century, participants of these initiatives realized that the most effective way to carry out these plans would be to work in partnership by bringing together the resources, both human and financial, to protect and restore the habitats and landscapes North America's diversity of birds depend upon for survival. The North American Bird Conservation Initiative (NABCI) evolved out of this realization of the value of an integrated approach to bird conservation (US NABCI Committee 2000). In this way, NABCI is not a new and separate initiative, but part of the natural evolution of bird conservation in North America.

The vision of NABCI is to see populations and habitats of North America's birds protected, restored, and enhanced through coordinated efforts at international, national, regional, state, and local levels, guided by

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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sound science and effective management. To realize this vision, NABCI participants are working toward the goal of delivering comprehensive bird conservation through a network of regionally based, biologically driven, landscape-oriented partnerships (US NABCI Committee 2000).

The creation of an effective delivery system for integrated bird conservation entails building upon the dynamic partnerships of Joint Ventures and the biological foundation of Bird Conservation Regions (BCR) to avoid redundant partnership structures and separate biological planning processes. The key to realizing such a delivery system lies in assuring that a communications network exists among individuals and organizations working within particular geographic areas at various scales (Ford 2000). The internet provides a means of fostering communications and coordination by enabling web users to share information efficiently and interact with it in novel ways that have no precedents in paper document design (Lynch and Horton 1999).

The United States Integrated Bird Conservation Web Site

A team of organizations participating in NABCI developed a web site in the United States that is facilitating coordination and collaboration among people working towards a vision of integrated bird conservation. Concurrently, an international communications team developed an international site to foster coordination among bird conservationists in the United States, Canada, and Mexico. The international NABCI web site (see http://www.nabci.org) provides access to information of interest to the three countries and functions as a portal to each of the national sites, including the United States integrated bird conservation web site that is the topic of this paper. The short-term objectives of the United States web site (http://www.nabci-us.org) are to 1) provide basic information on integrated bird conservation and NABCI's role as a forum for integrated bird conservation, 2) enable users to link up to individual bird conservation initiative web sites which contain bird conservation plans and species assessment work, and 3) make available a variety of tools and resources that help foster an integrated approach.

The site is divided into four main sections that function as navigational aids: Vision, Partnerships and Plans, Tools and Resources, and News and Events. Under Vision, one section provides information on NABCI, including the United States NABCI Action Plan, access to outreach and other documents, and lists of Committee and Working Group members and meeting minutes. Vision also includes a "Stories from the Field" section which presents information about progress being made by partners in each BCR toward coordinating and integrating conservation activities. The pathways to integrated bird conservation are diverse and unique to the ecological, geopolitical, and cultural settings within each BCR. However, by sharing stories and information, partners can help one another face hurdles that may seem insurmountable and gain a greater sense of possibility.

The Partnerships and Plans section provides links to the major bird conservation initiatives and their plans, to Joint Venture and BCR staff contact information, and to a host of conservation organizations in the United States. The Tools and Resources section provides state-of-the-art web-based information, including an easy-to-browse Bird Conservation Regions map hyper-linked to descriptions of habitats and species of interest in each BCR. It also includes a link to the National Biological Information Infrastructure (NBII) Bird Conservation Node, sponsored by the U.S. Geological Survey and U.S. Fish and Wildlife Service. NBII is an electronic information network that provides access to biological data and information on our nation's plants, animals, ecosystems, and conservation resources. In the future, this section will link to a directory of funding sources for bird conservation work.

The News and Events section contains information on upcoming conferences, workshops, meetings, and other events, as well as news briefs about noteworthy developments in integrated bird conservation.

The long-term objective of the site is to allow users to stay up-to-date on progress being made in the field of integrated bird conservation by expanding ecoregional information provided on the hyper-linked BCR map to include a host of species, management, policy, and contact information that will help users to define their role in conserving birds on landscapes within their region. Toward this end, if desired by users, the site may also incorporate advanced interactive discussion boards and chat rooms to facilitate communications among users on specific topics. Discussion boards could help users find information or share experiences that might help others facing similar challenges.

Acknowledgments

Special thanks goes to the US Geological Survey and the National Biological Information Infrastructure for hosting the web site and providing funds for initial web site development, to S. Chambers of AtomicWeb, Inc., for creating the site's splash page and navigation structure based on the authors' guidance, to M. Zavori for technical assistance, to B. Battle graphics assistance,

and to D. J. Case and W. S. Schwenk for insightful recommendations on the site's content and structure. Thanks to many partners for offering helpful edits and suggestions for developing the site.

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National Audubon Society's Technology Initiatives for Bird Conservation: A Summary of Application Development for the Christmas Bird Count[1]

Kathy Dale[2]

Abstract

Since 1998, Audubon's Christmas Bird Count (CBC) has been supported by an Internet-based data entry application that was initially designed to accommodate the traditional paper-based methods of this long-running bird monitoring program. The first efforts to computerize the data and the entry procedures have informed a planned strategy to revise the current technology tools supporting the needs of the CBC. A tightly integrated life-cycle development path, outlined within, has now been employed to revise the CBC application. This document will give a brief overview of this process.

Introduction

Bird conservation efforts have gone through several shifts in strategy over the past 30 years – from a purely regulatory approach to conservation to a grassroots one. In the late 1990's the National Audubon Society and the Cornell Laboratory of Ornithology decided to make use of developing technical opportunities to gather data to better inform bird conservation efforts locally, regionally and nationally, to leverage public interest and participation in birding, and make the results of bird monitoring efforts more available to the public (Fitzpatrick and Gill, 2002).

The National Audubon Society and the Cornell Laboratory of Ornithology implemented one of the first publicly available citizen science websites dedicated to bird conservation information and Internet-based monitoring tools in 1997 through the creation of BirdSource (http://www.birdsource.org). The development of a data entry application for compilers and regional editors of the Christmas Bird Count (CBC), the longest running bird monitoring project in existence, was an early, and the largest, interactive data entry project available online through this portal. Efforts to get this valuable dataset into a centralized database were an important first step to setting the stage for future Internet-based data collecting initiatives. The CBC data had been partially computerized, having benefited from work done by the USGS Patuxent Wildlife Research Center's efforts at computerizing data subsets for efficient analysis and earlier work done at the Cornell Laboratory of Ornithology and at the University of Colorado in Boulder. Audubon then contracted to have the remaining data put into the database. Currently there are 104 years of data in a centralized database available for efficient regional or sub-continental analysis of early winter North American bird population trends (http://www.audubon.org/bird/cbc).

Discussion: The First Generation CBC Application

The first generation of the CBC online data entry application was coded in JavaScript and presented data entry screens for CBC compilers that were based on the original paper forms developed by compilers and used for recording field data before the CBC data was computerized. The intention was that the traditional paper forms be mimicked on the screen so that minimal adjustment had to be made to the data entry procedures. The user interface screen design led compilers, via a central forms selection page, through the required entry on each screen form: compiler information, participant list, weather information, effort information, checklist of birds, and rare bird information. The checklist of species presented for each CBC count circle was customized to that circle, displaying a list of species based on the previous 25 years of species seen in that location (a CBC count circle is 15 miles in diameter and is fixed around a latitude and longitude). Initially these customized checklists were dynamically generated, but there was a delay in processing behind the scenes before sending the resulting species list back to the user's browser, which presented too much waiting time as most users had the limited bandwidth of a dial-up internet connection. The decision was made to pre-generate the checklists prior to user access and then store the checklists in a library of files, from which it

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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could be accessed on demand at the time of data entry. The required flow of data entry was not obvious to users, and mandatory elements were not indicated on the screen until after an attempt to submit information. Once compilers were finished with circle data entry, the checklist for each circle was then made available to the corresponding regional editors so that they could perform their authorization process to the numbers entered by tagging rare or unusual species with editorial codes.

The project administrator used a central administrative tool that allowed circle setup in the database, circle login and password administration, follow-up on data entry status of all circles, and centralized reporting. This administration tool was envisioned to be a virtual complete database management tool for the project administrator, with little support required from technical personnel. But after several years of use, the project manger found the tool did not allow the flexibility needed to query the database beyond the predefined reports provided for the most frequently asked questions. This tool also required several manual processes to create new circles, permit access to the circle data entry, and to check the status of data entry.

In this first generation of the CBC application, some tabular output reports for access by the general public were created, including the ability to view checklists within each circle, the number of circles submitted for each year in each state, list of circles where each species was seen sorted highest to lowest, and a report indicating which years specific count circles were active. These first reports (e.g. with highest counts listed first) addressed some of the "competitive birders games" traditions of the CBC. Data could be requested and obtained from the central database, but much analysis was still being done through use of paper-based data, such as data published in American Birds. Users could not, at that time, download data at will for offline analysis. Compilers, editors and researchers requested more access to the data, one of the original intents of the project; and at the end of the first generation, additional data output capability, including graphs and maps, and interactive download capability, were implemented.

None of the project administrative tasks, such as receipt of fees and forms, creation of mailings, and tracking of data entry status, were implemented into the first CBC application, and collection and management of participant names by compilers continued to be a manual process.

Due to time constraints and the experimental nature of moving the CBC data entry application onto the Internet, a centralized development methodology for the applications was followed, allowing little opportunity for user input during this first effort. The lack of a feedback mechanism created obstacles to adoption of this first CBC application by compilers and regional editors. In addition, the strategy of intentionally developing input screens to mimic paper forms revealed some shortcomings that produced a cumbersome user experience.

The efforts of BirdSource staff to develop and implement this Internet-based initiative for the CBC were intensive, valuable, and informative. Virtually all of the other Internet-based projects that have been developed under the BirdSource partnership and Cornell and Audubon individually have been informed by the lessons learned through this process. Audubon now is in the process of applying a new generation of programming languages to the Christmas Bird Count Internet-based experience as well as addressing CBC workflow processes in a comprehensive manner and has determined the following guidelines to be important as we work on this important task.

Discussion: The Second Generation CBC Application

In 1997 home computers and Internet access were not as widely used, web-based application development was expensive, and web-based computing not widely adopted by the public. Now that we have better tools and more widespread Internet access, a more integrated CBC system can become part of the compiler, editor and participant's routine computing experience.

Taking a manual process and moving it to an automated environment requires the evaluation of the business processes around the project itself. There are many reasons for this. With the movement to automated methods of conducting business, processes should be assessed as to their true value; how many paper forms should be mailed and returned by mail versus just accessing online? Processes should be optimized for adoption within a technical platform; the checklist that compilers fill out must be displayed in smaller amounts on the computer screen because it is hard to see small print on a computer screen, whereas on paper, all species can fit on one page. In addition, because there are over 1600 users of the data entry system annually, the communication dynamic and workflow among the stakeholders changes along with adoption of the automated environment. These must be considered when designing the system so that interaction amongst users and those supporting them is kept efficient. While no CBC processes were determined to be expendable, in fact it was determined that not all processes should be automated. One example of a process best left as a manual one was the submission of

rare bird reports. A rare bird report, containing detailed notes, is submitted to the count compiler by the participant who views the bird first-hand. It is important that the regional editor reviewing this sighting see the original paper form with notes, rather than see a transcribed computer form submitted by a third party (the compiler or designated data entry person).

Audubon plans to follow a model of application development that will consider the needs of all of the CBC "roles" – the compilers, editors, participants, support personnel, and project administrator – to create a CBC community. To achieve this, the CBC application will provide an online interface to the database customized for each role; compilers, participants, regional editors, project administrator, associate project administrators, and support personnel. Participants will be able to register for a CBC online, search for, find and contact their compiler online, find resources about their count (dates, checklists, regional editor contact information), and receive updates on the upcoming CBC season. Previously, record keeping on participants was kept offline and decentralized, so beyond the boundaries of one circle we had little knowledge of the true numbers of participants. When the ability for participants to register online is completed the CBC community will finally better understand the number of total participants, repeat participants, those who count on more than one CBC, and those receiving American Birds (a publication of the summary results of each CBC, American Birds, is now distributed to all registered, paying, U.S. participants of the CBC).

Access to the new CBC application will be similar to any accounting or financial database. Each person using this system will be assigned a virtual "role" that will determine what they see on the screen; a compiler will have be able to enter, edit and see data corresponding to their circle(s), regional editors will be able to see and edit data corresponding to their regions (one or more states), a participant sees information about circles in which they have been involved or circles in which they want to become involved in the future (as well as compiler contact information and dates of counts). The project administrator has the flexibility to flag each person in one or more roles, at will, without having to separately maintain individual login or password information. The project administrator will also have the flexibility to assign "associate administrator" roles so that as more CBCs are conducted, project support can be distributed across many people (*fig. 1*)

Back office (support) tasks will be accessed through this application so that compiler contact information, forms and money submission, and entry progress can be monitored using the same centralized dataset.

This new application will maximize effective support strategies through improved online help, implement an intuitive design, make use of bulk email distribution capability for year-round consistent communication, and encourage an online CBC community of shared information by providing many ways to be involved.

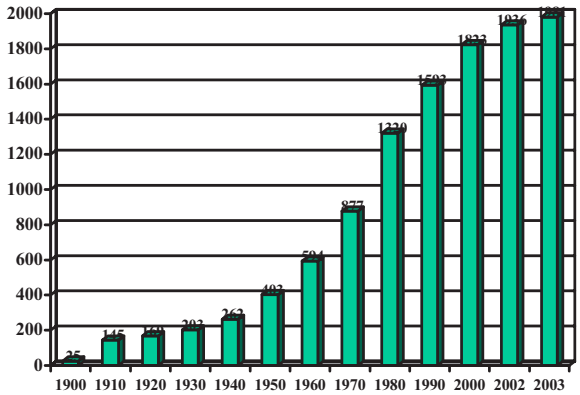

Figure 1— Number of Christmas Bird Counts 1990-2003. The number of circles conducting counts has dramatically increased in the first 103 years of the CBC. Implementing an efficient technology strategy for Compilers, Editors and support personnel to maintain the CBC is critical due to the sheer growth in numbers of circles. Since December 1998 all circle data has been entered online during the count season.

Methods: Development and Planning

Audubon will proceed to develop this CBC application using current technology planning methods based in professional software development practices. A successful Internet application can benefit from full life-cycle development processes listed below as well as project management methods designed to contain and monitor the timeline toward achievement of the project goals. Because the CBC program happens consistently during a specific "Count Period" each year, we have a well-defined timeline within which we must achieve the completed project.

The software development life cycle being employed for this application consists of the following stages:

1) Project planning, determining staff allocation and general timeframe, as well as defining project goals,

2) Definition of the application requirements, details on the features and functionality of the application and translating the CBC "business procedures" into the application, e.g. defining what types of data to record, reporting requirements, and formulas such as what constitutes a "species" in the world of the CBC,

3) Creation of the application design, such as how the screens will look and the navigation of how a users move through the application to reach the various parts,

4) Development of the application, the actual programming of the computer instructions,

5) Integration of application pieces and testing phases (two rounds, which are iterative), the second testing phase involving a group of the users,

6) Implementation and unveiling of application to the user community or the general public. A timeline is assigned to each stage based on the system specifications and complexity of features.

During all phases a careful project management focus will be used to achieve goals in an orderly and integrated process and to minimize the addition of additional, but unnecessary, functions that would delay the project timeline and waste precious staff time. Integrated into these steps is a frequently used strategy, known as Rapid Application Development (RAD), that is iterative and incorporates user feedback (in this case the various testers of the system; compilers and others) from tests of a live application prototype during the development phase. This will result in a rapid regeneration of the application and changes to user interface based on this feedback, for immediate tester rechecking and ultimately for an improved user experience. This RAD process will be tightly managed so that changes implemented adhere to the project goals.

Most importantly, a common goal among professional programmers, code will be written in a manner flexible enough so that it may be reused in other Audubon Science projects in the future. The code developed for the CBC application can apply to other similar monitoring programs within Audubon, such as bird monitoring projects on Important Bird Areas and at Audubon Centers and Sanctuaries. Examples of data these projects would have in common are names and addresses of people associated with the project, along with their assigned roles (editor, administrator, participant project manager), species lists and associated attributes such as sort order, political and geographic region, numbers of birds seen with associated date, time and location values, and weather information. In addition, the common processes that applications for these projects would use include the security system (login and access to data), data entry (ability to create, edit or delete data), reporting, data verification and scientific editing by bird specialists, and project administration tools for the person responsible for assigning roles and handling full access into all tables in the database. It is easy to see how project similarities mean that code can be efficiently re-purposed.

The history of the CBC is rich with the collective experience of tens of thousands of participants, compilers, regional editors and others, who have created a valuable resource for informing bird conservation. The ultimate goal of those involved in the CBC application development process will be to preserve this important value while adding flexible capability to store, track and query a bird population dataset valuable for conservation.

Acknowledgments

I thank F. B. Gill, G. S. LeBaron, and G. Butcher for their review of earlier drafts of this paper. I also thank the information technology staff members of Audubon and BirdSource for their intensive efforts on behalf of the CBC.

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Integrating the Distributed Data Resources of the Bird Monitoring Community Using Information Technology Strategies[1]

Steve Kelling[2] and Craig Stewart[3]

Summary

An increasing number of bird monitoring projects are assembling massive quantities of data into numerous decentralized and locally administered storage systems. These data sources have enormous significance to a wide range of disciplines, but knowing that they exist and gaining access to them is difficult if not impossible. Attempts are being made to organize these data sources into a unified data resource, with the biggest challenge being to develop an infrastructure that facilitates data integration without compromising local control, and maintaining, when appropriate, the privacy of the data. Broadband networks provide a means to make this data available, and advances in hardware and software applications provide tools to organize and supply access to these data sets. This paper attempts to identify the key issues in organizing the contents of the bird monitoring data sets, and to discuss the technologies and solutions to overcome them.

Identifying the Problem

A major theme at the Third International Partners in Flight Conference, *A Workshop on Bird Conservation Implementation and Integration*, held 20-24 March 2002, was how to provide ways that encourage partnerships among various levels of government and non-government organizations interested in bird conservation. Beginning with a keynote address by David Brackett (this volume), Director General of the Canadian Wildlife Service, the Internet and Information Technologies (IT) were identified as playing key roles in providing the tools for integrated bird conservation. Developing an IT strategy that supplies the necessary infrastructure to unify the thousands of bird monitoring projects into a useable organization for eco-regional planning, to make biological assessments for bird conservation, and to provide a means for cooperative research and education is now a goal that can be achieved.

But there are challenges. Bird monitoring data are widely distributed across an unorganized array of data structures, many of which are poorly maintained, and have limited access. First, as time progresses there is a risk of losing valuable, even unknown, data unless the bird monitoring community comes together with a common goal of preserving and making this data available. Second, while it is imperative to organize these resources into a federated system that provides access to the data, the system must not compromise local control, and must ensure the necessary privacy of sensitive data. Finally, and most importantly, a complete terminology has not been defined that describes the basic attributes associated with bird monitoring data. Categorizing the various survey methods (i.e. various point count methodologies, migration monitoring studies, banding stations protocols) into useable entities, which can be integrated through a variety of analytical tools, is essential.

Based on these challenges, several goals can be established. The first and foremost is to preserve and expand the bird monitoring dataset. Second, it is to make the information more accessible to people (including educators, policy makers, land managers, conservationists, and researchers). Finally, it is to integrate the bird monitoring dataset seamlessly with other online resources for use in multidisciplinary activities. The result will be that the contribution of the many monitoring projects to a larger network will create the "authoritative" source of information on birds and their environments.

Internet Technology Solution

There are Internet solutions to the challenges of organizing distributed and disparate data sets, but many of these are seriously flawed for the following reasons:

- There is only a very rudimentary "lingua franca," or common language, used by the numerous bird monitoring organizations for sharing information.

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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- There is no meta-catalog for organizing and accessing the bird monitoring information.
- There are only limited physical means to exchange and intermix data across disparate data formats and access policies.
- There are no means to determine the accuracy or authoritative nature of the bird data held within the distributed datasets.

Recent advances in several information technology sectors have successfully organized distributed data resources for collaborative computing. What follows is a brief overview of each of these advances, and how they can be integrated into a functional application to allow the bird monitoring community to organize access to their distributed data resources.

Data Grids

Advances in two distinct IT sectors provide the foundation for collaborative computing and information sharing at a global level. First, the ubiquitous availability of broadband networks such as the commodity Internet and Internet 2 provide the connectivity necessary to share information at a global level. Second, progress in distributed computing technologies, which have been available but on a smaller scale for many years, provide a means for collaborative computing across an integrated data environment. Combining broadband networks with distributed computing technologies has led to data grid computing strategies. These are based on a software infrastructure (eXtensible Markup Language (XML) requests bundled within Simple Object Access Protocols (SOAP) that link multiple computational resources via broadband networks. Data Grids provide solutions for decentralized projects that require a high level of computing, with data widely distributed across a network of users and resources. For distributed data collections, such as those for bird monitoring applications, the data grid model provides a single point of access for referencing data stored on multiple storage systems. The result is that from a single location, such as a web URL, all information stored within the data grid becomes available.

Metadata

The development of a metadata (information about data) standard for the bird monitoring community is central to making any vision of organizing the disparate bird data sources into a reality. In order to provide grid access to these distributed data resources common descriptors must be developed that associates the basic attributes of the disparate sources. By creating a relevant metadata schema the bird monitoring community will create a standard mechanism that describes the content, characteristics, condition and other qualities of the data. Creating this schema is not a trivial task, and is where the IT technologists interface with the bird monitoring experts.

The relationship between the metadata, and the data sources the metadata describe, supplies access points to data sources with similar content, even though the structure of the sources may be different. The most developed metadata standard is Dublin core (http://dublincore.org/). Developed by the Dublin Core Metadata Initiative, which promotes the adoption of interoperable metadata standards, Dublin core provides a common description for many basic attributes associated with publishing. It will be necessary for the Bird monitoring community to develop a specialized metadata vocabulary for describing its resources to enable more intelligent information discovery systems. Some progress has been made in this direction. For example, the Darwin core (http://speciesanalyst.net/docs/dwc/), developed by the University of Kansas Natural History Museum, describes the minimum set of attributes for search and retrieval of natural history collections and observation databases.

Data Handling and Resource Sharing

Middleware services are sets of distributed software that connect separate applications across the Internet and make resource sharing transparent. They act as the "glue" that integrates and organizes a network of servers, each brokering a specific set of data resources, into a single logical collection. Users can connect to any server in the network, and have full access to any data resource on it.

There are several client/server based middleware applications potentially useful for the bird monitoring community. These applications function within a federated server system in which each server manages a set of storage resources, and all servers respond to requests emanating from any of the servers on the network.

Species Analyst (http://tsadev.speciesanalyst.net), developed by the University of Kansas Natural History Museum, is a client/server application based on Microsoft Windows technology and uses a version of the Z39.50 server protocol developed by the Library of Congress. Its primary function is to search and retrieve information from distributed databases as if they were one. Species Analyst functions similar to any web server in that it listens to TCP/IP traffic. When a networked client makes a request, the Z39.50 server generates an SQL query to the database it supports, and obtains the requested information. The second genera-

tion of Species Analyst, DigiR, is currently under development. DiGiR (http://digir.sourceforge.net) obviates the need for a Z39.50 server by supporting web services using XML and SOAP. Species Analyst can support connections to a variety of database management systems such as Microsoft SQL Server, Oracle, Informix, Access, Paradox, DBase, FoxPro, Excel and even Text files.

Storage Resource Broker (SRB) (http://www.npaci.edu/dice/srb/), developed at the San Diego Supercomputer facility, is an across-platform application that provides a uniform interface across heterogeneous data resources. Users are provided with a set of operations to create, maintain, view, and search metadata objects within SRB. These metadata objects are organized in a meta-information cataloging system (MCAT) that can manage a large number and types of data sets of unlimited size. MCAT manages the attributes of all the collections within the grid's domain through a hierarchical metadata structure. When a request is made in SRB it is first routed to MCAT where the attributes of the requested information are determined. A query generator then embeds within an XML statement the appropriate query schema, relationships, and semantics and sends this to the correct SRB server. For example, if the requested information were stored in a database MCAT would generate an SQL query, but if the information were stored within a Unix file system then a Unix file system-specific query would be generated. Finally, a 'ticketing' system allows providers to designate which data can be made public and which data, e.g. on sensitive species, should be provided only to authorized users. Active development is underway to ensure that SRB has the appropriate application programmer's interface for as many different types of data handling processes as possible. SRB can access data in a variety of formats, held on many different file systems (Mac, Unix, Windows NT), platforms (disk or tape), and in varying formats (databases, text files, ADSM, object files).

Information Discovery and Presentation

Once the bird monitoring metadata attributes have been created, and a meta-catalog established, then the bird monitoring community can use data grid and resource sharing technologies to provide access to their data. Access to this information will provide a tremendous resource to assist educators, policy makers, land managers, conservationists, and researchers for ecoregional planning, and to make biological assessments for bird conservation. But simply providing access to the data is only the first step. Using the digital library approaches for information discovery and presentation, the bird monitoring data can be assimilated into a much broader set of data resources, which could provide meaningful visualizations, analysis packages, and other services. For example these applications could provide authentication and security for the collections, provide an organized data structure with easy navigation, provide tools for data analysis and visualization, and are made to be scalable to handle datasets of any number or any size.

What follows are several case studies that describe approaches which assimilate disparate data resources into meaningful representations. Once the technical considerations mentioned above are achieved, then the following is only a glimpse of what we firmly expect to be possible.

The Miistakis Institute (http://www.rockies.ca/) has developed a conservation planning portal focusing on the birds of the Northern Rocky Mountains. This portal, which is part of the Yellowstone to Yukon Conservation Initiative, allows conservation planners to access bird data from a distributed set of databases using the Species Analyst middleware application (http://www.rockies.ca/birds). These data are then superimposed on numerous GIS coverages and presented via the Internet on interactive maps using ESRI mapping products.

The Hayden Planetarium (http://www.haydenplanetarium.org/) at the American Museum of Natural History (AMNH) wanted to present a visualization of star and emission nebula evolution. To accomplish this involved integrating data resources, computational power, and manpower from three sites (AMNH, the National Center of Supercomputing Applications in Urbana Ill, and the San Diego Supercomputer Center). Using two supercomputers, over 1100 processors, and a total of 7 terabytes of data in 30,000 data files were used to render over 116,000 images. The final result was a 3.2-minute presentation showing the evolution of a star that can be viewed at the Hayden Planetarium. The three sites were networked via Internet 2, and all of the data was managed with Storage Resource Broker middleware (http://access.ncsa.uiuc.edu/Releases/02Releases/03.07.02_San_Diego_.html).

The Cornell Lab of Ornithology (http://birds.cornell.edu) has developed interactive mapping tools which access mapping information from distributed resources. For example, eBird (http://www.ebird.org/beta/MyEBird), a joint project with Audubon, integrates aerial photographs and topographic maps from Microsoft's TerraServer (http://terraserver.microsoft.com) with information stored in databases at Cornell, to assist participants in pinpointing the locations where they have made bird observations. Both web services and application programmer interfaces are provided to

allow access to the images and data stored within the TerraServer database.

Conclusion

The technology is now available to interconnect all of the bird monitoring data assets through a single accession point while still providing local control of the individual data resources. Using data grid strategies, information access over a widely distributed network of resources and users in the bird monitoring community can be accomplished.

An essential ingredient to make this successful is a metadata information-tagging schema that provides the common protocol that links all of the disparate information sources. While some progress has been made in developing this metadata schema, simply extending the Dublin Core metadata structure is not sufficient. It is recommended that a concerted effort by both biologists interested in monitoring issues, and technologists who understand digital libraries and their technology be made. For example, there are almost as many bird count protocols as there are data resources. Developing a hierarchical metadata structure that allows a stepped integration of data from these count types is necessary.

Most, but not all, of the bird monitoring data is stored "electronically." But this data is stored in a variety of formats; some in databases, some as text or html files, others as rich media (images and video), and some of this data may be unreliable or erroneous. Providing access to this information with the appropriate considerations of data security and reliability is of paramount importance. With an ever-increasing variety of bird monitoring information available it is essential to expand beyond database queries the middleware applications used in the bird monitoring network data grid scheme.

Once the underlying architecture of interlinked data resources is achieved, emphasis can shift to expanding the digital library services available. These services can present the data in meaningful visualizations, and analysis packages for bird conservation, research, and education. Access management strategies can be implemented to ensure that access to sensitive information is restricted. Analytical nodes that use all of the grid's data resources can provide tools that enable users to understand the trends and dynamics of bird populations. Comprehensive educational pages that integrate the analytical results for a particular species with videos, sounds, maps could be developed. Finally, collaborative computing projects that use the expertise of several partners can use the large volume of data available on the grid, to generate visualizations and analysis for research, education, and bird conservation.

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A Summary and Comparison of Bird Mortality from Anthropogenic Causes with an Emphasis on Collisions[1]

Wallace P. Erickson,[2,3] Gregory D. Johnson,[2] and David P. Young Jr.[2]

Abstract

We estimate that from 500 million to possibly over 1 billion birds are killed annually in the United States due to anthropogenic sources including collisions with human-made structures such as vehicles, buildings and windows, power lines, communication towers, and wind turbines; electrocutions; oil spills and other contaminants; pesticides; cat predation; and commercial fishing by-catch. Many of the deaths from these sources would be considered unlawful take under federal laws such as the Endangered Species Act, Migratory Bird Treaty Act, and the Bald and Golden Eagle Protection Act. In this paper, we summarize this literature and provide the basis for the mortality projections for many of the apparent significant sources. Most of the mortality projections are based on small sample sizes, and on studies typically lacking adjustments for scavenging and searcher efficiency biases. Although the estimates for each source often range by an order of magnitude, the cumulative mortality from all these sources continues to be a concern.

Key Words: avian mortality, avian fatalities, collisions, communication towers, contaminants, electrocutions, fishing by-catch, power lines, vehicles, wind turbines.

Introduction

All taxonomic groups of birds are subjected to significant human-caused mortality. Most of the anthropogenic-caused bird mortality would be considered unlawful take under the Migratory Bird Treaty Act, Endangered Species Act, and Bald and Golden Eagle Protection Act. The recently well-publicized prosecution of a utility for Golden Eagle (*Aquila chrysaetos*) electrocutions in Colorado by the United States Fish and Wildlife Service has increased the awareness of these issues (Manville this volume a). Collisions with artificial structures are a significant and well-documented source of bird mortality. Bird collisions with artificial structures and associated fatalities have been documented in the United States (US) since the late 1880s (Crawford and Engstrom 2000). A large amount of published and unpublished literature exists on avian collisions with artificial structures and vehicles. Bird mortality associated with pesticides, oil spills, oil pools, and other contaminant sources have also received significant attention. Domestic and feral cats have also been considered a major source of anthropogenic-caused mortality with estimates near 100 million annual bird deaths. However, calculating accurate numbers of bird fatalities associated with any of these sources is difficult due to limitations in the scope of most mortality studies, as compared to the extensive distribution and extent of these sources. Some individual studies have been well designed to obtain accurate fatality estimates for the particular structure(s) investigated (e.g., Kemper 1996, Johnson et al. 2002); however, most studies that are available for making these estimates lack standardized methods for searching, and often do not consider sources of bias, such as scavenging and searcher efficiency.

Many of the studies are limited to documenting avian collisions at a particular season or location. For example, many of the studies are limited to fall migration periods. Furthermore, many of the studies were conducted in response to suspected or actual large mortality events, and focus on areas where the number of fatalities may be unusually high. For example, many power line studies involved monitoring fatalities associated with lines near wetlands with high waterfowl use. In many cases, fatality estimates derived from data reported in the available literature would most likely be an over-estimate of the true mortality. Estimating the annual fatality rate for any of these sources requires a random or at least representative sample of experimental units (e.g., buildings, communication towers, miles of road, number of agricultural fields) with information replicated across time, but due to obvious logistical and financial constraints, a large representative sample of experimental units for each source has not been studied.

We did not attempt to develop our own estimates of avian mortality from sources other than wind turbines

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California**.

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due to the lack of standardized information. We feel that the available data cannot be used to make projections based on averages of individual estimates. Instead, we have updated previous estimates provided in the literature based on increases in the number (e.g., buildings) or extent of collision sources. Although the many difficulties in making fatality projections is widely recognized, the shear magnitude of these projections should continue to bring an awareness and concern to anthropogenic-caused bird mortality.

Sources of Biases in Estimating Fatality Rates

Determining the extent of wildlife mortality due to environmental perturbations such as oil spills or due to collisions with structures such as power lines, buildings, communication towers, or wind plants is a difficult sampling and estimation problem (Erickson et al. 2000a, 2001). Biases associated with observer detection and scavenging rates can lead to biased mortality estimates (Morrison 2002). Observers conducting searches for carcasses often may not detect some of the carcasses for various reasons including dense vegetative cover, size of carcass and cryptic coloration of the carcasses. During fatality studies at the Buffalo Ridge wind plant in southwest Minnesota, the proportion of carcasses detected by observers, (i.e., searcher efficiency rates) for small birds (e.g., most passerines) was estimated at 30 percent when averaged across several habitat types (e.g., plowed field, corn, wetland, CRP/grassland) and across spring, summer and fall seasons (Johnson et al. 2002). In contrast, searcher efficiency rates for small birds at the Foote Creek Rim wind plant, Wyoming in short grass prairie habitat was 57 percent (Young et al. 2003). Searcher efficiency rates for large birds (e.g., waterfowl and raptors) were 49 percent on average at Buffalo Ridge, but over 90 percent at Foote Creek Rim. Similar protocols for searching (transect widths, etc.) were used at both sites. Comparisons of fatality rates at Foote Creek Rim and Buffalo Ridge that unadjusted for searcher efficiency would be very misleading.

Estimated disappearance or scavenger removal rates vary significantly in the literature. Nearly 80 percent (79.2) of the chicks placed in a mixed grazed pasture were removed within 24 hr of being placed (Wobeser and Wobeser 1992). In Maryland, approximately 75 percent of 78 trial carcasses placed in agricultural fields were removed in the first 24 hr (Balcomb 1986). During a study at a TV tower in Florida, 93 percent of 157 birds purposely placed underneath the tower at dusk to monitor predation were partially or completely removed by the next morning (Crawford 1971). In France, Pain (1991) estimated duck carcasses lasted an average of 1.5 d in open habitats, whereas those concealed by vegetation or those in water lasted between 3.3 and 7.6 d. In one orchard during this study, scavengers removed all 25 of the placed carcasses within 24 hr, with lower rates in the other orchards studied. At the Vansycle wind plant in Oregon, small carcasses or evidence of the carcass (e.g., feather spot) lasted an average of 15.0 d, and large carcasses lasted on average longer than 28 d (Erickson et al. 2000b). At the Buffalo Ridge wind plant, small carcasses persisted an average of 4.7 d, whereas small birds at Foote Creek Rim persisted 12.2 d. Disappearance rates also likely vary by species or avian group. For example, it is speculated that raptor carcasses last longer than other large bird carcasses such as game birds and waterfowl, although limited empirical data exist to test this hypothesis.

Carcass detection rates and scavenging rates do vary among sites, habitats, seasons and sizes of birds. Comparison of fatality rates that are not adjusted for these two primary sources of bias can be very misleading. Differences in observed fatality rates may only reflect true differences in scavenger densities or carcass detection rates. Many, if not most of the studies of bird mortality we present below, do not account for the biases described above. The following sections provide a review of studies of mortality for collision sources such as power lines, buildings and windows, communication towers and wind turbines.

Collision Mortality

Avian Mortality Due to Collisions with Automobiles, Trains, and Airplanes

Study examples

Although several studies have been conducted in Europe (e.g., Finnis 1960, Hodson 1962, Dunthorn and Errington 1964, Hodson and Snow 1965, Hugues 1996), we found relatively few documents that reported vehicle-related avian mortality in the United States. In Illinois, Decker (1987) traversed a 4.4-mile (7 km) stretch of road daily and estimated mortality at 33 birds per mile per year (21 birds/km/year). The most common fatalities were passerines or other small birds, including Yellow-billed Cuckoo (*Coccyzus americanus*), Blue Jay (*Cyanocitta cristata*), Red-winged Blackbird (*Agelaius phoeniceus*), and Indigo Bunting (*Passerina cyanea*). In Ontario, Canada, Ashley and Robinson (1996) searched a 2.2 mile (3.6 km) stretch of road located near wetlands three days a week and calculated that 223 birds were killed per mile per year (139 birds/km/year), most of which were passerines. No adjustments were made for searcher efficiency or scavenger removal in either of these studies.

From 1969 to 1975, Case (1978) searched the entire length of Interstate 80 in Nebraska (458 miles, 732 km) and documented a total of 7,195 Ring-necked Pheasant (*Phasianus colchicus*) vehicle collision fatalities. Based on finding 562 dead ducks over a 10-year period, Sargeant (1981) estimated that vehicles killed an average of 13,500 ducks each year in the prairie pothole regions of North and South Dakota. Mean annual mortality of ducks was estimated to be 0.250 ducks per mile (0.156 ducks/km) of interstate, 0.008 ducks per mile (0.005 ducks/km) of unsurfaced roads, and 0.042 ducks per mile (0.026 ducks/km) for all road types combined. Although the number of fatalities appears high, it was estimated to represent less than 0.2 percent of the breeding population in the study area. Much lower mortality was documented during other studies. McClure (1951) documented only four road-killed ducks while driving 76,250 miles (122,000 km) of road in Nebraska. In Minnesota, Sargeant and Forbes (1973) found only three road-killed ducks along 17 miles (27 km) of roads driven almost daily for an 18-month period. Raptors also appear susceptible to vehicle collisions in some areas. Based on driving surveys over a 10-year period in New Jersey, Loos and Kerlinger (1993) estimated that 25 raptors were killed per year within a 90-mile (145 km) survey route. Most of the fatalities were owls; however, six species of hawks were also found among road fatalities.

Annual mortality predictions

Banks (1979) summarized several studies and reported estimates of avian fatality rates ranging from 2.7 to 6.1 deaths per mile of road per year to 60 to 144 bird fatalities per mile per year. From U.S. studies reported in Banks (1979), use of the minimum (2.7) and maximum (96.25) reported values for bird deaths per mile yields estimates of 10.7 million to 380 million annual bird deaths on U.S. roads. Banks (1979) estimated total annual avian road mortality to be 57.2 million. This figure was derived from the estimate of 15.1 bird fatalities per mile reported by Hodson and Snow (1965), who conducted a fairly extensive study in England, although no scavenging or searcher efficiency bias was considered which would result in an underestimate of true fatality rates. The U.S. Census Bureau (Statistical Abstract of the United States 1999) estimated 3,944,597 miles of road in the US in 1997. Using this number to update Banks' estimate yields a 1997 estimate of approximately 60 million avian fatalities on U.S. roadways annually. The number of registered vehicles has increased 35 percent from 1980 to 1998 alone, so an alternative estimate would be 1.35 times 60 million, or approximately 80 million avian fatalities. It is believed that some of the mortality observed along roads is actually caused by collisions with adjacent power and telephone lines (C.J. Ralph, pers. comm.).

Although most avian fatalities caused by vehicles occur on roadways, avian collisions also occur with trains (Spencer 1965) and airplanes. Avian collisions with airplanes present a significant hazard to both military and commercial aircraft. The Federal Aviation Administration (FAA) keeps records of avian collision strikes involving aircraft in the US. In 1998, the U.S. Air Force reported over 3,500 bird strikes by planes, and it is estimated that civil aircraft strike over 25,000 birds per year. Data collected from 1990 to 1999 indicate that gulls (31 percent), waterfowl (31 percent) and raptors (15 percent) comprised 77 percent of the reported bird strikes causing damage (Bird Strike Committee USA 2000). No estimates for train-caused avian mortality were found in the literature. It is likely that train collisions also result in several thousand bird deaths annually in the United States.

Avian Mortality Due to Collisions with Buildings and Windows

Study examples

Numerous studies have documented extensive avian collision mortality associated with buildings and similar structures such as smokestacks or monuments. Fatalities associated with buildings are usually the result of collisions with tall buildings and collisions with windows at residential houses. Studies may be divided into two categories, studies of short-term or episodic mortality events, and longer-term studies. Some mortality events at tall buildings have involved extensive numbers of birds. At one oil flare stack in Alberta, 1,393 dead birds comprised of 24 species of passerines were found over a 2-day period in May 1980 (Bjorge 1987). Over a 3-day period in October 1964, Case et al. (1965) searched several buildings in Florida and recovered 4,707 dead birds, most of which were passerines. Also in Florida, Maehr et al. (1983) searched the base of four smokestacks over a 2-day period in September and recovered 1,265 dead passerines. The authors estimated that 5,000 birds might have collided with the structures during this period. In the fall of 1970, 707 dead birds were documented below the Empire State Building in New York (Bagg 1971). Extensive numbers of nocturnal migrant fatalities have also been documented at the Washington Monument in Washington, D.C. (Overing 1936). From October 5-8, 1954, 9,495 dead birds (mostly passerines) were found at 25 tall buildings in the eastern and southern US following a cold front during fall migration, and it was estimated that 106,804 birds were actually killed (Johnston and Haines 1957).

Several long-term studies have documented the chronic nature of collision mortality associated with some buildings (Erickson et al. 2001). Over a 3-year period in Toronto, Ontario, Ogden (1996) counted 5,454 dead

birds at 54 tall glass buildings and estimated that 733 birds (mostly passerines) were killed per building per year. Following nights with inclement weather conditions, Taylor and Kershner (1986) searched one building in Florida from 1970 to 1981 and documented 5,046 avian fatalities comprised of 62 species, the majority of which were passerines. Two smokestacks in Citrus County, Florida were searched five times per week from 1982 to 1986, and 2,301 dead birds were found (Maehr and Smith 1988). From this, the authors estimated that 541.4 birds were killed per year. Fatalities included 50 species, most of which were neotropical migrant passerines. Daily searches of two smokestacks in Ontario, Canada over a 4-year period yielded 8,531 dead birds. Again, most of these were passerines (Weir 1976).

Klem (1990) searched two houses in Illinois and New York daily from 1974 to 1986. A total of 100 dead birds were found at the houses, and the author estimated that 55 percent of window collisions result in death. Over the 1989-1990 winter, 5,500 residential houses in the U.S. were searched for dead birds using a standardized procedure, and a total of 995 dead birds were found (Dunn 1993). The author estimated that an average of 0.85 birds are killed per house each winter based on actual mortality ranging from 0.65 to 7.7 birds per house per year. The fatalities were comprised of 66 species, most of which were passerines commonly found at feeders during the winter.

Annual mortality predictions

In 1995 there were an estimated 4,579,000 commercial buildings (warehouse, religious/worship, public assembly, offices, mercantile/services, lodging, health care, food sales, education) in the United States (Statistical Abstract of the United States 1999). Klem (1990) reported there were 93.5 million residential houses in 1986. Due to the large number of structures in this class, and only a few good studies, it is difficult to obtain very accurate fatality estimates for the US. Most of the building and window collision data come from studies of known or suspected problem structures. Accurately predicting the number of building-related avian fatalities would require random selection of numerous buildings of all types and sizes, followed by long-term standardized and systematic searches for dead birds.

Banks (1979) acknowledged a lack of information on building and window collision mortality, and estimated 3.5 million avian fatalities per year based on an arbitrary estimate of 1 bird fatality per square mile in the US. An estimate of 97.6 to 976 million bird deaths per year in the U.S. due to collisions with windows was based on an estimated 1 to 10 bird deaths per structure per year from a fatality study in New York (Klem 1990).

Avian Mortality Due to Collisions with High Tension Lines

Study examples

Concern over avian collisions with high-tension lines has existed at least since 1876, when Coues (1876) counted approximately 100 avian carcasses (primarily Horned Larks (*Eremophila alpestris*) beneath a 3-mile long (4.8 km) section of telegraph wire between Denver, Colorado, and Cheyenne, Wyoming. Since then, there have been numerous studies of power line collisions involving birds. Faanes (1987) searched 6 miles (9.6 km) of power lines in North Dakota in the spring and fall of 1977 and 1978. Based on a total of 633 dead birds found, he estimated that 200 avian fatalities per mile per year (125 birds/km/yr) were occurring at those sites. The power lines included in the study were located near wetlands or lakes and most of the fatalities consisted of waterbirds (46 percent) and waterfowl (26 percent), followed by shorebirds (8 percent), and passerines (5 percent).

For some types of birds, power line collisions appear to be a significant source of mortality. Waterfowl band recovery data collected prior to 1967 indicated that powerline strikes were responsible for 65 percent of the collision fatalities involving 3,015 banded birds (Stout 1967). Of 75 Trumpeter Swan (*Cygnus buccinator*) deaths recorded from 1958 to 1973, 19 percent of the fatalities were due to powerline collisions (Weaver and St. Ores 1974). During a 2-year study of Mute Swans (*C. olor*) in Rhode Island, Willey (1968) found that 26.7 percent of adult fatalities were due to collisions, mostly with powerlines.

Annual mortality predictions

The U.S. electrical energy system includes more than 500,000 miles (800,000 km) of bulk transmission lines (Edison Electric Institute 2000). Estimates for the total length of distribution lines (power lines to residences and businesses) in the US could not be found in the literature, but are far greater than for bulk transmission lines. Estimates of avian fatalities due to collisions with high-tension lines are lacking due to minimal monitoring efforts on a large-scale basis. As with most other sources of collision mortality, most monitoring and/or studies are conducted in response to a known or perceived problem, and few data have been collected at randomly-chosen sites. Based on the limited studies, waterfowl including ducks, geese, swans, cranes, and shorebirds appear to be most susceptible to collisions when powerlines are located near wetlands. In upland

habitats away from wetlands, raptors and passerines appear most susceptible to collision.

In the Netherlands, where approximately 2,875 miles (4,600 km) of high-tension lines are present, Koops (1987) estimated that approximately 750,000 to 1 million birds are killed annually by collisions based on variation in extrapolation made in three other Netherlands studies. Estimates in all three studies were in the same order of magnitude. The latter study estimated (unadjusted for scavenging and searcher efficiency) 113 fatalities per km of high tension line in grasslands, 58 fatalities per km of high tension line in agricultural lands, and 489 fatalities per km of high tension line near river crossings. We use the mean estimate (adjusted for scavenging and searcher efficiency bias) of 750,000/2,875 = 261/mile of high tension line. Extrapolating the mid-range of this estimate to the 500,000 miles (800,000 km) of bulk transmission lines in the United States would lead to a fatality estimate of approximately 130 million birds per year. Given the large, but unknown number of miles of power and other high tension lines in the U.S., and the lack of standardized data in the U.S., this estimate may be off by an order of magnitude or more.

Avian Mortality Due to Collisions with Communication Towers

Study examples

Substantial concern over the recent proliferation of communication towers in the U.S. has arisen in response to large fatality events, such as an estimated kill of 5,000 to 10,000 birds, mostly Lapland Longspurs (*Calcarius lapponicus*), at 3 associated communication towers and a natural gas pumping facility in western Kansas on the night of January 22, 1998 (Evans 1998). Large, single-night fatality events are not new. Kemper (1996) counted and identified species for over 12,000 birds killed one night in 1963 at a television tower in Wisconsin. As a result of this concern, avian collision mortality associated with communication towers has received more study and review than other sources of collision mortality, with the possible exception of wind turbines. During our review we located numerous studies covering avian collision mortality with communication towers in 25 states. The vast majority of the studies were one-day searches at single towers following nights of substantial avian mortality. Most avian fatalities at communication towers involve nocturnal migrant passerines, especially warblers, vireos, and thrushes.

Erickson et al. (2001) reported on 17 studies where collision mortality was measured for periods of time ranging from one to 38 years. For studies conducted over a period of at least two years, with searches conducted on a daily or almost daily basis, the estimated mean number of annual collisions per tower ranged from approximately 82 birds per year at an 825-ft (250-m) tall television tower in Alabama (Bierly 1968, 1969, 1972; Remy 1974, 1975; Cooley 1977) to 3,199 birds per year at a 1,000-ft (305-m) tower in Eau Claire, Wisconsin (Kemper 1996). Very few of these studies measured scavenger removal and searcher efficiency. The research at Eau Claire, Wisconsin, was the longest study conducted at any one tower and covered the period from 1957 to 1994 (38 years). Two other continuous studies at individual communication towers include a study from 1960 to 1997 (37 years) at a 1,368-ft (417-m) tower in Nashville, Tennessee (Nehring 2000), and another study that took place at a 1,010-ft (308-m) tower from October 1955 to December 1983 (28 years) at Tall Timbers Research Station in Tallahassee, Florida (Crawford and Engstrom 2000). At the Tennessee tower, 19,880 fatalities were recovered over the 37-year period. At the Florida tower, 1,517 birds on average were killed per year.

Annual mortality predictions

Based on the July 2002 statistics from the Federal Communication Commission's (FCC) Antenna Structure Registry Database (FCC 2002), more than 138,000 towers were listed with the Commission, of which some 106,000 were lighted. Since an undetermined number of towers are not registered with the FCC, and the number of new towers are increasing at a high rate (Manville this volume a), the total number of communication towers may be as high or higher than 200,000. Numerous types of towers are being built, including radio, television, cellular, microwave, paging, messaging, open video, public safety, wireless data, government dispatch, and emergency broadcast towers (Manville this volume a). Due to the recent proliferation of cellular phones and the advent of digital television, approximately 5,000 to 10,000 new towers are being added each year (6-8 percent increase annually). Some have estimated there will be a total of 600,000 towers in the United States within the next 10 years, creating a potentially catastrophic impact on avian migrants (M. Manville, pers. comm.). Avian mortality appears to increase with tower height. Taller towers also tend to have more guy wires and more lights, often more solid or pulsating red lights, which may increase the potential for collision mortality.

Most lighted towers are lit due to FAA pilot warning regulations. On foggy or low cloud-ceiling nights, these lighted towers appear to attract neotropical nocturnal migrants (Manville 2000, Kerlinger 2000), increasing the risk of collision. Lighting appears to be the single most critical attractant, and preliminary research indicates that solid and pulsating red lights seem to be more attractive to birds at night during inclement

weather conditions than are white strobe lights. It is speculated that the birds are attracted to the lighted towers, become disoriented and fly around them in a spiral, colliding with the tower, the guy wires, other birds, or falling to the ground in exhaustion (Larkin and Frase 1988, M. Manville, pers. comm.).

There are very few long-term studies of avian mortality at communication towers, although there are concerted efforts by both the industry and other interested parties to begin collecting standardized data and using standardized metrics following the methods and metrics recommended and used at many wind power plants (Anderson et al. 1999). Currently, much of the published and unpublished information regarding avian fatalities at communication towers is based on single observations of carcasses found at the base of the towers (Erickson et al. 2001). Based on estimates of Banks (1979) and models developed by Tall Timber Research and Bill Evans (M. Manville, pers. comm.), conservative estimates range from 4 million to 5 million avian fatalities per year (Manville this volume a). These estimates could be off by an order of magnitude, especially as the number of towers increases at a high rate each year (Manville this volume a). Further studies are obviously needed to ascertain the true impact.

Avian Mortality Due to Collisions with Wind Turbines

Study examples

Many of the early studies of bird mortality at wind plants involved examining impacts associated with single, large experimental turbines. The first study took place in Sandusky, Ohio, where a single large turbine was monitored for avian mortality during four migratory seasons. Two dead birds were found during this period (Gauthreaux 1994). Two large experimental turbines and a meteorological tower in Wyoming were monitored for avian mortality in the early 1980s. Twenty-five fatalities were found over a one-year period, most of them involving passerines that had collided with guy wires on the meteorological tower (U.S. Bureau of Reclamation 1984). At a single, 60-m tower wind turbine in Solano County, California, seven fatalities were documented from September 1982 to January 1983, and the total fatality estimate with adjustments for scavenger removal and searcher efficiency was estimated at 54 birds (Byrne 1983, 1985).

Most of the concern over bird mortality from wind turbines began at one of the first large-scale wind energy developments in the US In response to several reported incidents of avian collisions, the California Energy Commission (CEC) obtained data on bird strikes at the Altamont and Tehachapi wind plants in California through interviews and review of unpublished data collected over a 4-year period from 1984 to 1988 (CEC 1989). This study documented 108 raptor fatalities of seven species. Collisions with wind plant structures accounted for most of the avian fatalities (67 percent), including 26 Golden Eagles and 20 Red-tailed Hawks (*Buteo jamaicensis*), while collision and electrocutions associated with power lines comprised the majority of the other fatalities. Several subsequent studies were initiated to further examine fatalities at California wind plants. Many of these studies have been conducted at Altamont Pass, where more than 5,000 turbines exist within the WRA. In general, these studies focused on obtaining raptor fatality estimates with other bird fatalities recorded coincidentally. An early 2-year study documented 182 bird deaths on study plots, 68 percent of which were raptors and 26 percent of which were passerines. The most common raptor fatalities were Red-tailed Hawk (36 percent), American Kestrel (*Falco sparvarius*) (13 percent), and Golden Eagle (11 percent). Causes of raptor mortality included collisions with turbines (55 percent), electrocutions (8 percent), and wire collisions (11 percent) (Orloff and Flannery 1992). Based on the number of dead birds found, the authors estimated that as many as 567 raptors may have died over the 2-year period due to collision with wind turbines. Further investigations at Altamont continued to document levels of raptor mortality sufficient to cause concern among wildlife agencies and others (Orloff and Flannery 1992, 1996; Howell 1997).

Raptor mortality at other older wind plants in California is apparently less that what has been observed at Altamont. Researchers estimated 6,800 birds were killed annually at the San Gorgonio wind facility (more than 3000 turbines) based on 38 dead birds found while monitoring nocturnal migrants at a small sample of turbines. McCrary et al. (1983, 1984) estimated that 69 million birds pass through the Coachella Valley annually during migration; 32 million in the spring and 37 million in the fall. The 38 avian fatalities were comprised of 25 species, including 15 passerines, seven waterfowl, two shorebirds, and one raptor. Considering the high number of passerines migrating through the area relative to the number of passerine fatalities, the authors concluded that this level of mortality was biologically insignificant (McCrary et al. 1986), although the mortality estimates were based on a small sample size. During a more recent study at San Gorgonio, (Anderson, pers. comm.) documented 58 fatalities near wind turbines, including fifteen doves (mostly *Columba livia*), five waterfowl, seven rails (mostly American Coot [*Fulica americana*]), seven passerines, four gulls, three owls, two ravens, one diurnal raptor, one egret, and eleven unidentified birds. The waterfowl, rail and shorebird mortality generally occurred when water was

present in the vicinity of the wind resource area, attracting large numbers of waterfowl and shorebirds.

The high levels of raptor mortality associated with the Altamont wind plant has not been documented at newer wind plants constructed in other states (*table 1*). We discuss three wind resource areas that have been monitored for mortality and have included adjustments for scavenging and searcher efficiency bias (Osborn et al. 2000, Johnson et al. 2002, Young et al. 2003, Erickson et al. 2000b), although other studies listed in *table 1* include Erickson et al. 2003a and 2003b, Howe et al. 2002, Nicholson 2003 and Johnson et al. 2002.

Several studies have been conducted at the Buffalo Ridge wind resource area, which is located an agricultural landscape in southwestern Minnesota. At the 73-turbine Phase I wind plant, eight collision fatalities were documented during the initial two-year period of operation (Osborn et al. 2000). The fatalities consisted of one Ruddy Duck (*Oxyura jamaicensis*), one Franklin's Gull (*Larus pipixcan*), one Yellow-bellied Sapsucker (*Sphyrapicus varius*), and four passerines. The estimated total number of annual fatalities for the entire wind plant was 36, equivalent to an annual mean of 0.49 collisions per turbine per year. A more extensive study of this wind plant plus two additional wind plants on Buffalo Ridge totaling over 350 turbines was conducted from 1996 through 1999. Total annual mortality was estimated to average 2.8 birds per turbine based on the 55 fatalities found during the study. Only one raptor, a red-tailed hawk, was found during the 4-year monitoring period. Most of the fatalities were passerines (76.4 percent), followed by waterfowl (9.1 percent), waterbirds and upland gamebirds (5.5 percent each). Many of the fatalities documented were nocturnal migrants (Johnson et al. 2002). Radar studies at Buffalo Ridge (Hawrot and Hanowski 1997) indicate that as many as 3.5 million birds per year may migrate over the wind development area (Johnson et al. 2002). The two largest single mortality events reported at a

Table 1–*Estimates of avian collision mortality by wind projects.*

Location of study[1]	No. turbines	No. MW	No. birds/ turbine/year	No. birds/ MW/year	No. raptors /turbine/year	No. raptors /MW/year
West (excluding California)						
Stateline, Oregon/Washington	454	300	1.69	2.56	0.053	0.080
Vansycle, Oregon	38	25	0.63	0.96	0.000	0.000
Klondike, Oregon	16	24	1.42	0.95	0.000	0.000
Nine Canyon, Washington	37	48	3.59	2.76	0.065	0.050
Foote Creek Rim, Wyoming	105	68	1.50	2.34	0.035	0.053
Subtotal	650	465	1.71	2.40	0.044	0.068
Upper Midwest						
Wisconsin (MG&E and PSC)	31	20	1.30	1.97	0.000	0.000
Buffalo Ridge, Minnesota	354	233	2.86	4.21	0.002	0.008
Subtotal	386	254	2.73	4.03	0.002	0.008
East						
Buffalo Mountain, Tennessee	3	2	7.70	11.67	0.000	0.000
Grand Total	1039	721	2.11	3.04	0.029	0.045
California (older projects)						
Altamont, California	~5400	548	na[2]	na	0.100	na
Montezuma Hills, California	600	60	na	na	0.048	na
San Gorgonio, California	~2900	300	2.31	na	0.010	na
Subtotal	~8900	878	na	na	0.067	na

Total fatality projections	Overall	Outside California
Projected annual bird fatalities[3]	20,000-37,000	9200
Raptors[4]	933	195

[1]We excluded studies of 4 small project sites in Vermont, Pennsylvania, Colorado, and Iowa that were conducted short-term and/or did not include adjustments for scavenging and searcher efficiency bias.
[2]Not available; data on scavenging or searcher efficiency or average MW of study turbines not available
[3]The per turbine/year and per MW/year estimates applied to the number of MW in U.S. at the end of 2003
[4]Based on the per turbine estimate in California (11,500 turbines) and the per MW basis outside California

U.S. wind plant were fourteen spring migrant passerines at two turbines at the Buffalo Ridge, Minnesota wind plant on one night and approximately 30 spring migrant passerines at a floodlit substation and nearby turbines in West Virginia on one night.

At the Foote Creek Rim wind plant located in Carbon County, Wyoming within native grassland-steppe and shrub-steppe habitats, total mortality associated with the 69 turbines and 5 meteorological towers was estimated to be approximately 143 birds per year, based on the 122 collision fatalities actually found during the first three years of operation (Young et al. 2003). Mean annual mortality was estimated to be 1.5 birds per turbine and 0.03 raptors per turbine per year. Of the 122 fatalities found during the study, raptors comprised only 4.0 percent, whereas passerines comprised 90.2 percent. Furthermore, while many of the fatalities at this location were nocturnal migrant passerines, the largest number of carcasses detected at a turbine during one search was two, suggesting no large mortality events of nocturnal migrants have occurred at this site.

At a 38-turbine wind plant completed on Vansycle Ridge, Oregon, which is located in an agricultural landscape, 12 avian fatalities were located during the first year of operation (Erickson et al. 2000b). The casualties were comprised of at least six species, and most of the fatalities (58 percent) were passerines. Total estimated mortality adjusted for scavenging and observer detection rate estimates, was 24 birds per year, or 0.63 birds per turbine per year. No raptors were among the fatalities (Erickson et al. 2000b).

We are unaware of any studies that directly compare communication tower mortality to wind turbine mortality; although, we do have limited information on guyed meteorological tower mortality compared with wind turbine mortality at the Foote Creek Rim, Wyoming wind plant. At this site searches of both wind turbines (600-kW, approximately 200-ft (60-m) towers) were conducted and guyed met towers (200 ft (60 m) in height) once every 28-d during the study. During this period of study, the met towers had estimates of 8.1 bird fatalities per tower per year, whereas the turbines had estimates of 1.5 bird fatalities per turbine per year (Young et al. 2003).

Annual mortality predictions

The average number of avian collision fatalities per turbine and per MW (Megawatt) are 2.11 and 3.04 per year, respectively. There were approximately 17,500 turbines and 6,374 MW of installed wind generation capacity at the end of 2003 in the United States, with approximately 6,000 turbines and 4,331 MW outside California. Therefore, on average, we calculate approximately 20,000 (3.04 times 6374 MW) to 37,000 (2.11 times 17,500 turbines) die annually from collisions with wind turbines in the United States. We estimate approximately 9,200 birds will die annually outside California from the 4331 MW of installed wind generation capacity (2003). This extrapolation assumes fatality rates observed at wind projects that have been studied are representative of rates at wind projects not studied. Fatality estimates for all birds are generally not available at most old projects in California, and for all birds and raptors from Texas and Iowa, two states with significant wind development.

Because much attention has been given to the issue of raptor/wind power interaction, we also developed separate fatality estimates for raptors. Estimates of raptor fatalities per turbine per year from individual studies through 2001 (Erickson et al. 2001) ranged from 0 at the Vansycle, Oregon; Searsburg, Vermont; Ponnequin, Colorado; Somerset County, Pennsylvania; and Buffalo Ridge, Minnesota, Phase II and Phase III sites, to 0.10 per turbine per year at the Altamont, California site (C. Thelander, pers. comm.). Based on these statistics, we estimate 933 raptors are killed annually (2003) by turbines in the United States, with approximately 80 percent of the raptor mortality occurring at the older projects in California. We project raptor mortality at wind plants outside California to be 195 per year (2003) based on relatively small number of raptors found at Buffalo Ridge Minnesota (Johnson et al. 2002), Foote Creek Rim Wyoming (Young et al. 2003), Stateline Oregon and Washington (Erickson et al. 2003a), and Nine Canyon Washington (Erickson et al. 2003b).

Other Non-collision Related Sources of Bird Mortality

The previous sections have focused on collision-related sources of bird mortality. We will now discuss in much less detail other significant sources of bird mortality which include oil spills, oil pools, cat predation, pesticides and other contaminants, electrocutions and fishing by-catch. The latter two sources are covered in more detail in Manville (this volume a, this volume b). Hunting is another obvious source of bird mortality, but since it is a permitted source, we do not discuss it.

Pesticides

Pesticides are a significant source of bird mortality in the US as well as other countries (Pimentel et al. 1991; Mineau, this volume). Large die-offs of Swainson's Hawks (*Buteo swainsoni*) were observed in Argentina due to exposure to the pesticide monocrotophos in 1996 (Di Silvestro 1996). Approximately 160 million acres of cropland are treated with pesticides each year

in the US (Pimentel et al. 1991) using data collected in the 1980s and 1990s. It has been estimated that approximately 67 million birds die annually in the US due to pesticides (Pimental et al. 1991). This estimate is based on the assumption that 10 percent of the estimated 672 million birds exposed to pesticides die each year. This estimate may be conservative, since the empirical data on bird mortality at crop fields is reported as 0.1 to 3.6 per acre (Mineau 1988). Lawn, turf, golf course and other pesticide uses were not included in this estimate.

Oil Spills

Oil spills can be a significant source of bird mortality, but the occurrence of spills and the effect and are obviously difficult to predict. Over 30,000 bird carcasses were recovered, including 250 Bald Eagles (*Haliaeetus leucocephalus*) following the 1989 Exxon Valdez oil spill in Prince William Sound Alaska, but between 100,000 and 300,000 birds of all species were estimated to have died (Piatt et al. 1990). Flint et al. (1999) conservatively estimated over 1750 birds died as the result of the M/V Citrus spill near St. Paul Island, Alaska. Small spills or chronic oiling is much less publicized, yet possibly a significant source of seabird mortality (Burger 1993). Estimates of annual mortality based on counting oiled corpses on beaches from small or chronic oiling have ranged from less than 0.01 per km of shoreline to 3.68 per km. Many oiled birds which die at sea are never found on beaches. Considering the US, including the island territories, has approximately 90,000 miles of marine tidal shoreline, annual bird mortality from chronic oiling may easily be in the 10,000 to 100,000 range.

Oil Pits

Man-made pits associated with oil and gas development are another well-documented source of bird mortality. Esmoil (1995) found 282 dead birds during weekly sampling of 35 oil pits in 1989, and 334 dead birds during weekly sampling of 53 pits in 1990. The largest affected taxonomic group was passerines (41 percent). Banks (1979), based on estimates made for the San Joaquin Valley in the early 1970s, conservatively estimated 1.5 million birds die annually due to these pits.

Cat Predation

Domestic and feral cats might also be considered an anthropogenic source of bird mortality. 1990 U.S. census data report 60 million cats claimed as pets by owners, and an unknown number of unclaimed feral cats. Coleman and Temple (1996) estimated that between 8-219 million birds are killed by free-ranging cats in Wisconsin alone. These figures are derived from estimates that there are 1.4 - 2 million free-ranging cats in rural Wisconsin, that each cat on average kills between 28 and 365 animals per year, and that on average 20 to 30 percent of the animals killed by cats are birds (5 -100 birds/cat/year). We use the estimate of 100 million birds killed by cats on an annual basis, but this estimate is likely conservative. If the Wisconsin estimates are representative of the averages nationwide, this estimate is highly conservative given that there are 50 states and because it only accounts for cats claimed as pets by owners.

Electrocutions

Recent prosecution of the Moon Lake Utility for violations of the Bald and Golden Eagle Act and the Migratory Bird Treaty Act (Manville this volume a) has brought more attention to the continued problem of electrocutions of raptors from powerlines. It appears that nation wide mortality estimates from electrocutions are not available. Most data available were not collected in a systematic fashion, and do not attempt to adjust for scavenging and searcher efficiency biases.

In a review of mortality reports from utilities, wildlife rehabilitators and falconers between 1986 and 1996, 1450 raptor electrocutions representing 16 species were confirmed, with Golden Eagles accounting for the largest percentage of fatalities (Harness and Wilson 2001).

Fishing By-catch

Many groups of seabirds have been reported drowned by fishing nets and gear (Atkins and Heneman 1987) and yearly mortality may reach hundreds of thousands (Manville this volume b). Quality studies on the impacts from commercial fishing are absent except for a few studies (e.g., Brothers 1991), and most mortality reports are largely anecdotal.

Cumulative Mortality

Based on the estimates derived or reviewed in this paper, annual bird mortality from anthropogenic sources may easily approach 1 billion birds a year in the US alone (*table 2*). Buildings, power lines and cats are estimated to comprise approximately 82 percent of the mortality, vehicles 8 percent, pesticides 7 percent, communication towers 0.5 percent, and wind turbines 0.003 percent. Other sources such as mortality from electrocution, oil spills and fishing by-catch are also contributors but estimates were not made and we have not even considered the impacts from loss of habitat which could also be considered anthropogenic.

Discussion

Based on existing projections and projections made in this paper, annual avian mortality from anthropogenic causes may be near 1 billion. Given the uncertainty in the estimates, the true avian mortality, especially for communication towers, buildings and windows, vehicles, powerlines, pesticides, oil spills, fishing by-catch, cats, and vehicles could easily be different by an order of magnitude. In general, these sources of mortality continue to grow as our population grows (e.g., buildings and houses), and demand for efficient communications (e.g., cellular telephones), electricity (e.g., wind turbines and powerlines), fuel and other comforts of life grow as well. Although there is high variability in the estimated magnitude of total bird mortality for the different sources, there is also high variability in the types of birds (nocturnal migrants versus residents) and species that individual sources impact. Therefore, the significance on any one source or a particular location of a unit (e.g., a communication tower) may vary greatly depending on the species or groups of birds that may be impacted.

Many of the collision mortality studies have been conducted in response to a known or perceived risk, and therefore are probably not appropriate for extrapolation in the same manner we extrapolated for wind turbines. However, it has been argued by several researchers making mortality projections that their estimates are probably conservative (underestimates), given that scavenging and searcher efficiency biases have generally not been incorporated into the estimates. For example, Banks' (1979) estimate of vehicle mortality was based on the Hodson and Snow (1965) estimate of 15.1 birds per mile (9.4 bird/km), which was based on weekly surveys that did not adjust for scavenging and searcher efficiency.

The large uncertainties associated with estimates of mortality from one or multiple sources, along with the even larger uncertainties in bird populations (e.g., size, reproduction), makes it extremely difficult to understand the biological significance of human-caused mortality on birds at a population, regional, or even local level (Manville this volume a). Aldrich et al. (1975) estimated there are approximately 10 billion breeding landbirds in the US (excluding Alaska and Hawaii) in the spring, and approximately 20 billion breeding landbirds in the autumn, based on 1973 Breeding Bird Survey data. Based on these estimates and our mortality estimates, approximately 5-10 percent of the populations of breeding landbirds are killed each year from human caused factors. Impacts on individual species may be higher or lower depending on their population levels. The recently published Birds of Conservation Concern (BCC) by the USFWS lists 131 species that may currently have declining population numbers from numerous factors including loss of habitat and human-caused mortality. These are in addition to the 92 species currently listed as Federally threatened or endangered. Very few studies have attempted to determine the significance of human-caused mortality at a population level of an individual species. Based on an intensive radio-telemetry study of a population of Golden Eagles at the Altamont Pass wind plant, it was determined the wind plant was currently not causing a population level decline, but the long-term impact was unknown (Hunt 2002). This study of a relatively small and definable population of eagles was expensive, relatively short-term, and not conclusive.

Rosenberg and Blancher (this volume) discuss a method using Breeding Bird Survey data for better understanding the population status and the impact of human-caused mortality of individual breeding birds. Their approach uses breeding bird survey data, but given the limited and highly variable data on population sizes, survival and reproduction, there are likely huge uncertainties. Until we start to better understand mortality rates and parameters of bird populations, we will not truly understand the biological significance of the mortality. Research and monitoring efforts need to continue and expand so that we can better understand the levels and significance of these mortality sources and we can find better and more effective means for reduction and mitigation of human-caused bird mortality.

There does appear to be a greater awareness of the level of human-caused bird mortality, and there are measures being undertaken to reduce mortality from most, if not all these sources. Programs to reduce night lighting at tall buildings and encourage use of tinted windows appear to be an effective measure to reduce mortality. Marking powerlines with bird flight diverters appears to be an effective and relatively inexpensive way of reducing collision mortality along power lines (Morkill and Anderson 1991, Brown and Drewien 1995). Effective wind project siting, use of underground power lines, unguyed meteorological towers, and reduced lighting within wind projects appears to be an effective way of reducing the collision potential at wind projects (Johnson et al. in press). Programs like Audubon's "Keep Cats Indoors" likely reduce bird mortality from free-ranging cats. The U.S. ban on some granular pesticides know to be highly toxic to birds has presumably reduced cumulative mortality from pesticides. Use of unguyed cell towers and better lighting on communication towers may also be contributing to reduced avian mortality. Guidelines for pole configurations to reduce electrocution mortality (APLIC 1996) have undoubtedly help reduce the electrocution risk from power lines. The use of these measures needs to be expanded and other more effective measures need to

Table 2—*Summary of predicted annual avian mortality.*

Mortality source	Annual mortality estimate	Percent composition
Buildings[1]	550 million	58.2 percent
Power lines[2]	130 million	13.7 percent
Cats[3]	100 million	10.6 percent
Automobiles[4]	80 million	8.5 percent
Pesticides[5]	67 million	7.1 percent
Communications towers[6]	4.5 million	0.5 percent
Wind turbines[7]	28.5 thousand	<0.01 percent
Airplanes	25 thousand	<0.01 percent
Other sources (oil spills, oil seeps, fishing by-catch, etc.)	not calculated	not calculated

[1] Mid-range of fatality estimates reported from Klem (1990), 1 – 10 bird fatalities per house, extrapolated to 100 million residences
[2] Based primarily on a study in the Netherlands (Koops 1987), extrapolated to 500,000 miles of bulk transmission line in U.S.
[3] One study in Wisconsin estimated 40 million (Coleman and Temple 1996), there are 60 million cats claimed as pets in the U.S.
[4] Based primarily on one study in England (Hudson 1965, Banks 1979) that estimated 15.1 fatalities/mile of road each year, no searcher efficiency or bias adjustments in that study, updated based on increase in vehicle registrations
[5] Conservative estimate using low range of empirical fatality rate (0.1 to 3.6 birds/acre), studies typically adjusted from searcher efficiency and scavenging
[6] Estimates from models derived by Manville and Evans (M. Manville, pers. comm.).
[7] Mid-range of per turbine and per MW estimates derived from empirical data collected at several wind projects (*table 1*).

be developed to help compensate for the continued growth of human development on the landscape resulting in loss of bird habitat.

Acknowledgments

The effort to gather and summarize much of the literature in this document was funded by DOE, with direction and support from the Wildlife Working Group of the National Wind Coordinating Committee. Most of the collision mortality information was first reported in the NWCC Resource Document entitled "Avian collisions with wind turbines: A summary of existing studies and comparisons to other sources of avian collision mortality in the United States" (Erickson et al. 2001). We appreciate the comments from the reviewers of that report, including K. Sinclair (National Renewable Energy Laboratory), A. Manville (USFWS), P. Kerlinger (Curry and Kerlinger), S. Ugoretz (Wisconsin Department of Natural Resources), T. Gray (American Wind Energy Association), and J. Stewart (FPL Energy). We also appreciate the comments on this manuscript from C. J. Ralph.

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Mitigation Measures for Highway-caused Impacts to Birds[1]

Sandra L. Jacobson[2]

Abstract

Highways cause significant impacts to birds in four ways: direct mortality, indirect mortality, habitat fragmentation, and disturbance. In this paper I discuss highway-related impacts, and suggest solutions from a highway management perspective. Non-flying birds (either behaviorally or structurally) such as gallinaceous birds and ducklings; waterbirds such as terns; owls; ground-nesters; scavengers; Neotropical overwater migrants; frugivorous birds; and birds attracted to salt are often killed from highway-related causes. Suggested solutions include highway crossing structures, diversion poles on bridges or medians, modified right-of-way mowing regimes, road kill removal, appropriate median vegetation, and modified deicing agents. Indirect mortalities caused by highway construction or maintenance include habitat loss and decreased quality; predator attraction or bridges to nesting habitat; increased incidence of invasive species; increased associated lethal structures; and maintenance practices that disrupt reproduction. Suggested solutions include highway management strategies that consider avian needs.

Key words: birds, direct mortality, disturbance, fragmentation, highway, indirect mortality, mitigation, vehicle-animal collision, wildlife crossing structure.

Introduction

As the most mobile of terrestrial wildlife, birds are not often considered significantly affected by highways (Keller et al. 1996). However, highway impacts to birds occur in four major ways, some of which are unique to birds: by fragmentation, disturbance, and direct and indirect mortality. These impacts could have considerable negative effects on populations, especially when considered in combination with other sources of mortality and habitat loss. The mitigation measures reviewed here have the potential to reduce impacts to birds from all four categories.

Many mitigation techniques reviewed in this paper have been developed for other taxa, particularly ungulates and large carnivores, but are applicable to birds as well. Further information on the projects from which these suggested solutions are drawn can be found at the USDA Forest Service's 'Wildlife Crossings Toolkit' at http://www.wildlifecrossings.info. This database is the most complete compilation available of case histories of highway impact mitigation for all taxa. It includes a glossary for biologists unfamiliar with highway infrastructure terminology[3].

Several publications have reviewed highway impacts to birds, with most focusing on direct mortality and few offering suggestions for mitigation. A thorough review of impacts of linear developments, including highways, to birds and other wildlife is found in Jalkotzy et al. (1997); suggested mitigation measures focus on large mammals. Forman and Hersperger (1996) review mitigation measures for most taxa, but include relatively little information on measures effective for birds. A review of the impact of forest roads on wildlife, including some information on birds, is in Gucinski et al. (2000).

The current transportation paradigm dictates that highways will continue to be built and expanded to meet increasing transportation needs, and impacts to birds and other wildlife will continue as a result. No mitigation by itself or in combination with others can totally remove the impacts to wildlife. Several methods suggested here might reduce impacts to birds, however, and are based on successes with other taxa. Expensive structural mitigation techniques such as wildlife overcrossings are unlikely to be initiated to mitigate avian impacts alone, but additional benefits to birds might raise the benefit/cost ratio. The first step to reducing the impacts of highways on birds through improved highway design and retroactive mitigations is to understand how highways affect birds. In this paper I review

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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[3]The purpose of the website is to provide a database of known mitigation techniques for terrestrial wildlife for use by professional biologists and highway engineers. The Wildlife Crossings Toolkit was developed by a partnership of the USDA Forest Service's San Dimas Technology and Development Center, Utah State University's College of Natural Resources. Montana State University-Bozeman's Western Transportation Institute, and the Federal Highway Administration.

the current state of knowledge regarding these impacts and effective mitigations.

Fragmentation

Highways can fragment bird populations and habitats in three ways: loss of large carnivores, habitat dissection, and the isolation of less mobile species (*table 1*).

Loss of Large Carnivores

When highways fragment large carnivore populations, birds can suffer increased depredation from smaller carnivores such as bobcats, skunks and weasels (Crooks and Soulé 1999). Many structural designs for encouraging large carnivores to cross highways have been developed, and are being increasingly if not universally considered in appropriate highway projects. Large underpasses or extended bridges are used successfully for such species as Florida panthers (*Puma concolor coryi*), black bears (*Ursus americanus*), and wolves (*Canis* spp.) (Foster and Humphrey 1995; Roof and Wooding 1996; Clevenger and Waltho 2000). In most cases, barrier fencing is needed to encourage these highly mobile species to use the prepared crossing.

Habitat Dissection

Highways are designed to minimize costs. These routes are often the shortest distance between two points, in areas without human development to avoid the cost of land acquisition and to avoid noise effects to homes, and with minimal elevation changes. This may result in rare habitats such as wetlands being disproportionately affected by highway development (FHWA 2000). Habitat dissection may result in patches of habitat too small to complete a territory. Woodland species are more affected by habitat dissection than grassland species, which appear to be more willing to cross highways as part of their territories (Keller et al. 1996).

Planning the location of a highway to avoid environmental as well as construction costs may be the simplest but least considered solution. If the lands crossed are public lands, then an environmental analysis might develop an alternative that keeps habitat patches intact over one that bisects them. The public's role as stakeholders in this process is very important because many public land managers are still awakening to the avoidable impacts of highway design.

Crossing structures can be a tool to reduce impacts. Structures that are high, wide and open tend to retain the most functional ecosystems (Ruediger 2002). Causeways, viaducts, and expanded bridges provide the most opportunities for birds to cross under a highway because of their openness and the surrounding vegetation is usually continuous under the structure. In Europe, woodland bird species use wildlife over-crossings with planted vegetation significantly more to cross highways than direct overflights, and in some cases have incorporated the over-crossing into territories (Keller et al. 1996).

Isolation

Highways can isolate small populations or individuals because of habitat dissection. Isolation is a variant of habitat dissection, but it also includes those situations where a portion of a daily or annual habitat is difficult or dangerous to access because of the presence of a highway. The tendency of Mountain (*Oreortyx picta*) and California (*Lophortyx californica*) quail to avoid large openings (Gutierrez 1980) may make seasonal habitat virtually unavailable if multiple-lane, high volume highways bisect seasonal or daily movements, and their low flight and tight flocking behavior may increase the risk of mortality when crossing highways.

Correctly locating crossing structures is critical to their effectiveness. Although many wildlife travel along ridges and drainages, some animals, such as Mountain Quail, might have consistent but less obvious crossings. Knowing the location of frequent crossings can help situate the most effective structure.

Table 1— *Fragmentation impacts to birds from highways.*

Impact	Problem	Suggested solution
Loss of large carnivores	Increased small carnivores prey disproportionately on birds.	Highway crossing structures for large carnivores.
Habitat dissection	Habitat parcels are too small to contain complete territories.	Avoid dissection by highway placement. Use causeways or viaducts to maintain small scale habitat continuity.
Isolation	Highways are barriers to less mobile or reclusive birds.	Overall connectivity strategy. Use open-span bridges, viaducts or wildlife over-crossings.

Disturbance

Disturbance from highways may be most pronounced during the breeding season, but can also affect other life history periods (*table 2*).

Noise

Territorial song is only effective if it is heard by other birds, and noise from traffic can be so loud that bird song may be distorted, resulting in difficulties in attracting and keeping females (Reijnen and Foppen 1994). While the mechanism causing decreased numbers of woodland breeding birds next to highways (Riejnen and Foppen 1994) is not clearly understood, noise can disturb birds and render otherwise suitable habitat next to highways less effective (Reijnen et al. 1995, Stone 2000). Increased predation may also occur due to the inability of birds to hear predators (Scherzinger 1973).

Most noise from highways is produced by engines and tires as they contact the surface, with noise varying by tire and surface qualities (FHWA 2000). Noise can be mitigated by providing a barrier to the source of noise, or reducing the source itself. Because most of the noise derives from the road surface, a change in elevation of the road surface may reduce noise, and cuts and fills can be used to advantage. Noise barriers are commonly used in city situations and can be seen as large cement block walls along city highways. While this effectively reduces noise in lower vegetation layers, it also eliminates permeability for most essentially non-flying species, and is expensive. A variant of the common city sound wall can be created by less dense material such as wood, vegetation, or fabric.

The Federal Highway Administration (FHWA) has commissioned much research on environmental noise reduction. Smooth surfaces have been developed to reduce noise while retaining safe traction control; in addition, some tires are much less noisy than others. Land management agencies could reduce noise through public lands by considering road surface design when constructing or upgrading highways.

Lights

One method of migrant navigation is by reference to stars (Emlen 1975). Light pollution from all sources reduces the visibility of stars, and may entrap migrating birds in dangerous environments especially during inclement weather, causing collision, apparent confusion, and mortality (Ogden 1996). Highway lighting standards are based on the Illuminating Engineering Society of North America's (IES) standards, and newer designs are available that meet the IES standards but have reduced light pollution effects. Lower wattage flat lens fixtures on highways and city streets direct light down and reduce glare, thus reducing light pollution. They are currently being used in a major retrofitting project in Calgary, Alberta to reduce light pollution and to save money and energy (City of Calgary 2002). Increasing the reflectivity of signs and road striping (retro-reflectivity) is a method of increasing the visibility of roads to drivers while reducing the need for electrical lighting (Hasson 2000).

Direct Mortality

Direct mortality is the impact most people likely associate with highways. Birds are listed as killed most frequently in most multiple taxa road mortality studies (Forman et al. 2003). One estimate of bird mortalities from all causes lists vehicle deaths as the fourth or fifth most numerous at 60 million or more per year in the United States, after pesticides and high-power transmission lines (U.S. Fish and Wildlife Service 2002), both of which can be associated with highways and cause cumulative impacts. The extent of mortality from highways is underestimated (as it is in most studies of mortality from man-made structures) because scavengers pick up small bird carcasses rapidly, often within minutes (Morris 2002). Bird mortality from vehicle collisions affects some groups more than others (*table 3*).

Table 2— *Disturbance impacts to birds from highways.*

Impact	Problem	Suggested solution
Noise	Noise disrupts song or intimidates shy species.	Noise barriers. Reduce noise sources such as tires and road surfaces.
Lights	Migrants can't see stars to navigate.	Coordinate light-pollution reduction. Ensure lights are necessary before installation. Use lower wattage flat lens fixtures on highways, retroreflective elements on signs and pavement.

Table 3— *Direct mortality from highways.*

Impact	Problem	Suggested solution
Walking birds	Non-flying birds incur greater mortality risk.	Crossing structures with large openness ratios (underpasses) or wildlife over-crossings.
Water birds	Winds over bridges can slam flying birds into vehicles.	Diversion poles on bridge decks.
Owls	Owls hunt at headlight height.	Diversion poles or short fences along highway medians and rights-of-way.
Ground nesters	Mowing rights-of-way kills nesters.	Mow after August 1.
Scavengers	Corvids or raptors are killed while foraging on roadkill.	Reduce roadkill.
	Attracted scavengers reduce productivity adjacent to highways.	Remove roadkill from road.
Migrant landfalls	Exhausted cross-gulf migrants fly into vehicles.	Low temporary fences to encourage higher flight across roads.
Frugivores	Fruiting median plants attracts birds across traffic.	Plant non-fruiting varieties.
		Remove fruiting varieties.
Winter finches	Deicing salt or sand attracts birds to road surface.	Velocity spreaders.
		Road temperature sensors to reduce quantities.
		Concentrate runoff appropriately.
		Public education program.

Ground-Dwelling Birds

Birds that fly infrequently because of morphology, foraging behavior or age are at greater risk of vehicle collisions because they spend longer time on the roadway, and often have a shallow escape flight trajectory. Species affected include gallinaceous birds, juvenile anatids, and *Melanerpes* woodpeckers foraging on roadkilled insects (Stoner 1925). Crossing structures such as open bridges, large V-shaped underpasses, viaducts or causeways with vegetation maintained beneath highways can be used to mitigate impacts to these species. Causeways elevated on pilings or other intermittent supports across wetlands maintain ecological function better than causeways built on dikes because they allow water flow and uninterrupted movement of marshland species of all taxa.

Water Birds

When bridges are approximately perpendicular to wind direction they can cause downdrafts that increase the risk of collisions between birds and traffic or bridge structures. At Sebastian Inlet State Park, Florida, Royal Terns (*Sterna maxima*) and Brown Pelicans (*Pelecanus occidentalis*) suffered mortality particularly during northeasterly winds. In one case, a semi truck killed several Brown Pelicans at once (A. Bard, pers. comm.). The installation of aluminum fence poles spaced at intervals along the edge of the bridge created an apparent barrier that caused birds to fly higher, resulting in significantly fewer mortalities (Bard et al. 2002). On Queen Isabella Causeway on South Padre Island, Texas, avian mortalities during certain wind directions included Common Loons (*Gavia immer*), Peregrine Falcons (*Falco peregrinus*), and Brown Pelicans. Signs warning of the danger of pelican collisions on the bridge may not be effective at reducing mortalities (G. and S. Colley, pers. comm.).

Owls

Several species of owls, particularly Barn Owls (*Tyto alba*), Great Horned Owls (*Bubo virginianus*), and Short-eared Owls (*Asio flammeus*), often forage near roads at about the same height as vehicle windshields and are common victims of vehicle collisions. In the Central Valley of California, juvenile Barn Owls suffer heavy mortality from vehicles along Interstate 5 and smaller county roads (Moore and Mangel 1996). No mitigation has been attempted in this case, however, a concept similar to the Sebastian Inlet State Park barrier poles may be effective for owls as well. If so, a low fence or fence material such as plastic construction fence or closely spaced, frangible reflective highway markers may be effective if installed along highway verges and medians.

Ground Nesters

Birds nesting in highway rights-of-way are vulnerable to direct mortality due to mowing practices. Most states mow rights-of-way to maintain sight distances and for esthetic reasons. The most vigorous spring growth and onset of mowing in May or June coincides with nesting season. Mowing affects primarily grassland species or waterfowl by directly killing eggs, fledglings or adults attending nests. An estimated 4,500 ducks are killed on

highway rights-of-way each year in the prairie pothole region of North Dakota because about a third of nesting ducks have not hatched by the early July mowing (Cook and Daggett 1995). Illinois Department of Transportation currently delays mowing until August 1 to protect nesting birds (Cook and Daggett 1995). Mowing for esthetic purposes instead of vegetation control may be possible to forego. Highway users in several states supported unmowed verges when the environmental ramifications were explained (Harper-Lore 2000). In addition, naïve fledglings of many species nesting near roadways are vulnerable to collisions with passing vehicles.

Scavengers

Scavengers such as corvids and raptors are at risk of being hit by vehicles as they forage on other road killed carcasses (Mumme 2000). At the same time, because road kills are a reliable source of food, the same avian and mammalian scavengers patrol highways for food, and thus are at higher densities along highways. These scavengers may then turn to adjacent habitat for other foraging opportunities, including nesting birds. In most states, the state Department of Transportation (DOTs) is responsible for removing road kills (Cook and Daggett 1995). Where this is the case, it may be helpful to encourage agencies to expeditiously follow the policy to remove large animal carcasses, or create one where no policy exists.

Migrant Landfalls

Exhausted cross-Gulf migrants can congregate by the thousands at first landfall. Some of these locations are now prime oceanfront real estate with developments that include highways. In 1996, many cross-Gulf migrants were blown off course and landed in the Florida Keys. Florida State Park road kill records indicate a huge number of warblers and vireos that year (Fahrig et al. 2002), suggesting a situation likely to be repeated at many other locations. Some normal landfalls such as the Mississippi and Alabama coastline contain highways immediately adjacent to the nearest vegetation after shoreline, thus concentrating birds near a high mortality risk (B. Sargent, pers. comm.). While land use planning to maintain habitat adjacent to the shoreline is the ultimate solution, some areas known to be mortality hotspots, such as Highway 180 near Fort Morgan, Alabama (B. Sargent, pers. comm.), may need to be monitored after heavy flights (predictable by radar images broadly available over the Internet) and extraordinary measures taken to prevent birds from attempting low flights across highways while still exhausted. In some of these locations, it might be possible to erect temporary fences or other barriers that encourage migrants to fly at some height over passing traffic, in a manner similar to the Sebastian Inlet State Park approach.

Frugivores

Frugivores such as Cedar Waxwings (*Bombycilla cedrorum*) and thrushes are attracted to fruiting plants grown in highway medians as barriers to vehicles. In many eastern states, thorny eleagnus (*Elaeagnus pungens*) has been planted in medians, causing the attraction and death by collision of hundreds of waxwings, American Robins (*Turdus migratorius*) and Common Grackles (*Quiscalus quiscula*) (Watts and Paxton 2001). Removal of thorny eleagnus is being accomplished in Virginia as a result of the identification of the problem and effective negotiations with the Virginia DOT.

Winter Finches

Deicing highways in snow country costs transportation agencies considerable expense and time. Solutions to this safety concern are continually being sought. Both sand and salt as deicing agents are deadly for gregarious winter finches such as Pine Siskins (*Carduelis pinus*) and crossbills (*Loxia* spp.) when ingested. Salt is highly toxic to birds and causes lethargy or passive escape reactions to vehicles; the combination of salt and sand sometimes causes massive mortality (Environment Canada 2001). Solutions are complex but may include continued research into better deicing agents, velocity spreaders, and temperature sensors in roadways to minimize application rates. In Glacier and Mount Revelstoke National Parks in Canada, visitors are given a brochure explaining the issue and advising motorists to honk their horns at congregated birds to give them time to escape (Morris 2002).

Indirect Mortality

Habitat Loss and Habitat Sinks

Habitat loss to highway development is huge and insidious because highways may facilitate further development. Highways cover about 1 percent of the land base of the United States, or an area about the size of South Carolina (Forman 2000). Land use planning, and transportation options such as mass transit, intermodal transportation (transportation between public and private modes), and intelligent transportation systems are urgently needed. It is probably safe to assume that at least some percentage of that highway growth forever alters valuable bird habitat.

Highway medians and rights-of-way do provide some habitat for species in heavily developed areas, particularly grassland species in the eastern states, but it is still

unknown whether or not these small, linear habitats function as overall population sinks or as sources.

Predator Bridges

Land-filled bridges across open waterways can allow predators to access previously predator-free island seabird nesting colonies. Following the construction of a new highway in Norway, foxes, martens and badgers were able to cross to the island of Tuatara on rocky fill below the highway. Remedial measures such as noisemakers and an open-grid drawbridge have been unsuccessful to date (Quell 2001). Avoidance of these situations is the best policy.

Brood Parasitism and Noxious Species

The expansion of Brown-headed Cowbirds (*Molothrus ater*) and several species of noxious plants and animals is facilitated by the cleared line of sight along highways, particularly where these species had been limited by blocks of unsuitable habitat. Line of sight clearing is a safety measure that normally is a minimum of 10 m (30 ft). Where cowbird brood parasitism is a concern, large blocks of minimally cleared rights-of-way may be part of a suite of mechanisms used to control this species.

Lethal Associated Structures

When associated with highways, powerlines, railroads and canals are a few structures cumulatively more hazardous to birds. Vehicle traffic may cause birds to fly higher to avoid cars only to collide with parallel powerlines. Raptors continue to be electrocuted on powerlines, possibly in greater numbers along highways because of the attraction of roadkill scavenging opportunities. Gallinaceous species are attracted to canals in desert areas only to become vehicle mortalities (or drowned). Some of these structures can be buried, relocated or made safer if planners are aware of the cumulative impacts to birds because of their proximity to highways. The guidelines recommended by the Avian Power Line Interactions Committee to minimize electrocutions and collisions should be followed whenever possible (APLIC 1994, 1996).

Maintenance Practices

Peregrine Falcons and Cliff Swallows (*Hirundo pyrrhonota*), among others, may use bridges as nesting habitat. Bridge maintenance, however, typically occurs in warmer seasons, so it can conflict with successful nesting. Washington DOT developed specific and strict protocols to minimize impacts to Peregrine Falcons, formerly a State- and Federally-listed endangered species (Carey 1998). Under the Migratory Bird Treaty Act active nests containing eggs or young, or colonies with at least one such nest, are protected; intermitted take sometimes occurs regardless. On a bridge in Montana, DOT officials removed Cliff Swallow nests prior to the breeding season and applied a sticky repellent. The repellent was removed after maintenance was completed, limiting the loss of productivity to at most one year (Wabash et al. 2002).

Table 4 is a summary of these indirect sources of mortality to birds from highways, associated structures, and maintenance activities.

Conclusion

There are few data regarding the impacts of highways on birds and fewer on the effectiveness of the relatively few mitigation measures devised to reduce those effects. Nationwide, estimates of direct mortality from bird-car collisions range from 10 to 380 million (see Erickson et al. this volume). These are based on extrapolations from local studies, none of which corrected for the unquestionably large bias from carcass scavengers and searcher efficiency. There are no estimates for the sub chronic effects on populations from habitat loss, fragmentation, disturbance and other indirect effects of highway construction. Thus, there is a need for systematic efforts to assess these impacts locally and nationwide. Without these data, it is difficult to promote effective mitigations to highway planners. There might be little to be done to minimize impacts along the majority of the roughly 4 million miles of roadway in the United States, but protective measures addressed in this paper and other innovative solutions should be attempted along certain highly vulnerable locations, e.g. next to wetlands, over rivers, through riparian areas, and along migration corridors or fallout locations.

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Table 4— *Indirect mortality from highways.*

Impact	Problem	Suggested solution
Habitat loss	Highways facilitate development.	Land use planning; Mass transit or other change in transportation paradigm.
Habitat sink	Suitable habitat near highway increases mortality.	Make habitat unsuitable; Haze birds away; Reduce mortality through above methods.
Predator bridges	Bridges or land causeways allow access to nesting islands.	Design to avoid predator crossings; Drawbridge or open grid deck on bridge; Noise.
Brood parasitism	Cowbirds increase along cleared rights-of-way.	Reduce line-of-sight clearing; Other cowbird control mechanisms to break continuous pathway.
Noxious species	Highways facilitate noxious species travel.	Plants: herbicides, biological controls; Work with local DOTs to emphasize control.
Lethal structures	Birds fly into associated structures; Additional structures increase distance to cross.	Follow APLIC guidelines; Attach visibility markers; Bury telephone/power lines; Require raptor-safe power poles; Consider cumulative impact of railroads, power lines, canals, frontage roads.
Maintenance practices	Maintenance often occurs during nesting season.	Maintenance protocols; Timing restrictions; Acceptance of one year loss of productivity.

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Bird Strikes and Electrocutions at Power Lines, Communication Towers, and Wind Turbines: State of the Art and State of the Science – Next Steps Toward Mitigation[1]

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Abstract

Migratory birds suffer considerable human-caused mortality from structures built to provide public services and amenities. Three such entities are increasing nationwide: communication towers, power lines, and wind turbines. Communication towers have been growing at an exponential rate over at least the past 6 years. The U.S. Fish and Wildlife Service is especially concerned about growing impacts to some 836 species of migratory birds currently protected under the Migratory Bird Treaty Act of 1918, as amended. While mortality estimates are often sketchy, and won't be verified until nationwide cumulative impact studies are conducted, current figures are troubling. Communication towers may kill from 4-50 million birds per year. Collisions with power transmission and distribution lines may kill anywhere from hundreds of thousands to 175 million birds annually, and power lines electrocute tens to hundreds of thousands more birds annually, but these utilities are poorly monitored for both strikes and electrocutions. More than 15,000 wind turbines may kill 40,000 or more birds annually nationwide, the majority in California. This paper will address the commonalities of bird impacts among these industries; those bird species that tend to be most affected; and research (completed, current, and proposed) intended to reduce bird collisions and electrocutions nationwide. The issues of structure location (siting), lighting, guy supports, lattice or tubular structures, bird behavior, and habitat modifications are reviewed. In addition, this paper reviews the respective roles and publications of the Avian Power Line Interaction Committee and the Wildlife Workgroup of the National Wind Coordinating Committee, the roles of the Service-chaired Communication Tower Working Group and Wind Turbine Siting Working Group, and the Fish and Wildlife Services' voluntary tower and turbine siting and placement guidelines. An update on recent Communication Tower Working Group research initiatives will also be discussed along with promising research findings and needs.

Key words: APLIC, avian impacts, avian mortality, BGEPA, bird strikes, collisions, communication towers, CTWG, electrocutions, ESA, MBTA, mitigation measures, NWCC, power lines, transmission and distribution lines, wind turbines.

Introduction

Acquiring reliable estimates of avian population mortality is difficult, even under controlled circumstances, and the threats to birds from human development continue to increase in the United States and elsewhere globally. As the U.S. human population grows – now the third largest in the world – human structures and the services needed to meet population demands continue to increase. Unfortunately, the impacts of these structures and services on birds, bats, and other species are generally unaccounted for, unknown, or only roughly estimated. This paper will address three of these structural impacts, those from power lines, communication towers, and wind turbines.

To better understand the impacts of human-caused mortality on landbirds – and recently on bats, attempts have been made not only to estimate these mortality factors, but also to assess the spring and fall populations of breeding landbirds in North America to determine rough mortality percentages. While bird hunting mortality has been documented back to at least Biblical times, mortality caused by structures was first documented in the United States in 1874 at lighthouses and lamps (Forest and Stream 1874) and in 1876 at telegraph wires (Coues 1876). The first U.S. Fish and Wildlife Service (USFWS or Service) attempt to estimate nationwide human-caused annual mortality was published by Banks (1979) where he estimated 196 million bird deaths caused by human activity. This estimate represented 1.9 percent of the then existing estimated bird population in North America. Of the 196 million estimated deaths, 61 percent were from hunting, 32 percent from collisions with structures, and 2 percent from pollution and poisoning. To assess the nationwide status of breeding bird populations, Aldrich et al. (1975) used the 1973 Breeding Bird Survey, which averaged 1,284 birds/km^2 (3,325 birds/mi^2), to

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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estimate 9.975 billion breeding landbirds in the United States exclusive of Alaska and Hawaii. They concluded that the autumn landbird population was probably twice that figure – 20 billion. Banks (1979) used the figure of 10 billion breeding birds in the contiguous United States and assumed an average annual mortality of 10 billion birds. J. Trapp (unpubl. data), of the USFWS' Division of Migratory Bird Management, examined Breeding Bird Censuses for 1991 and 1992, extrapolated from these figures, and concluded that it was probably safe to talk about minimum breeding populations on the order of 10 billion birds, and minimum fall populations on the order of 20 billion birds in North America north of Mexico. While there are far more birds than people generally realize, population impacts can be sizable and most human-caused avian mortality factors are not systematically monitored or assessed.

The USFWS is currently responsible for the conservation and management of 836 species of migratory birds in the United States; these birds are killed by myriad non-hunting-related factors. These include collisions with communication towers, power lines, wind turbines, buildings and windows, smokestacks and monuments, automobiles, and aircraft; electrocutions at power lines; predation by domestic cats; poisoning from pesticides, oil and contaminant spills; drowning in oil and wastewater pits; entanglement, strangulation, and drowning in fishing gear; and loss or degradation of habitat.

Of the 836 migratory bird species managed by USFWS, at least 223 are in trouble. These include 92 listed on the Federal Endangered Species Act (ESA; 16 U.S.C. 1531 et seq.: 77 are endangered and 15 are threatened), and 131 on the USFWS's National List of Birds of Conservation Concern 2002 (USFWS 2003). Populations are declining precipitously for some of these species. To add yet another challenge to managing birds, we essentially lack data on the status of fully one-third of all North American bird populations. These challenges make management difficult. Recent extrapolations from various databases indicate that human-caused mortality could account for billions of bird deaths per year (Klem 1990, Corcoran 1999, Erickson et al. 2001, Manville 2001a, Manville 2001b). Based only on estimates of annual mortality from vehicles strikes (60- 80 million), building and window collisions (98- 980 million), smoke stack casualties (tens to hundreds of thousands), power line electrocutions (tens to hundreds of thousands), power line impacts (hundreds of thousands to perhaps 175 million), communication tower accidents (4-5 to 40-50 million), and wind turbine impacts (~ 34,000), Erickson et al. (2001) estimated from 100 million to well over one billion birds killed annually. The extent to which cumulative mortality from all human-caused factors affects bird populations, and measures that can be taken to reduce these events, are matters of considerable interest and concern to the Service and others (Manville 2001b).

Structural Review

The U.S. Power Grid

Since the U.S. power grid was first constructed in the late 1880s, power line expansion has increased tremendously. With a growing U.S. population, industrial expansion, and public demand for more electricity as exemplified by energy challenges in California in 2001, more power lines are being installed. The most recent nationwide estimates indicate that there are more than 804,500 km (500,000 mi) of bulk transmission lines in the U.S. (transmission lines in the U.S. carry ≥115,000 volts/115 kV, with conductors attached to either tall wood, concrete or steel towers; APLIC 1996, Harness 1997, Edison Electric Institute 2000). Much of the problem with bird collisions is associated with transmission lines. Distribution lines (those in the U.S. carrying ≤69,000 v/69kV) are constructed on 11- 15 m (36- 49 ft) wooden, steel, or concrete poles, typically configured with one, two, or three energized (phase) wires and one neutral (grounded) wire. Raptor electrocutions, especially in the western United States, are most frequently associated with distribution lines. Distribution lines have phase-to-phase and phase-to-ground wire clearances which place birds perching on the supporting poles at much greater risk of completing a circuit and suffering electrocution, often resulting in a power outage (Boeker and Nickerson 1975, Harness 1997). Because of rapid expansion, new development, and jurisdictional issues, no good accounting of the total amount of distribution line is available for the United States; it is certainly in the millions of kilometers. Williams (2000) cites the figure of 116,531,289 distribution poles in the United States but lists no figure for wire length.

Power Line Electrocutions

Birds have been subject to electrocutions and collisions in the United States since the first overhead telegraph wires were strung in the late 1860s, initially reported by Coues (1876) in rural Colorado. Electrification of the United States and development of the U.S. power grid began by the late 1880s and has rapidly expanded since. Not surprisingly, by 1922, eagle electrocutions were first reported at transmission lines, followed in 1933 by hawk electrocutions at distribution lines, and in 1940 by power outages on Idaho Power lines which subsequently were retrofitted with a deterrent device intended to discourage eagles from landing (R. Harness, EDM International, pers. comm.). By the early 1970s the electric utility industry had become

acutely aware of bird electrocutions – especially to eagles, hawks, and owls. Reports of significant bird mortality during the winter of 1970-1971 in Colorado and Wyoming drew the attention of state and Federal law enforcement agents and the industry; nearly 1,200 eagle deaths were reported resulting from poisoning (N = 30+), shooting from aircraft (N = 800+) and electrocution or shooting along a power line (N = 300+) (Olendorff et al. 1981; L. Suazo, USFWS, pers. comm.). M.W. Nelson's 1980 film "Silver Wires, Golden Wings" followed, which was one of the first public relations efforts designed to help prevent eagle electrocutions and to encourage use of nesting platforms on power poles (Lehman et al. 1999). Nelson filmed trained Golden Eagles (*Aquila chrysaetos*) during take-offs and landings on un-energized mock-up power poles to determine how electrocutions occurred and how they might be prevented. His and other research led to an update to the Suggested Practices document (Olendorff et al. 1981).

In an attempt to begin addressing both collision (specifically Whooping Cranes [*Grus americana*]) and electrocution problems, an ad hoc committee represented by several investor-owned electric utilities (IOUs), the National Audubon Society (NAS), and the Service was created in 1983. By 1989, a more formal relationship was established with the creation of the Avian Power Line Interaction Committee (APLIC) composed then of nine IOUs and the FWS (Lewis 1997) – with technical advice from staff of NAS, Clemson University, and the University of Idaho. APLIC was housed in the IOU trade association Edison Electric Institute (EEI), Washington, DC (Huckabee 1993). Following research and earlier publications in 1975 and 1981, Suggested Practices for Raptor Protection on Powerlines (APLIC 1996) became the first definitive work on raptor electrocutions. It was reprinted in 2000 in Spanish. That same year the instructional video, Raptors at Risk (North American Falconers' Association et al. 2000) was released to the public, documenting raptor electrocutions and illustrating inexpensive avoidance techniques. Copies can be obtained from R. Harness at EDM International, <rharness@edmlink.com>.

While the efforts of APLIC to reduce bird electrocutions and collisions have been key, many in the electric utility industry may still not be getting the message that human-caused bird deaths are unacceptable (Williams 2000). At present, APLIC is composed of 18 IOUs (out of 186-some IOUs within this country); one IOU trade association (EEI); some 960 cooperatives represented by the National Rural Electric Cooperative Association (NRECA; out of approximately 1,056 cooperatives housed under the U.S. Department of Agriculture [USDA]); one research organization (Electric Power Research Institute); and three Federal agencies (including USFWS, the Bonneville Power Administration, and the Western Area Power Administration) (L. Suazo, USFWS, pers. comm.; R. Loughery, Edison Electric Institute, pers. comm.; www.APLIC.org). To be a more effective arm of the overall industry, APLIC still needs to recruit additional utility membership. However, many of the cooperatives are small companies, and the $5,000 APLIC initiation fee and $2,500 annual dues are viewed by many as better spent on mitigation or for other purposes.

NRECA – somewhat like APLIC – is the not-for-profit national service organization representing most of the USDA cooperatives which provide electricity to more than 30 million consumer-owners primarily in sparsely population rural areas in 46 states. NRECA published a definitive manual for their industry, Animal Caused Outages (Southern Engineering Company 1996), which addresses wire configurations and situations unique to this segment of the industry. APLIC and NRECA are working to integrate guidance in Suggested Practices for Raptor Protection on Power Lines (APLIC 1996) that conforms to both types of utility structures and needs. USDA cooperatives, for example, now must construct distribution lines using non-conducting wooden braces and cross arms, and install ground wires that are raptor safe.

Prior to 1999, only two fines had been levied by law enforcement agents against electric utility companies for electrocuting birds protected under the Migratory Bird Treaty Act (MBTA; 16 U.S.C. 703-712) and the Bald and Golden Eagle Protection Act (BGEPA; 16 U.S.C. 668-668C), one in 1993 and the other in 1998. MBTA is a strict liability statute; the killing of any protected migratory bird is not technically allowed under law unless a permit is obtained, and the Service does not issue "incidental or accidental take" permits. The landscape changed in August 1999 with the District Court's decision against the Moon Lake Electric Association in western Colorado and eastern Utah. Beginning in 1997, agents of the Service's Office of Law Enforcement (LE) in the West investigated bird mortalities from electrocutions and strikes, and found to their dismay that the statistics rivaled those from the 1970s. As a result of this investigation, the Department of Justice prevailed in its first criminal prosecution of a utility under BGEPA and MBTA. Moon Lake pleaded guilty and agreed to pay $100,000 in fines and restitution, serve 3 year's probation, sign a memorandum of understanding (MOU) with the Service, implement an avian protection plan, and retrofit poles that were killing raptors. The message was a powerful one, sending shock waves through the electric utility, wind generation, and communication tower industries. In addition to fines as high as $500,000, company officers could be convicted of felonies, lose their right to vote, pay per-

sonal fines as high as $250,000, and be jailed for up to two years (Williams 2000).

Following release of the Moon Lake MOU, LE was inundated with requests for other MOUs. In 2002, an historic MOU was signed with Xcel Energy and the USFWS Denver, Colorado, Regional Office in concurrence with the Department of Justice. The proactive agreement presently covers Colorado and Wyoming. The USFWS is currently finalizing the template for an avian protections plan (APP) with APLIC These voluntary, proactive agreements will call for the development of comprehensive APPs which are intended to reduce electrocutions and bird strikes by participating companies.

Looking specifically at the problem of electrocutions, eagles are the most commonly reported electrocuted birds, Golden Eagles reported 2.3 times more frequently than Bald Eagles (*Haliaeetus leucocephalus*) by Harness (1997) in the West, with juveniles more frequently reported killed than adults. Red-tailed Hawks (*Buteo jamaicensis*) and Great Horned Owls (*Bubo virginianus*) were the most commonly reported hawk and owl species by Harness (1997) and Harness and Wilson (2001). Power outages can result in damaged equipment, safety problems, brush and forest fires, and loss of service to customers. Nationwide, animals are the third leading identifiable cause of all power outages, with birds causing more outages than any other animal (Southern Engineering Company 1996). Of 4,300 eagle mortalities investigated by the Department of Interior from the early 1960s to 1995, electrocution was reported as the second greatest cause of mortality to Golden Eagles and the third greatest cause to Bald Eagles (LaRoe et al. 1995). Electrocution is now rated the fourth leading cause of death for Bald Eagles, following accidental trauma, poisoning, and shooting (Lehman 2001).

Where vegetation is low and terrain is flat, power poles are particularly attractive to raptors in the West since they provide structures from which to hunt and roost (Boeker 1972, Benson 1981). Eagles and buteos (soaring hawks) actively seek out poles, especially where prey is abundant and few other perches exist, increasing their range of vision, allowing greater attack speed when hunting, and advertising territorial ownership (Olendorff et al. 1981, Colson and Associates 1995). It was commonly believed in the 1980s that a very small percentage of distribution poles was actually electrocuting raptors. These were designated as "preferred poles," situated in good habitat or near high prey concentrations (Olendorff et al. 1981). Nelson and Nelson (1976) even estimated that 95 percent of electrocutions could be prevented by modifying 2 percent of the poles. Conventional wisdom indicates that these assessments were probably unrealistic due, in part, to lack of a nationwide reporting system and systematic nationwide studies, and observational and data-collection biases (Lehman 2001).

Twelve North American raptor species are known nesters on utility structures. In the East, Osprey (*Pandion haliaetus*) is frequently seen nesting on power poles (Blue 1996). Due to lack of staff and funding, very little of the U.S. power grid is assessed – if even infrequently – for bird electrocutions. The estimates of tens of thousands to hundreds of thousands or more birds killed each year are only very rough approximations based on very limited data. True mortality could be much higher. Recent information suggests that raptor electrocutions may be under-reported, possibly larger by several orders of magnitude (Lehman 2001).

Mitigation measures can vary in cost, depending on whether or not they are required for new construction or are retrofitted. Sufficient phase-to-phase and phase-to-ground wire spacing is critical for large-winged birds. This can be costly if wires have to be re-strung for wider separation. Three-phase transformers can be especially deadly where bare energized jumper wires connect transformers, protective cutouts, and surge arresters. These can be deadly to small and large raptors (Negro and Ferrer 1995). Jumper wires on all electrical equipment should be insulated, including at tap and dead-end locations. Existing transformers can be retrofitted by replacing bare wire with either 600 v insulated jumpers or by sliding insulating material over bare jumpers; new jumpers should contain 600 v insulated jumpers and be insulated with bushing covers (Harness 1997, Harness and Wilson 2001). Specifications are provided by APLIC (1996) and Southern Engineering Company (1996). With the use of cost-effective new or replacement steel distribution poles – steel has been used on transmission towers for years – we see a new electrocution challenge. The mitigation measures used on wooden poles are not effective on metal ones. In a European study, insulating cross-arm braces on steel distribution poles proved most effective, while perch guards were less effective (Janss and Ferrer 1999). Harness and Wilson (2001) call for more research to attempt to qualify the relationships between raptor electrocutions and different types of electrical power structures. The Service strongly agrees.

Power Line Collisions

Birds of a much greater variety strike power transmission and distribution lines. Coues (1876) was the first to report over 100 dead birds, mostly Horned Larks (*Eremophila alpestris*), along a 4.8-km (3-mi) section of telegraph line, and even witnessed the deaths of three birds. Cohen (1896) reported 14 Red Phalaropes (*Phalaropus fulicaria*) and a Ruddy Duck (*Oxyura jamaicensis*) verified by necropsies as telegraph wire

kills. Emerson (1904) reported shorebirds and a Black Rail (*Laterallus jamaicensis*) colliding with electrical wires over a salt marsh and evaporation ponds – representing the first reported power line strikes. Large, less maneuverable birds are more vulnerable to collisions with power lines, including Great Blue Herons (*Ardea herodias*), cranes (*Grus* spp.), swans (*Cygnus* spp.), and pelicans (*Pelicanus* spp.; Huckabee 1993). Line collisions resulted in 36 percent of the known mortality to fledged Greater Sandhill Cranes (*G. canadensis tabida*) in the Rocky Mountains (Drewien 1973), 44 percent mortality of fledged Trumpeter Swans (*C. buccinator*) in Wyoming (Lockman 1988), and 40 percent of the know mortality of endangered fledged Whooping Cranes in the Rocky Mountains (Lewis 1993). In a study near wetlands in North Dakota, Faanes (1987) found that waterbirds (based on 46 percent documented mortality), waterfowl (26 percent), shorebirds (8 percent), and passerines (5 percent) were most vulnerable to strikes with transmission lines. In habitats away from wetlands, raptors and passerines appear to be most susceptible to collisions with power lines. Collisions from many other species have also been reported (Erickson et al. 2001).

On Kaua'i, Hawaiian Islands, studies by Podolsky et al. (1998) and Ainley et al. (2001) documented rather unique lighting and power line impacts to Newell's Shearwaters (*Puffinus auricularis newelli*). During the first nocturnal flights of fledglings from nests to the ocean, a high percentage (≥2 to ≥10 percent) of fledglings were reported blinded by man-made lighting, disoriented, and killed while colliding with lights, utility poles, wires, buildings, and automobiles (Ainley et al. 2001). Contrary to recommendations by APLIC, wide spacing of power transmission lines appeared to increase collisions of summer nesting season adults and subadults during their nocturnal and crepuscular flights to and from bird colonies (Podolsky et al. 1998). It was hypothesized that the wide spacing increased the incidence of collisions as birds attempted to avoid hitting one line, only to hit another. In experimental areas, light shielding was shown to reduce attraction by as much as 40 percent while reducing light intensity also lowered deaths significantly (Ainley et al. 2001). Burying power lines was also recommended for particular hot spots.

Estimates of mortality from avian collisions with power lines have varied considerably and have frequently been based on extrapolations. Faanes (1987) estimated 124 avian fatalities/km/yr (200 fatalities/mi/yr) near prairie wetlands and lakes in North Dakota. Koops (1987) examined 4,666 km (2,900 mi) of bulk transmission line in the Netherlands, estimating 0.75 - 1 million birds killed there per year. U.S. mortality could range from hundreds of thousands up to perhaps 175 million birds per year, based on extrapolations by Erickson et al. (2001) and Koops (1987). Very little of the power grid, however, is currently being examined so these estimates are not particularly meaningful.

In an attempt to comprehensively address the collision problem, APLIC (1994) provided voluntary guidance to the industry on avoiding power line strikes. The document will be updated once research being conducted by the Electric Power Research Institute and others at the Audubon National Wildlife Refuge, North Dakota, is completed, and results of tests on a Bird Strike Indicator and Bird Activity Monitor can be published. Other research findings will also likely be included. For example, marker balls, bird diverters, and paint have been shown to reduce collisions, sometimes significantly. Strikes were reduced by 53 percent at a South Carolina transmission line outfitted with yellow marker balls (Savereno et al. 1996). In southwestern Colorado, polyvinyl chloride plastic dampers reduced collisions of cranes and waterfowl by 61 percent while yellow fiberglass square plates reduced mortality to the same species by 63 percent (Brown and Drewien 1995).

Communication Tower Collisions and Related Problems

Communication towers, whether monopole cellular telephone, or tall, lattice structured digital television (DTV) antennas, are an increasingly familiar sight in neighborhoods, near highways, and along ridge tops. For at least the past 6 years, the number of communication towers (including but not necessarily limited to radio, television, cellular, microwave, emergency broadcast, national defense, paging, and related) constructed across the landscape has been growing at an exponential rate. Based on the July 2002 statistics from the Federal Communication Commission's (FCC) Antenna Structure Registry Database (FCC 2002), more than 138,000 towers were listed with the Commission – of which some 106,000 were lighted. Revised published statistics (FCC 2003) may have indicated some double-counting of the 2002 numbers, since nearly 93,000 towers were reported registered in June 2003. Due to an under-reporting to the FCC of up to some 35 percent, the actual number of existing towers is likely higher (Manville 2001b).

While this is positive news for the communications industry, it is decidedly problematic for migrating birds. Towers today pose a likely significant impact on migratory birds, especially some 350 species of passerines. The earliest known report of a bird-tower kill in the United States took place in September 1948 at a 137-m (450-ft) radio tower in Baltimore, Maryland, although no details about the incident were available (Aronoff 1949). The first long-term study of the impact of a television tower on birds was begun in 1955 by the

Tall Timbers Research Station in northern Florida. After the first 25 years of the study, 42,384 birds representing 189 species were tallied (Crawford and Engstrom 2000). On average, 1,517 birds were killed per year over the 29-year period of this study, 65 percent of the mortalities documented in the fall and 20 percent in the spring (Crawford and Engstrom 2001). The longest study yet conducted – over 38 years – was performed by physician C. Kemper, beginning in 1957. He collected nearly 121,560 birds representing 123 species and he still holds the all-time record for most birds collected and identified from a single-night tower strike: more than 12,000 birds were retrieved in 1963 from the base of a television tower in Eau Clair, Wisconsin, not accounting for almost certain scavenging by wild and domestic predators (Kemper 1996). Able (1973) reported single night kills exceeding 1,000 birds at television towers in Tennessee and Florida during the fall 1972. While published accounts of kills at short towers are limited, Herndon (1973) reported 1,801 birds of 44 species killed during two foggy nights in the fall 1972 at 38-m (125-ft) and 26-m (85-ft) towers and floodlit buildings. In bad weather, bird strikes have been recorded near or at ground level, usually associated with lighting. James (1956) retrieved 2,421 dead birds of 39 species (mostly warblers) beneath light poles on a coastal island following a single stormy spring night in 1951. Lord (1951) reported 200 birds of 23 species killed after apparently being confused by floodlights and striking a lodge on the Blue Ridge Parkway during a foggy night in the fall 1950. In 1975, Wylie (1977) reported 73 birds of 21 species killed by striking an unlit, 30-m (100-ft) tall fire tower during a night of rain and fog. Until more research is conducted on the effects of short towers on birds, we cannot assume that they are not having an impact on populations of songbirds.

To assess tower mortality, Banks (1979) estimated that 1.25 million birds were killed per year in strikes with towers, basing this estimate on 505 tall towers likely to impact birds in 1975. Evans (1998) reassessed mortality based on increased numbers of tall towers, estimating 2-4 million bird deaths per year. Manville (2001a, from a December 1999 evaluation) estimated annual mortality at 4-5 million birds, while Manville (2001b, based on a December 2000 assessment) again cited the 4-5 million figure but indicated that mortality could range as high as 40-50 million. He cautioned that only a cumulative impacts study would assess the true magnitude of the problem and again raised concerns over impacts on already imperiled bird species.

A recently discovered and potentially troubling problem for birds is the impact of low-level, non-thermal radiation emitted from towers. Several studies have recently been conducted using standard 915 MHz cell phone radio frequency microwave radiation on domestic chicken embryos for either 4 days of continuous exposure or at timed intervals twice daily for 4 days (Farrel et al. 1998, data published in DiCarlo et al. 2002; T. Litovitz, Catholic University, pers. comm.). Radiation levels in one study (T. Litovitz, Catholic University, data, published in DiCarlo et al. 2002) were far below current FCC-approved and permissible human health radiation standards (i.e., 1.6 W/kg of whole body tissue). With exposures of 30 minutes or more of radiation per day, embryos developed deformities (e.g., induced DNA damage at 1/600th [0.0024 W/kg] the current permissible level) and in some cases died (e.g., due to affected calcium levels in the heart at 1/10,600th [0.00015W/kg] the permissible level under hypoxic conditions). While extended low doses of microwave cell-phone radiation are being shown to be a distinct risk to human health through enhanced probabilities of cancer (Hardell and Mild 2001) and Alzheimer's disease (Sobel et al. 1996), what effects tower-emitted radiation have on nesting and roosting wild birds on or next to towers are only now being studied. Preliminary research in Valladolid, Spain, has shown strong negative correlations with levels of tower-emitted microwave radiation and bird breeding, nesting, and roosting in the vicinity of these electromagnetic fields. In the House Sparrow (*Passer domesticus*), White Stork (*Ciconia ciconia*), Rock Dove (*Columba livia*), Magpie (*Pica pica*), Collared Dove (*Streptopelia decaocto*), and other species, nest and site abandonment, plumage deterioration, locomotion problems, and even death were reported among those species found close to cellular phone antennas (A. Balmori, 2003 unpubl. ms). Laboratory mice were treated with radiation to replicate conditions found close to an "antenna park" by Magras and Xenos (1997) in Greece. After five generations of newborns, irreversible infertility occurred. What similar effect antennas may have on birds is unknown.

From a collision perspective, the towers that cause the most problems are tall (especially those exceeding 305 m [1,000 ft]), illuminated at night with solid or pulsating incandescent red lights, guyed, near wetlands, in major songbird migration pathways or corridors, and with a history of inclement weather during spring and fall migrations (Manville 2001a). All towers, however, have the potential to kill birds. Light appears to be a key attractant for night-migrating songbirds, especially on nights with poor visibility, low cloud ceilings, heavy fog, or various forms of precipitation associated with either passing or stationary cold fronts (Tordoff and Mengel 1956, Ball et al. 1995). Its attractant effects were first reported in Forest and Stream (1874) and later Allen (1880, cited in Cochran 1959) reported birds killing themselves by flying against lighthouse lights. Cochran and Graber (1958) and Cochran (1959) reported that songbirds were heavily attracted to red

incandescent lights at a television tower during inclement weather. In two studies where lighted towers attracted songbirds, and the lights were extinguished, birds continued on their migrations leaving previously lit, cloud enshrouded towers (Cochran and Graber 1958, Avery et al. 1976). In both studies, when the lights were turned back on, within minutes birds began circling the towers in large numbers. Gauthreaux and Belser (1999) showed a greater proportion of bird attraction to red flashing incandescent lights than to white strobes; strobes still attracted some birds compared to unlit controls that attracted none. When nighttime weather conditions and visibility improved, in all cases reported in the literature, the birds left the lighted towers, apparently continuing on their migrations. While tall lighted towers appear to be a major problem, lights can draw birds close to or at ground level, as James (1956) reported on South Padre Island, Texas, when several thousand carcasses were retrieved following a one-night storm.

The Service's Division of Habitat Conservation and our 78 Ecological Services field offices have been involved, to varying degrees, for decades in assessing towers and their impacts on species listed under ESA and required consultations under Section 7 of the Act. However, not until 1998 did the Division of Migratory Bird Management become actively involved in the tower collision issue when in January 1998, up to 10,000 Lapland Longspurs (*Calcarius lapponicus*) and several other species died in a one-night multi-tower accident in western Kansas (Manville 2000). In response to pressure from the environmental community to address this growing problem, the Service developed a tower risk model in late 1998 (the key points of the model referenced in Manville 2001a) and in June 1999 chaired a meeting facilitated by the environmental dispute resolution group, RESOLVE. The most noteworthy outcome of the RESOLVE meeting was the formation of the multi-stakeholder group, the Communication Tower Working Group (CTWG) – made up of more than 14 Federal and several state agencies; most of the communication industry trade associations and several companies; radar, acoustical and physiological ornithologists; consultants; and a number of conservation organizations. The purpose of the CTWG is to develop research protocols, seek funding, and implement pilot studies and a strategic nationwide tower monitoring and cumulative impacts study. Specific details of Working Group developments and related tower challenges are referenced in Manville (2001a, 2001b; see also http://migratorybirds.fws.gov/issues/towers/abcs.html).

In 1999, the USFWS co-sponsored a workshop on "Avian Mortality at Communication Towers" at Cornell University (complete transcripts available at http://migratorybirds.fws.gov/issues/towers/agenda.html). Following meetings in 1999 and 2000, the CTWG developed protocols for conducting pilot studies; approved the framework for a nationwide monitoring study; and prioritized research needs for pilot studies on lighting attraction, behavior effects of lighting, dead bird searches, a critique for dangerous towers, and Geographic Information System needs. Three pilot studies were peer-reviewed by members of the Ornithological Council of which one on lighting has been funded and implemented in the spring 2003.

In 2001, Florida-based Richland Towers funded and implemented the first avian mortality study west of the Rocky Mountains in Sacramento County, California. Avian mortality was small; researchers discovered some ten dead birds during the one-month spring migration study. No bad weather events occurred during the research.

In February 2002, the CTWG met to discuss developing a public-private partnership. Since that meeting, the National Fish and Wildlife Foundation (NFWF) has contributed $50,000 in funding to be matched 1:1 by industry or another source. At the February 2004 meeting of the CTWG, NFWF continued to commit the $50,000. The monitoring of NFWF funding will likely be used to match a portion of $200,000 in funding from the state of Michigan for a lighting study now under way.

Like the voluntary Suggested Practices used by the electric utility industry, the Service developed voluntary tower siting and placement guidelines for the communication tower industry in September 2000 (http://migratorybirds.fws.gov/issues/towers/comtow.html) – based on two years of comments and concerns from the industry, key scientists, and conservationists, and based on the best science available. As new research findings are discovered, for example through pilot studies, the guidelines will be updated with this information.

The U.S. Forest Service is to be commended for using the USFWS's siting guidelines for companies proposing to site short, unguyed cellular phone towers in Arizona National Forests, and for requiring the companies to fund and implement three-year tower monitoring studies in Coconino, Prescott, and Kaibab NF s. They have also adopted the Migratory Bird Division's suggested monitoring protocol for these studies that should yield needed data on the magnitude of avian mortality at short towers in the West. The U.S. Coast Guard is also to be commended for signing a memorandum of understanding with the Service, in which they will use the Service's voluntary communication tower guidance to collocate existing and some proposed new antennas on other towers, buildings, or similar structures; and they will fund and implement a joint Service-USCG research study at a select number

of new towers around the U.S. coastline and the Great Lakes. Lighting will be a key component of the research.

Wind Generation

Wind-generated electrical energy is renewable, produces no emissions, and is a generally environmentally clean technology that is becoming competitive with electricity produced from fossil fuels and nuclear power (American Wind Energy Association [AWEA] unpubl. data, http://www.awea.org). However, like so many technologies, "there is no free lunch." Wind generation has one significant downside: rotor blades kill birds – especially raptors – and bats; birds can strike the towers; electrocutions can occur if designs are poor; and wind farms may impact bird movements and habitat use. Wind turbine technology is not new to the United States. In the late 1930s, Vermont boasted the world's then-largest turbine that was likely disabled by high winds due to design flaws, and Cape Cod supported over 1,000 working windmills in the 1800s (Ferdinand 2002). But wind turbine 'farms' and their impacts to birds are a recent phenomenon, as compared to power lines and communication towers where mortality has been documented for decades or longer. The problem in the United States surfaced in the late 1980s and early 1990s at the Altamont Pass Wind Resource Area – a facility then containing some 6,500 turbines on 189 km^2 (73 mi^2) of gently rolling hills just east of San Francisco Bay, California (Davis 1995). Orloff and Flannery (1992) estimated that several hundred raptors were killed each year due to turbine collisions, guy wire strikes, and electrocutions. The most common fatalities were those of Red-tailed Hawks, American Kestrels (*Falco sparvarius*) and Golden Eagles, with less mortality of Turkey Vultures (*Cathartes aura*), Common Ravens (*Corvus corax*), and Barn Owls (*Tyto alba*). The impacts of this wind farm were of most concern to the population of Golden Eagles which was showing a "disturbing source of mortality" to a disproportionately large segment of the population (Southern Niagara Escarpment [WI] Wind Resource Area unpubl. ms). Of the variety of wind turbines at the site, the smaller, faster moving, Kenetech-built, lattice-supported turbines caused most of the mortality at Altamont Pass. As part of a re-powering effort, these turbines are now being replaced with slower moving, tubular-supported turbines. While mortality has declined, an average of 40-60 Golden Eagles and several hundred Red-tailed Hawks and American Kestrels are still estimated to die annually (Hunt 2002) – a continuing concern to the Service. While Europeans have used tubular towers almost exclusively, the United States has almost solely used lattice support – at least until recently (Berg 1996).

Wind farms can also disturb and fragment habitats and disrupt birds (Manes et al. 2003). A 6-year ongoing radio telemetry study of Lesser Prairie-Chickens (*Tympanuchus pallidicinctus*) in the Midwest (R. Robel, unpubl. data, Kansas State University) raises serious questions about turbine impacts to breeding grassland birds that use leks. Because of habitat fragmentation, prairie chickens and Sage Grouse (*Centrocercus urophasianus*) are already in serious trouble.

Colson (1995) indicated that some 16,000 wind turbines operated in California, making the State the largest concentration of wind energy development in the world. Since 1995, that statistic has changed. While California still boasts the greatest number of turbines in the United States, many smaller turbines are being replaced by fewer but larger models. Worldwide, an estimated 50,000 turbines are generating power (Ferdinand 2002; AWEA unpubl. data), of which over 15,000 are currently in 29 states in the United States Turbine numbers are often difficult to track since statistics are generally presented in megawatts (MW) of electricity produced, rather than number of turbines present – the latter statistic is of greater concern to ornithologists. In 1998, for example, Germany was the greatest producer with 2,874 MW of electricity produced by turbines, followed by the United States (1,884), and Denmark (1,450; AWEA unpubl. data). While some project that the number of wind turbines in the United States may increase by another 16,000 in the next 10 years, current trends indicate an even greater potential growth. While the United States presently produces less than 1 percent of its electrical energy from turbines – compared, for example, to Norway's 15 percent – 2001 was a banner year for U.S. turbine technology, doubling the previous record for installed wind production. Companies installed 1,898 turbines in 26 states, which will produce nearly 1,700 MW, at a cost of $1.7 billion for the new equipment (J. Cadogan, U.S. Department of Energy, pers. comm.). Over the past decade, wind power has been the fastest growing energy industry in the world. By 2020, the AWEA (unpubl. data) predicts that wind will provide 6 percent of this nation's electricity to as many as 25 million households. Enron Wind Corporation constructed some 1,500 of the 1,898 turbines installed in the United States in 2001. Although Enron is now bankrupt, General Electric purchased the company and is now producing wind turbines.

In 2002, President Bush signed the Job Creation and Worker Assistance Act, extending the production tax credit to the wind industry for another two years. However, the race to meet the tax credit deadline is forcing the industry to rush turbine development without critical pre-construction site evaluation. Extending the reauthorization period for this Act for more than two years would partially solve this problem. Even with a

bright future for growth, and with low speed tubular-constructed wind turbine technology now being stressed, larger and slower moving turbines still kill raptors, passerines, waterbirds, other birds, and bats. Low wind speed turbine technology requires much larger rotors, blade tips often extending more than 128 m (420 ft.) above ground, and blade tips can reach speeds in excess of 320 kph (200 mph) under windy conditions (J. Cadogan, U.S. Department of Energy, pers. comm.). When birds approach spinning turbine blades, "motion smear" – the inability of the bird's retina to process high speed motion stimulation – occurs primarily at the tips of the blades, making the blades deceptively transparent at high velocities. This increases the likelihood that a bird will fly through this arc, be struck by a blade, and be killed (Hodos et al. 2001).

What cumulative impact these larger turbines will have on birds and bats has yet to be determined. Johnson et al. (2002) raised some concerns about the impacts of newer, larger turbines on birds. Their data indicated that higher levels of mortality might be associated with the newer and larger turbines, and they indicated that wind power-related avian mortality would likely contribute to the cumulative impacts on birds. Since little research has been conducted on the impacts of large land-sited and offshore turbines on birds and bats, this newer technology is ripe for research.

Howell and Noone (1992) estimated U.S. avian mortality at 0.0 to 0.117 birds/turbine/yr., while in Europe, Winkelman (1992) estimated mortality at 0.1 to 37 birds/turbine/yr. Erickson et al. (2001) reassessed U.S. turbine impact, based on more than 15,000 turbines (some 11,500 in California), and estimated mortality in the range of 10,000 to 40,000 (mean = 33,000), with an average of 2.19 avian fatalities/turbine/yr. and 0.033 raptor fatalities/turbine/yr. As previously mentioned, this may be a considerable underestimate. As with other structural impacts, only a systematic turbine review will provide a more reliable estimate of mortality. While some have argued that turbine impacts are small (Berg 1996), especially when compared to those from communication towers and power lines, turbines can pose some unique problems especially for birds of prey and mortalities must be reduced especially as turbine numbers increase. In addition to protections under the MBTA, Bald and Golden Eagles are afforded protections under the ESA for the former and the BGEPA for both raptors. As strict liability statutes, MBTA and BGEPA also provide no provisions for un-permitted "take." Wind farms can affect local populations of Golden Eagles and other raptors whose breeding and recruitment rates are naturally slow and whose populations tend to have smaller numbers of breeding adults (Davis 1995). Large raptors are also revered by Native Americans as well as by many others within the public, they are symbolic megafauna, and they provide greater emotional appeal to many than do smaller avian species. Raptors also have a lower tolerance for additive mortality (Anderson et al. 1997). In the eastern United States, recent and proposed installations of hundreds of turbines on Appalachian Mountain ridges raise new concerns for raptors and songbirds. Environmentalists are calling for a systematic area-wide preconstruction review of these sites. As with all other human-caused mortality, we thus have a responsibility to reverse mortality trends at wind farms.

Until very recently, U.S. wind turbines have mostly been land-based. Perhaps following the European lead of siting wind turbines in estuarine and marine wetlands (van der Winden et al. 1999, van der Winden et al. 2000), and perhaps due to an assessment of a large number of potential offshore turbine locations in the U.S. (based on Weibull analyses of "good, excellent, outstanding, and superb" wind speed potentials [National Renewable Energy Laboratory 1987]), a new trend is evolving in North America. Several proposals for huge offshore sites are being submitted for locations on both Atlantic and Pacific coasts. These, at the very least, should require considerable research and monitoring to assess possible impacts to resident and migrating passerines, waterfowl, shorebirds, and seabirds. One site at Nantucket Shoals, offshore of Nantucket Island near Cape Cod, Massachusetts, is proposed by the Cape Wind Association to contain 170 turbines, many over 128 m (420 ft.), within a 65 km^2 (25 mi^2) area (Ferdinand 2002, AWEA unpubl. data). What impacts will this wind farm have on wintering sea ducks and migrating terns, especially the Federally endangered Roseate Tern (*Sterna dougallii dougallii*), and on Northern Gannets (*Morus bassanus*)? The Long Island Power Authority is proposing a site offshore of Long Island, New York's south shore, covering as much as 813 km^2 (314 mi^2). Other sites are being proposed for Portland, Maine, and Lake Erie. The largest proposed wind farm in North America is being planned for a 130 km^2 (50 mi^2) area between Queen Charlotte Island, BC, and Alaska. It is being designed to contain 350 turbines, many exceeding 122 m (400 ft.) in height. While the potential for significant offshore turbine impacts on waterbirds is great, virtually no research has been conducted in the United States to quell these concerns, and finding carcasses at sea is very challenging.

In an attempt to begin addressing the bird mortality issue – and ancillary to this the issue of ESA-listed bat strikes also of concern to the USFWS – the National Wind Coordinating Committee was created in 1994 as part of President Clinton's Global Climate Change Action Plan (Colson 1995). Shortly following the creation of the Committee, the Avian Subcommittee – now called the Wildlife Workgroup – was formed, co-founded by the Service. In 1999, the Avian Subcommittee pub-

lished a Metrics and Methods document to study turbine impacts on birds (Anderson et al. 1999). The document provides an excellent resource for conducting research on proposed and existing turbines and wind farms.

To address the turbine collision and habitat fragmentation problems in-house, the Service's Wind Turbine Siting Working Group developed interim voluntary site evaluation, siting, placement, and monitoring guidelines for the wind industry, much like those that exist in the Suggested Practices for power companies, or the tower guidelines for the communication tower industry. We encourage use of this guidance and are soliciting input from industry, other experts, and the public for a 2-year period since the guidance was released to the public in July 2003. Once the public comment period closes in 2005, we will reassess and update this voluntary guidance, based on input. The guidance is intended to assist the wind industry in avoiding or at least minimizing wildlife impacts by evaluating potential wind development sites, properly siting and designing turbines within these areas, and conducting pre- and post-construction research and monitoring to identify impacts to wildlife and their habitats. The guidance also contains a detailed protocol for evaluating and ranking a site before it is developed.

Based on the efforts of a team of Federal, state, university, and wind industry biologists in Montana, a protocol was developed to evaluate and rank potential sites proposed for wind development. The process is designed to identify and evaluate so-called "reference sites" – areas where wind development would result in a maximum negative impact to wildlife and habitats – then use these reference sites to rank sites proposed for actual development. Ranking a site results in an index score for that location. The protocol is intended to be used nationwide.

Based on considerable published information from the Wildlife Workgroup and from other sources, the Service's Working Group also agreed to a number of recommendations under the categories listed below. Some of these include:

Site development:

- avoid siting turbines in major bird migration corridors or in areas where birds are highly concentrated;
- avoid placing turbines in areas that attract raptors; specifically, consider setbacks from cliff/rim edges, avoid dips or passes along ridges, and avoid turbine sites in or near prairie dog and ground squirrel colonies;
- avoid attracting high densities of prey animals consumed by raptors, reduce carrion availability, and avoid creating wetlands adjacent to turbines;
- in known prairie grouse habitat, avoid siting turbines within at least 8 km (5 mi) of documented lek breeding areas;
- where rotor swept area is a risk to wildlife, adjust turbine tower height where feasible to reduce or eliminate the risk from turbine strikes;
- avoid siting turbines near bat hibernation and breeding colonies, migration corridors, and in flight paths; and
- avoid siting turbines in areas with Federally ESA-listed plants, animals, and designated critical habitat.

Turbine design and operation:

- use tubular supports with pointed tops rather than lattice supports to minimize bird perching and nesting opportunities;
- avoid using guy support wires for turbines and meteorological study towers. Where guys must be used, mark them with recommended bird deterrent devices (APLIC 1994);
- for turbines whose rotor-swept area exceeds 61 m (199 ft) above ground level, use white strobe lighting with the minimum number, minimum intensity, and minimum number of flashes per minute allowed by the Federal Aviation Administration during nighttime operations. Avoid lighting all turbines but flash lights simultaneously on lighted structures. Avoid solid red or pulsating red incandescent lighting;
- where feasible, place electric power lines underground to avoid electrocuting birds and use the Suggested Practices (APLIC 1996, Southern Engineering Company 1996) for above-ground lines, transformers, and conductors;
- in areas of high seasonal bird concentrations, where feasible, shut down turbines during periods when birds are highly concentrated at those sites; and
- when retrofitting, specifically where studies indicate high levels of mortality, follow the above guidance as closely as possible.

The Working Group also included a monitoring and dead-bird-search protocol that is being used by the Forest Service to study communication towers; this should easily be modified to study wind turbines. The Group also identified these additional research needs:

- assess the effects of inclement weather in attracting birds – especially passerines – and bats to lighted turbines and their rotor-swept areas;
- monitor and assess local impacts of turbines on wildlife, including habitat loss and fragmentation, effects of noise, and habituation;
- assess turbine string configuration and its potential for mortality, including end-of-row, dip and pass, and setback placements;
- determine the effectiveness of deterrents including blade colors (black/white and UV gel coatings to reduce the "smear effect"), lighting, infrasound, and visual markers;
- assess acoustic, infrared, and radar technologies to detect bird presence, movement, flight level, and position in relation to turbines;
- assess mortality estimates, including the number of lost carcasses (especially passerines) fragmented by the blades and lost to the wind, review the size and shape of dead-bird-search areas, and review possibilities of recording collisions through acoustic, radar, or infrared monitoring;
- determine the utility of GIS as a tool to assess migratory pathways and stopovers, particularly for passerines, bats, and butterflies;
- assess the effectiveness of time-specific or seasonal shutdowns to prevent mortalities; and
- compare the impacts of newer larger turbines to their smaller counterparts.

In conclusion, the challenges posed by power lines, communication towers and wind turbines are daunting and our avian friends need all the help we can provide them. This will require the collective minds of many individuals and interest groups.

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Direct Losses of Birds to Pesticides – Beginnings of a Quantification[1]

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Abstract

Recent analyses and modeling of avian pesticide field studies have led to the conclusion that bird kills are regular and frequent in insecticide-treated fields. Unfortunately, data are seldom adequate to quantify this mortality. Also, mortality is expected to be highly variable in response to varying bird presence in and around treated fields. Studies reporting kills of birds in cornfields treated with granular formulations of carbofuran provide a good example of the types of calculations that are needed to estimate direct bird losses in farm fields. Several studies provide the means to correct carcass counts for search efficiency and scavenging. Based on typical Midwest cornfields, use of granular carbofuran resulted in an estimated annual mortality rate of 3.0 to 16 songbirds per ha of treated field, the higher number corresponding to better field edge habitat. Much larger kills also occurred where fields bordered non-crop habitat more suitable for birds. At the peak of its popularity in the United States, this single product was conservatively giving rise to an estimated annual loss of 17-91 million birds in cornfields alone. Granular carbofuran formulations continue to be sold and used in most Latin American countries on a wide variety of crops.

Key words: agriculture, bird kills, carcass counts, cornfields, *Eremophila alpestris,* Horned Lark, pesticides, scavenging.

Introduction

Birds are extremely mobile, and it is therefore difficult to exclude them from areas that have been treated with pesticides. Also, birds are opportunistic foragers and several species respond to agricultural pests by entering treated areas to gorge themselves on the pest species (Kirk et al, 1996). As reviewed by Brown (1978), birds were amongst the first casualties recorded in the course of our earliest attempts to control pests on a broad scale with chemicals. For example, application of calcium arsenate dust to German forests in the mid 1920s resulted in extensive mortality of Woodlarks (*Lullula arborea*) and Whitethroats (*Sylvia communis*). The first comprehensive institutional review of agrochemical use in the US – otherwise known as the Mrak Commission – concluded that "Much of the significant evidence on the worldwide effects of insecticides have been provided by birds." (Mrak 1969) The main 'effects' the authors of this report had in mind was undoubtedly such impacts as eggshell thinning from the persistent organochlorine insecticide DDT as well as the extensive contamination and kills of seed eaters and their predators by cyclodiene insecticides such as aldrin and dieldrin. The use of persistent and bioaccumulating pesticides such as the organochlorines has now been greatly reduced in most of the world but the replacements are not without their impact on birds also.

Two groups of neurotoxic pesticides, the organophosphorous and carbamate compounds tend to be very acutely toxic to birds and cases of mortality are frequently reported (e.g. Mineau et al. 1999). Ongoing cases of mass mortality and the apparent indifference to such mortality has been roundly denounced in the popular press (e.g. Williams 1997). However, it has been difficult to quantify the full extent of this mortality. Pimentel (1992) advanced a figure of a direct pesticide (poisoning) kill of birds in the US of 67 million per year based on the estimate that 10 percent of exposed birds would be killed. Unfortunately, whether high or low, this figure is not easily defensible. Recent analyses and modeling of avian pesticide field studies (Mineau 2002) have led to the conclusion that bird kills are regular and frequent in insecticide-treated fields; to arrive at a scientifically defensible estimate of the actual number of bodies will be much more difficult. One reason is the difficulty of finding carcasses because of the high scavenging rates that are the norm in farmland (Mineau and Collins 1988). For example, Balcomb (1986) found overnight disappearance rates of songbirds as high as 92 percent in Maryland cornfields.

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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Also, it is exceedingly difficult to define an average agricultural field and quantify the bird presence (and hence, possible impact) in such a field at the time of pesticide application. In some cases, the extent of bird mortality is defined not so much by the pesticide as it is by the number of birds present to be killed. This will be apparent in the example provided below – that of granular formulations of carbofuran, specifically the silica-based formulations formerly used at planting in corn, potatoes and a number of other crops. The use in corn specifically has been thoroughly studied and, because it became part of a US special review, the information is in the public domain and available from the US EPA (Environmental Protection Agency) docket office, or obtainable through the provisions of the Freedom of Information Act. These studies were reviewed in earlier publications (e.g. Mineau 1988, 1993, US EPA 1989) but this is the first attempt to make them fully quantitative by correcting the figures for scavenging losses and search efficiency.

Case Study: Estimating Numbers of Birds Killed by Granular Carbofuran at Seeding in Corn

The following case study is used to highlight a 'worst-case' impact of pesticides on birds in an agricultural setting. Carbofuran is especially toxic to birds, and its formulation on silica particles (ideal grit material) ensured ample exposure to birds (Mineau 1993). Fortunately, most uses of granular carbofuran formulations have now been discontinued in the US and no granular formulations of this pesticide are permitted in Canada. However, they remain registered on a large variety of crops in most of Latin America where they continue to place our migratory birds at risk. A recent (June 2002) emergency exemption for 10,000 acres of rice in Louisiana and subsequent revocation about a month later shows that the pros and cons of this chemical continue to be the subject of debate. In addition, there are other granular pesticides, although perhaps slightly less toxic, which have similar albeit slower acting effects on birds in agricultural settings.

Available Studies

There are few pesticide use patterns whose effects on birds have been characterized as thoroughly as granular carbofuran in corn. Studies were carried out in Utah (Booth et al. 1983) as well as in Iowa and Illinois (Booth et al. 1986). Other studies (e.g. Balcomb et al. 1984, Stinson 1991) provide additional supporting evidence but the studies by Booth and colleagues were done on a scale and intensity that allow for a better quantification of the mortality. Because mortality from carbofuran is reasonably quick, it is probably easier to detect mortality with this product than with some of its competitors. *table 1* provides details of the study designs and carcass searching protocols. Searching for carcasses pre- and post-treatment is the traditional method used to quantify mortality. In the studies presented, virtually all the documented mortality could be ascribed to treatment, as deduced from the following lines of evidence:

1. a virtual absence of carcasses pre-treatment despite very intensive searches of the fields;
2. very low levels of mortality on 'control' plots and indications that virtually all of this 'control' mortality consisted of birds moving in from treated plots before dying;
3. chemical and/or biochemical diagnosis of a number of carcasses still suitable for analysis; and
4. obvious signs of intoxication in several birds.

The three studies as a group are probably a fair representation of typical spring corn planting in the US and of the hazards this type of pesticide treatment poses to birds. One possible exception is the Iowa study where granule spills at row ends and throughout the field area were covered manually by observers on foot in an effort to reduce exposure to birds. Although this is not standard agricultural practice, it probably had minimal effect on the study outcome. Regardless of the rate and exact method of application, there is always a surplus of granules left on the soil surface available to kill birds (Mineau 1993) and a single carbofuran granule is generally lethal to a songbird (Balcomb et al, 1984). The different study designs provide us with different measures that can be used to estimate true mortality rates for both the field centers and field perimeters (*table 2*). The latter typically receive much more bird visitation than field centers (Best et al, 1990). For most species inhabiting farmland, visits into the field are generally from one of the field edges. It is therefore most logical to quantify the kill rates of some species on the basis of field edge rather than field area. This is in sharp contrast to a few species such as the Horned Lark (*Eremophila alpestris*) which shuns edges and is found at similar density throughout the field. This species was therefore quantified on the basis of field area. Other edge-aversive species such as the Killdeer (*Charadrius vociferus*) or Eastern Meadowlark (*Sturnella magna*) were not found in sufficient numbers to warrant separate treatment, as was the case for the Horned Lark.

Table 1— *Carcass search protocol*.

State	Risk of exposure[a]	Average field size	Search effort	Search method	Duration of search post-application	Number of searches
Iowa[b]	lower than average	20.7 ha	high	lines of searchers – entire crop area	45 days	18-20 per field
Illinois[c]	average	11.5 ha	high	same	45 days	18-20-field
Utah[d]	higher than average	17.1 ha	very high	same	69 days	daily

[a]Risk of exposure based on application rate and method.
[b]Granule spills at row ends and throughout field area were manually covered by observers on foot in an effort to reduce exposure to birds. This is not standard agricultural practice. Surrounding area was primarily grassy and agricultural.
[c]Surrounding habitat was considered superior for birds than in Iowa. More trees and cover available.
[d]Surrounding habitat: grass and pastures with high weed content. These were plots rather than separate fields, some of the plots being contiguous.

Table 2— *Mortality by species group.*

		Raw carcass counts (primary poisoning in searched treated area only)[a]			Uncorrected carcass counts standardized for area or length of field edge	
State	Species	Field center	Field perimeter	Total	Total carcasses per 100 ha of field	Total carcasses per km of field edge
Iowa	all birds	8	20	28	22.5	2.2
	HOLA[b]			9	7.2	-
	non-HOLA			19	-	1.5
Illinois	all birds	20	70	90	130.4	9.9
	HOLA			11	15.9	-
	non-HOLA			79	-	8.7
Utah	all birds			873	849.2	N/A[c]
	HOLA			799	777.2	-
	non-HOLA			74	-	N/A[c]

[a]Primary kills only. Kills of raptors and other scavenger species excluded. Secondary poisoning with carbofuran is frequent (Mineau et al 1999) but difficult to quantify because most individuals expected to die offsite.
[b]HOLA - Horned lark
[c]Several 'fields' are actually plots bordered by other corn plots which precludes a measurement of the amount of field edge available.

None of the studies searched the habitat adjacent to the field for carcasses despite evidence that birds were flying between fields and therefore ran a high risk of dying away from the immediate area of the crop. Working with a similar product (a granular formulation of diazinon insecticide used in corn at planting in south-central Iowa), Johnson (1990) documented an additional 1.4 bird carcasses per unit of transect in the habitat adjacent to the field for each carcass actually found in the perimeter of the corn field. This suggests a correction factor of 2.4 to be applied to perimeter counts of carcasses where the search did not extend beyond the crop area. This is probably a very conservative correction because Johnson did not search the entire habitat adjacent to the field but merely a single transect of approximately 6 m in width.

Correcting for Search Efficiency and Scavenging

So far, none of the estimates presented in *table 2* has been corrected for search efficiency or for scavenging. As reviewed elsewhere (Mineau and Collins 1988), these factors can result in most of the carcasses not being located by the search teams. Unfortunately, scavenging rates measured by Booth and colleagues in the carbofuran studies only documented the loss of older carcasses and 'feather spots' and not that of fresh ones (they were taken for residue analysis). For this reason, the study by Johnson (1990) was used again. Under similar conditions of intensive search (12 systematic transect searches including 5 daily searches immediately post application), and in similar agricultural settings, they determined that 15

percent of carcasses (in a range of sizes) 'seeded' on the search transects over the first three days post application were recovered by the search teams. This correction factor, which accounts for both searcher efficiency and scavenging, appears to be a reasonable all-around factor for studies in freshly-seeded cornfields. Balcomb (1986) found that scavenging alone resulted in an average 24-hour loss of 75 percent of songbird carcasses from bare cornfields in Maryland. The average search efficiency reported by Booth and colleagues (1983, 1986) in the Iowa and Illinois studies for 'dummy carcasses' was about 60 percent for any one search. Combining these two independent values places the likely success rate of finding a carcass at 15 percent also ((1-0.75) x 0.60 = 0.15). This assumes that subsequent searches do not improve very much the probability of finding fresh carcasses, a reasonable assumption given the high scavenging rates documented by most observers. A 15 percent recovery rate was therefore applied to all studies, although it is possible that, in the case of the Utah study, scavenging rate was less because of a 'swamping' effect of so many carcasses in such a small area.

Focus on the Horned Lark

It is difficult to find estimates of densities of Horned Lark or of other species inhabiting cornfields in order to estimate what proportion of birds may have been killed by treatment. Beason and Franks (1974) reported 13 Horned Lark territories in a 35.6 ha corn and hayfield plot in Illinois. This equals a breeding bird density of 73 birds per 100 ha, or a total lark density of 100 birds per 100 ha, assuming the simultaneous presence of all fledged young (average fledging rate calculated to be 0.75 young per clutch by Beason and Franks). Territory size in their study ranged from 0.6 to 3.1 ha with a mean of 1.6 ha. Using their average territory size would place the maximum number of breeding larks at 125 birds per 100 ha (or 172 per 100 ha with fledglings) given perfect 'packing' of territories. Graber and Graber (1963) in Illinois gave Horned Lark densities (based on strip counts of field centers) averaging between 7.4 larks per 100 ha to 106 larks per 100 ha depending on the year and location within the State. The carbofuran kill rates of 48 and 106 larks per 100 ha estimated from the Iowa and Illinois studies (*table 3*) would therefore represent the majority of the larks on site if densities were in line with the estimates given above. Yet, based on transect counts obtained during the carbofuran impact studies in Iowa and Illinois, Best and colleagues (Best et al 1990) reported that carbofuran use did not result in significant differences in transect counts between treated and untreated fields. They estimated Horned Lark densities of 0.5 per 100 ha (sd = 1.1) in the middle of Iowa cornfields and 6.8 per 100 ha (sd = 9.6) in Illinois. These clearly are very low density estimates compared to the estimated kills in those same fields. This suggests that their transect counts were not very sensitive to on-going mortality and/or that floaters were coming in from adjacent areas to fill the vacancies or simply to forage in the fields regardless of the field-specific kill rate. Movement of birds from off-site areas was clearly happening in the Utah field study. A total of 799 Horned Lark carcasses were actually recovered in that study (*table 1*). Most were young of the year birds hatched in surrounding fields. After correcting for search efficiency and scavenging, it can be estimated that over 50 birds were drawn in from surrounding habitat and poisoned for each treated hectare (*table 3*). It is noteworthy that, despite this very large kill rate, these authors also were unable to show any decrease in bird activity based on transect counts, thus clearly pointing out the limitations of that technique.

Table 3— *Uncorrected and corrected estimates of mortality.*

	Horned Lark per 100 ha		Non-Horned Larks per km field edge			
Study	Uncorrected	Corrected[a]	Uncorrected	Corrected[a]	Including habitat adjacent to the fields[b]	Total average primary poisoning per ha cornfield[c]
Iowa	7.2	48	1.5	10	24	3.05
Illinois	15.9	106	8.7	58	139	15.9
Utah	777.0	5180	-	-	-	-

[a]Corrected by estimates of searcher efficiency and scavenging rates.
[b]This correction deemed necessary for 'edge species' likely to leave fields to die. Edge-aversive species such as Horned larks are less likely to leave the fields to die. A correction factor of 2.4 was used after Johnson (see text).
[c]Total for all species (Horned Lark and non-Horned Lark). This estimate is based on a hypothetical field constructed from the sample of fields studied in Iowa and Illinois: The sample of cornfields in the two States combined had a median area of 15 ha and an aspect ratio of 1.7. This corresponds to a 297 m x 505 m field with a perimeter of 1604 m.

Extrapolating to the US as a Whole

Kill rates for Horned Larks and other species were corrected separately as described earlier. Assuming a hypothetical corn field 'constructed' from the median size and aspect ratio of the fields used in the Iowa and Illinois studies, an average rate of kill can be estimated to be between 3.05 and 15.9 songbirds per hectare of corn (*table 3*). If birds are drawn to a treated field from surrounding areas, then clearly the 'ecological footprint' of the treatment is much larger that the field itself. However, in calculating the overall loss of birds from the use of a chemical, there is bound to be a certain degree of 'double accounting' in the case of adjoining fields where both are treated: The same birds cannot be killed twice. This aspect will be ignored in the following extrapolation although it may result in kill estimates being slightly inflated. A countervailing bias is that we know the number of birds dying off-site to be grossly underestimated (see below). Assuming that the Illinois and Iowa fields were more typical of the main US Corn Belt than the Utah field sites, we can estimate the overall loss of birds resulting from the use of granular carbofuran. According to the US EPA, the US use of carbofuran granular to seed corn declined from a high of 5.7 million ha in 1978 to about 1.8 million ha in 1985 for a cumulative total of about 26 million ha for this 8-year period (USEPA 1989). At its peak, therefore, this single chemical formulation was killing an estimated 17 to 91 million songbirds annually in the US Corn Belt (depending on whether the estimate is based on the Iowa or on the Illinois numbers – *table 3*). This does not include kills in other crops in which the product was registered and applied under similar conditions (e.g. at planting to relatively bare ground) such as soybean, sorghum, peanuts, tobacco, cotton or sunflowers. It also does not include the occasional large scale kill as seen in the Utah study where the surrounding habitat was conducive to a large movement of birds into the treated field. Finally, this estimate also excludes the secondary kills of predators and scavengers.

Conclusions

Under normal circumstances, mortality of birds in fields is not likely to be detected unless the birds in question are large and highly visible, and they happen to die in large groups in areas of high public visibility (e.g. the case of waterfowl killed by diazinon (Stone and Gradoni 1980)). Even then, cases rarely come to the attention of regulatory authorities. Conversely, we can predict that most of the ongoing pesticide-induced avian mortality in North American agriculture is likely to be of small, highly cryptic, and widely dispersed species. Little of that mortality is likely to come to light without the benefit of large-scale expensive field surveillance exercises. Even then, efforts to detect carcasses are likely to be unsuccessful if time to death is increased (the case with some newer products), search intensity inadequate or scavenging excessive (Mineau and Collins 1988). As mentioned above, the use of the granular formulations of carbofuran has been greatly reduced in the US, and, after a 15-year struggle, all granular formulations were completely withdrawn from Canada. However, our information is that these granular formulations are widely registered in Latin America where our neotropical migrants and many local resident species are most certainly exposed to lethal doses. On wintering or staging grounds where certain species might be concentrated, the activities of a few individual farmers or pesticide applicators can have enormous impacts relative to those calculated for the breeding grounds. For example, an estimated 20,000 Swainson's Hawks (*Buteo swainsoni*) were killed in a small area of the Argentine pampas by applications of the organophosphate monocrotophos (Hooper et al. 1999); the same chemical had killed an estimated 10,000 American Robins (*Turdus migratorius*) in two small Florida potato fields (Lee 1972) and several thousand migrants of 37 species were killed by a single mosquito control application of the insecticide fenthion (Seabloom et al. 1973). Recent analysis of the entire corpus of avian field studies (studies such as the ones described here – Mineau 2002) indicates that these publicized kills are not isolated events but rather the 'tip of the iceberg.' Given the usual application rates at which current use insecticides are sprayed, direct mortality of exposed birds is both inevitable and relatively frequent with a large number of insecticides currently registered. The absence of bird carcasses is not a good indication that any given pesticide use pattern is safe for birds. Before the US EPA mandated field testing with granular carbofuran (based on an acute toxicity trigger), only a handful of very small kills had come to light.

It is also clear, however, that the full extent of avian pesticide-induced mortality will be very difficult to calculate. Very few pesticides have received sufficient scrutiny to allow for the type of calculations that were done here for granular carbofuran in corn. Finally, even when the direct kill can be estimated, it ignores the less obvious chronic or sub-acute behavioral or physiological effects that some pesticides have on birds, such as compromised escape behaviors or breeding success (Grue et al 1997) or the indirect food-mediated effects (Potts 1986) that might also negatively affect bird populations.

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Seabird and Waterbird Bycatch in Fishing Gear: Next Steps in Dealing with a Problem[1]

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Abstract

Seabirds, a variety of related waterfowl species, and some wading birds and shorebirds (hereafter, "waterbirds") are accidentally captured, entangled, injured or killed in active or derelict fishing gear. Accidentally or intentionally lost or discarded gear can also continue to "ghost fish," often until the gear sinks or washes ashore. Seabirds are most affected by set and drifting gillnets and longlines – both the focus of this paper – while seines, trawls, traps, pots, and related equipment can capture and kill waterbirds. While estimates of local population mortality from site-specific gear use are prevalent, the effects of this 'bycatch' on populations, and the cumulative impacts of fishing gear on waterbirds are generally unknown or only crudely estimated, with but a few exceptions. This paper addresses several bycatch reduction initiatives, including a 1991 ban by the United Nations General Assembly of large-scale high-seas driftnetting worldwide and 1992 passage of implementing US legislation, unanimous approval by the U.N.'s Food and Agriculture Organization in 1998 of an international plan to reduce seabird bycatch in longline fisheries, development and implementation of a US national plan to reduce seabird bycatch in US longline fisheries in 2001, and efforts by the US Fish and Wildlife Service (USFWS) to address waterbird bycatch in all US commercial and recreational fisheries. Documented waterbird bycatch in both gillnets and longlines within US waters is reviewed, as are operational and technical measures to reduce or eliminate bycatch problems. Also discussed are efforts to address both problems by nations represented on the Arctic Circumpolar Council, the need for greater bycatch observer coverage on vessels at sea, and research. Jurisdiction of the Migratory Bird Treaty Act is reviewed.

Key words: bycatch, entanglement, Food and Agriculture Organization, gillnets, high seas, Interagency Seabird Working Group, longlines, Migratory Bird Treaty. Act, seabirds, technical and operational measures, territorial waters, waterbirds, Waterbird Bycatch Working Group.

Introduction

As the world's human population grows, and as the ever-increasing human demand for fish and shellfish continues, heightened fishing effort will invariably result in additional negative impacts to living marine resources including birds. Today, more than 70 percent of marine fish species worldwide need urgent attention to prevent population declines by overfishing, according to a recent United Nations report (Alverson 1998). This paper focuses primarily on the impacts of commercial fishing on seabirds, a variety of related waterfowl species, some wading birds, and even some shorebirds (hereafter "waterbirds") that are incidentally entangled and killed or injured by fishing gear that is actively fishing, or has been accidentally or intentionally lost or discarded. For purposes of discussion, the waterbirds taken by this gear are called "bycatch" – "wasted catch" that commercial and recreational fishers harm or kill although they don't intend to catch them. The problem is by no means unique to US waters. Globally, an estimated 44 billion pounds of fish are wasted, 25 percent of the entire world catch (Alverson 1998, Dobrzynski et al. 2002), along with estimates of hundreds of thousands or more of waterbirds. The offending gear includes gillnets, trammel nets, longlines, seines, trawls, traps, pots, and related equipment. Gillnets and longlines are the focus of this paper.

The literature is replete with estimates of fishery impacts to local waterbird populations generally from gear-specific fisheries. Alcids, shearwaters, albatrosses, waterfowl, cormorants, loons, and even osprey (*Pandion haliaetus*) have been reported drowned in fishing gear (Atkins and Heneman 1987). Unfortunately, the closer we look at the overall problem in the US, the less we seem to know about the extent of its impacts on waterbirds population-wide. In US waters, the overall level of mortality suffered population-wide and the cumulative impacts on populations of most waterbirds are generally unknown, crudely estimated, or largely anecdotal, with but a few exceptions (Brothers et al. 1998).

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California**.

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Discussion

Gillnet Impacts

Gillnets are generally made of panels of monofilament or multifilament Nylon® or related plastic materials and are designed to capture fish whose gill plates become ensnared in the netting, the fish become entangled, they suffocate, and die. The nets can drift, with a float line at the sea or lake surface and lead line suspending vertical panels to varying depths; or they can be set, anchored in place with the lead line resting on the bottom and the float line suspending panels vertically in the water column (Atkins and Heneman 1987). Both types of gillnets have been shown to be deadly to birds (Manville 1988, 1991).

In US waters, mortality data from gillnet entanglement is generally anecdotal. Two exceptions include former fisheries – now both closed – in waters off the western Aleutian Islands and central California where monitoring was more extensive. In waters off Alaska's northern North Pacific and Bering Sea, a large Japanese mothership salmon (*Oncorhynchys* spp.) driftnet fishery in the late 1970s and early 1980s was estimated by King et al. (1979) to be killing from 75,000 to 250,000 seabirds annually, while Ainley et al. (1981) felt the estimates to be conservative, suggesting at least a doubling of annual mortality. King (1984) reassessed his estimates to include 250,000 to 750,000 seabirds killed annually – Short-tailed (*Puffinus tenuirostris*) and Sooty Shearwaters (*P. griseus*) comprising 60 percent of the mortality. DeGange et al. (1985) estimated an average of 38,000 Tufted Puffins (*Fratercula cirrhata*), 8,250 Horned Puffins (*F. corniculata*), and 101,500 Short-tailed Shearwaters were killed annually in this mothership fishery, likely having a negative impact on local breeding populations of birds in the western Aleutians. The fishery was closed in the mid-1980s.

In the California set gillnet fishery for halibut (*Hippoglossus stenolepis*), flounder (*Paralichthys* spp.) and croaker (family Sciaenidae), close monitoring between 1981 to 1986 at beaches on Monterey Bay and in the Gulf of the Farallones indicated declines in the population of Common Murres (*Uria aalge*) from 210,000 in 1982 to some 90,000 in 1986 (Atkins and Heneman 1987) – roughly 75 percent of the decline attributable to gillnetting. King (1984) estimated up to 10,000 birds per month killed during the summertime. By 1987, where murre populations in individual colonies declined by 47-100 percent, the California fishery was either totally closed or restricted to depths greater than 73m (40 fathoms; Atkins and Heneman 1987, Melvin et al. 1999).

Anecdotal information regarding gillnet take of waterbirds in US waters varies from fishery to fishery, with some estimates having higher levels of confidence than others. In the New England bottom fish fisheries, Northern Gannets (*Morus bassanus*), Northern Fulmars (*Fulmarus glacialis*), and Sooty Shearwaters have been reported taken, while in the Chesapeake Bay nearshore set shad (*Alosa sapidissima*) gillnet fishery, Ruddy Ducks (*Oxyura jamaicensis*), Canvasbacks (*Aythya valisineria*), Scaup (*Aythya* spp.), Red-throated (*Gavia stellata*) and Common Loons (*G. immer*), and others have been reported (O'Hara et al. 1986, Forsell 1999). Forsell (1999, D. Forsell pers. comm.) assessed nearshore mid-Atlantic shad gillnets and speculated that nets were having a significant impact on the wintering population of Red-throated Loons. During the first season of a survey in 1998, 68 percent (N = 1,633) of the birds observed dead in shad gillnets were Red-throated Loons, while 21 percent (N = 503) were Common Loons. An estimated 67,300 Red-throated Loons migrated past Cape May, New Jersey, during the fall 1997. Since much of the total mortality was likely unobserved, the population impact could be significant. D. Forsell continues to monitor this fishery and he recently reported a significant but untabulated take of scaup in the Mid-Atlantic region shad fishery (pers. comm.). In South Carolina waters, waterfowl and loons were reported to be the primary species caught in 0.3-0.4 km (900-1,200 ft.) long shad gillnets. Loons have been reported caught in Great Lakes gillnets as well (Atkins and Heneman 1987).

One problem in assessing waterbird bycatch in coastal gillnet and other fisheries has been inconsistent monitoring despite the fact that breeding colonies worldwide occur in coastal waters (Melvin et al. 1999). Diving seabirds of the family Alcidae, most especially the Common Murre, have been well documented as bycatch in coastal gillnets (Evans and Nettleship 1985). These long-lived birds have low levels of fecundity and delayed maturity, making their populations particularly sensitive to changes in adult mortality. Murres have been routinely observed in gillnets retrieved from depths as great as 180m (591 ft.) and Atlantic Puffins (*F. arctica*) are commonly seen in nets set to depths of 60m (197 ft.; Piatt and Nettleship 1985, Atkins and Heneman 1987, J. Piatt pers. comm.). Because Alcids are sensitive to climate change and vulnerable to oil spills, additional anthropogenic sources of mortality such as bycatch raise further conservation concerns for these species (Melvin et al. 1999).

Not only murres, but seabirds in general are long-lived, exhibit delayed maturity, and may produce only one egg annually or biannually. Populations can decline when adult survivorship decreases by as little as 3-5 percent annually. Population recovery is slow where mortality has been significant, e.g., from oil spills, El

Nino events, introduced predators, ingestion of plastic debris, fishing mortality or bycatch (Melvin and Parrish 2001). Many species of seabirds are exposed to several or all of these sources of mortality, and the cumulative effects on populations are of great concern.

Studies in Canadian and Greenland waters have also documented gillnet mortality. In Barkley Sound, British Columbia, more than 6 percent of the breeding population of Marbled Murrelets (*Brachyramphus marmoratus*) were estimated killed in the salmon drift gillnet fisheries (Carter and Sealy 1984). In Newfoundland, Piatt and Nettleship (1985, 1987) estimated from 1981-1984 that 2 percent of Newfoundland's 800,000 Common Murres were drowned in salmon (*Salmo salar*) drift and cod bottom-set gillnets with local murre populations suffering more than 16 percent annual mortality. Razorbills (*Alca torda*) suffered an alarming 12.4 percent average annual mortality during this period, while Northern Gannets and Atlantic Puffins suffered less mortality from bycatch. Gillnet mortality was first raised as an important marine conservation issue in 1972 when Tull et al. (1972) estimated the take of some 500,000 Thick-billed Murres (*U. lomvia*) in salmon gillnets offshore of West Greenland. Piatt and Reddin (1984) fine-tuned the estimate to 200,000 Thick-billed Murres taken annually in these gillnets. Between 1976-1980 when fishing effort diminished and shifted, they estimated mortality reduced by 80-90 percent.

In the 1980s, attention was focused on pelagic drift gillnet fishing on the "high seas" – waters beyond the jurisdiction of any nation (e.g., beyond territorial waters and Exclusive Economic Zones [EEZs], and for the United States, beyond our 12 nautical mile [NM] territorial seas). Research conducted in the 1980s and early 1990s in the North Pacific Ocean by scientists from the United States (including this author), Canada, Japan, Taiwan, Republic of Korea (ROK), and others indicated that large-scale high-seas drift gillnets were having significant impacts on well over 100 species of living marine resources including seabirds that were being captured as bycatch, and usually killed as a result of strangulation or drowning in this gear (Manville 1991). The problem was particularly egregious in the North Pacific Ocean where, at its peak, over 1,000 Japanese, Taiwanese and ROK vessels were deploying up to 64,000 km (40,000 mi) of gillnet per night – sometimes up to 64 km (40 mi) of net per vessel. These so-called "walls of death" were capturing non-target species, ensnaring undersized and under-aged target fish, and losing target fish to "fallout." In 1990, Safina (1995) estimated that 42 million seabirds and marine mammals were captured as bycatch in high-seas driftnets. Gear was often lost or discarded, sometimes in large quantities. This netting can then "ghost fish" conceivably for years until it degrades, sinks, or washes ashore (Manville 1990, 1992). Estimates of mortality of 500,000 seabirds per year in both the North Atlantic (Tull et al. 1972) and North Pacific oceans (DeGange et al. 1993) were factors that helped contribute to United Nations involvement with drift gillnets in international waters around the world (Alverson et al. 1994).

In 1989, the General Assembly of the United Nations (UNGA) unanimously adopted Resolution 44/225, calling for a moratorium on all large-scale driftnet fishing on the high seas by 1992, revocable if scientifically sound conservation and management measures could be implemented. By December 1991, non-binding UNGA Resolution 46/215 was unanimously approved calling for full implementation of a global moratorium on all large-scale pelagic driftnet fishing by December 1992. The US responded by implementing the U.N. moratoria in US waters and directed continued negotiations to permanently ban this destructive fishing practice by passing the United States' Driftnet Act Amendments of 1990 (§ 107, P.L. 101-627; expanding and incorporating provisions of the Driftnet Impact Monitoring, Assessment, and Control Act of 1987 [P.L. 100-220]) and the High Seas Driftnet Fisheries Enforcement Act of 1992 (P.L. 102-582). The latter law denies port entry to any large-scale driftnet vessel (deploying >2.5 km [1.55 mi] of net), implements mandatory sanctions on fish products from countries that continue large-scale pelagic driftnet fishing, and expands presidential authority under the Pelly Amendment (P.L. 92-219, 85 Stat. 786, 22 U.S.C. 1978) to the Fishermen's Protective Act of 1954 calling for sanctions on non-fisheries imports. By 1993, enforcement efforts had been expanded by the US Coast Guard, US Navy, and the National Marine Fisheries Service (NMFS); (Earthtrust 2002).

Through the early to mid-1990s, some large-scale driftnetting continued to varying degrees by vessels flagged by Italy, Taiwan, ROK, the Peoples Republic of China, France, Ireland, and Great Britain. Large-scale pelagic driftnetting was eventually phased out including by license revocation, re-license closure, compensation, buy backs, vessel conversion (e.g., longlining, jigging, trawling, and purse seining), and vessel sinking.

"Ghost fishing" from lost or discarded gillnets is yet another cause of waterbird mortality. Atkins and Heneman (1987) estimated 68,000 seabirds killed per month in unrecovered lost derelict gear in the North Pacific Ocean. Manville (1988), using 0.06 percent net loss estimate per night, calculated a 19 km (12 mi) nightly loss of net in the North Pacific pelagic gillnet fishery, with an estimated 1,028 km (639 mi) of nets lost per season in the 1980s. The estimates did not account for discarded nets or net fragments.

Gillnet Bycatch Mitigation

While large-scale pelagic driftnetting may no longer be a problem, gillnets continue to be used within our US 370 km (200 NM) EEZ, our Federal 6-22 km (3-12 NM) territorial waters, and within our 6 km (3 NM) state waters, bays, rivers, estuaries, and in some inland fisheries. Gillnets may be either drifting or bottom set. Other countries also use gillnets within their EEZs. To get a better handle on the impacts of these fisheries, sufficient assessment and sound monitoring – especially at breeding colonies and feeding areas during the nesting season – are absolutely critical if we are to demonstrate the existence of a biological problem. Monitoring must be consistent, well designed, and statistically significant if it is to be meaningful.

Efforts to reduce avian bycatch in gillnets will – like the problems created by using some other types of gear – require both technological and operational solutions. Modifications have been made in the design and use of other types of gear, e.g., turtle excluder or trawling efficiency devices have been deployed to reduce sea turtle bycatch in shrimp trawls (Renaud et al. 1997), tuna purse seines have been modified to reduce the capture of small cetaceans, operational procedures such as backdown allow dolphins to escape seines (Francis et al. 1992), and acoustic pingers have been installed in coastal gillnets (Kraus et al. 1997) and fish traps (Lien et al. 1992) to alert marine mammals. However, few modifications have been used successfully with gillnets to reduce avian bycatch. Hayase and Yatsu (1993) successfully altered the design of high-seas drift gillnets by submerging nets 2 m (7 ft.) below the sea surface, significantly reducing seabird entanglement, but also reducing fishing efficiency by up to 95 percent, making net use economically unfeasible. In a coastal salmon drift gillnet fishery in North Puget Sound, Washington, Melvin et al. (1999) identified three complimentary tools to significantly reduce bycatch of Common Murres and Rhinoceros Auklets (*Cerorhinca monocerata*) in salmon gillnets without compromising target fishing efficiency. These included gear modifications (specifically the use of pingers and upper net panel visual alerts), abundance-based fishery openings, and time-of-day restrictions (especially at dawn and dusk). The authors suggested these gillnet technologies and procedures had application in other coastal gillnet fisheries worldwide.

Longlines Impacts

With the global cessation of large-scale high seas driftnetting in the 1990s, concern was raised by some nations – including the United States – that longline fishing might soon replace large-scale driftnetting as the next major global killer of seabirds. Although longlining has been regarded as a species- and size-selective fishing technique known to be "environmentally friendly" (Manville 2000), longlining has been documented to kill at least 64 species of seabirds worldwide. These include albatrosses, petrels, shearwaters, gulls, skuas, gannets, cormorants, penguins, and boobies. At least 23 of these birds are currently listed as "threatened" (meaning vulnerable, endangered, or critically endangered) by the IUCN-World Conservation Union including 16 of the 21 albatross species (American Bird Conservancy [ABC] 2002).

Baited longlines are used in all the world's oceans and seas, ranging from small-scale artisanal fisheries to mechanized commercial operations comprising from 15-90 percent of the commercial fishing activities. Some types of commercial longliners can deploy up to 35,000 hooks per set from lines up to 97 km (60 mi) long (Brothers et al. 1998) with perhaps millions of hooks set each day globally. The catching success of baited hooks is based on the target fish's attraction to the baits. Typically, longlines are set from the stern of fishing vessels traveling at speeds of 6-11 km/hr (3-6 knots). Due to line tension and turbulence from the stern and propellers, baited hooks do not always sink immediately and the baits may be seized by seabirds, some becoming hooked and killed. Less frequently, still-baited hooks may be taken by seabirds during haul-in. In some Norwegian fisheries, up to 70 percent of the baits are consumed by seabirds (Lokkeborg 1998). Brothers (1996) reported 20 baits lost for every bird caught in the Southern Oceans. In some fisheries, more than 10 birds/1,000 hooks have been recorded killed, and in one South Atlantic fishery, that rate was 15 birds killed/1,000 hooks set (Brothers et al. 1998, Manville 1998). Brothers (1991), in fact, focused attention on the longline bycatch problem when he estimated annual albatross mortality in Japanese tuna (*Thunnus maccoyii*) longlines at 44,000 birds per year in the Southern Oceans. Today for some species, this level of incidental mortality is considered to be unsustainable and their populations are in decline. Many species of southern albatross lose from 1-6 percent of their annual breeding populations ostensibly due to bycatch (ABC 2002). A drop of as little as 3-5 percent in adult survivorship from all mortality factors can cause a population decline (Melvin and Parrish 2001). Fortunately, deep-diving and non-scavenging species such as penguins, cormorants, and auks are rarely caught in longlines, and smaller seabirds such as terns, storm petrels, and auklets are rarely captured since they generally are unable to swallow the large baits on longlines (Manville 1998).

All longline gear is based on four parts: the mainline, the snood, the hook, and the bait. Gear is set on the seabed (called demersal longlining), floated off the bottom at various depths (semipelagic longlining), or is suspended from line drifting freely at the sea surface

(pelagic longlining). There is considerable variation in the setting and hauling operations (FAO 1998a). Bycatch rates are influenced by the type of fishing gear set (e.g., pelagic, semipelagic, or demersal), bird species present, and temporal (i.e., year, season, time of day), spatial, and physical factors (Brothers et al. 1999, Melvin et al. 2001). Seabird bycatch is greatest – approaching or exceeding 10 birds/1,000 hook sets – at high latitudes in the cold-fish, bird-rich waters off the North and South Atlantic, North Pacific, and Southern Oceans. Little mortality has been documented in the tropical Atlantic, Indian, and Pacific oceans, but this may be due mostly to a lack of data. Mortality to Laysan (*Phoebastria immutabilis*) and Black-footed Albatross (*P. nigripes*) is the exception in the vicinity of Hawaii where bigeye tuna (*T. obesus*) and broadbill swordfish (*Xiphias gladius*) longlining occurs (Brothers et al. 1998).

Partly as a result of concerns over longline bycatch in the Southern Oceans, the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) adopted mitigation measures in 1992 to reduce seabird bycatch by its 23 member nations. These measures included modifications to fishing practices and equipment designed to reduce the likelihood of incidental seabird take. Under authority of the Commission for the Conservation of Southern Bluefin Tuna, Australia, Japan, and New Zealand adopted policies in 1995 specifically targeted at data and information collection, use of mitigation measures, and dissemination of educational information about reducing seabird bycatch. One document used by both Commissions includes the CCAMLR (1996) publication, Fish the Sea Not the Sky, which has turned out to be an excellent educational tool.

As had been forecast with the closure of the high-seas driftnet fishery, some high-seas gillnet vessels were reflagging to avoid legitimate management controls. This was reported as a serious emerging problem in a number of high seas fisheries worldwide (U.N. Secretary General's 1992 Report in Earthtrust 2002). In part as an effort to address this problem, the U.N.'s Food and Agriculture Organization (FAO) developed a draft Code of Conduct for Responsible Fishing which was expanded, finalized, and published in 1995 (FAO 1995). Of particular note are two provisions within the Code that address conservation and bycatch issues. Section 6.12 addresses the need for nations to "... promote conservation and management, ensure responsible fishing and ensure effective conservation and protection of living aquatic resources..." while Section 7.6.9 calls for nations to take "...appropriate measures to minimize waste, discards, catch by lost or abandoned gear, catch of non-target species, both fish and non-fish species, and negative impacts on associated or dependent species, in particular endangered species."

In 1997, the FAO's Committee on Fisheries (COFI) met at its 22nd meeting in Rome to discuss the global reduction of seabird bycatch in longline fisheries, overfishing in shark fisheries, and global overfishing. Subsequent to this meeting, the governments of the United States and Japan agreed to collaborate with the FAO to organize a technical consultation on these three issues in 1998 (FAO 1998b). In 1998, the International Plan of Action for Reducing Incidental Catch of Seabirds in Longline Fisheries (IPOA-S) was unanimously approved by the FAO and implemented by the FAO Council in 1999. While a voluntary plan, it is to be implemented in a manner consistent with the Code of Conduct and consistent with any applicable rules of international law and rules of international organizations.

The IPOA-S tasks all FAO member-nations with a longline seabird bycatch problem – including the US – to develop and implement seabird national plans of action (NPOA-S). The US NPOA-S, for example, applies to US and foreign flagged vessels longline fishing in our EEZ, and to US flagged vessels longline fishing on the high seas and the EEZs of other nations. The FAO set a February 2001 deadline for submission of final NPOA-Ss to the COFI. Only the United States and Japan met that deadline with final documents. To produce and implement the Final United States National Plan of Action for Reducing the Incidental Catch of Seabirds in Longline Fisheries, an Interagency Seabird Working Group was created in 1999. The Working Group is co-chaired by the USFWS (this author) and NMFS, with representation from most of the Service's Regions, all of the NMFS regional offices, each of the eight Regional Fisheries Management Councils, and the Department of State. While some within the environmental community are not happy with the US NPOA-S in its present state – claiming the Plan is too weak and needs mandatory avoidance measures in all fisheries (ABC 2002) – the Plan is a voluntary one and mitigation measures are generally fishery, avian, and time specific, not universally applicable to all fisheries and for all waterbirds. There, unfortunately, is no single "silver bullet" that effectively resolves bycatch issues in all longline fisheries. One also needs to recognize that what works to reduce seabird bycatch may not necessarily work to reduce sea turtle bycatch (Dobrzynski et al. 2002).

The FWS acknowledges that the US Plan does need to be strengthened. In particular, we remain concerned about the timeline for implementation, including assessments and mitigation. The Plan called for national seabird bycatch assessments for all US longline fisheries to be completed and submitted to COFI by February 2003. The document was submitted on time but USFWS had little opportunity to comment. In those fisheries where bird bycatch is determined or continues to be a problem (e.g., Alaska and Hawaii), the Plan

calls for the development and implementation of mitigation measures within two years. Where mitigation needs to be taken, measures may be incorporated as part of NMFS' regional fishery management plans (FMP), as part of new FMPs, or as regulatory amendments that will subsequently be incorporated as regulations (see beyond). The USFWS is also concerned that fishery-specific mitigation measures which would have to be implemented by one or several of the Regional Fishery Management Councils might become mired in politics and delayed before being required in FMPs. Part of the role of the Interagency Seabird Working Group may be to resolve such possible problems.

Alaska Longline Impacts and Mitigation

The estuaries and offshore waters of Alaska contain one of the world's largest concentrations of seabirds, estimated at 100 million, of which 40 species breed. Alaska's breeding population is estimated to be 50 million birds, comprising some 96 percent of all seabirds breeding in the continental United States (Wohl et al. 1995). The waters are also highly productive for commercial trawl, pot and longline (also called "hook and line" gear) fisheries (Stehn et al. 2001). Unfortunately, seabirds are taken in large numbers in Alaska's groundfish and halibut longline fisheries where from 10,000 to 27,000 are hooked each year (Melvin et al. 2001). There may be more than 4,000 longline vessels that ply these waters. The commercial halibut fishery is currently unmonitored by NMFS observers. While bycatch can vary from year to year, it includes Northern Fulmars (66 percent), gulls (*Larus* spp.; 16 percent), albatross (9 percent [5 percent Laysan, about 4 percent Black-footed, and few Short-tailed (*P. albatrus*)]), and shearwaters (*Puffinis* spp.; 4 percent; Melvin et al. 2001, Stehn et al. 2001).

The worldwide population of the endangered Short-tailed Albatross numbers only some 1,800 and although it is increasing, longline mortality may be critical to population recovery (Melvin et al. 2001, H. Hasegawa pers. comm.). Under the requirements of ESA (§7), Federal agencies must consult with the USFWS (or NMFS for certain endangered or threatened species under their stewardship) for activities agencies undertake or regulate that affect endangered species. The outcome of the consultation between NMFS and USFWS over the take of Short-tailed Albatross in Alaska's demersal longline fisheries was a Biological Opinion, which stated that no more than six birds could be captured within each two-year period, including no more than two in the Pacific halibut fishery (USFWS 1998) and four in the groundfish fishery (USFWS 1999). The Opinion additionally requires bycatch reporting, salvage of dead birds, fisher education regarding bycatch avoidance, use of seabird bycatch avoidance measures, and a NMFS study to evaluate the effectiveness of bycatch deterrents (USFWS 1997). Take of more than six birds within a two-year period could trigger another ESA Section 7 consultation, likely interrupting or perhaps even closing Alaska's $300 million (ex-vessel value) fishery (Melvin et al. 2001).

In a two-year NMFS-mandated study conducted by Melvin et al. (2001) in Alaskan waters in 1999 and 2000, the researchers recommended use of a suite a bycatch mitigation measures with a goal of no loss of target catch or increase in bycatch of other living marine organisms. Paired streamer or tori (= bird) lines created a "moving fence" that precluded seabird attacks on baits and virtually eliminated both Laysan Albatross and Northern Fulmar bycatch. A line setting funnel that sets gear below the turbulence of propellers was favorably tested and suggested as a reliable method for this and other longline fisheries worldwide. Putting additional weights on lines to sink baits more rapidly had mixed results; vessel speed and vessel design were more important that weighting alone. Night setting was not recommended as an effective deterrent strategy for night-active seabird species – especially Northern Fulmars – in the North Pacific. Line shooter devices actually increased bird bycatch and were thus not recommended for Alaska.

In the mid-1990s, prior to release of the Service's first Biological Opinion – and seeing things likely to come – fishermen with the North Pacific Longliners Association began a concerted and proactive effort to address the Short-tailed Albatross bycatch problem by petitioning the North Pacific Fisheries Management Council – the Federal regulatory body in North Pacific waters – for emergency regulations (Matsen 1997). As a result, rules and regulations were put into place in 1997 in Alaska's groundfish longline fishery, and in 1998 in the halibut longline fishery (50 CFR Part 679.24(e)) which mandated use of at least one mitigation measure for vessels >7.9 m (26 feet) in length. These rules include using tori lines, towing buoys, using underwater lining tubes, night setting, and modifying discharge of offal. The research conducted by Melvin et al. (2001) recommends changes to current regulations. To assist fishers, the USFWS has been distributing free bird scaring streamers to Alaska's longline fishermen thanks to two $550,000 grants acquired through Federal appropriations in Fiscal Years 2001 and 2002. As of February 2004, vessels >17m (55ft.) are required by regulations to deploy paired streamer lines during line setting to reduce access of birds to baited hooks (Federal Register 69: 1930-1951).

Hawaii Longline Impacts and Mitigation

From 1990-1994, based on data provided by NMFS, the USFWS estimated that longliners in Hawaii's waters killed 32,500 Laysan and 23,382 Black-footed

Albatross. These take rates were comparable to or exceeded bird bycatch in the Southern Oceans (Environment Hawai'i 1996).

Black-footed Albatross number about 300,000 (and declining) comprised of some 62,000 pairs in 12 colonies, with 77 percent of the population nesting in three colonies on Laysan Island, Midway Atoll, and French Frigate Shoals in the northwestern Hawaiian Islands. Under IUCN criteria for identifying threatened status, Black-footed is listed as "vulnerable," showing a population decline of over 20 percent in three generations/45 years (Cousins and Cooper 1999). Most are taken in broadbill swordfish fishing operations around bird breeding colonies in the Hawaiian Archipelago, with much smaller numbers taken in bigeye tuna longlines. An estimated 1,600-2,000 are taken annually based on NMFS observer data collected since 1994. The NMFS Bycatch Report (1998) indicated that the Black-footed Albatross could not sustain the level of mortality caused by longline fishing at that time (Dobrzynski et al. 2002).

Laysan Albatross are generally more numerous but also susceptible to longline take in Hawaiian waters. Longlining has been implicated as the primary threat to this species particularly around their breeding colonies on Midway and Laysan Islands where more than 90 percent of the population breeds. A 30 percent decline in the breeding populations around these two islands has been reported since 1992 (ABC 2002).

In 1999, Garcia and Associates (1999) tested several mitigation measures specific to Hawaiian waters. The results of those studies suggest that blue-dyed squid (e.g., *Sepioteuthis lessoniana*) baits, line weighting with 80 g (2.8 ounce) weights, and night setting for swordfish reduced seabird bycatch significantly. In June 2001, NMFS issued regulations for longline fishing in Hawaiian waters (50 CFR Part 660.35) based in part on the research by Garcia and Associates (1999). The regulations require the following: thaw bait and dye it blue, discharge offal on the side opposite longline setting or hauling, remove all hooks from offal prior to discharge, use a line-setting machine or line shooter to set the main longline, use specified line weighting, and handle Short-tailed Albatross in a designated safe manner so they may be released alive. In addition to using these mitigation measures, court-ordered emergency closures within the Hawaiian Archipelago designed specifically to reduce sea turtle bycatch (50 CFR Parts 660.34 and 660.35) will certainly also benefit seabirds. At this writing, with a proposal to reopen the Hawaiian swordfish fishery, NMFS is reinitiating consultations with USFWS for the Short-tailed Albatross, which will amend the current Hawaiian Biological Opinion.

Longline Mitigation

The solution to the problem of seabird bycatch in longlines is – in theory – a simple one: deploy and rapidly sink longlines and baits, avoid bait stealing as a consequence, and increase bait availability, catchability, and profitability. During retrieval, avoid bait stealing. Recognizing that no single solution will eliminate seabird bycatch in all longline fisheries, the FAO appended two technical notes to the IPOA-S. The first note contains recommendations for developing NPOA-Ss for FAO member nations. This note describes how to conduct assessments to determine the extent and nature of a nation's seabird bycatch; why and when to use mitigation measures; the need for research, education and training in using deterrent devices; and the importance of data collection.

The second note lists examples of technical and operational measures which may be useful in reducing seabird bycatch. They are not considered mandatory nor are they exhaustive and as previously mentioned, some do not work in specific fisheries. Technical measures include such recommendations as: increase the sink rate of baits (e.g., add weights, thaw baits, use line setting machines); use below-the-water setting chutes, capsules, or funnels; properly position bird scaring (i.e., streamer or tori) lines over baited areas; deploy bird scaring curtains; use bait casting machines; use artificial lures or baits; modify hooks; assess acoustic and magnetic deterrents; and review the effectiveness of water cannons. Operational measures include the following recommendations: set baits at night to reduce bait availability to birds; reduce the attractiveness of vessels to seabirds (e.g., do not discard offal and garbage during setting and haul-in); review area and seasonal closures; give preferential licensing to vessels that use mitigation measures that do not require compliance monitoring; and release live birds. Brothers (1996) and CCAMLR (1996) also provide a list of technical and operational suggestions many of which are applicable to US fisheries, or are in fact being required by regulation.

United States Recreational Fisheries and Plastic Debris Concerns

This author is unaware of any concerted effort to assess the impacts of recreational fishing and its related gear on waterbirds within the US Lost and discarded fishing line, leaders, lures, hooks, nets, traps, pots and other equipment can entangle waterbirds, and the breakdown products from discarded finished plastic items are frequently ingested by waterbirds (Manville 1988). Birds apparently mistake the plastic pellets for food. Robards et al. (1995) examined stomach contents of 1,799 Alaskan seabirds of 24 species; 15 species were found to ingest plastic. Day et al. (1985) reported that

more than 50 of the 280 species of waterbirds are know to ingest plastics. These were generally surface feeders (shearwaters, petrels, gulls) or plankton-feeding divers (auklets and puffins). Manville (1988) reported 45 of 50 Laysan Albatross chicks were fed plastic debris by their parents. While the discard of plastic from any vessel within US waters (including the EEZ) is illegal under the Marine Plastic Pollution Research and Control Act of 1987 (P.L. 100-200, Title II), the law is rarely enforced. Education is key to alerting fishers of these problems and to the solutions.

CAFF Initiative

Representatives of the Arctic circumpolar nations (i.e., Canada, Finland, Greenland, Iceland, Norway, Russia, Sweden, and the United States) met in 2000 in Nova Scotia, Canada, to participate in a seabird bycatch workshop focused on problems and solutions with gillnets and longlines in the waters of Arctic countries. The Conservation of Arctic Flora and Fauna (CAFF), a working group of the Arctic Council, was established in 1991 to address the special needs of Arctic species and their habitats in the rapidly developing Arctic region (J. Hohn 2001 pers. comm.). The USFWS (this author) presented the US position on the then developing NPOA-S. Preliminary recommendations to reduce bycatch in gillnets and longlines were presented, some of which were discussed previously in this paper. In particular, the CAFF group recognized the need to apply both adaptive management and the precautionary approach in addressing seabird bycatch. Four specific needs were recognized: outreach and education, monitoring and assessment, mitigation, and implementing mechanisms. More monitoring through greater coverage by observers was recognized as an especially important need.

"Pirate" Fisheries

Despite United Nations Resolution 46/215 calling in 1991 for a worldwide ban and global moratorium on large-scale high-seas driftnetting, illegal fishing still occurs. Eleven vessels were reported fishing in the North Pacific in violation of the ban in 1999 alone (NMFS 2000). Increased surveillance by our military and US Coast Guard, as well as enforcement efforts of other nations, will help to curtail this problem. Of particular concern in the North Pacific is the bycatch of Short-tailed Albatross documented to have been taken in this "pirate" fishery. Since this is an unreported fishery, unless fishers can be caught with bird evidence in-hand, impacts remain unknown.

Of perhaps far greater concern is the take of seabirds and the unregulated over-harvest of the "Chilean Sea Bass" or Patagonian toothfish (*Dissostichus eleginoides*) "pirate" fishery in the Southern Oceans. Ryan et al. (2001) cautioned that the level of seabird mortality from this unsanctioned and illegal fishery was of grave concern since fishing effort is estimated at more than ten times the effort of the legal fishery with an almost certain greater rate of bird bycatch. CCAMLR and its Working Group on Incidental Mortality Arising from Longline Fishing recently adopted a catch documentation scheme for toothfish in an attempt to reduce unregulated and unreported activities of "pirate" fishing vessels in Antarctic waters (Cooper et al. 2001). The problem is a serious one since an estimated 50 percent of the world's toothfish comes from "pirate" fisheries where CCAMLR quotas and seabird avoidance measures are ignored, and where 0.33 million seabirds, including some 67,000 Albatross, were reported killed in this pirate fishery from 1997-2000 (ABC 2002). Citizen action is helping with this effort; Whole Food Markets in the US recently stopped selling this fish.

Jurisdiction of the Migratory Bird Treaty Act

The Migratory Bird Treaty Act (MBTA; 16 U.S.C. 703-712) is a strict liability statute; the killing of any protected migratory bird is not technically allowed under law unless permitted, and the FWS does not issue "incidental or accidental/unintentional" permits. Waterbirds are also included among the protected species. They include more than 150 species found primarily on or dependent upon our US extraterritorial waters (those waters more than 22 km [12 NM] from our shores).

One of the many challenges faced by nations in reducing bird bycatch, including first world nations such as the US, is a distinct lack of conservation law to protect seabirds in fisheries. Melvin and Parrish (2001) observed that where a legal framework does exist, such as in the US with the MBTA, it is rarely enforced, and where existing laws of one country are in force, they are rarely matched with similar laws in neighboring countries. The latter situation is represented by the US Endangered Species Act and its lack of comparable legislation in Canada, Mexico, Japan, or Russia.

At this writing, jurisdiction of the MBTA creates a particular challenge for the USFWS. In 1918 when the Act was passed, implementing what was later to become four bilateral treaties, the Act's intent was clear: conserve and protect migratory birds shared with our treaty partners. Today, 836 migratory bird species are protected, including waterbirds. However, what environmentalists call "...misguided and contrary to law" (Pacific Seabird Group April 1996 letter to US Government officials), the Assistant Solicitor for the Department of Interior (DOI) issued a 1980 legal opinion regarding enforcement of MBTA only to the US 22 km (12-NM) territorial sea, not the 371 km (200-NM) EEZ

(Department of Interior 1980). Representatives of the Pacific Seabird Group also pointed out that language in the negotiation report for the US delegation for the USA-Russia Migratory Bird Treaty of 1976, prepared by the Assistant Secretary of Interior for Fish, Wildlife and Parks, was clear. "...The intention of the American negotiators [was] to have this Convention apply to the 50 states (including the high seas out to the 200 mile limit)..." (Bohlen 1977). Requests from the Pacific Seabird Group and others to enforce the Act to the EEZ were submitted to DOI officials on various occasions in the 1990s. By the mid-1990s, DOI's Office of Solicitor began a new legal review. By 2000, a draft was distributed to other Federal agencies, and briefings were conducted with these agencies by the USFWS (this author) and a representative of the Department of State. The briefings were generally well received, with moderate support, but eventual concurrence by NMFS. However, when they were presented to Solicitors with the National Oceanic and Atmospheric Administration (NOAA; the legal advisors to NMFS), some disagreements developed. Suggested changes were added to the document and it was released as a DOI Solicitor's opinion for review by NOAA Solicitors in January 2001.

The legal opinion would apply to all US citizens and all persons on US-flagged vessels in US waters beyond 6 km (3 NM) from the US coastline and would extend into the international waters to the EEZs of other countries. Because the opinion is still being reviewed by NOAA Solicitors, it continues to be treated as privileged and confidential, not for distribution outside the Executive Branch. While some have argued that by extending MBTA jurisdiction the Service's intention is to shut down commercial fisheries, this could not be further from the truth. While the USFWS has been enforcing MBTA to the 22 km (12-NM) limit since the 1980s, no recreational or commercial fishery has been shut down as a result of any investigations or prosecutions to date. If the extension is approved, it would allow the Service to use its prosecutorial discretion, concentrating on intentional or egregious takes of migratory birds on the "high seas," especially in cases where take is shown to be harming a particular population of seabirds.

In *Humane Soc'y of the United States v. Glickman* (217 F.3d 882, 888 (D.C. Cir. 2000), the court determined that the MBTA applies to Federal agencies. In major part as a result of this and a previous court decision, President Clinton signed Executive Order (EO) 13186 in January 2001. The EO requires NMFS to develop and sign a memorandum of understanding (MOU) with USFWS that "shall promote the conservation of migratory bird populations." In the MOU, NMFS must identify principles and practices that will lessen the unintentional take of seabirds. At this writing, although those elements have yet to be identified, NMFS continues to develop an MOU which has yet to be shared with USFWS.

FWS Waterbird Bycatch Plan – a Look at Solutions

While Service representatives generally attend most meetings of the eight Regional Fishery Management Councils (FMCs) and the three Marine Fisheries Commissions, we do so particularly in regard to issues of special concern to USFWS. Based on the legislative design of the FMCs, the USFWS is not a voting member, although we certainly work to raise our concerns, especially in regard to seabirds in Alaska and Hawaii. The Service, however, does not currently have a Service-wide plan to deal with waterbird bycatch.

In late 1999, Service representatives met to develop a waterbird bycatch policy statement which was approved by the Director in 2000. In part, the statement reads,

"It is the policy of the [USFWS] that the Migratory Bird Treaty Act of 1918, as amended, legally mandates the protection and conservation of migratory birds... The goal of the [USFWS] is the elimination of waterbird bycatch in [commercial and recreational] fisheries. The Service will actively expand partnerships with Regional, national, and international organizations, States, tribes, industry, and environmental groups to meet this goal. The Service, in cooperation with interested parties, will aggressively promote public awareness of waterbird bycatch issues, and gather the scientific information to develop and provide guidelines for management, regulation, and compliance."

To develop an action plan to implement this policy statement, the Service created a Waterbird Bycatch Working Group (chaired by this author) in 2001 represented by all seven regional offices of the FWS. A draft of that plan is currently in the Crafting Subcommittee. While the plan will focus on commercial gillnet and longline impacts on waterbirds, the impacts of other gear – including in recreational fisheries – will also be discussed. The plan will be designed to address all fisheries where the USFWS has interaction, authority, or jurisdiction. The plan will also address assessments of waterbird bycatch in each of our Regions; review use of an at-sea monitoring database; discuss the roles of fisheries (both commercial and recreational) in each Region; assess Regional interaction with NMFS and the FMCs; develop a plan for in reach, outreach, and education; and suggest mitigation, implementation, and international involvement. Once released from the Crafting Subcommittee, the document will be reviewed by the full Waterbird Bycatch Working Group, and then released for regional and Washington office approval, with review anticipated to begin in February 2004.

In conclusion, it is clear that many challenges remain. We acknowledge that research will continue to provide significant breakthroughs which can be used to mitigate bycatch. The US, especially the USFWS, must continue to lead the charge to resolve these bycatch problems on both the national and international fronts. One way to accomplish this is by being proactive, and by encouraging our Federal partner, NMFS, to adopt a broader, conservation-oriented approach to resource management.

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Relationships of Fire Ecology and Avian Communities in North America[1]

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Key words: fire ecology, avian communities, North America.

Wild and managed fires have become increasingly prevalent across North America since the 1980's. Interest and concern about the influence of fire on ecological systems has also increased (Laverty and Williams 2000, USDA 2000). We summarize a symposium on fire and avian ecology, identifying patterns and differences in bird responses to various fire conditions in vegetative communities across North America. The symposium was presented at the Third International Partners in Flight Conference, Asilomar, California, on 23 March 2002. Fourteen major vegetation types, their corresponding fire regimes, and the associated bird communities are reviewed in ten chapters. Summaries of these chapters are included in this volume, but more developed treatments will appear in the monograph series, Studies in Avian Biology (Saab and Powell, in press).

Vegetative communities summarized at the symposium included boreal forests of Canada, grasslands and forests of northern Mexico, and within the United States, grasslands and shrublands in the northeast; eastern deciduous forests; pine-grasslands of the southeast; tallgrass prairie of the mid-west; shrubsteppe of the interior west; deserts, grasslands, shrublands, and forests of the southwest; coniferous forests of the Rocky Mountains; and oak woodlands of California (*table 1*). Most of these vegetation types have fire as some component of their natural disturbance regime. The diversity of climate, topography, and vegetation across North America results in a wide range of wildfire regimes from small-scale, frequent, low-severity fires to large, infrequent, high-severity events (*fig. 1*). Historical fires differ from contemporary fire regimes in most cases, although historical fire regimes are not always well understood (e.g., Baker and Jehle 2001).

Primary causes of altered fire regimes include livestock grazing, timber harvest, fire suppression, spread of invasive plant species, and habitat fragmentation (*table 1*). Fire suppression was the most pervasive problem in causing alterations of natural fire regimes. Secondly, invasive plants and livestock grazing were reported with equal frequency as a primary cause of disrupted fire regimes.

Changes have occurred in the timing, frequency, severity, and spatial scale of fires. Major vegetation types in which there has been little change in natural fire regimes are those outside of the United States, in boreal forests of Canada and pine/grasslands of Mexico. The spatial scale of fires has generally decreased in eastern and central United States, while it has increased in size in the western United States and across Canada in boreal forests. Prescribed fire is being used as a habitat restoration tool in 10 of the 14 major vegetation types, but not in desert scrub, xeric shrubsteppe, and riparian woodlands of the western United States or boreal forests of Canada.

Disruptions of natural fire regimes have not only led to alterations in landscape patterns and processes, but also to changes in population structure and the composition of bird communities (Brawn et al. 2001, Kotliar et al. 2002). Based on summaries of the literature, we observed general patterns of bird responses to fire over the short-term (within five years after fire). Cavity-nesting species generally favored high to moderate burn severity; open-cup, ground-nesting birds responded favorably to moderate and low severity burns; while open-cup, canopy-nesting species preferred unburned habitats. Longer-term responses will likely differ in that species within each of the above nest types (open vs. cavity) and nest layer (ground, shrub, and canopy) could respond positively to all burn severities.

Research and conservation issues included in the symposium were: determining the appropriate spatial and temporal scales for fire and the mosaic of habitats necessary to conserve avian communities; identifying potential negative and positive effects of post-fire salvage logging; understanding the ecological consequences of using management tools (e.g., mowing, prescribed fire, timber harvest) to mimic natural fire; and predicting the effects of climate change on fire regimes, vegetation types, and associated bird communities. Efforts by ecologists will continue to

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California**.

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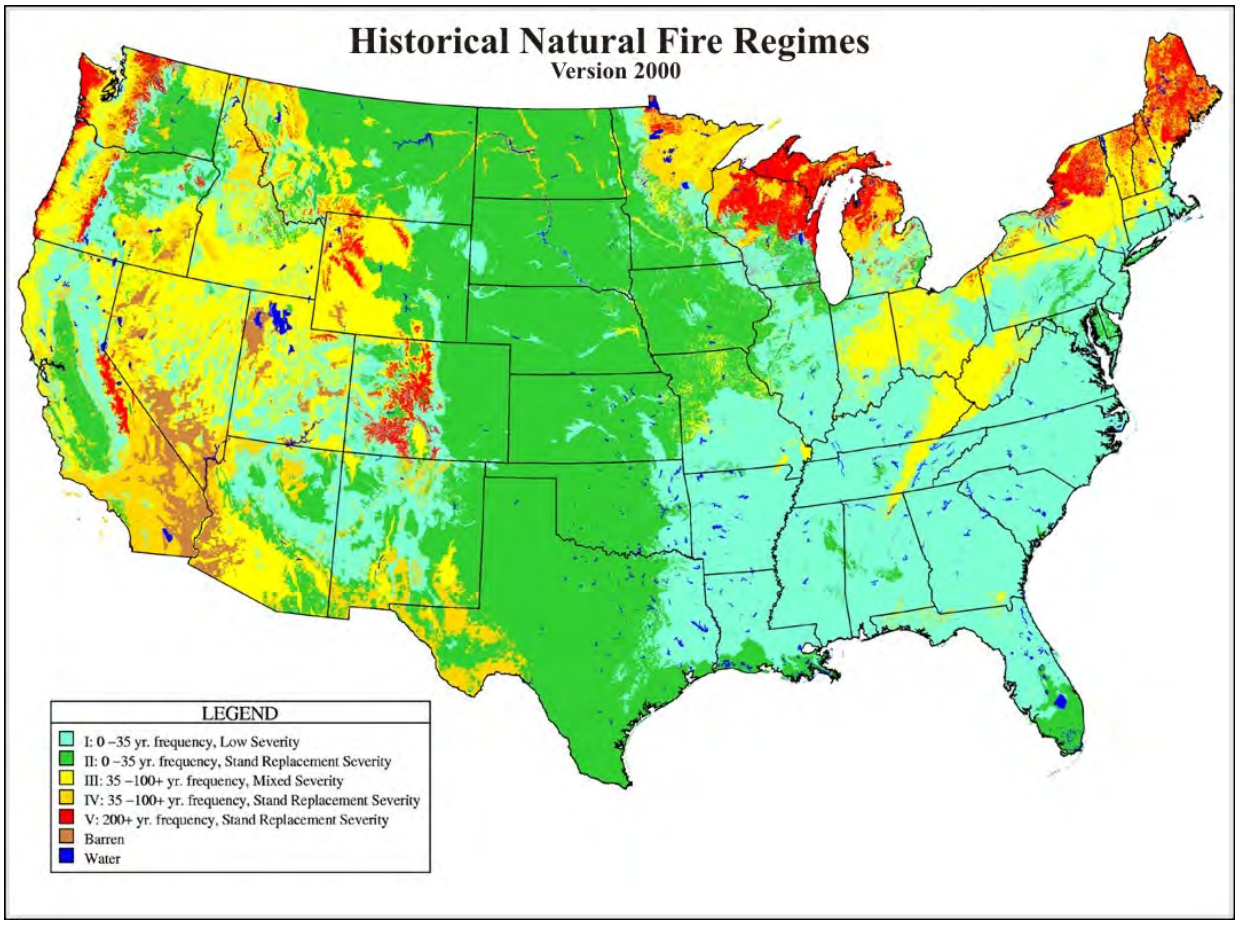

Figure 1— Historical natural fire regimes estimated for the last 500 years within the United States. The source for this image is http://www.fs.fed.us/fire/fuelman/firereg2000/maps.html. Metadata for this map are found at http://www.fs.fed.us/-fire/fuelman/firereg2000/firereg_v2k.html.

understand how the process of fire influences patterns in bird communities and to determine the mosaic of fire and habitat conditions that are necessary for the long-term persistence of avian communities.

Acknowledgments

We thank C. Groves and C. Bock for reviews of the manuscript. C. Bock's seminal work on fire and avian ecology has inspired us to pursue more research and to obtain greater knowledge of this fascinating topic in ecology.

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Table 1— *Reported causes of altered fire regimes in major vegetation types across North America.*

Vegetation type	Livestock grazing	Fire suppression	Logging	Invasive plants	Habitat fragmentation	Other causes	Reference
Grass/Shrublands Northeast U.S.		X					Vickery et al., in press
Pine/Grasslands Southeast U.S.		X		X	X	Hydrologic	Engstrom et al., in press
Eastern Deciduous Forest Northeast U.S.		X		X		American Indians	Artman et al., in press
Boreal Forest Canada		X	X		X	Climate	Hannon and Drapeau, in press
Tallgrass Prairie Midwest U.S.	X				X	Drought	Rienking, in press
Pine/Grasslands Northern Mexico	X						_____
Coniferous Forests Rocky Mountains U.S.	X	X	X	X			Kotliar et al., in press
Desert Scrub/Grasslands Southwest U.S.	X	X		X		Climate, Prairie Dogs	Bock and Block, in press
Riparian/Woodlands/Coniferous Forests Southwest U.S.	X	X	X	X	X	Drought	Bock and Block, in press
Shrubsteppe Interior West U.S.	X	X		X			Knick et al., in press
Oak Woodlands California U.S.	X	X		X	X	American Indians	Purcell and Stephens, in press
Maritime Pacific Northwest U.S.	X	X				American Indians	Huff et al., in press

Influence of Fire and Other Anthropogenic Practices on Grassland and Shrubland Birds in New England[1]

Peter D. Vickery,[2,3,4] Benjamin Zuckerberg,[3] Andrea L. Jones,[2] W. Gregory Shriver,[5] and Andrew P. Weik[6]

Key words: Ammodramus savannarum, Bartramia longicauda, blueberry barrens, Bobolink, *Dolichonyx oryzivorus,* Eastern Meadowlark, Eastern Towhee, Grasshopper Sparrow, grassland birds, New England, *Passerculus sandwichensis*, *Pipilo erythrophthalmus*, *Pooecetes gramineus*, prescribed fire, Savannah Sparrow, *Sturnella magna*, Upland Sandpiper, Vesper Sparrow.

Since 1966, many species of grassland and shrubland birds have declined substantially in New England (Askins 2000). The extent of grassland and shrubland habitat in New England has changed dramatically over the past 400 years. Presently, grassland and shrubland habitat in New England are created and maintained primarily as a result of four types of habitat management: mowing, livestock grazing, clearcutting, and prescribed burning.

Agricultural land clearly represents the largest proportion of graminoid-dominated open land in New England. In 1997, there were 1,760,000 ha of open farmland in New England, approximately 718,500 ha were hayfields, pastures, and idle cropland (National Agricultural Statistics Service 2002), sites that are most likely to provide suitable nesting habitat for grassland birds. Hayfields in New England are rarely burned, but are mowed or cut one or more times annually.

Livestock grazing is also an important form of habitat management that affects grassland birds. In New York, Smith (1997) found that moderate annual grazing with stocking rates of 0.12 – 0.24 head of cattle per hectare provided adequate habitat for Henslow's Sparrows (*Ammodramus henslowii*) and Grasshopper Sparrows (*A. savannarum)* in the Fingers Lake National Forest. The same stocking rates are likely to be applicable for New England as well.

Clearcutting, a silvicultural practice that removes essentially all of the standing wood, is more widespread and is an important disturbance mechanism that benefits shrubland birds. Clearcutting has created extensive shrubland patches in northern Maine. Although the extent of this silvicultural practice has declined in the past 10 years, approximately 3.5 percent of the commercial forest land (243,000 ha), has been clearcut within the past 20 years (Maine Forest Service 2001). This practice has created a continuum of early-successional shrubland habitats used by a wide variety of shrubland warblers and sparrows, especially Chestnut-sided Warbler (*Dendroica pensylvanica*), Palm Warbler (*D. palmarum*), Mourning Warbler (*Oporornis philadelphia*), Common Yellowthroat (*Geothlypis trichas*), Wilson's Warbler (*Wilsonia pusilla*), Lincoln's Sparrow (*Melospiza lincolnii*), and White-throated Sparrow (*Zonotrichia albicollis*).

Prescribed fire is used primarily for two separate reasons in New England: habitat management of rare plant and animal assemblages and pruning of commercial lowbush blueberry (*Vaccinium angustifolium*) fields. In the first case, prescribed fires are used for conservation purposes to maintain rare, pyrogenically-mediated habitats such as sandplain grasslands, coastal heathlands, and pitch pine (*Pinus rigida*)-scrub oak (*Quercus ilicifolia*) barrens. Prescribed fires are used to maintain vegetation structure and composition, reduce fuel loads, and provide an important mechanism to protect and enhance globally rare plants and animals (Dunwiddie and Caljouw 1990). In the absence of fire, some rare organisms have declined sharply.

Importantly, the scale of prescribed burns in New England for management of endangered ecosystems tends to be small. In the past 10 yrs, fewer than 400 ha were burned annually and burns were rarely larger than 15 ha. For example, in 2002, 301 ha of native grassland and heathland were burned in New England; average burn size was 10 ha, although somewhat larger burns (60 – 65 ha range) have taken place on Nantucket Island.

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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Despite their small size, these burns can have important benefits for grassland birds, at least locally. In Maine, the 210 ha Kennebunk Plains supports a rich assemblage of grassland birds that clearly benefit from fire management, including: Upland Sandpiper, Grasshopper Sparrow, and Vesper Sparrow (Vickery et al. 1999). Prescribed fires in coastal Massachusetts primarily benefit Savannah Sparrows, Eastern Meadowlarks (*Sturnella magna*), and Bobolinks, and foraging Northern Harriers (*Circus cyaneus*) (Zuckerberg 2002).

In Maine, lowbush blueberry production covers approximately 26,000 ha, and represents the greatest extent of fire management in New England. Blueberries are harvested on a two year rotation. In the past 10 yrs, approximately 20-30 percent of the non-harvest year fields, or ≈ 3,000 ha, have been burned annually. The remaining non-harvest fields are generally flail-mowed (D. Yarborough, pers. comm.). These barrens provide important nesting habitat for Upland Sandpipers (*Bartramia longicauda*) and Vesper Sparrows (Weik 1998, Shriver et al. this volume; *fig. 1*).

The effects of burning differ in grasslands versus shrublands. In native grasslands, burning has a strong effect on the vegetation, which, in turn, affects a suite of grassland and shrubland specialists. In an 8-yr study at Kennebunk, Maine, prescribed fire affected all eight nesting species that breed at that site. Savannah Sparrow, Grasshopper Sparrow, Bobolink, and Eastern Meadowlark densities declined for one yr following fire, but remained high for 5-7 yrs following prescribed burns (*fig. 2*). Horned Larks (*Eremophila alpestris*) and Vesper Sparrows preferred recently burned sites. Abundances of both these species and Upland Sandpipers declined with time since fire. Field Sparrows (*Spizella pusiila*) preferred sites that had not been burned or mowed in 5 years (Vickery et al. 1999).

On Nantucket Island shrublands, Eastern Towhees (*Pipilo erythrophthalmus*) were more abundant in areas that had been burned or were left unmanaged, as compared to those shrublands that had been mowed. Song Sparrow territory densities in shrublands were similar in mowed, burned, and unmanaged units (Zuckerberg 2002). In general, these results indicate that burning has a strong effect in grassland systems but does not affect shrubland birds. Not surprisingly, mowing has a more substantial effect on bird occupancy in shrubland habitats because this form of habitat manipulation has a much more pronounced effect on vegetation structure (Zuckerberg 2002).

Large-scale prescribed burning in most of New England will continue to be a difficult management issue because of the density and spatial distribution of

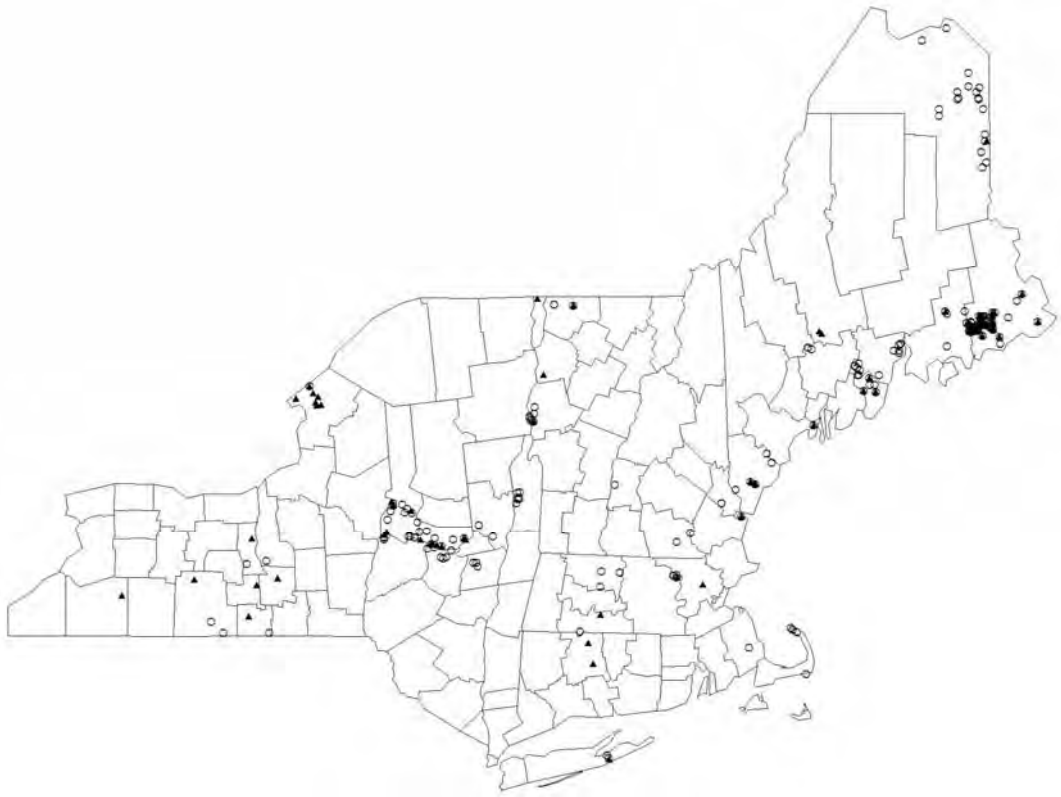

Figure 1—A grassland bird inventory of New England and New York (1997-2000) revealed that Upland Sandpipers (filled triangle) and Vespers Sparrows (open circle) were most common on the large commercial blueberry fields in eastern Maine. These two species frequently occurred together on these sites (Shriver et al. 2003).

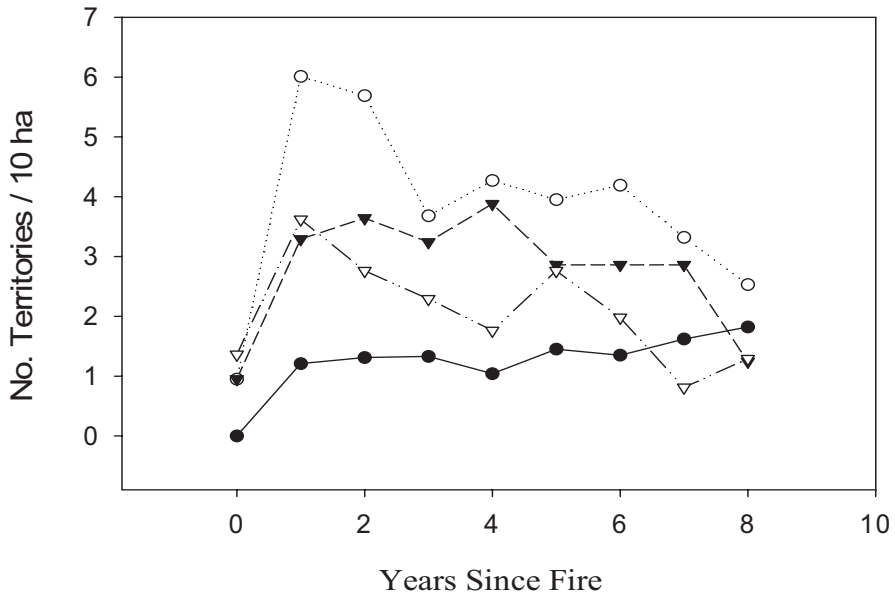

Figure 2—Breeding densities of four species of grassland birds followed the same general pattern at Kennebunk, Maine, 1984-1991. Breeding densities of all species were very low during the burn-year but increased markedly in the yr following the burn. Eastern Meadowlark (black circle) densities remained high for 8 yrs following fire. Bobolink (open circle) and Savannah Sparrow (open triangle) were high in the yr following but generally decreased thereafter. Grasshopper Sparrow (black triangle) densities remained high for 4 yrs following fire but then decreased. Standard errors, not shown, were less than 0.2 territories per 10 ha (Vickery et al. 1999).

houses and other man-made structures. Consequently, prescribed fires will generally continue to be small and isolated, usually occurring in the winter months. Small-scale prescribed fires alone are unlikely to substantially increase habitat for declining grassland birds in New England. It seems likely that grassland and shrubland sites will eventually be managed by a combination of burning, mowing, and grazing.

Acknowledgments

R. Askins, T. Hodgman, T. Maloney, E. Steinauer, and D. Yarborough are warmly acknowledged for providing thoughtful suggestions and unpublished information.

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Fire on the Mountain: Birds and Burns in the Rocky Mountains[1]

Natasha B. Kotliar,[2] Victoria A. Saab,[3] and Richard L. Hutto[4]

The diversity of climate and topography across the Rocky Mountains has resulted in a broad spectrum of fire regimes ranging from frequent, low-severity fires to infrequent stand-replacement events. Such variation in fire history contributes to landscape structure and dynamics, and in turn can influence subsequent fire behavior (Allen et al. 2002). In essence, landscapes across the Rocky Mountains are shifting mosaics that reflect variation in disturbance frequency, severity, and time since the last disturbance. Superimposed on, and interacting with, fire regimes are other natural disturbances (e.g., insect outbreaks) and the influence of human activities. In turn, the collective influence of fire and human activities on the landscape influences avian community structure and dynamics.

Here we review the current state of knowledge about past fire regimes and how they have been altered by human activities. We also highlight the limited information on how avian communities respond to fire. We conclude with implications for fire management programs in the Rocky Mountains. See Kotliar et al. (in review) for more extensive discussion of these topics.

The degree to which human activities have altered fire regimes is not consistent across Rocky Mountain landscapes or through time (Veblen and Lorenz 1991, Knight et al. 2000). During Euro-American settlement, a number of activities collectively influenced fire frequency including grazing, logging, human-caused fires, and active fire suppression (Allen et al. 2002). More recently there has been unprecedented rapid growth of communities in many forested regions of the Rocky Mountains (Theobald 2000). Attempts to restore natural fire regimes are constrained by the ever-increasing wildland-urban interface; in Colorado, for example, ~80% of forests are within 3 km of private lands (Theobold 2000). Thus, historic and current settlement and land use patterns have substantially altered the structure and dynamics of fire-dominated landscapes.

The degree of deviation from historic landscape functioning, and the persistence of such changes, varies among disturbance regimes (Romme 1982, Romme et al. 2000, Veblen et al. 2000). In general, alteration of historic fire regimes has been most pronounced in ponderosa pine (*Pinus ponderosa*) forests. At lower elevations and in the southwest, ponderosa pine systems were characterized by frequent, understory fires (Veblen et al. 2000, Allen et al. 2002). Historically, the frequent fires helped to maintain open stands (Brown et al. 1999, Veblen et al. 2000, Allen et al. 2002). At higher elevations, where ponderosa pine is mixed with Douglas-fir (*Pseudotsuga menziesii*), fire occurred less frequently, resulting in a mixed regime that included both understory and crown fire events (Brown and Sieg 1996, Brown et al. 1999, Veblen et al. 2000). Fire exclusion, caused by active suppression or grazing, and subsequent increase in tree density have been more pronounced in forests that burned frequently (Veblen et al. 2000). Thus, the greater continuity of fuels resulting from a century of fire exclusion is believed to have resulted in more extreme fire behavior over the past several decades (Allen et al. 2002). However, the relative influence of climate (e.g., extreme drought, high winds) versus fuels (i.e., fire suppression) on recent fire behavior in forests characterized by mixed regimes is unclear (Veblen et al. 2000).

Fire suppression in subalpine forests is generally presumed to have been less effective than in montane forests because of limited accessibility and strong climatic drivers of fire behavior (i.e., extreme drought and high winds), which characterize high-elevation forests (Romme 1982, Romme and Despain 1989, Romme et al. 2000, Veblen 2000). Furthermore, even in areas where fire frequency may have declined, burn severity may remain unchanged (Romme and Despain 1989). However, logging and other landscape disturbance during Euro-American settlement may have altered subsequent landscape dynamics by creating more homogeneous forests and a preponderance of subalpine forests ca. 200 yr old (Veblen and Lorenz 1991).

Our understanding of how avian communities respond to burned forests is quite rudimentary. In a recent review of the literature, Kotliar et al. (2002) summarized general patterns for 41 bird species observed in at least three of 12 studies comparing burned and unburned forests in the western United States. They found that many woodpeckers and aerial insectivores are generally more abundant in recently burned forests,

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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including Back-backed (*Picoides arcticus*), Three-toed (*P. tridactlyus*), and Hairy Woodpeckers (*P. villosus*), Olive-sided Flycatchers (*Contopus cooperi*), and Mountain Bluebirds (*Sialia curricoides*). In contrast, foliage gleaners and other species preferring closed canopy forests, such as Varied Thrush (*Ixoreus naevius*), Townsend's Warbler (*Dendroica townsendi*), Mountain Chickadee (*Poecile gambeli*), and Ruby-crowned Kinglets (*Regulus calendula*), are more abundant in unburned forests (Kotliar et al. 2002). These patterns were consistent across a wide geographic area and a variety of conifer cover types.

However, most species exhibit varied responses to burns, such as Western Tanagers (*Piranga ludoviciana*), Townsend's Solitaire (*Myadestes townsendi*), Chipping Sparrow (*Spizella passerina*), and Dark-eyed Junco (*Junco hyemalis*). Several factors may contribute to this variation, including burn severity and spatial heterogeneity in burn patterns, geographic variation, edge effects, time since fire, and cover types (Huff and Smith 2000, Kotliar et al. 2002). Several studies have been initiated to begin to tease apart the effects of these factors. Preliminary data from a study of burns across the southern Rocky Mountains indicate that burn severity and cover type can influence how birds respond to burned forests. For example, the White-breasted Nuthatch (*Sitta carolinensis*) was most abundant in low-severity burns compared to unburned or severely burned forests (Kotliar, unpubl. data). However, some species (e.g., Townsend's Solitaire) showed similar abundance across a range of burn severities, including unburned forest. Many generalist species preferring a mixed open canopy exhibited an apparent tolerance to a wide variety of burned conditions (Kotliar, unpubl. data).

The variation observed in the response of avian communities to fire, coupled with variation in, and uncertainty about, historic fire regimes (Baker and Ehle 2001), argues for caution in the implementation of recent fire initiatives to reduce fuel loads. These initiatives are based on the premise that millions of acres are susceptible to uncharacteristically large and severe wildland fires due to decades of fire suppression (Allen et al. 2002). However, there are a number of untested assumptions about historic fire regimes and forest structure that affect the validity of the fire-management initiatives. Moreover, it is assumed that specific forest structures will ensure the integrity of natural communities (e.g., avian communities). These assumptions, which are unlikely to be valid across the broad spatial scales at which the fire initiatives are implemented, have ramifications for the ecological integrity of avian communities of the Rocky Mountains. Because the lack of information on the effects of fire on wildlife is a major stumbling block for developing ecologically sound fire management policies, basic research on fire effects is urgently needed.

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Response of Birds to Fire in the American Southwest[1]

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Abstract

Fire was a common prehistoric disturbance in most southwestern grasslands, oak savannas, and coniferous forests, but not in Sonoran and Mojave desertscrub, or in riparian ecosystems. Prescribed burning should be applied, but under experimental conditions that facilitate studying its impacts on birds and other components of biodiversity. Fire plays a critical role in maintaining a balance between desert grassland and Chihuahuan desertscrub, but unburned areas also are important for birds dependent upon woody vegetation and/or heavy grass cover. Understory fire probably once played a critical role in maintaining relatively open oak (*Quercus* spp.), pinyon-juniper (*Pinus- Juniperus*), and ponderosa pine (*Pinus ponderosa*) woodlands and their bird assemblages, while stand replacement fires sustained aspen groves (*Populus tremuloides*) at higher elevations. Carefully controlled prescribed burning, thinning, and grazing management will be needed to return fire to its prehistoric role in these habitats. There is an urgent need for cooperative effort between managers and researchers to implement replicated burns to quantify avian responses in appropriate habitats.

Key words: birds, desert, fire, grassland, mixed-conifer, pine-oak, prescribed burning, riparian, savanna, Southwest.

The ecological importance of fire in the American Southwest has long been recognized (Leopold 1924), but the nature of these fires has been altered drastically by disturbances such as logging, livestock grazing, and suppression efforts (Moir et al. 1997, McPherson and Weltzin 2000). Southwestern ecosystems range from low desert to high montane, and fire ecology and management issues differ greatly among them (Krammes 1990).

The Sonoran and Mojave Deserts consist of structurally complex vegetation (Turner et al. 1995), and they have correspondingly rich avifaunas dependent upon trees and large succulents (Mills et al. 1991). The spread of exotic grasses such as red brome (*Bromus rubens*) and buffelgrass (*Pennisetum ciliare*) have increased the frequency and intensity of fire in these deserts, killing much of the native vegetation (Miller et al. 1995). Fire effects on birds in these deserts therefore are almost entirely negative.

Most southwestern grasslands were invaded by woody plants from the Chihuahuan Desert, beginning especially in the late 1800s, largely because of decreased frequencies and intensities of fire (Archer et al. 1995, McPherson 1995). Birds associated with grasslands have declined more than other avian groups, both nationally and in the Southwest (Brown and Davis 1998, Vickery and Herkert 2001), at least in part because of the conversions of former grassland to desertscrub. Fire has the short term effect in southwestern grasslands of reducing grass cover while stimulating forb cover and seed production for two or three post-fire growing seasons. Such burning favors grassland birds associated with relatively open ground, such as Mourning Dove (*Zenaida macroura*), Horned Lark (*Eremophila alpestris*), and Lark Sparrow (*Chondestes grammacus*), over those requiring heavy grass cover, such as Grasshopper Sparrow (*Ammodramus savannarum*), Botteri's Sparrow (*Aimophila botterii*), and Cassin's Sparrow (*Aimophila cassinii*; *fig. 1*). Prescription fire should be applied in these ecosystems, especially in relatively mesic sites, to restore open grasslands and retard woody encroachment (Bock and Bock 1992, Gordon 2000). However, a balanced approach is called-for, since other species prefer or require woody cover in Chihuahuan shrub/grasslands (Whitford 1997, Pidgeon et al. 2001).

Interior chaparral occurs from northwestern Arizona to southwest Texas and northern Mexico, and supports a variety of shrubland birds (Szaro 1981, Pase and Brown 1982). Drought, livestock grazing, and fire suppression have increased shrub cover and reduced cover of perennial grasses and forbs in Arizona chaparral (Brejda 1997). Virtually nothing is known about avian

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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responses to fire in this ecosystem (but see Szaro 1981), and experiments with prescribed fire are strongly recommended.

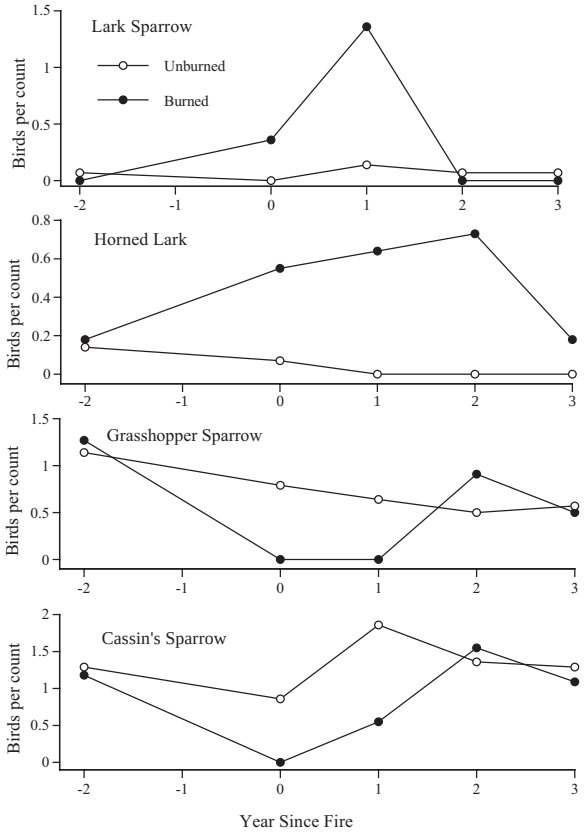

Figure 1— Relative abundances of four grassland birds two years before, just following, and for three summers after fire in a semi-arid grassland in southeastern Arizona (data from Bock and Bock 1992).

Fire once maintained oak (*Quercus* spp.) savannas in the Mexican borderlands in an open condition, by frequently killing smaller trees and shrubs (McPherson 1997). These ecosystems became more densely wooded when livestock grazing and fire suppression reduced fine fuels (McPherson and Weltzin 2000). Typical birds of southwestern oak savannas include species specializing on acorns, insect hawkers, foliage gleaners, and species dependent on the grassy understory (Brown 1982). Responses of these birds to prescribed or wildfire in southwestern oak woodlands are largely unknown, but studies in Midwestern savannas suggest that fire would favor insect hawkers and understory species over foliage gleaners (Davis et al. 2000).

Southwestern riparian woodlands support an abundance and variety of breeding birds vastly greater than adjacent ecosystems (Carothers et al. 1974), but many of these woodlands have been damaged or completely eliminated by anthropogenic forces such as alteration of natural flooding regimes and the spread of exotic vegetation (Ellis et al. 1998). The result has been a substantial decline in abundance and variety of birds in these ecosystems (Rosenburg et al. 1991), although remnant patches continue to support high avian biodiversity (Strong and Bock 1990, Skagen et al. 1998). There is little evidence that fire was a common historical event in southwestern riparian woodlands, perhaps because of moisture. Recent fires have been highly destructive of native riparian vegetation, most particularly the large trees such as cottonwood (*Populus* spp.) and sycamore (*Platanus* spp.) that are especially important to birds (Bock and Bock 1984, Busch 1995). Therefore, prescribed fire is not recommended for these ecosystems.

Pinyon-juniper (*Pinus-Juniperus* spp) woodland is widespread throughout the Southwest, but little is known about fire effects in this ecosystem (Balda and Masters 1980, Severson and Rinne 1990). We found no studies related to birds and fire in pinyon juniper woodlands. Fire likely would favor species associated with more open habitats, while negatively impacting species that depend on trees for foraging or nesting, but this tenuous conclusion is based on responses of birds to mechanical clearing of dense stands rather than to fire itself (Sedgwick and Ryder 1987).

Fire is perhaps the most important natural disturbance in southwestern ponderosa pine (*Pinus ponderosa*) forests, and frequent low-intensity fires were part of their evolutionary history (Pyne 1996, Moir et al. 1997). Suppression efforts, livestock grazing, and logging have altered natural fire regimes, resulting in dense forests and increased risk of unnatural stand replacement fires. Most studies of fire effects on birds in these forests have focused on stand replacement burns, where woodpeckers and ground foragers are the main short-term beneficiaries (Dwyer and Block 2000). Species likely to benefit from cooler understory fires are those requiring relatively open habitats, such as flycatchers, swallows, and bluebirds (Marshall 1963, Horton and Mannan 1988).

Bird numbers and species richness seemed to respond positively shortly after the 1996 Horseshoe and Hochderffer fires on the Coconino National Forest Arizona (*table 1*). During the breeding season three years post-fire, more species were detected in areas where fires were severe (stand-replacement) and moderate (understory) than in adjacent unburned forests (45, 41, and 31 species, respectively). A similar trend was found during the nonbreeding season with 33, 35, and 26 species detected in severe, moderate, and unburned forests. Major species groups that increased in response to fire included woodpeckers, flycatchers, and thrushes. In contrast, many foliage-gleaning birds (Mountain Chickadees, Plumbeous Vireo, Pygmy Nuthatch, Yellow-rumped Warbler, and Grace's Warbler) were detected less frequently within severe fire areas.

Table 1– *Simple counts of birds detected during point counts conducted within ponderosa pine forests burned during the 1996 Horseshoe and Hochderffer fires, Coconino National Forest, Arizona (Block, unpubl. data). Counts were conducted in the breeding season of 1999 and nonbreeding season 1999-2000, approximately three years after the fires.*

		Breeding			Nonbreeding		
Species		**Severe**	**Moderate**	**Unburned**	**Severe**	**Moderate**	**Unburned**
Golden Eagle	*Aquila chrysaetos*				1		
Bald Eagle	*Haliaeetus leucocephalus*				1	1	
Sharp-Shinned hawk	*Accipiter striatus*	1			7	1	
Cooper's Hawk	*Accipiter cooperii*		1				
Northern Goshawk	*Accipiter gentilis*						2
Red-tailed Hawk	*Buteo jamaicensis*	1	3		3	1	
American Kestrel	*Falco sparverius*	1	3		3		
Merlin	*Falco columbarius*					1	
Wild Turkey	*Meleagris gallopavo*				2		
Mourning Dove	*Zenaida macroura*	37	32	30	1	5	
Long-eared Owl	*Asio otus*					1	
Northern Pygmy Owl	*Glaucidium gnoma*				6		
Common Nighthawk	*Chordeiles minor*		2				
Broad-tailed Hummingbird	*Selasphorus platycercus*	20	34	5			
Rufous Hummingbird	*Selasphorus rufus*		1				
Northern Flicker	*Colaptes auratus*	32	28	17	103	83	42
Acorn Woodpecker	*Melanerpes formicivorus*	6					
Lewis's Woodpecker	*Melanerpes lewis*	9					
Williamson's Sapsucker	*Sphyrapicus thyroideus*				1	12	4
Yellow-bellied Sapsucker	*Sphyrapicus varius*					1	
Hairy Woodpecker	*Picoides villosus*	88	28	10	149	46	29
Three-toed Woodpecker	*Picoides tridactylus*	1			11		
Red-naped Sapsucker	*Sphyrapicus varius nuchalis*						3
Cordilleran Flycatcher	*Empidonax difficilis*	1		1		1	
Olive-sided Flycatcher	*Contopus borealis*	12	1				
Western Wood-pewee	*Contopus sordidulus*	51	93	11			
Horned Lark	*Eremophila alpestris*	1					
Violet-green Swallow	*Tachycineta thalassina*		3	10			
Pinyon Jay	*Gymnorhinus cyanocephalus*	4	36	17	22	23	2
Steller's Jay	*Cyanocitta stelleri*	33	94	88	152	189	114

Table 1— *contd.*

Species		Breeding			Nonbreeding		
		Severe	Moderate	Unburned	Severe	Moderate	Unburned
Clark's Nutcracker	*Nucifraga columbiana*	3	4		39	44	22
American Crow	*Corvus brachyrhynchos*	5		3	15	16	20
Common Raven	*Corvus corax*	11	5	8	96	87	83
Mountain Chickadee	*Poecile gambeli*	2	74	111	11	117	104
Bushtit	*Psaltriparus minimus*				4	7	6
Brown Creeper	*Certhia americana*	8	10	6	3	25	23
White-breasted Nuthatch	*Sitta carolinensis*	43	65	76	63	121	95
Red-breasted Nuthatch	*Sitta canadensis*				2	1	
Pygmy Nuthatch	*Sitta pygmaea*	1	26	26	17	130	116
House Wren	*Troglodytes aedon*	2	1				
Rock Wren	*Salpinctes obsoletus*		1				
Golden-crowned Kinglet	*Regulus satrapa*					3	1
Ruby-crowned Kinglet	*Regulus calendula*					1	
Western Bluebird	*Sialia mexicana*	144	136	77	116	106	74
Mountain Bluebird	*Sialia currucoides*	6			4	3	1
Townsend's Solitaire	*Myadestes townsendi*	1	5	17	1	6	4
Hermit Thrush	*Catharus guttatus*	3					
American Robin	*Turdus migratorius*	53	46	17	35	43	13
Plumbeous Vireo	*Vireo plumbeus*	10	36	24		1	
Warbling Vireo	*Vireo gilvus*		1				
Virginia's Warbler	*Vermivora virginiae*			3			
Yellow-rumped Warbler	*Dendroica coronata*	10	69	78	1		
Grace's Warbler	*Dendroica graciae*		31	32			1
Olive Warbler	*Peucedramus taeniatus*			2			2
Black-headed Grosbeak	*Pheucticus melanocephalus*	3	5				
Vesper Sparrow	*Pooecetes gramineus*	2					
Lark Sparrow	*Chondestes grammacus*	6	4	4			
Chipping Sparrow	*Spizella passerina*	19	51	9	1	4	
Dark-eyed Junco	*Junco hyemalis*	31	89	60	71	94	46
Western Meadowlark	*Sturnella neglecta*	35	14		1	2	
Brown-headed Cowbird	*Molothrus ater*	1	13	2			
Western Tanager	*Piranga ludoviciana*	24	103	20			
Summer Tanager	*Piranga rubra*		3				

Table 1— *contd.*

Species		Breeding			Nonbreeding		
		Severe	Moderate	Unburned	Severe	Moderate	Unburned
Hepatic Tanager	*Piranga flava*	1					
Pine Siskin	*Carduelis pinus*	3	3	3	11	2	5
Lesser Goldfinch	*Carduelis psaltria*	1	1				
Red Crossbill	*Loxia curvirostra*	4	4	7	14	30	54
House Finch	*Carpodacus mexicanus*	2	1				
Evening Grosbeak	*Coccothraustes vespertinus*	2		5		1	1
Total number of species		45	41	31	33	35	26
Total number of detections		734	1160	779	967	1209	867

[a] N = 49 counting stations within severe, moderate, and unburned areas. Counting stations were sampled three times during the breeding season and four times during the nonbreeding season.

Mixed conifer forests of the Southwest are dominated by Douglas-fir (*Pseudotsuga menziesii*), white fir (*Abies concolor*), Engelmann spruce (*Picea engelmanni*), and aspen (*Populus tremuloides*; Brown 1982). Many fires that occur at higher elevations in these forests are stand replacing, providing opportunities for establishment of aspen (Moir 1993), and the variety of birds associated with it (Finch and Reynolds 1987, Hutto 1995). However, a variety of other birds, including the threatened Mexican Spotted Owl (*Strix occidentalis lucida*), depend on substantial conifer forests (Smith 1980, U.S. Department of Interior 1995). More field research specific to Southwestern conditions needs to be conducted to understand fire effects on birds in mixed-conifer forests.

Both deliberately-set prescribed fire and prescribed natural fire (natural ignition, allowed to burn within pre-set limits) are essential approaches in reducing fuels and returning southwestern grass/shrublands, oak savannas, and conifer forests to their prehistoric conditions. Given the historical importance of fire in these ecosystems, there have been surprisingly few studies of the effects of either wildfire or prescribed burning on southwestern bird populations and communities. We call for managers and researchers to cooperate in the design and implementation of replicated, large-scale, properly controlled field experiments to examine avian responses to prescription burning.

Acknowlegdments

We thank Victoria Saab for organizing the session on fire and birds, of which this paper was a part.

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Natural and Anthropogenic Fire Regimes, Vegetation Effects, and Potential Impacts on the Avifauna of California Oak Woodlands[1]

Kathryn L. Purcell[2] and Scott L. Stephens[3]

Introduction

Fire was once an important component of the disturbance regime in oak woodlands of the Sierra Nevada foothills. In addition to lightning-ignited fires, anthropogenic sources of ignition have historically been important until fire suppression activities in the mid-20th century lengthened fire return intervals. Few fire history studies have addressed oak woodlands, and studies of the effects of fire on birds of oak woodlands are even more scarce. We review existing information on changes in the fire regime of California's oak woodlands and the effects of fire on the vegetation and attempt to predict the response of the bird community to fire and fire suppression.

Native Americans used fire to modify oak woodland vegetation for at least 3000 years (Johnston 1970, Lewis 1973). We do not know to what extent fires ignited by Native Americans were a significant factor in modifying oak woodlands, but ethno-ecological evidence indicates that these fires were very common. Fire frequency is believed to have been annual in some areas (Lewis 1982, Kay 1995), and the timing was usually in late summer or early fall (Lewis 1980, Timbrook et al. 1982, Lewis 1985). The spatial extent of burning is unknown. The high frequency of fires resulted in low-intensity fires and little damage to mature oaks. Understory woody vegetation was reduced. Tree density was lowered, although trees of all sizes were present. Recruitment was low but relatively continuous (Mensing 1992). The overall resulting pattern was a fine-grained mosaic of vegetation patches. Burning by Native Americans declined in the mid-19th century because of the reduction in the Native American population due to disease and genocide and also as a result of early state regulations (Sampson 1944, Lewis 1993).

Increased fire frequency occurred in some areas following settlement by Euro-Americans subsequent to the discovery of gold in 1848. Studies of burning by Euro-American settlers have revealed average fire return intervals of 8–15 years during this period (Sampson 1944, McClaran and Bartolome 1989, Stephens 1997). The objectives of burning generally were to increase forage production for livestock and for vegetation type conversions (Cooper 1922, Biswell 1989). Ranchers used fire to reduce the area covered by shrubs and to increase grassland area. Large areas were converted into grasslands or savannas. These fires were probably of low intensity but spread extensively because of the high horizontal fuel continuity from introduced grasses and forbs. Differences in patterns of burning by the Native Americans and Euro-Americans are related to differing objectives: ranchers burned to increase forage for livestock, whereas the Native Americans burned to increase numerous plant and animal species (Lewis 1985).

Fire suppression began in earnest on private ranch lands in the 1940s to 1950s. Suppression has resulted in increases in surface and crown fuels and changes in species composition (Kilgore 1981, Biswell 1989, Stephens 1997). The invasion of woody vegetation in the understory has probably been the most noticeable change (Dodge 1975, Griffin 1976, Rotenberry et al. 1995). Tree density has also increased (Byrne et al. 1991, Lewis 1993). The end result is that high-intensity fires are more likely (Rossi 1980).

Interest in prescribed burning has increased recently owing to concerns about fuel accumulation. Current land ownership patterns complicate prescribed burning plans in many areas. With careful planning and attention, however, low-intensity prescribed fires can be safely implemented and the desired results achieved. Prescribed burning can reduce the risk of wildfire and potentially restore habitat conditions similar to those under which many bird species of the oak woodlands evolved.

In the absence of studies of the fire effects on birds in oak woodlands, knowledge of avian habitat relations should enable us to predict the response of birds to fire by examining the expected changes in vegetation structure and comparing those changes to known habitat associations of birds (Rotenberry et al. 1995). The most obvious and agreed-upon effect of fire, regardless of its intensity, is reduced brush cover (Lawrence 1966,

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20–24, 2002, Asilomar Conference Grounds, California.**

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Lewis 1973, Dodge 1975, Griffin 1976, Vreeland and Tietje 1998). With frequent fire we also expect a reduction in the density of trees of all sizes, resulting in decreased total basal area and increased spacing of trees (Jepson 1923, Byrne et al. 1991, Lewis 1993). Mean tree size will be larger because larger trees are more likely to survive following fire, and saplings may be fewer. Fire also reduces the number of snags, logs, and woody debris (Fry 2002, Vreeland and Tietje 2002). At the landscape scale, we expect a complex mosaic of habitats to result from fire, with an overall structure of irregular patches and abundant edges.

Methods

To the extent that nesting habitat relates to habitat requirements for these species, we examined the expected responses of 17 common oak woodland bird species to fire. We collected habitat data at nest sites for these species at the San Joaquin Experimental Range in Madera County from 1988 through 1994.

Results

Our results suggest that Western Kingbirds (see *fig. 1* for scientific names), Western Bluebirds, and Violet-green Swallows would benefit from fire, because they consistently nested in habitat similar to that expected to result from frequent, low-intensity fires. These three species nested in open areas with the lowest shrub cover (*fig. 1*) and the lowest tree density (see Purcell and Stephenson [in press] for details). Bluebird nest sites had intermediate cover of logs, but nest sites of swallows and kingbirds had low log cover. All three species nested in areas with few snags and saplings. Despite the paradigm of the importance of snags to birds in coniferous forests, oak snags are not commonly used by cavity nesters. The species predicted to be negatively affected by fire varied widely among the variables examined. Species nesting in areas with the highest shrub cover were Western Scrub Jays, California Towhees, and Bewick's Wrens (*fig. 1*). Bewick's Wrens, Nuttall's Woodpeckers, and Common Bushtits nested in areas with dense trees. Ash-throated Flycatchers, Nuttall's Woodpeckers, and House Wrens selected nesting areas with high snag densities, and California Towhees and Nuttall's Woodpeckers nested in areas with numerous saplings. House Wrens, Bewick's Wrens, and Acorn Woodpeckers nested in areas with more logs.

In short, our results consistently predicted that the same three fire-adapted species will benefit from the effects of fire, whereas the negatively affected species vary widely among the variables examined. If fire produces a mosaic of habitat patches, rather than a homogeneous landscape, we expect that most species' habitat needs will be provided for.

As with fire, grazing also reduces brush cover (Duncan and Clawson 1980, Purcell and Verner 1998). On the basis of our work at the Experimental Range, the most obvious change resulting from excluding livestock was an increase in shrub cover. A site ungrazed for more than 60 years had nearly nine times the cover of wedgeleaf ceanothus (*Ceanothus cuneatus*), the most common shrub species (Purcell and Verner 1998). The question that naturally arises is, to what extent does livestock grazing create habitat similar to that created by historical fire? We know little about how other effects of grazing may differ from those of fire. Grazing impacts are selective and differ from those of fire primarily because of livestock behavior and selectivity. Cattle seek out shade and water, form trails, compact the soil, and eat and trample oak seedlings, saplings, and acorns (Wells 1962). Other differences relate to differences in nutrient cycling. These differences between the effects of fire and grazing remain unstudied.

More fire-history research is needed to understand past fire regimes of oak woodlands in the time periods discussed above. The effects of prescribed fire on the vegetation and the bird community clearly require more research. Perhaps most importantly, the effects of grazing and the extent to which grazing mimics fire require more study. To conserve avian diversity, we need to monitor bird population trends in oak woodlands and understand the conditions needed to maintain healthy, diverse populations. Finally, we need to test our working hypothesis that a mosaic of habitat patches will provide the habitat conditions needed to sustain high avian diversity in oak woodlands.

Acknowledgments

We thank those who have assisted with fieldwork at the San Joaquin Experimental Range. An earlier version of this manuscript benefited from reviews by J. Verner and L. de Jong.

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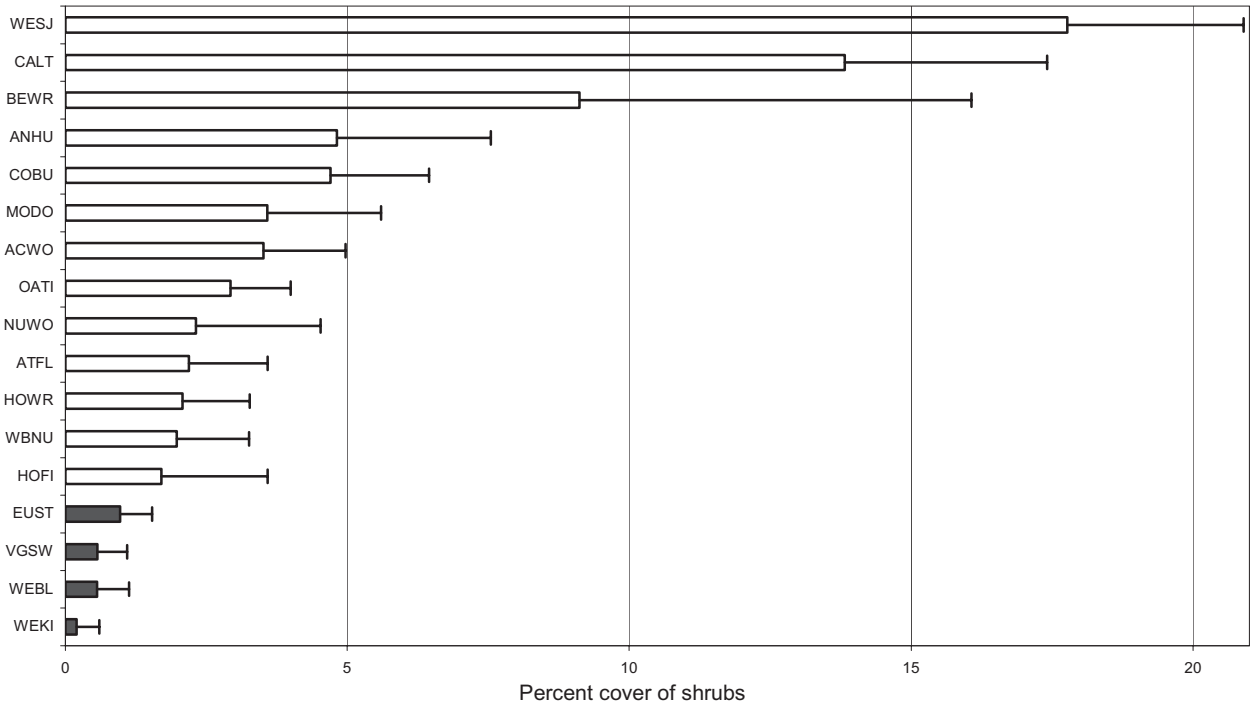

Figure 1— Percent cover of shrubs in a 0.04-ha circle centered on nests. Error bars represent 2 se. Low shrub cover is expected to result from fire, high cover from lack of fire. Species codes (scientific names and sample sizes) are as follows: ACWO = Acorn Woodpecker (*Melanerpes formicivorus*; 92), ANHU = Anna's Hummingbird (*Calypte anna*; 33), ATFL = Ash-throated Flycatcher (*Myiarchus cinerascens*; 47), BEWR = Bewick's Wren (*Thryomanes bewickii*;17), CALT = California Towhee (*Pipilo crissalis*; 73), COBU = Common Bushtit (*Psaltriparus minimus*; 126), EUST = European Starling (*Sturnus vulgaris*; 107), HOFI = House Finch (*Carpodacus mexicanus*; 20), HOWR = House Wren (*Troglodytes aedon*; 39), MODO = Mourning Dove (*Zenaida macroura*; 60), NUWO = Nuttall's Woodpecker (*Picoides nuttallii*; 19), OATI = Oak Titmouse (*Baeolophus inornatus*; 112), VGSW = Violet-green Swallow (*Tachycineta thalassina*; 23), WBNU = White-breasted Nuthatch (*Sitta carolinensis*; 42), WEBL = Western Bluebird (*Sialia mexicana*; 32), WESJ = Western Scrub Jay (*Aphelocoma californica*;118), WEKI = Western Kingbird (*Tyrannus verticalis*; 20).

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Bird Responses to Burns and Clear Cuts in the Boreal Forest of Canada[1]

Susan J. Hannon[2] and Pierre Drapeau[3]

Key words: bird communities, boreal forest, burns, clear-cutting, even-age forest management, forest fire, Black-backed Woodpeckers (*Picoides arcticus*), logging.

Introduction

Unlike many other ecosystems in North America, the boreal forest in Canada still retains a natural fire regime. However, increasing industrial forestry, primarily clear cutting, could alter natural fire dynamics and adversely affect some species. A possible solution to this, promoted by many forest managers, is to cut the forest in a way that emulates natural fire patterns on the landscape (e.g. Hunter 1993). This can be done by retaining some live trees on clear cuts to emulate wood left after a burn and by laying out cutblocks on the landscape in a similar size and shape distribution as that produced by fire. A major assumption of this approach is that the responses of biota to clear cutting are similar to their responses to burns. Here we evaluate this assumption by summarizing information on bird assemblages in burns and recent clear cuts in boreal mixed-wood stands (aspen (*Populus tremuloides*) and white spruce (*Picea glauca*)) in Alberta and boreal black spruce (*Picea mariana*) forest in Quebec.

Bird Assemblages Associated with Burned and Logged Stands

Clear cutting and stand-replacing fires both reinitiate forest succession, but are not likely to provide the same habitat conditions for birds (e.g. Hobson and Schieck 1999). In Alberta mixed-wood stands, immediately after a fire the stand is dominated by large burned snags and the ground cover is dominated by herbs. By contrast, immediately after clear cutting only a few live residual canopy trees remain singly or in clumps and the ground is covered by grass. In recent burns, cavity nesters and species that forage on beetles in the dead trees predominate, whereas clear cuts are dominated by open country or parkland-type species (*Table 1*). By about 25 years post-disturbance, many of the snags have fallen in burns and the shrubby understory is well developed. Conversely, on clear cuts some of the residual live trees have died, increasing snag density to levels similar to burns at this age. The shrub layer is more developed in clear cuts but amount of dead wood on the ground is lower than in burns. Generally, snag dependent bird species decreased and shrub-breeding species increased 25 years after burns, whereas in clear cuts there were more species that foraged and nested in canopy trees, because of the retention of live residuals (*Table 1*; Hobson and Schieck 1999). Eventually, as the canopy closed, both the vegetation structure and bird communities converged in mature stands at about 50-60 years post-fire (Song 2002).

Vegetation changes and bird communities in Quebec black spruce forests show similar patterns to those in Alberta mixed-wood stands. The largest differences between bird communities in burns and clear cuts occurred shortly after disturbance (*Table 1;* Imbeau et al. 1999). Species that forage and nest in snags were present in recent burns and absent in clear cuts. Vegetation structure and bird communities in black spruce burns and logged areas converged after 80-100 yrs (Drapeau, unpubl. data).

Fire Associates

Black-backed and Three-toed Woodpeckers (*P. tridactylus*) exploit recently burned coniferous forest to forage on wood-boring insect larvae (Cerambycidae and Buprestidae) and bark beetle larvae (Scolytidae) up to 8-10 years post-fire and then decline (Nappi 2000, Hoyt and Hannon 2002). Black-backs are absent from mature forests (80 yr), are found more frequently in old growth forest (95-150) and then appear to decline in the very old forests in Quebec (*Table 3*), as snags are lost and the forest reverts to a treed state. Hutto (1995) and Saab and Dudley (1998) found similar trends in Northern Rocky Mountain coniferous forests. These results suggest that over the long term, burns may be temporal sources for fire-specialists (Hutto 1995).

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California**.

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Table 1— *Vegetation structure and common bird species up to 25 yr after fire and logging in the boreal forest of Alberta and Quebec. Adapted from Hobson and Schieck (1999), Imbeau et al. (1999) and Drapeau et al. (2002). See* Table 2 *for common and scientific names of birds.*

Years post-disturbance	Vegetation		Common birds			
			Alberta		Quebec	
	Burn	Clear cut	Burn	Clear cut	Burn	Clear cut
0	many burned snags high herb cover	few live residual trees high grass cover	BBWO TTWO BRCR AMKE TRSW WIWR HAWO	LISP COYE LCSP RUBL PISI MOWA ALFL TEWA YWAR	BBWO TRSW AMKE WIWR	LISP ALFL COYE WIWA
25	few snags standing shrubby understory	dead and live residual trees shrubby understory	COWA GRJA HETH AMRO PHVI OCWA	AMRE BAWW CAWA MOWA RUGR WETA RBGR	LISP WIWR EABL OSFL TRSW COYE	LISP ALFL CEWX COYE PHVI

Conservation Issues

The major conservation issue for burn-dependent species is salvage logging, which will increase as forestry expands north. Trees that are salvaged are in the same diameter classes that woodpeckers use for foraging and nesting (Hoyt 2000, Nappi 2000). In addition climate change will alter fire cycles: they will be shorter in Alberta leading to a shortage of old growth forest and will be longer in Quebec leading to a shortage of early seral stages. Maintenance of suitable amounts of post-fire forests spared from salvage logging should be a prerequisite condition for sustainable forest management.

Acknowledgments

We thank C. McCallum for drawing the figures.

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Table 2— *Common names, scientific names and four-letter species codes for birds referenced in this article.*

Species code	Common name	Scientific name
ALFL	Alder flycatcher	*Empidonax alnorum*
AMRE	American Redstart	*Setophaga ruticilla*
AMRO	American Robin	*Turdus migratorius*
BAWW	Black-and-white Warbler	*Mniotilta varia*
BBWO	Black-backed Woodpecker	*Picoides arcticus*
BRCR	Brown Creeper	*Certhia americana*
CAWA	Canada Warbler	*Wilsonia candensis*
CEWX	Cedar Waxwing	*Bombycilla cedrorum*
COWA	Connecticut Warbler	*Oporornis agilis*
COYE	Common Yellowthroat	*Geothlypis trichas*
EABL	Eastern Bluebird	*Sialia sialis*
GRAJ	Gray Jay	*Perisoeius canadensis*
HAWO	Hairy Woodpecker	*Picoides villosus*
HETH	Hermit Thrush	*Catharus guttatus*
LCSP	LeConte's Sparrow	*Ammodramus leconteii*
LISP	Lincoln's Sparrow	*Melospiza lincolnii*
MAKE	American Kestrel	*Falco sparverius*
MOWA	Mourning Warbler	*Oporornis philadelphia*
OCWA	Orange-crowned Warbler	*Vermivora celata*
OSFL	Olive-sided Flycatcher	*Contopus borealis*
PHVI	Philadelphia Vireo	*Vireo philadelphicus*
PISI	Pine Siskin	*Carduelis pinus*
RBGR	Rose-breasted Grosbeak	*Pheucticus ludoviciana*
RUBL	Rusty Blackbird	*Euphagus carolinus*
RUGR	Ruffed Grouse	*Bonasa umbellus*
TEWA	Tennessee Warbler	*Vermivora peregrina*
TRSW	Tree Swallow	*Tachycineta bicolor*
TTWO	Three-toed Woodpecker	*Picoides tiydactylus*
WETA	Western Tanager	*Piranga ludoviciana*
WIWA	Wilson's Warbler	*Wilsonia canadensis*
WIWR	Winter Wren	*Troglodytes troglodytes*
YWAR	Yellow Warbler	*Dendroica petechia*

Table 3— *Occurrence of Black-backed Woodpeckers over time post-fire in black spruce forests in Alberta and Quebec.*

Time after fire (yr)	Percent occurrence[1]		No. sites sampled
0-2	Alberta	38	20
	Quebec	87	56
16-20	Alberta	0	45
	Quebec	5	49
80	Alberta	0	21
95	Quebec	9	53
150	Alberta	37	21
>200	Quebec	3	61

[1]Data compiled from Nappi (2000) and Hoyt and Hannon (2002); Nappi used point counts and play-backs of territorial calls and Hoyt used only playbacks of territorial calls, so data are not strictly comparable between regions.

A Review of Climate Change Impacts on Birds[1]

Robert W. Butler[2] and William Taylor[3]

Abstract

Regions of the world with high coastal zone biological productivity often support large numbers of birds. Important sources of this productivity are oceanographic upwelling created by winds and ocean currents, and runoff from the land. It is suggested that climate change effects on winds and ocean currents will potentially affect the timing and magnitude of coastal biological productivity, and that bird populations will seek new levels and distributions in response to these changes. We are at an early stage in projecting trends. However, ecological responses to climate change are clearly visible which underscores the importance of basic research into ecological processes that support birds in coastal environments, and to provide advice on how to mitigate against the impact of climate change.

Key words: climate change, climate variability, ENSO, global warming, PDO, waterbirds.

There is ample evidence that global climate change has already had a detectable effect on terrestrial and marine environments (reviewed by Walther et al. 2002). Two issues for us to consider are which species will be most sensitive to climate change and what actions should we take? In this paper, we examine how birds have adapted to natural fluctuations in climate to understand which bird groups might be most at risk to climate change, and propose some actions we might take to ameliorate the future impact of climate change on birds.

Many birds have evolved adaptations in response to climate fluctuations. One of the most studied systems is the north Pacific Ocean where climate variability over the past 400 years has been characterized by a 2-8 year El Niño-Southern Oscillation (ENSO) cycle, a 20-40 year interdecadal oscillation, and 60-80 year multi-year oscillation (reviewed by Ware and Thomson 2000). Emerging from these studies is evidence suggesting that the ENSO intensified in the late 20th century, and North American droughts were far more severe in the 16th century than in the 'Dirty Thirties' (Woodhouse and Overpeck 1998). Biological studies in North America and Australia indicate that waterfowl either postpone breeding or move to other regions in drought years (Batt et al. 1989, Norman and Nicholls 1991, Bethke and Nudds 1995).

Climate variability also affects bird distribution and abundance indirectly through trophic level impacts on food availability. Some of the best examples are the population changes in seabirds in relation to ocean productivity (e.g., Briggs et al. 1984, Ainley et al. 1988, Ainley and Boekelheide 1990, Duffy 1993, Springer et al. 1999, Kitaysky and Golubova 2000, Bertram et al. 2001, Hedd et al. 2002). Ocean productivity has naturally occurring seasonal, decadal and multi-decadal oscillations (Ware and Thomson 2000). During ENSO years, some seabirds postpone reproduction and incur higher mortality than in non-ENSO years (Duffy 1993).

The link between ocean processes and seabird nesting success and survival is now being extended to other species of birds. For example, the world-wide distribution and abundance of shorebirds has been shown to be positively related to the strength of coastal zone productivity in waters adjacent to the coastal habitats where they spend the winter (Butler et al. 2001). These authors suggested that shorebird behavior, physiology, and the choice of migration pathways evolved in response to the spacing of rich foraging habitats created in part by coastal zone productivity. Taken together, these diverse studies of bird groups with very different life histories and from disparate parts of the world, suggest that the climate has always played a large role in the distribution, abundance and ultimately the evolution of many waterbirds.

The mechanism that links waterbird abundance to climate processes is likely associated with nutrient availability in the food chain. At-sea studies suggests that the availability of nitrates carried by ocean currents and up welling is a key feature of plankton growth and the prey species eaten by seabirds (Springer et al. 1999). In the tropics, the presence of small fish and invertebrates on beaches in Panama coincide with the time of year of ocean upwelling of phosphates in local waters (Kwiecinski and Chial 1983, Delgado 1998). These

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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studies suggest that ocean processes are an important component in the temporal and spatial distribution and abundance of many marine birds. Timescale climate variations in the North Pacific Ocean have been recognized as having world-wide effects (Ware and Thomson 2000). This suggests that fluctuations in climate might alter the spatial and temporal distribution of many birds (Walther et al. 2002).

Conservation response to climate change should address means to ensure adequate habitats are available and mitigating against climate change impact on ecological processes that support birds. Species groups that are likely most at risk from habitat loss are species that are restricted to island, alpine and coastal beaches backed by dikes. Similarly, tundra-nesting species are vulnerable to encroachment of southern, incompatible habitats and species. Coastal-dwelling species that depend on beaches backed by impregnable dikes will lose habitat as sea level rises. For other species with room to move, it is also imperative that suitable habitat is made available for populations to recover in good years, and that refugia be identified for the survivors in poor years. Specifically, ensuring that breeding colonies remain for seabirds is an important policy and we need to discover where non-breeding populations go during ENSO events.

Waterfowl populations appear to closely track periods of precipitation. The conservation policy of the North American Waterfowl Plan correctly aims at providing sufficient habitat for populations to recover when wet years fill dried ponds. Ponds that are present during dry years might become refuges during droughts. Most of the world's shorebirds spend the winter in tropical or sub-tropical environments (Hayman et al. 1986). We need to know how ENSO events affect those populations and if there are refugia during ENSO events. For example, estuaries and bays might be less affected by ENSO events and hence provide refuge to shorebirds from other coastal habitats.

Our review indicates that climate change will likely result in increased fluctuations in biological productivity, which will be reflected in the numbers of seabirds, shorebirds and waterfowl. In the case of waterfowl and shorebirds residing in freshwater habitats, it is important to ensure that adequate dried out ponds during dry years remain in place for the recovery of breeding populations in wet years. In addition, it is important to secure areas used as refugia during periods of climatic uncertainty.

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Climate Resources for Field Ornithologists: What is Climate, What do We Know, and Why Should You Care?[1]

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Abstract

As the ornithological community has become more aware of natural climate variability (as opposed to weather) impacts on the life histories of birds, especially seabirds, the meteorological community has been advancing our knowledge and predictive capabilities. The latest climate information, however, is slow to transfer to the ornithological community. Climate databases that show the seasonality of El Niño, and its opposite, La Niña, back to 1951 are often not used when correlating an ENSO event (El Niño, La Niña or neutral) with breeding season, migration or over wintering. For example, 1972 is referenced as a strong El Niño year, yet the first quarter was neutral, strengthening in the second quarter, becoming stronger in the third quarter and only reaching full strength at the end of the year. In addition to the El Niño Southern Oscillation (ENSO), the climate community is unraveling the influences of other oscillations, such as the Arctic Oscillation (AO), North Atlantic Oscillation (NAO), and Pacific Decadal Oscillation (PDO) on our climate. To date, only a few ornithologists are looking at how these oscillations interact with avian life history traits. Yet knowing how birds respond to natural climate variability is vital for conservation planning.

Key words: AO, bird conservation, climate variability, El Niño, ENSO, La Niña, NAO, PDO.

Introduction

Field ornithologists are well aware of the impact of natural climate variability on birds. A literature review of El Niño and La Niña revealed that field ornithologists have been looking at El Niño impacts on birds since 1925. More than 400 papers have been published on this subject covering work on all continents, from seabirds to passerines and covering topics from vagrancy to evolution. This paper will provide a definition of climate and a summary of what we know about natural climate variability and along with gleanings from the ornithological literature. Current definitions of frequently used climate terms will be discussed to clarify some emerging problems of their use in the ornithological literature. Implications for bird conservation will be noted. Finally, information will be provided on climate resources available on the web to help ornithologists as they try to unravel the role of climate on the life histories of birds.

What is Climate?

The old saying is "Climate is what we expect and weather is what we get." A climatologist's definition of climate is the average of weather over at least 30 years. These averages are then recalculated every ten years. The National Weather Service has just recalculated the baseline period for normal as running from 1961-1990 to 1971-2000. Since the cool decade of the 1960's has been replaced with the mild 1990's, normal temperatures in many areas will be higher.

What do we Know About Natural Climate Variability and Teleconnections?

One of the most prominent aspects of our weather and climate is its variability. This variability ranges over many temporal and spatial scales, from small-scale phenomena such as wind gusts, localized thunderstorms and tornadoes, to larger-scale features such as fronts and storms, to even more prolonged features such as droughts and floods, and to fluctuations occurring on multi-seasonal, multi-year, multi-decade and even multi-century time scales. Some examples of these longer time-scale fluctuations include an abnormally hot and dry summer, an abnormally cold and snowy winter, a consecutive series of abnormally mild or exceptionally severe winters, and even a mild winter followed by a severe winter.

In general, the longer time-scale phenomena are often associated with changes in the atmospheric circulation

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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that encompass areas far larger than a particular affected region. At times, these persistent circulation features occur simultaneously over vast, and seemingly unrelated, parts of the globe, and result in abnormal weather, temperature and rainfall patterns throughout the world, known as *teleconnections*.

El Niño-Southern Oscillation (ENSO)

During the past several decades, scientists have discovered that important aspects of this interannual variability in global weather patterns are linked to a global-scale, naturally occurring phenomenon known as the El Niño-Southern Oscillation (ENSO) cycle. Originally, ENSO referred only to the combined atmosphere/ocean system during an El Niño warm event. Currently, it refers to the cold *La Niña*, warm *El Niño* and neutral phase of the cycle. (See http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/lanina/ for more information).

Warm episodes (*El Niño*) tend to occur every 4-5 years, and usually last between 12 and 18 months. Not all El Niño episodes are alike. They vary in intensity from weak to very strong, with impacts that also vary considerably from event to event. (See http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.html for an El Niño and La Niña chart from 1950 to the present that gives intensity of event by season).

The greatest impacts from El Niño are generally in the region of the tropical Pacific from Indonesia eastward to the west coast of South America. However, other more remote regions, such as southern Africa, Northeast Brazil, the U.S. Gulf Coast and the U.S. northern Great Plains, also experience significant departures from normal during El Niño episodes. (See http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/impacts/warm.gif for graphic depiction of El Niño impacts). The warming or cooling of the waters that occurs in the central and eastern tropical Pacific during El Niño episodes results in an increase in the westerlies in the middle latitudes of both hemispheres, primarily during their respective late fall, winter and early spring seasons. For the United States, this pattern produces above-normal rainfall and storminess over southern California and along the Gulf Coast states and warmer-than-average temperatures over the northern half of the country. These precipitation and temperature anomalies along with changes in sea surface temperatures have an impact on humans and wildlife throughout the world.

Cold (*La Niña*) episodes tend to last from one to three years and have more variable event-to-event impacts outside of the tropical Pacific. The cooler-than-average waters that characterize La Niña in the central tropical Pacific result in weaker and more variable westerlies in the middle latitudes of both hemispheres. For the United States this pattern brings increased storminess, precipitation and frequency of significant cold-air outbreaks in eastern Alaska, western Canada and the northern boundary states from Minnesota to Washington. In contrast, the southern tier of the United States experiences less storminess and less precipitation. Also, there tends to be considerable month-to-month variation in temperature, rainfall and storminess across central North America during the winter and spring seasons. (See http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/lanina/cold_impacts.html for more information). With the establishment of an ocean observing system in the tropical equatorial Pacific Ocean and with increased knowledge of ENSO teleconnections, it is now possible to make ENSO related climate predictions for seasons in advance.

Tropical Intraseasonal Oscillation

An additional near-global phenomenon in the Tropics has many characteristics similar to ENSO, acts on a much shorter time scale (30-60 day), and is associated with intraseasonal variability. This phenomenon is frequently referred to as the Tropical Intraseasonal Oscillation or Madden-Julian Oscillation (MJO). The MJO tends to be strongest during ENSO-neutral periods, and strongly affects the wintertime jet stream and atmospheric circulation features over the North Pacific and western North America during some winters. As a result, it has important impacts on storminess and temperatures over the United States. The MJO is also important during summer, as it tends to modulate hurricane activity in both the Pacific and Atlantic basins resulting in alternating periods of high and low activity. The relative influences of ENSO and the MJO on the summer precipitation regime of North America are not well understood.

A recent example of the impacts of MJO teleconnections on the United States occurred in the winter of 1996/97, which featured heavy flooding in California and the Pacific Northwest. The ENSO cycle during this period was neutral, and the MJO was very active. The teleconnection pattern is as follows:

1) 7-10 days prior to the heavy precipitation event: heavy tropical rainfall associated with the MJO shifts eastward from the eastern Indian Ocean to the western tropical Pacific. A moisture plume extends northeastward from the western tropical Pacific towards the general vicinity of the Hawaiian Islands. A strong blocking anticyclone is located in the Gulf of Alaska with a strong polar jet stream around its northern flank.

2) 3-5 days prior to the heavy precipitation event: heavy tropical rainfall shifts eastward towards the date line and begins to diminish. The associated moisture plume extends further to the northeast, often traversing the Hawaiian Islands. The strong blocking high weakens and shifts westward. A split in the North Pacific jet stream develops, characterized by an increase in the amplitude and areal extent of the upper tropospheric westerly zonal winds on the southern flank of the block and a decrease on its northern flank. The tropical and extratropical circulation patterns begin to "phase", allowing a developing midlatitude trough to tap the moisture plume extending from the deep tropics.

3) The heavy precipitation event: as the pattern of enhanced tropical rainfall continues to shift further to the east and weaken, the deep tropical moisture plume extends from the subtropical central Pacific into the midlatitude trough now located off the west coast of North America. The jet stream at upper levels extends across the North Pacific with the mean jet position entering North America in the northwestern United States. Deep low pressure located near the Pacific Northwest coast can bring up to several days of heavy rain and possible flooding. These events are often referred to as "pineapple express" events, so named because a significant amount of the deep tropical moisture traverses the Hawaiian Islands on its way towards western North America.

However, it is important to note that the overall linkage between the MJO and extreme West Coast precipitation events weakens as the region of interest shifts southward along the west coast of the United States. As the region of interest shifts from the Pacific Northwest to California, the region of enhanced tropical precipitation shifts farther to the east.

Other Oscillations

Some additional climate features that are related to climate variability over North America, and which affect seasonal forecasts, include the Arctic Oscillation (AO)/North Atlantic Oscillation (NAO), and the Pacific Decadal Oscillation (PDO). Oscillations have been defined in terms of an index to mean a single number, numerically derived and representing the distribution of temperature and pressure over a wide ocean area.

As yet there are no tools available to reliably predict any of these phenomena more than a few days in advance. However, considerable research has been done on the impacts that each has on temperature and precipitation patterns over North America. At the moment, NOAA and other meteorologic organizations and the research community closely monitor each of these major teleconnection patterns and their relationship to weather, especially extreme events.

Arctic Oscillation (AO)

The Arctic Oscillation is a seesaw pattern in which atmospheric pressure at polar and middle latitudes fluctuates between positive and negative phases. The negative phase brings higher-than-normal pressure over the polar region and lower-than-normal pressure at about 45°N latitude – a line running through the northern third of the United States and Western Europe. The negative phase of AO allows cold air to plunge into the Midwestern United States and Western Europe, with storms bringing rain to the Mediterranean. The positive phase brings the opposite conditions, steering ocean storms farther north and bringing wetter weather to Alaska, Scotland and Scandinavia and drier conditions to areas such as California, Spain, and the Middle East. Additionally, frigid winter air does not reach as far into the interior of North America, keeping much of the United States east of the Rocky Mountains warmer than normal while areas such as Greenland and Newfoundland are typically colder than usual. In recent years, the Arctic Oscillation has been mostly in its positive phase resulting in the recent string of mild winters in the United States.

Colorado State maintains an excellent web site with further information and graphics on the Arctic Oscillation. (See http://horizon.atmos.colostate.edu/ao/).

North Atlantic Oscillation (NAO)

Some researchers argue that the North Atlantic Oscillation is in fact part of the AO. Nevertheless, the NAO is a large-scale see-saw in atmospheric pressure between the subtropical high pressure system located near the Azores in the Atlantic Ocean and the sub-polar low pressure system near Iceland. The surface pressure drives surface winds and wintertime storms from west to east across the North Atlantic affecting climate from New England to Western Europe as far eastward as central Siberia and eastern Mediterranean and southward to West Africa.

When the difference is positive, the northeastern United States sees an increase in temperature and a decrease in snow days; the central United States has increased precipitation, the North Sea has an increase in storms; and Norway along with Northern Europe has warmer temperatures and increased precipitation. When the difference is negative, the Tropical Atlantic and Gulf coast have increased number of strong hurricanes, the northeastern United States and northern

Europe are drier, and many Mediterranean countries have increased precipitation.

The Lamont-Doherty Earth Observatory at Columbia University maintains an excellent web sit on the North Atlantic Oscillation. (See http://www.ldeo.columbia.edu/NAO/).

Pacific Decadal Oscillation (PDO)

A recently described pattern of climate variation similar to ENSO, though on a timescale of decades and not seasons, is the Pacific Decadal Oscillation, which in part is associated with low-frequency variability in the ENSO cycle. The big difference between PDO and ENSO is the former is based on mid-latitude sea-surface temperatures (SSTs) (mid-North Pacific SSTs vs. eastern North Pacific SSTs) and the latter on tropical SSTs. The PDO may also be related to changes in the intensity of the oceanic gyres and the exchange of water among the oceans.

PDO primarily affects weather patterns and sea surface temperatures in the Pacific Northwest, Alaska, and northern Pacific Islands. A positive PDO is correlated with above normal wintertime precipitation along the coast of central Gulf of Alaska and over northern Mexico and south Florida, and correlated with reduced precipitation the Hawaiian Islands and over much of the Pacific Northwest and interior of North America (leading to reduced snow pack). Conditions similar to those expected during an El Niño event. A negative PDO leads to weather patterns similar to those produced by La Niña whereby North America would be colder than normal during winter.

Two other characteristics distinguish PDO from ENSO: first, 20th century PDO "events" persisted for 20-to-30 years, while typical ENSO events persisted for 6 to 18 months; and second, the climatic fingerprints of the PDO are most visible in the North Pacific/North American sector, while secondary signatures exist in the tropics. This is the opposite of that seen with ENSO events. Several independent studies find evidence for just two full PDO cycles in the past century: "cool" or negative PDO regimes prevailed from 1890-1924 and again from 1947-1976, while "warm" or positive PDO regimes dominated from 1925-1946 and from 1977 through (at least) the mid-1990's. Causes for the PDO are not currently known. Likewise, the potential predictability for this climate oscillation is not known.

Washington University maintains an excellent web site on the PDO. (See http://www.jisao.washington.edu/pdo/).

Climate Variability and Birds

To understand natural climate variability and its impact on birds, a review of the literature was performed. More than 500 articles have been identified and a preliminary analysis from 24 publications ranging from the Alberta Naturalist to Condor, found 14 El Niño events and 6 La Niña events associated with impacts on over 95 bird species, mostly seabirds, in 11 countries and all continents. Some of the research topics covered included breeding success rate, breeding relationship to precipitation and temperature, vagrancy, abundance, availability of prey, mortality, adaptation, economics, population trends, distribution, pollination, diet, predation, range expansion, evolution, water management, and migration.

In reviewing these papers it became obvious that some areas need to be better understood by the ornithological community. For example, many field ornithologists are using ENSO to mean a warm event, or El Niño, though it is not always clear. Climatologists today no longer use the earlier definition of ENSO to mean only El Niño but view ENSO as a cycle of warm, cold, and neutral phases. Thus, confusion would be avoided if the ornithological community referred specifically to El Niño and La Niña. Most of the articles ignored La Niña and made no note of the seasonality or strength of the ENSO event nor whose rating of events they were using. This lack of refinement of climate information can easily lead to incorrect correlations, missed explanations, and difficulty for future readers to interpret the results. (See http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.html for a El Niño and La Niña chart from 1950 to the present that gives intensity of event by season).

When analyzing data sets, most researchers focused on El Niño events even if a strong La Niña event occurred during the study period. Analysis of La Niña conditions as well would provide a more complete picture of climate variability impact on birds.

Several researchers follow the casual convention of assuming that a year that had at least one quarter with an El Niño was an El Niño year. This poor understanding of climatic cycles can lead to errors if a researcher is correlating breeding data to an El Niño that actually did not occur until November. Or, worse yet, when the breeding season occurred during a La Niña event that was winding down before a strong El Niño emerged in fall. Also, earlier publication of ENSO event years only included strong El Niño events. Knowledge of mild and weak events for El Niño and La Niña might explain some inconsistencies in several year data sets. The climate community now has information on seasonality and strength of ENSO events going back to 1950 and intensity going back to 1877

and this data can be found on the Climate Prediction Center Web site (www.cpc.ncep.noaa.gov). The process of classification by CPC for the years 1950 to present was primarily subjective using reanalyzed sea surface temperature analyses from a key region of the tropical Pacific (along the equator from 150°W to the date line, an area known as Niño 3.4). The climate community is trying to reach consensus on quantifying ENSO events and may use different methods for prediction than verification though use of Niño regions 3.4 and 4 will probably play a role. The reason for this is that major atmospheric circulation impacts are related to changes in the pattern of rainfall in these regions. The Niño 3.4 and Niño 4 regions encompass the area where slight increases or decreases in SSTs can have a big impact on where rainfall is found in the western and central Pacific and are the key areas for monitoring and predicting ENSO events.

Implications for Bird Conservation

Understanding the impact of climate variability on birds and its relationship to bird conservation is particularly important if the projections for global warming become a reality. Knowing how birds have adapted in the past may help us understand the future. Unfortunately, very little research is being performed to further understand the interrelationship of natural climate variability and birds. A seasonal climate outlook would be useful for game bird managers in setting bag limits, provided they know the relationships between breeding success or failure of the game species and precipitation. For those concerned with habitat requirements, natural climate variability is an important factor to include in setting range limits. More habitat conservation may be needed if a species, such as a grassland sparrow, shifts it range under certain climatic conditions. For those concerned with population trends, knowing what role climatic variability plays in population regulation helps understand whether a decline is due to climate of some other factor.

Climate Resources for Bird Conservation

Many government agencies and universities have web sites devoted to climate assessments, outlooks, and data. Some of the primary ones are:

- Climate Prediction Center (Federal Government official climate assessments and outlooks): www.cpc.ncep.noaa.gov
- International Research Institute (Experimental climate forecasts at global and regional scales): iri.ldeo.columbia.edu
- National Climatic Data Center (World's largest archive of weather and climate data): www.ncdc.noaa.gov
- Climate Diagnostics Center (Research on the nature and causes for climate variations on time scales ranging from a month to centuries): www.cdc.noaa.gov
- Joint Institute for the Study of the Atmosphere and the Ocean (JISAO) (Pacific Decadal Oscillation): www.jisao.washington.edu/pdo/
- Lamont-Doherty Earth Observatory (North Atlantic Oscillation): www.ldeo.columbia.edu/NAO/
- Colorado State University (Arctic Oscillation): horizon.atmos.colostate.edu/ao/

The Impact of Climatic Change on Wild Animals and Plants: A Meta-Analysis[1]

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Abstract

Over the last 100 years, the global average temperature has increased approximately 0.6° C. Using information from the literature, we examine the extent to which animals and plants are already exhibiting a discernible change consistent with changing temperatures and predicted by our understanding of the species' physiological constraints. The types of changes include poleward and altitudinal range expansions, movement of abundance patterns, and shifts in morphometrics, genetics, behavior, and in the timing of events such as animal breeding or plant blooming dates. We examined over 2500 articles to find those that met the following conditions -they span at least 10 years and meet at least two of the following criteria (all association had to be statistically significant): 1) A trait of at least one species (e.g., shifting range boundary) shows a change over time. 2) That trait is correlated with changes in local temperature. 3) Local temperatures change over the time period of the study. The 45 studies meeting these criteria examine over 1250 species. Meta-analyses provide a way to combine results from different studies and, when taken together, these studies reveal an underlying consistent shift, or "fingerprint," among species from various taxa examined at locations virtually around the globe. Hence, the balance of evidence obtained from these studies suggests that a significant impact from climatic warming is discernible in the form of long-term, large-scale alteration of animal and plant populations.

Key words: climate change, fingerprint, global warming, observed impacts, phenology.

Linking Observed Changes in Animals and Plants to Climate

In this study, we demonstrate that climate is apparently already causing significant discernible changes in animal and plant populations around the globe. For example, hypotheses based on our knowledge of the physiological responses of species predict poleward and elevational range shifts in response to increasing temperatures as species move to occupy areas within their temperature tolerances (providing suitable habitat is available). These types of changes have already been noted in insects in Europe and North America (Parmesan 1996, Ellis et al. 1997, Whittaker and Tribe 1998), birds in Europe and Costa Rica (Greenwood and Baillie 1993, Pounds et al. 1999), invertebrates in the Antarctic Ocean (Loeb et al. 1997), and trees and forbs in Europe (Grabherr et al. 1994). Additionally, many species depend on temperature-related cues, from which we predict that increasing temperatures could also lead to changes in the phenology (timing) of events. Phenological changes have been observed in behaviors such as migration arrival and departure in Europe and North America (Bezzel and Jetz 1995, Bradley et al. 1999), peak insect abundance (which reflect the timing of emergence) in Europe (Sparks and Yates 1997), breeding of birds in North America (Dunn and Winkler 1999), and bud burst and blooming by trees and forbs in Europe and North America (Walkovszky 1998, Bradley et al. 1999). Other hypothesized changes include altered morphologies as natural selection acts to favor forms that perform well under the altered climatic conditions. Recorded changes of these types include decreases in melanin concentration of an insect (de Jong and Brakefield 1998), increases in the size of bird eggs (Jarvinen 1996), loss of genetic diversity in a fast-breeding insect in Spain (Rodriguez-Trelles et al. 1998), and growth rate in trees (Barber et al. 2000).

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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Documented Responses of Animals and Plants

The similarity in the patterns of many recent changes in numerous species, when coupled with changes in climatic factors, provide strong correlative evidence that climatic changes can have direct, observable effects on animal and plant populations. Here we quantify some of these changes via a meta-analytic approach—a statistical aggregation of many different types of results from literature—to search for consistent patterns.

Forty-five studies are included in our analyses. The number would be higher if we examined climatic variables in addition to temperature, which is the variable predicted with most confidence to change with increasing greenhouse gases (Santer et al. 1996). Additionally, the effects of temperature on the physiology of species are fairly well understood and reliably demonstrated in the literature to cause changes in traits of species (Root 1988). These 45 studies indicate significant changes are occurring in Europe and northern Africa (32 studies), North America (six studies), Central America (one study), Antarctica (two studies), Southern Oceanic islands (one study), the North American Pacific Ocean shoreline (one study), the North Pacific Ocean (one study), and the Antarctic Ocean (one study). To measure the impact of global warming on species, the metric to use is not the number of species that changed out of the total number of species studied, but the number of species that changed in the direction expected out of the number that changed. The 45 studies report findings of change in 567+ (some studies do not provide the exact number of species examined) animal species (451+ in Europe, 24 in North America, 68+ in Central America, one in Southern Ocean islands, two in Antarctica, 18+ along the North American shoreline of the Pacific Ocean, one in North Pacific Ocean and two in Antarctic Ocean), and in 59+ plant species (14+ in Europe, 43 in North America and two in Antarctica). These 626+ species include 84+ invertebrates, one fish, 57+ amphibians, three reptiles, 412+ birds, ten mammals, six grasses, 49+ forbs, and 4+ trees. Of the 626+ 81 percent (453) show change in the direction expected based on the understanding of physiological constraints by the species to temperature.

Quantifying such a wide array of changes is problematic. Meta-analyses, however, provide a statistical method of summarizing results from many studies, even though such studies may not use common methods or databases. We used meta-analyses to investigate changes in phenology. If global warming was causing changes in phenology, then it would be reasonable to expect that phenological changes might be associated with regional temperature changes. To test this hypothesis, we performed a meta-analysis on 18 animal studies (195 species), and on four plant studies (50 species) reporting spring phenological changes.

Eight animal studies lacked information needed to determine correlation coefficients (r). Consequently, we performed two types of meta-analyses on these data: one taking advantage of the r values that were reported (12 studies, 34 species), and a second including all 21 studies and 193 species, but only taking into account the sign of the phenological change (i.e., negative for earlier in the year and positive for later). We also performed a meta-analysis using 49 plant species.

Our meta-analysis of the correlation coefficients between animal traits and time of year allows us to estimate a common fingerprint—a common correlation coefficient underlying the several studies. The estimated common correlation is –0.38, which is statistically significantly different from zero ($P < 0.05$) with a 95 percent confidence interval of $-0.45 \leq r \leq -0.31$. Consequently, species shifting the timing of events earlier in the spring are shifting them by approximately 4 days per decade.

The "vote counting" meta-analysis of all animals included in spring phenology studies incorporates data for species for which either a correlation coefficient or slope of the relationship between the changing species trait and time was reported. In total, we analyzed data for 195 species from 17 studies. This vote-counting statistic is based on the number of these associations indicating an earlier phenological shift compared to the number of species showing a change. The estimated common correlation using this method is –0.75 or in other words a change in the timing of events 7.5 days earlier per decade, which is statistically different from zero ($P < 0.05$). The 95 percent confidence limits indicate that r could range between –0.88 and –0.67, which indicates the strong negative association between phenological changes and time. The association is consistent among invertebrates, amphibians, reptiles, birds and mammals from several different locations in North America and Europe.

For the meta-analysis of plants showing a change in their blooming or budding dates, the common correlational "fingerprint" for the 48 species from North America and Europe is –0.26, which is statistically different from zero ($P < 0.05$, 95 percent confidence interval $-0.31 \leq r \leq -0.20$). Again, a strong pattern of consistent shifting toward earlier spring activities by about 2.5 days per decade is occurring in plants.

Numerous studies examined shifts in density, which can be created by a change in abundance within the range of a species, a shift in the range boundary, or both. To test for an underlying pattern using the data available we used the "vote counting" method. For

animals and plants, 201 species show a change in density, with 157 of these changes in the expected direction. The minimum number of years used in these studies was 11. The meta-analysis indicates that there is statistically significant ($P < 0.05$) movement in the direction expected for these species (0.35 ranging between 0.26 and 0.41). While "vote-counting" is often insensitive to detecting underlying effects, the strength of this result indicates that there is most likely a fingerprint in the shifts of densities in both plants and animals.

Results from most studies using long-term data sets provide circumstantial (e.g., correlational) evidence about the association between changes in climate-related environmental factors and animal traits. Circumstantial evidence, insufficient for "proving" causation by itself, is highly suggestive when numerous studies, examining many different taxa from several different locations, are found to be consistent with one phenological fingerprint. Indeed, given that 81 percent of the species showing change are changing in the manner expected, we conclude that animals and plants are already responding in concert with the increase in global average temperature of 0.6° C.

Conclusions

Many well-documented pressures (e.g., habitat loss, exotic invasive species) influence the lives of animals, plants and their communities. This study shows that temperature change is apparently also a major influence on many species. Meta-analyses provide a way to combine results from various studies and find an underlying consistent shift, or "fingerprint," among species from different taxa examined at disparate locations. Hence, the balance of evidence suggests that a significant impact from climatic warming is discernible in the form of long-term, large-scale alteration of animal and plant populations. Clearly, if such ecological changes are now being detected when the globe has warmed by only 0.6° C, it is likely that many more far reaching impacts on ecosystems would occur in response to changes in temperature up to 6° C by 2100. Projected future rapid climate could soon become a major concern, especially when occurring in concert with the other already well-established stresses. Research and conservation attention thus needs to be focused not only on each of these stressors by themselves, but the synergism of several pressures that together are likely to prove to be the greatest challenge to animal conservation in the 21st Century (Root and Schneider 1993, Myers 1997). Because anticipation of changes improves the capacity to manage, it behooves us to understand as much as possible about the responses of animals to a changing climate. This and further documentation of change may well indicate a need for action.

Acknowledgments

This paper has been modified, in part, from a paper by the same authors (Root et al. 2003).

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Global Climate Change and Sea Level Rise: Potential Losses of Intertidal Habitat for Shorebirds

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Abstract

Global warming is expected to result in an acceleration of current rates of sea level rise, inundating many low-lying coastal and intertidal areas. This could have important implications for organisms that depend on these sites, including shorebirds that rely on them for foraging habitat during their migrations and in winter. We modeled the potential changes in the extent of intertidal foraging habitat for shorebirds at five sites in the United States that currently support internationally important numbers of migrating and wintering shorebirds. Even assuming a conservative global warming scenario of 2°C within the next century (the most recent projections ranging between 1.4°C and 5.8°C), we project major intertidal habitat losses at four of the sites. These losses typically range between 20 percent and 70 percent of current intertidal habitat. The projected habitat losses would jeopardize the ability of these sites to continue to support their current shorebird numbers. The most severe losses are likely to occur in sites where the current coastline is unable to move inland because of steep topography or coastal defense structures such as sea walls.

Key words: climate change, global warming, sea level rise, shorebirds, WHSRN sites.

Introduction

During their energetically demanding migrations, most shorebirds depend for foraging habitat on tidal sand and mud flats. The ability of a site to support large numbers of shorebirds is determined by the extent of these habitats, and by the density of invertebrate prey (Evans and Dugan 1984, Goss-Custard 1996). However, unlimited numbers of birds cannot simultaneously exploit a site, since the availability of feeding habitat will impose a limit on its carrying capacity. As the area of feeding habitat is reduced, densities of shorebirds increase, and density-dependent interactions may be triggered, resulting in the exclusion of individuals from the site, increased mortality rates among the excluded birds, and, ultimately, in limitation of numbers (Goss-Custard 1980).

During the 20th Century, tidal sand and mud flats came under considerable anthropogenic pressure, particularly from agricultural or industrial development. More recently, a new threat has been recognized — sea level rise due to global climate change. Increasing global temperatures will result in rises in sea level due to thermal expansion of the oceanic water and to melting of glaciers and ice sheets. The most widely accepted projection is that over the next 100 years, sea level will rise globally by between 10 and 90 cm (IPCC 2001). However, local sea level rise may be much greater or smaller due to the confounding effects of crustal subsidence or uplift, respectively (U.S. EPA 1995). Inundation due to sea level rise could result in the conversion of tidal to subtidal habitat and reductions in the availability of shorebird foraging habitats.

In this study, we modeled the potential consequences of future sea level rise for shorebird tidal foraging habitat at five important migration sites in the US, and the ability of these sites to continue supporting important numbers of shorebirds.

Methods

Study sites that are classified as at least of International Importance for wintering or migratory shorebirds were selected: Willapa Bay (Washington), Humboldt and San Francisco Bays (California), Bolivar Flats (Texas), and Delaware Bay (New Jersey and Delaware).

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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At each site we:

1. Quantified the current areas of tidal feeding habitats (sand beaches or mudflats) from the U.S. Fish and Wildlife Service's National Wetland Inventory maps.

2. Identified probabilistic sea level change scenarios from U.S. EPA (1995). The data in U.S. EPA (1995) allow the estimation of probabilistic sea level changes for specific sites and are based on historical rates of sea level change (obtained from tide gauges) superimposed on projected 50 percent and 5 percent probability global sea level changes by 2100 of 34 cm and 77 cm, respectively. The 50 percent and 5 percent probability sea level change projections in U.S. EPA (1995) assume global temperature increases of 2°C (50 percent probability) and 4.7° C (5 percent probability), respectively.

3. Modeled changes in the extents of intertidal feeding habitats in response to sea level change using the Sea Level Affecting Marshes Model (SLAMM 4). SLAMM 4 converts the habitat type occurring in a 30 m cell to another for given changes in the inundation regime. The variables that are included in this process included elevation, habitat type, slope, sedimentation and accretion and erosion rates, and the extent to which the affected area is protected by sea walls. Additional details regarding SLAMM in general have been presented in Lee et al. (1992) and Park et al. (1993).

Results

All of the study sites are projected to lose tidal flat habitat (*Tables 1-3*). However, the extent of loss is site-specific. Habitat loss will be greatest at southern San Francisco Bay, Humboldt Bay, and Delaware Bay. Substantial areas of tidal flats are lost at these sites even under the 50 percent scenario and as soon as 2050. In southern San Francisco Bay more than half of the current tidal flats may be lost by 2100 at the current rate of sea- level rise, without factoring in any future acceleration due to climate change. At Bolivar Flats, the tidal flat habitat loss is predicted to be almost complete (though temporary) by 2100 at the historical rate of sea level rise.

The scale of these losses is likely to result in major reductions in shorebird numbers at these sites. Indeed, if our 50 percent probability predictions for southern San Francisco Bay and Delaware Bay are realized, they could not possibly support shorebird numbers that are even only fractions of their current sizes.

This study also illustrates an important general point about the likely effects of climate change on ecological resources: climate change does not happen in a vacuum. The impacts of climate change will interact with other already existing stressors. For example, our modeling predicts that the extent of habitat loss at any site will depend on local factors. These include local land surface movements and human exploitation patterns (e.g., of aquifers). At sites where crustal movements exacerbate the rate of sea level rise, the loss of feeding habitat is likely to be accelerated. For example, we predict that by 2100 under the 50 percent scenario, southern San Francisco Bay will have lost about 70 percent of its intertidal feeding habitat. Comparison with the corresponding prediction for northern San Francisco Bay (39 percent loss) shows that much of the habitat loss in the southern bay is likely to be due to factors unrelated to, but exacerbating, the rise in sea level. In parts of southern San Francisco Bay, the land surface has historically been subsiding because of, at least in part, aquifer depletion and compaction. It is this crustal subsidence, superimposed on global sea level rise that is responsible for the predicted large habitat loss. In contrast, we predict comparatively modest rates of habitat loss at Willapa Bay. At this site, global sea level rise is being mitigated by crustal elevation (i.e., orthostatic rebound).

All of the above model predictions assume that no new coastal protection structures will be installed. However, it is likely that the local human populations at these sites will protect themselves from the consequences of sea level rise. To evaluate the likely influence of human responses, we considered one simple protection scenario for Bolivar Flats in which all current dry land areas will be protected with new sea walls. This resulted in reductions in the amount of upland habitat predicted to be lost, but a 20 percent increase in tidal habitat loss by 2100 under the 50 percent scenario. Thus, the protection measures work in the sense that upland habitats are protected. However, this is at the expense of intertidal habitats where the rate of loss is exacerbated.

In this study, we did not evaluate the potential effects of climate change-induced habitat loss for shorebirds in their breeding areas. It is in the high-latitude areas where shorebirds breed that the greatest impacts of climate change may occur. Climate-induced habitat changes may already be occurring in arctic and subarctic areas of North America (Chapin et al. 1995). The combined effects of habitat change on their breeding areas and intertidal habitat loss at their wintering and migratory staging sites could, potentially, have even more severe effects than could be brought about by any

one factor. In future research we hope to adopt a "life-cycle" approach by incorporating climate change-induced effects on the wintering and breeding grounds. This should provide a more comprehensive appraisal of the likely effects of climate change on this group of migratory birds.

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Table 1— *Current extents (ha) and projected future percent changes in intertidal and upland habitat at Willapa and Humboldt Bays under three sea level rise scenarios.*

		Historical rate of sea level change[a]		50% Probability[b]		5% Probability[c]	
Habitat	**Current**	**2050**	**2100**	**2050**	**2100**	**2050**	**2100**
Willapa Bay							
Tidal Flats	21,157	-0.7	-0.7	-7.5	-18.1	-25.8	-61.5
Salt marsh	3,455	12.8	12.8	9.5	10.5	13.6	12.8
Upland and other	62,389	-0.5	-0.5	-0.5	-0.7	-0.8	-1.3
Humboldt Bay							
Tidal flats	1,078	-0.1	-0.1	-13.0	-28.6	-42.4	-91.3
Salt marsh	40	72.6	72.6	88.9	175.6	229.2	1,886
Upland and other	12,750	-0.2	-0.2	-0.3	-0.6	-0.7	-6.0

[a]The historical rate of sea level change projections are based on actual past sea level changes measured at the site.
[b]The 50 percent probability projections represent future sea level change with an assumed 2^0 C warming (U.S. EPA's "best estimate" temperature scenario).
[c]5 percent probability projections represent future sea level change with an assumed 4.7^0C warming (U.S. EPA's 5 percent probability temperature scenario)

Table 2— *Current extents (ha) and projected future percent changes in intertidal and upland habitat at northern and southern San Francisco Bays under three sea level rise scenarios.*

		Historical rate of sea level change[a]		50% probability[b]		5% probability[c]	
Habitat	**Current**	**2050**	**2100**	**2050**	**2100**	**2050**	**2100**
Northern							
Tidal flats	4,117	0.0	-4.0	-11.9	-39.4	-35.9	-80.7
Salt Marsh	613	0.0	0.0	0.0	0.0	0.0	-18.1
Upland and other	1,294	0.0	0.0	0.0	0.0	0.0	0.0
Southern							
Tidal flats	12,039	-12.9	-53.9	-24.0	-69.9	-42.9	-83.1
Salt marsh	3,534	0.8	-50.7	-2.2	-63.2	-11.6	-82.9
Upland and other	75,694	0.0	-0.2	-0.1	-0.5	-0.2	-0.6

[a]The historical rate of sea level change projections are based on actual past sea level changes measured at the site.
[b]The 50 percent probability projections represent future sea level change with an assumed 2^0 C warming (U.S. EPA's "best estimate" temperature scenario).
[c]5 percent probability projections represent future sea level change with an assumed 4.7^0C warming (U.S. EPA's 5 percent probability temperature scenario)

Table 3— *Current extents (ha) and projected future percent changes in intertidal and upland habitat at Bolivar Flats and Delaware Bay under three sea level rise scenarios.*

		Historical rate of sea level change[a]		50% probability[b]		5% probability[c]	
Habitat	**Current**	**2050**	**2100**	**2050**	**2100**	**2050**	**2100**
Bolivar Flats							
Tidal flats	398	-14.6	-93.8	-37.6	1.8	-80.6	1,073
Salt marsh	5,774	4.3	40.9	4.7	48.5	14.2	53.5
Upland and other	18,275	-1.3	-12.9	-1.4	-17.6	-4.4	-53.1
Delaware Bay							
Tidal flats	2,665	-6.1	-23.0	-19.8	-57.4	-43.1	19.8
Salt marsh	13,766	6.4	9.3	9.0	12.2	11.3	-4.2
Upland and other	20,538	-3.5	-5.5	-5.3	-7.5	-6.9	-11.3

[a]The historical rate of sea level change projections are based on actual past sea level changes measured at the site.
[b]The 50 percent probability projections represent future sea level change with an assumed 2^0 C warming (U.S. EPA's "best estimate" temperature scenario).
[c]5 percent probability projections represent future sea level change with an assumed 4.7^0C warming (U.S. EPA's 5 percent probability temperature scenario)

Potential Impacts of Climate Change on Neotropical Migrants: Management Implications[1]

Jeff T. Price[2] and Terry L. Root[3]

Abstract

The world is warming. Over the last 100 years, the global average temperature has increased by approximately 0.7°C. The United Nations Intergovernmental Panel on Climate Change projects a further increase in global mean temperatures of between 1.4° - 5.8° C by the year 2100. How will climate change affect Neotropical migrants? Models of changes in the breeding distributions of North American birds predict that most species will undergo some shift in their ranges. In parts of northern Minnesota and southern Ontario, this could lead to an avifauna with as many as 16 fewer species of wood warblers than currently occur. Unless all components of the ecosystem change at the same rate, an unlikely prospect, this potential disruption of the ecosystem could lead to major impacts on forest health. Data show that many changes have already occurred with earlier arrival dates, breeding dates and changes in distributions. This includes preliminary results showing the average latitude of occurrence of some species of North American birds has shifted northward by almost 100 km in the last 20 years, and many species in Michigan arriving in the spring an average of 21 days earlier now than 30 years ago. Climate change will add more pressure to bird populations and greater challenges to conservation planners and land managers.

Introduction

The Earth's climate is changing. As of the end of July, 2002 was on pace to supplant 1998 as the warmest year on record (or be a close second). Of the more than 100 years for which instrumental records are available, 1998 was previously the warmest year on record and 7 of the top 10 warmest years all occurred in the 1990s. Overall, the 1990s were the warmest decade (so far) and the 1900s the warmest century of the last 1000 years. The annual global mean temperature is now 1.3°F (0.7°C) above that recorded at the beginning of the century. Limited data from other sources indicates that the global mean temperature for the 20th century is at least as warm as any other period since at least 1400 AD (IPCC 2001).

Since pre-industrial times, there have been significant increases in the amount of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) in the atmosphere, leading to an enhancement of the Earth's natural greenhouse effect. These increases in greenhouse gases can largely be attributed to human activities, including burning of fossil fuels and land use changes (such as deforestation). In 1996, the Intergovernmental Panel on Climate Change published the statement that "the balance of evidence suggests that there is a discernable human influence on global climate." Increases in greenhouse gases (past and projected), coupled with the length of time these gasses remain in the atmosphere, are expected to cause a continued increase in global temperatures. Models estimate that the *average* global temperature, relative to 1990 values, will rise by between 1.5°C - 6°C by the year 2100. It is not only the magnitude of the change but also the rate of change that is of concern. The current projected rate of warming is thought to be greater than has occurred at any time in at least the last 10,000 years (IPCC 2001).

Anthropogenic warming due to increases in greenhouse gases is expected to be even greater in some areas, especially Northern Hemisphere land areas. For example, average temperatures in Alaska may increase by 5.4 - 18° F (1.5 - 6°C) (NAST 2000). With increases in temperature come increases in evaporation, likely leading to some increases in local precipitation but, coupled with increases in temperature, to declines in soil moisture in many areas. As such, both droughts and floods are expected to become more common in the future.

The summer ranges of birds are often assumed to be tightly linked to particular habitats. This is only partially true. While certain species are usually only found in certain habitats (e.g., Kirtland's Warbler breeding in jack pines), others are more flexible in their habitat use. Species found in a particular habitat type throughout their summer range may not be found in apparently equivalent habitat north or south of their current distribution. While habitat plays a role in bird distribution patterns, birds are also limited in their distributions by

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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their physiology and food availability. The link between physiology and the winter distributions of many species is well known (Kendeigh 1934, Root 1988a, 1988b) and recent research shows that physiology plays a strong role in limiting summer distributions as well (Dawson 1992, T. Martin, pers. comm.). While habitat selection, food availability, and competition may all play a role in influencing the *local* distribution of a given bird species, looking at a species' overall distribution often yields different results. Building on earlier work that found that many winter bird distributions are associated with climate (Root 1988a, 1988b), this study examined the association between summer bird distributions and climate and how these distributions may change with climate change.

Ultimately, the greatest impact on wildlife may not be from climate change itself, but rather from the rate of change. Given enough time, many species would likely be able to adapt to shifts in the climate, as they have done in the past. However, the current projected rate of warming is thought to be greater than has occurred at any time in the last 10,000 years (IPCC 1996). This rate of change could ultimately lead to changes in the distributions of North America's neotropical migrants.

Methods

To determine how summer distributions of birds might change, it is first necessary to look at whether there is any association between bird distributions and climate. If an association exists, then an examination of projected future climates can be used to see how the climatic ranges of birds might change. Logistic regression was used to develop models of the association between bird distributions (from Breeding Bird Survey data) and eighteen climate variables. These climate variables included average seasonal temperature and precipitation, temperature and precipitation ranges, extreme values (e.g., temperature in the hottest month and coldest months, precipitation in the wettest and driest months) and combinations (e.g., precipitation in the hottest month, temperature in the driest month). Climate variables used in these models act as surrogates for many factors possibly limiting a species distribution, including physiology, habitat, and food availability, and are similar to those used in other bioclimatic studies. Models developed for this study were then checked to see how well they predicted species occurrence at independent locations (statistically validated) and checked to see how well predicted species distributions matched maps of actual distributions based on similar bird data (Price et al. 1995). The results indicated that at least a portion of the summer distributions of many North American birds can actually be modeled quite well based on climate alone.

The next step was to examine how bird distributions might change in response to a changing climate. For this study climate projections from the Canadian Climate Center's General Circulation Model (CCC-GCM2) were used. This model projects what average climate conditions may be once CO_2 has doubled from pre-industrial levels, sometime in the next 75 to 100 years. Differences between modeled current climate and modeled future $2xCO_2$ climate, both derived from CCC-GCM2, were then applied to the original climate variables used in developing the bird-climate models. All bird distribution models were then run using $2xCO_2$-derived climate variables. The combined bird-$2xCO_2$ climate models were then used to create maps of the projected possible future climatic ranges of many North American birds. A complete explanation of the methods used to develop the models and maps has been published elsewhere (Price 1995, in press).

Distributional models and distributional maps have been developed for almost all passerine bird species. What these maps actually show are areas projected to have the proper climate for the species under conditions derived from CCC-GCM2, a *climatic range*. While model results cannot be used to look at fine points of how a given species' distribution might change, they can provide an impression of the possible direction and potential magnitude of change in suitable climate for the species. By examining these maps it is possible to develop lists of how species ranges might change in particular states or regions (Price and Glick 2002; Price 2001, 2000a, 2000b, 2000c, 2000d) or used to estimate how groups of species, such as neotropical migrants may change (Price 2000e; Price and Root 2001, 2000).

Results

The results in table 1 show how climate change might change the percentage of Neotropical migrants present in each of the U.S. National Assessment regions. Gross changes depict the overall loss of species currently found in areas while net changes depict species loss from an area offset by species moving into the area from outside of the region. For example, under climate change conditions projected by Canadian Climate Center, the Great Lakes region could see a potential gross loss of 53 percent of the Neotropical migrants currently found in the region's states. These losses would be somewhat offset by birds colonizing from outside the region so the net change would be 29 percent fewer species than are currently found there.

Bird lists used in creating this table are not all inclusive, since results obtained from models of some species were not adequate to assess how their climatic ranges might change. Additionally, the bird lists are

based on output from a single, commonly used climate model. There are many different models, and results vary between them. While the magnitude of projected temperature increase is somewhat similar between models, projected precipitation changes are often different. Using output from different climate models may therefore yield somewhat different results. Additionally, the geographic scale of these models, like those of the underlying climate change model, is quite coarse. As such, the models are unable to take into account localized topographic changes and the possible existence of suitable microclimates – along rivers, for example. Therefore, some species whose *climatic* ranges are projected as shifting out of a region may be able to persist in refugia if a suitable microclimate is available, especially in higher montane areas, on north facing slopes, or along riparian areas.

Table 1—*Changes in percent of neotropical migrants in U.S. National Assessment regions under the equilibrium conditions from the Canadian Climate Center GCM. See text for more information.*

	Neotropical migrants (%)	
Region	**Gross**	**Net**
California	-29	-6
Eastern Midwest	-57	-30
Great Lakes	-53	-29
Great Plains - Central	-44	-8
Great Plains - Northern	-44	-10
Great Plains - Southern	-32	-14
New England	-44	-15
Pacific Northwest	-32	-16
Rocky Mountains	-39	-10
Southeast	-37	-22
Southwest	-29	-4
Mid-Atlantic	-45	-23

Discussion

Observed Changes

How quickly these distributional changes might occur is unknown. The rate of change will largely depend on whether a given species' distributional limits are more closely linked with climate, vegetation, or some other factor. The rate of change will also likely be tied to the rate of change of the climate itself. If the climate changes relatively slowly, then species may be able to adapt to the new climate. However, changes could occur relatively quickly. One pilot study found that the average latitude of occurrence of some species of Neotropical migrants has already shifted significantly farther north in the last 20 years, by an average distance of almost 100 km (Price, unpublished data). In another study, the arrival date of 20 species of migratory birds was found to be 21 days earlier in 1994 than in 1965 (Root, unpublished data; Price and Root 2000). Many other species have been found to be arriving and breeding earlier, not only in the United States but in Europe and elsewhere (Root et al. 2003, this volume).

Shifts in individual species' distributions and phenologies are only part of the story. It is unlikely that ranges of coexisting species will shift in concert. Bird communities, as we currently know them, may look quite different in the future. As species move, they may have to deal with different prey, predators and competitors. So-called "optimal" habitats may no longer exist, at least in the short term. The potential rates-of-change of birds and the plants that shape their habitats are often quite different. While many birds may be able to respond quickly to a changing climate, some plant ranges may take from decades to centuries to move (Davis and Zabinski 1992).

Economic and Ecological Implications

Climatically induced changes in the ranges of Neotropical migratory birds may have other impacts. Ignoring aesthetic, cultural, and stewardship issues (all important), there are still economic and ecological reasons to be concerned about changes in bird distributions. Bird watching contributes to the United States' economic health. Watching and feeding wildlife (primarily birds) contributed more than $29 billion to the nation's economy in 1996 (USDOI 1997). Estimating how changes in bird distributions might affect the economics of watching and feeding birds is difficult. Although some birdwatchers might adjust to changes in distributions and diminished species richness, there could also be changes in the amount of money spent watching wildlife in the US as people traveled elsewhere to see birds.

Birds are critical components of their ecosystems. The ecological services provided by birds include, but are not limited to, seed dispersal, plant pollination, and pest control. Their role in the control of economically important insect pests should not be underestimated. Birds have been known to eat up to 98 percent of the overwintering codling moth (*Cydia pomonella*) larvae in orchards (Kirk et al. 1996) and several species of warblers are thought to be largely responsible for holding down numbers of spruce budworm (*Choristoneura fumiferana*) larvae, eating up to 84 percent of non-outbreak larvae (Crawford and Jennings 1989). Changes in bird distributions could lead to increases in outbreaks of some harmful insects with subsequent ecological and economic damage (Price 2002).

Management issues

One typically used method to adapt to declines in wildlife populations has been the establishment of refuges, parks and reserves. However, the placement of reserves has rarely taken into account potential climate change even though the problems of climate change and reserve placement were first pointed out in the mid-1980s (Peters and Darling 1985). Managers of current reserves and parks need to be encouraged to consider climate change in developing future management plans (Halpin 1997, Solomon 1994). Specifically, this includes assessing the vulnerability of the key taxa in the preserve (Herman and Scott 1994, Galbraith and Price in review) as well as monitoring for potential impacts related to climate change (Solomon 1994). It may also be possible to develop a series of bioindicators to monitor the potential impacts of climate change on parks and preserves (de Groot and Ketner 1994). In the light of potential climate change there is a need for a robust, adaptable nature conservation system. Site-based conservation needs to become more flexible, and non-site based conservation needs to be woven into other land use policies.

In part, the disparity between siting preserves where wildlife currently are versus where they may be in the future may stem from uncertainties in the rate and amount of projected climate change. If a species' range shifts out of a reserve created for its survival, then the current reserve placement could even be considered mal-adaptive. However, if reserves are not created and species are lost to other pressures then the potential effects of climate change on species distributions are moot.

Another way in which humans have dealt with endangered wildlife populations has been through the use of captive breeding and translocations. These techniques have been put forward in the past as methods to deal with future population pressures caused by climate change (Peters 1992). However, captive breeding and translocation, while effective tools for the conservation of some species, may be appropriate for only a handful of species owing to the expense and technical difficulty inherent in any such effort (IPCC 2001).

Given the length of time it takes for species to adapt to new conditions how can mangers adapt their practices to dealing with a changing climate? Given that conservation resources are limited the goal needs to be moving towards 'no regrets' management practices. That is, practices that are beneficial now and are expected to also be beneficial in the future as the climate changes. For example, concentrating efforts to conserve species in areas where they both currently occur and are expected to occur under a changing climate – all things being equal. The models discussed here provide some measure of information as to where species might move in the future and maps showing the 'no regrets' zones are currently being prepared for a number of species.

Another 'rule-of-thumb' that managers can go by is that the better able they are to manage under climate variability (e.g. El Niño) or manage under climatic extremes (drought), the better they will likely be able to manage under climate change. The reverse is also true. If current management practices are not adequate to deal with drought, for example, then it is unlikely that they will be able to deal with climate change.

Conclusions

In summary, a high probability exists that climate change will lead to changes in bird distributions. Even a relatively small change in average temperature could impact neotropical migratory bird distributions, arrival and departure dates and breeding dates. Some of these changes could occur (and are occurring) relatively quickly. While these changes may have some ecological and, possibly, economic effects, the magnitude of these effects is unknown.

Projected future rapid climate change is of major concern, especially when viewed in concert with other already well-established population stresses (e.g., habitat conversion, pollution, and invasive species). Research and conservation attention thus needs to be focused not only on each stressor by itself, but also on the synergy of several stressors acting together. These synergistic stresses are likely to prove to be the greatest challenge to wildlife conservation in the 21st Century. Because anticipation of changes improves the capacity to manage, it is important to understand as much as possible about the responses of animals to a changing climate.

Managers may ultimately need to adapt not only in terms of wildlife conservation but also to replace lost ecosystem services normally provided by wildlife. For example, it may be necessary to develop adaptations to losses in natural pest control, pollination and seed dispersal. While replacing providers of these services may sometimes be possible, the alternatives may be costly. Finding a replacement for other services, such as contributions to nutrient cycling and ecosystem stability/biodiversity are much harder to imagine. In cases where the losses of the values of wildlife are associated with subsistence hunting, cultural and religious ceremonies, any attempt at replacement may represent a net loss.

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A Comparison of Ectoparasite Infestation by Chigger Mite Larvae (Acarina: Trombiculidae) on Resident and Migratory Birds in Chiapas, Mexico Illustrating a Rapid Visual Assessment Protocol[1]

Thomas V. Dietsch[2]

Abstract

This study presents a protocol developed to rapidly assess ectoparasite prevalence and intensity. Using this protocol during a mist-netting project in two different coffee agroecosystems in Chiapas, Mexico, data were collected on ectoparasitic chigger mite larvae (Acarina: Trombiculidae) found on resident and migratory birds. Surprisingly high infestation rates were found for some long-distance migrants, as high as 73 percent for Swainson's Thrush (*Catharus ustulatus*), while many species remained uninfested. During the study, 17 of 26 species of long distance migrants and 24 of 44 resident species had at least one infested individual. Total prevalence averaged 0.18, with 0.16 for migrants and 0.23 for residents. The mite score protocol provided a useful relative measure of infestation intensity. Mean infestation intensities and abundances are reported for 70 species captured and opportunistically inspected during the course of this study. While this study does not directly link survival with infestation by ectoparasites, variation in infestation intensity among individuals could help explain differences in condition when birds arrive on the breeding range. Further study is merited on the ecology of ectoparasites, including the geographic distribution and degree to which human landscape management contributes to infestation. Constant effort mist-net monitoring stations could provide important data toward this effort by routinely collecting ectoparasite information.

Introduction

Temperate Neotropical birds that migrate long distances to tropical habitats, face a range of hazards that reduce survival. One such hazard is parasitism. Internal and external parasites may reduce survival during migration and leave birds in poor condition upon arrival on the breeding or wintering grounds. Despite potentially grave consequences, little is know about the distribution and abundance of ectoparasite infestation in birds, especially in the tropics. However, over 2500 species from 40 families of mites (Acarina) are known to parasitize birds (Proctor and Owen 2000). Constant effort mist-net programs may provide an opportunity to gather information on ectoparasites. For such an effort to be compatible with on-going mist-net monitoring programs, rapid assessment methods need to be developed that complement data already collected without adding significantly to the processing time of each bird.

Chigger mites (Trombiculidae) are one parasitic group that may be difficult to sample using conventional methods. Chigger mites are parasitic only in their larval stage, when they are firmly anchored in difficult to reach areas behind the wings and legs. While in the successive nymphal and adult stages they are free moving and predominantly predatory on the eggs and young instars of small arthropods (Baker et al. 1956). Chigger mite larvae typically remain attached to their host for 3-4 days but some species can remain attached on their host as long as 30 days (Wharton and Fuller 1952, Clayton and Walther 1997).

A number of methods have been developed that use destructive sampling to collect ectoparasites for accurate counts (Walther and Clayton 1997). There are also non-destructive methods, such as dusting, that are less accurate but allow resampling of individual birds over time (Fowler and Cohen 1983, Bear 1995, Walther and Clayton 1997). These methods require specialized equipment, chemicals, and increased processing time per bird. They also poorly sample parasites that anchor themselves to the host (Walther and Clayton 1997). A simpler and more efficient approach would be more appropriate and likely to be implemented by routine monitoring programs, especially those that rely on volunteers. Visual inspections are straightforward and work well for longitudinal studies of ectoparasite dynamics (Clayton and Walther 1997), but counting individual mites can be time-consuming and tedious.

This study presents a protocol to assess infestation intensity of birds by a visually obvious ectoparasite with minimal extra time requirements for handling individual birds captured in mist nets. This relative

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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measure is tested against actual ectoparasite abundance levels on infested individuals from visual counts. This study then uses the relative mite ranking scores to compare infestation differences between Neotropical resident and migratory birds.

Study Area and Methods

This study was conducted in the Soconusco region of Chiapas, Mexico. The Sierra Madre de Chiapas mountain range east of Tapachula is just north of the Guatemala border near the Pacific coast. Coffee is grown in this region at altitudes from 300 m to 1500 m. During January 9-25, 2001 and January 28 - February 4, 2002, mist netting was conducted at 1000 m elevation in two coffee agroecosystems of Finca Irlanda. These coffee agroecosystems use diverse shade with several *Inga* species and *Alchornia latifolia* the most abundant trees in the shade canopy (Martinez and Peters 1996). One agroecosystem contains greater canopy cover and a higher species richness and abundance of shade trees with additional native forest trees planted by the landowner. While differing in management intensity, both these agroecosystems would be classified as commercial polyculture using the "gestalt" system described by Moguel and Toledo (1999).

Resident birds were banded during winter 2001, 25 nets were run (198 m total) for 3 consecutive days in each plot. In winter 2002, 12 nets were used (96 m) for 2 consecutive days. Nets were opened at dawn (~ 6 am) and closed at 11 am each day. Tail feathers of migratory birds and resident hummingbirds were clipped to identify recaptured individuals. Weight, fat level, molt, and other standard banding measurements were taken for each bird captured (Ralph et al. 1993). While checking for body molt and fat, each bird was scored using a mite infestation ranking protocol (*table 1*). This study focused on red chigger mite larvae (Acarina: Trombiculidae). The ranking protocol (scored from 0-4) was designed to provide a rapid assessment of the relative abundance of mites on infested individuals. The general procedure is as follows. Each bird caught was visual inspected while checking for body molt by blowing feathers aside to examine the skin surface. This inspection included focal areas where mites seem to colonize, in particular along feather tracts behind the legs and wings (*Figs. 1a* and *1b*). A single location refers to a general body area, such as behind one leg, behind a single wing, or the lower belly (common areas for chigger mites). A colony is a single grouping of mites. Individual mite larvae are visible as bumps within a grouping. During Winter 2002, after each bird was scored using the ranking protocol, individual mite larvae were counted. Mite scores from field assistants were verified until their rankings were consistent with the protocol.

Table 1— *Ranking protocol for Mite Score (MS). The following ranking system is an attempt to cover the variation from no mites to high infestation. While most possibilities are covered, there are likely to be birds with unusual infestations that are difficult to categorize. In these cases, judgment should be used to provide a relative scoring for the bird. If time permits, additional notes should be made with counts of individual mites. Each bird caught is visual inspected while checking for body molt by blowing feathers aside to examine the skin surface. This inspection should include focal areas where mites regularly colonize, in particular behind the legs and wings. A single location refers to a general body area, such as behind one leg, behind a single wing, or the lower belly (common areas for chigger mite larvae). A colony is a single grouping of mite larvae. Individual mite larvae are visible as bumps within a grouping (see* Figure 1b*).*

Mite Score	Description
0	Absence of mites (none observed).
1	One small colony (<5 mites) in one location.
2	One large colony (>5 mites) or several colonies in one location. Two locations with mites, including from both locations with small colonies to both with large colonies but no heavy infestation.
3	Two locations with large colonies, at least one with heavy infestation (multiple colonies including one large). Three locations with small or large colonies.
4	Four or more locations with mites. Three locations with heavy infestation (multiple colonies including one large).

Statistical Analysis

In this account, prevalence refers to the proportion of individuals infested by at least one mite, mean abundance is the average number of mites recorded across all individuals examined, and mean intensity is the average number of mites recorded across all infested individuals (Margolis et al. 1982, Duffy and Campos De Duffy 1986, Pruett-Jones and Pruett-Jones 1991, Bush et al. 1997). Difference in prevalence was evaluated using contingency table χ^2 tests. Differences in mean abundance and intensity were tested using unpaired t-tests. Multiple tests conducted for species with greater than five captures per year used Bonferroni correction to determine $\propto$-values (Manly 2001). Statistical analyses were conducted with StatView (v5.0.1, SAS Institute, Inc).

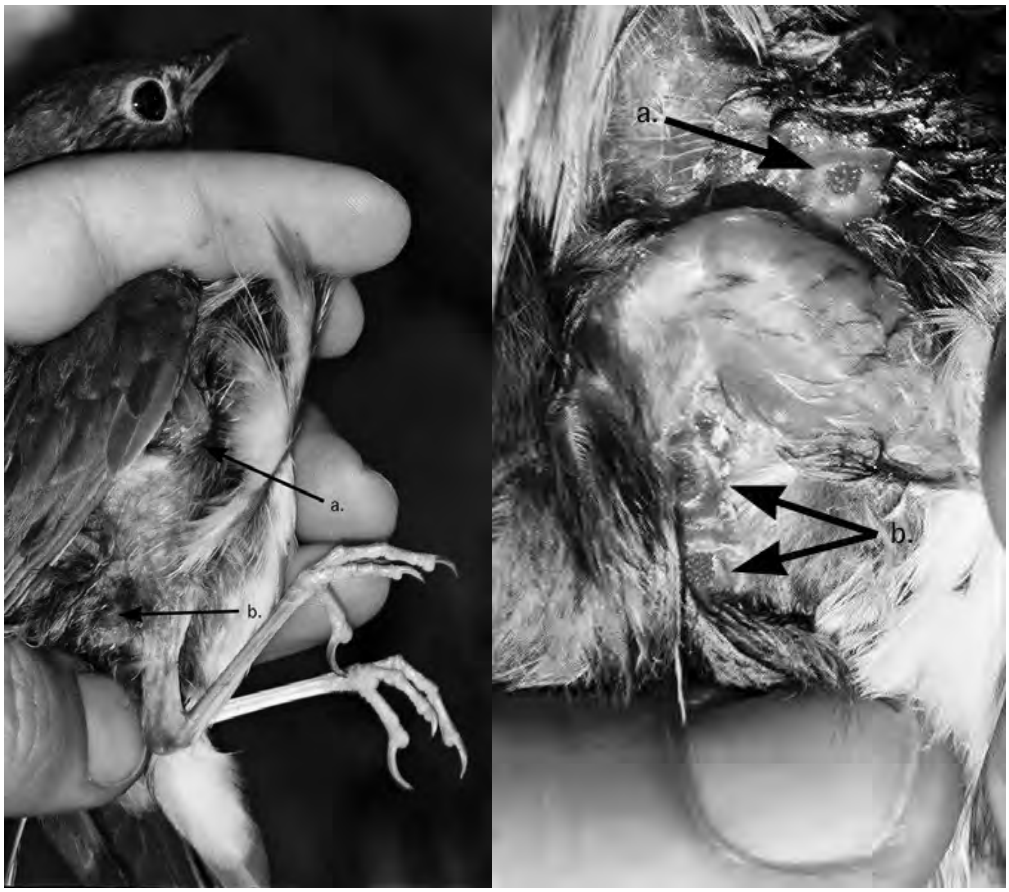

Figure 1—Swainson's Thrush (*Catharus ustulatus*) with chigger mite larvae. Two areas of infestation are shown (a and b) along feather tracts on either side of the right leg. Location b is a common location for these larvae behind each leg. In the close-up to the left, location a is a large colony with 9 individual mites while location b is a heavy infestation with 2 large colonies. Based on similar infestation on its opposite side, this bird received a mite score of 4.

Results

In total, 24 of 42 resident species and 16 of 26 migratory species had at least one captured individual with mites (*Appendix 1*). Mite score ranking system separated mite larvae abundance into significantly different categories ($F_{3,71} = 28.44$, $P < 0.0001$, *fig. 2*). Mite score was also significantly associated with actual mite larvae abundance using Pearson correlation ($N = 76$, $r = 0.723$, $P < 0.0001$). When present, mite-larvae abundance ranged from 1 to 164 individuals with a mean intensity of 21.8 with standard error of 3.37. Mite scores for birds with actual counts of mites (used in correlation above) had a mean intensity of 2.17 and standard error of 0.12. Based on this significant correlation, I use mite scores in place of actual abundance levels to evaluate mean intensity and mean abundance.

There was significantly higher prevalence in individuals from resident species than migrants, 0.23 and 0.16 respectively ($\chi^2 = 7.1$, $P = 0.008$). However, when analyzed by year, there was only a significant difference in prevalence for 2001 (residents: 0.17, migrants 0.10, $\chi^2 = 6.9$, $P = 0.009$) not 2002 (residents: 0.38, migrants: 0.5, $\chi^2 = 2.2$, $P = 0.14$). Interestingly, there was no significant difference between residents and migrants in mean intensity or mean abundance in either year (*table 2*). Between-year comparisons for mean abundance were significantly different for both migrants and residents, while mean intensity was only different for migrants (*table 2*).

Swainson's Thrush had the highest infestation prevalence for migrant species with >5 captures at 0.73. For the Swainson's Thrush, the distribution of mite scores was significantly different between years (*fig. 3*, $\chi^2 = 29.1$, $P < 0.0001$, $df = 4$). This corresponds with significant differences in mean abundance and mean intensity between years. Swainson's Thrush mite score mean abundance was 1.2 for 2001 and 2.8 for 2002, a significant difference of 1.6 (Mann-Whitney U test, $P < 0.0001$). Swainson's Thrush mite score mean intensity was 1.9 for 2001 and 2.9 for 2002 (Mann-Whitney U test, $P < 0.0001$).

Table 2— *Mean abundance and mean intensity mite scores for long distance migrants and resident birds each season with differences between years and migratory status. Mann-Whitney U test (MW) used to test for significance. Significant differences shown in bold.*

Mean abundance	**Winter 2001**	**Winter 2002**	**Difference**
Migrants	0.16	1.07	**0.91, MW, P < 0.0001**
Residents	0.33	0.87	**0.53, MW, P = 0.004**
Difference	0.17, MW, P = 0.13	0.21, MW, P = 0.24	
Mean intensity	**Winter 2001**	**Winter 2002**	**Difference**
Migrants	1.64	2.15	**0.51, MW, P = 0.02**
Residents	1.94	2.24	0.31, MW, P = 0.33
Difference	0.3, MW, P = 0.15	0.09, t = 0.36, P = 0.75	

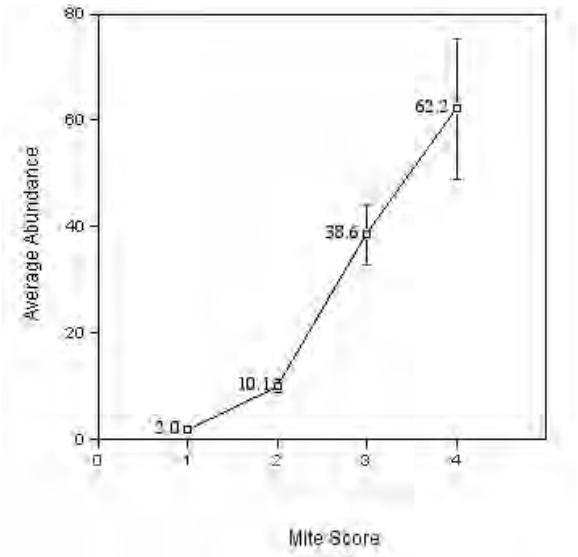

Figure 2— Ranking system reflects actual abundance of chigger mite larvae. The mite scores separated into significantly different categories (F = 28.44, P < 0.0001). Each mite score is labeled with the average number of mite larvae and standard error bars.

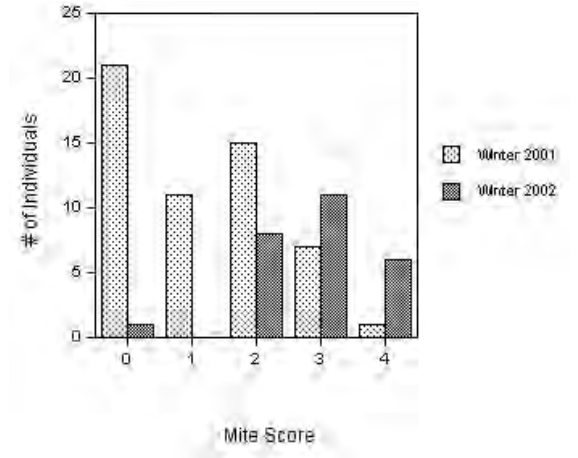

Figure 3— Mite score distribution for Swainson's Thrush (*Catharus ustulatus*) comparing Winter 2001 and Winter 2002. The distribution of mite scores was significantly different between years (χ^2 = 29.1, P < 0.0001, df = 4).

Individual mites were collected and identified as larvae from the chigger mite family (Acarina: Trombiculidae) at the University of Michigan Museum of Zoology (B. O'Conner, pers. comm.). Voucher specimens have been stored in the museum entomology collection.

Discussion

In Chiapas, Mexico, ectoparasitic chigger mites (*Acarina: Trombiculidae*) affect a wide range of resident and migratory species and for many species there is a high and Winter 2002. The distribution of mite scores was prevalence of infestation (*Appendix 1*). This study opportunistically took data on chigger mite larvae during the course of a mist-netting project using a mite score ranking protocol. The mite score ranking protocol provides a rapid assessment of chigger mite infestation that can be readily incorporated into constant effort mist-net programs. The scoring process takes about the same time per bird as estimating body molt or fat level. Combining the mite scoring with normal body molt or fat level procedures can be done with minimal additional processing time. Mite scores were significantly correlated with actual mite abundance indicating that the ranking system provides a good estimate of infestation intensity (*fig. 2*).

At higher mite ranking scores, there is greater variability in actual abundance, due to chigger mite phenology and the relatively short duration that each larvae is on the host. Some birds that received higher ranking scores but with relatively low abundance had extensive scarring indicating that larvae had recently detached from their host. After engorgement larvae detach from their host, thus individual birds that have experienced high infestation levels may maintain the extent of infestation (i.e., the number of areas on each bird containing mites), even as mite abundance drops off. Thus, the ranking system may mask some of the variation in actual mite abundance. Nonetheless, the ranking scores provide a good relative measure of infestation intensity.

Useful characteristics that can be used to rank infestation are extent (i.e., proportion of body affected by ectoparasites) and localized intensity. I designed the protocol to evaluate the extent of infestation, then adjust for the intensity of infestation in each area (see *table 1*). Consequently, there is some margin of error when a bird is infested with multiple small clusters in different places or has a few large clusters in only a few locations. The most frequent location for infestation was behind the thighs, where occasionally large colonies (or multiple clusters merged together) were not matched by infestation in other locations, such as behind the wings. Another approach might be to count clusters. However, there is considerable variation in cluster size and cluster can grow and merge together as the larvae move into prime feeding areas. A method that counted clusters would also need to compensate for this variation.

Research on parasites usually requires specialized equipment and time consuming methods that may not be easily used by routine monitoring programs (Clayton and Walther 1997). Exact counts usually require sacrificing the host (Clayton and Drown 2001). Among non-lethal methods compared to sample chewing lice on Pigeons, dust-ruffling was the most effective and chemical fumigation was moderately effective, while visual counts sampled a low proportion of the actual lice on each bird (~10 percent, Clayton and Drown 2001). Nonetheless, visual counts were well correlated with actual lice abundance, performing as well or better than the chemical fumigation method (Clayton and Drown 2001). Lemke and Collison (1985) had similar results with northern fowl mites on laying hens.

Chigger mite larvae are fairly conspicuous once they have attached to the host and become engorged (personal observation). Their bright red color distinguishes them from surrounding skin and feathers quite readily. Though a comparison of sample methods has yet to be done for this ectoparasite, the difficulty in obtaining precise counts is not detectability, but rather adequate processing time to count individual mites within clusters on birds with heavy infestations. The mite score protocol presented here provides a straightforward approach to reducing processing time for each bird.

Simple and rapid methods can provide useful coarse data on the geographic distribution and prevalence of parasites across bird host species. This protocol should be useful for other ectoparasites that cluster in visible locations and can be adapted depending on clustering patterns. The high score could be adjusted to reflect the number of locations infested when individuals have high levels of infestation.

During winter, resident species had overall higher prevalence than migratory species overwintering on the study area (*Appendix 1*). However when analyzed by year, only 2001 was significantly different. During the 2002 field season, which began slightly later than 2001, the climate was much hotter and dryer and the flowering period of the main overstory tree, *Inga* sp., had passed (personal observation). Consequently, many of the birds that forage in the overstory were absent or only present in small numbers. In particular, there was only one capture of the normally abundant Tennessee Warbler compared to 205 the previous year. Resident and migratory birds had higher prevalence the second year (*table 2*). Chigger mites are usually associated with the soil, which may lead to a greater susceptibility for birds that forage or spend time near the ground. Literak et al. (2002) found that birds with a higher prevalence of trombiculid larvae (>20 percent) were members of ground or near ground foraging guilds. The stronger effect of dryer conditions on the overstory foraging birds, especially among migrants, may have reduced the difference in mite prevalence between migrants and residents the second year of the study, 2002.

Unlike the temperate zone where only one or two generations of chiggers occur each year, chiggers reproduce year round in the tropics (Wharton and Fuller 1952). Consequently, resident species susceptible to chiggers maintain an ectoparasite load year round. On the other hand, migratory species probably accumulate larvae over time after arrival on the wintering grounds until reaching an equilibrium level based on the rate of larvae attachment and detachment following engorgement. This is supported by the significantly higher mean intensity during the second year than the first for migrants. This difference was mostly due to the dramatic difference between years for Swainson's Thrush (*table 2*). This difference may be due to the slightly later sampling in 2002 reflecting the build up of infested individuals with more time or may also reflect more favorable conditions for chigger mite reproduction and host location. Swainson's Thrushes traveling south in the fall captured at United States and Canadian constant effort banding stations do not have chigger mite infestations (Dietsch unpubl. data). A longitudinal study across the wintering season would help determine how this ectoparasite affects migrants each year on their wintering grounds.

Conclusions

Further study is merited on the ecology of ectoparasites, including the geographic distribution and degree to which human landscape management contributes to infestation. There are about 1600 species of chigger mite (Trombiculidae and Leeuwenhoekiidae) and they have a cosmopolitan distribution (Wharton and Fuller 1952, Vercammen-Grandjean 1968). Some species

have been identified as vectors for one serious human disease, scrub typhus (*Rickettsia tsutsugamushi* Ogata), and a number of wildlife diseases (Wharton and Fuller 1952, Proctor and Owens 2000). Given that migratory birds can travel considerable distances in the time necessary for larvae to engorge themselves and detach, monitoring programs for ectoparasites may be important for recognizing the spread and causes of emerging diseases. The protocol presented here can be readily adopted by ongoing constant effort mist-net programs to begin collecting these data.

Acknowledgments

Thanks to Dr. G. Ibarra-Núñez, Dr. I. Perfecto, Dr. T. Root, Dr. J. Vandermeer, Dr. R. Greenberg, and my fellow graduate students and field assistants. Special thanks to Dr. B. O'Conner at the University of Michigan Museum of Zoology for specimen identification and assistance on chigger mite ecology. J. L. Rangel, P. Bichier, and A. Garcia-Ballinus provided important technical assistance. This work was also made possible by the generous help of the following landowners: W. Peters - Finca Irlanda and the ISMAM Cooperative - Finca Belen. Funding was generously provided by Latin American and Caribbean Studies Department, School of Natural Resources and Environment, and Rackham Graduate School of University of Michigan, Kalamazoo Audubon Society, Chicago Zoological Society, Sigma Xi, and National Science Foundation grant # CEB-9981526.

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Appendix 1— *Prevalence, mean abundance and mean intensity listed by species for each season. The number of individuals scored for each species per season is n. The number of species with at least one infested individual is totaled for migrants and residents below each column.*

		Winter 2001				Winter 2002				Total	
Scientific name	**English name**	**N**	**Prevalence**	**Mean abundance**	**Mean intensity**	**N**	**Prevalence**	**Mean abundance**	**Mean intensity**	**N**	**Prevalence**
Archilochus colubris	Ruby-throated Hummingbird	24	0.00	0.00						24	0.00
Empidonax minimus	Least Flycatcher	14	0.29	0.29	1.00	5	0.60	1.00	1.67	19	0.37
Vireo gilvus	Warbling Vireo	3	0.00	0.00						3	0.00
Vireo solitarius	Blue-headed Vireo	6	0.17	0.17	1.00					6	0.17
Polioptila caerulea	Blue-gray Gnatcatcher	3	0.00	0.00						3	0.00
Catharus ustulatus	Swainson's Thrush	55	0.62	1.20	1.94	26	0.96	2.81	2.92	81	0.73
Catharus mustelinus	Wood Thrush					1	1.00	2.00	2.00	1	1.00
Vermivora pinus	Blue-winged Warbler	1	0.00	0.00						1	0.00
Vermivora peregrina	Tennessee Warbler	205	0.00	0.01	2.00	1	0.00	0.00		206	0.00
Vermivora ruficapilla	Nashville Warbler	83	0.01	0.01	1.00	13	0.08	0.08	1.00	96	0.02
Dendroica pensylvanica	Chestnut-sided Warbler	5	0.00	0.00						5	0.00
Dendroica magnolia	Magnolia Warbler	14	0.00	0.00		6	0.50	0.50	1.00	20	0.15
Dendroica virens	Black-throated Green Warbler	9	0.00	0.00						9	0.00
Mniotilta varia	Black-and-White Warbler	13	0.08	0.08	1.00	4	0.25	0.25	1.00	17	0.12
Helmitheros vermivorus	Worm-eating Warbler	8	0.13	0.13	1.00	2	0.50	1.00	2.00	10	0.20
Seiurus aurocapillus	Ovenbird	13	0.08	0.08	1.00	8	0.13	0.13	1.00	21	0.10
Seiurus motacilla	Louisiana Waterthrush					1	1.00	1.00	1.00	1	1.00
Oporornis formosus	Kentucky Warbler					1	0.00	0.00		1	0.00
Oporornis tolmiei	MacGillivray's Warbler	3	0.33	0.33	1.00					3	0.33
Wilsonia citrina	Hooded Warbler	1	0.00	0.00		2	0.00	0.00		3	0.00
Wilsonia pusilla	Wilson's Warbler	38	0.11	0.11	1.00	9	0.33	0.44	1.33	47	0.15
Icteria virens	Yellow-breasted Chat	2	0.50	1.00	2.00	1	1.00	2.00	2.00	3	0.67
Piranga ludoviciana	Western Tanager	5	0.00	0.00						5	0.00
Pheucticus ludovicianus	Rose-breasted Grosbeak	20	0.00	0.00		12	0.42	0.42	1.00	32	0.16
Passerina cyanea	Indigo Bunting	13	0.23	0.23	1.00	2	0.50	0.50	1.00	15	0.27
Passerina ciris	Painted Bunting	1	0.00	0.00						1	0.00
Migrant Totals/Averages		539	0.10	0.16	1.64	94	0.50	1.07	2.15	633	0.16
		13 of 23 species				14 of 16 species				17 of 26 species	

Appendix 1— continued.

Scientific name	English name	Winter 2001 N	Winter 2001 Prevalence	Winter 2001 Mean abundance	Winter 2001 Mean intensity	Winter 2002 N	Winter 2002 Prevalence	Winter 2002 Mean abundance	Winter 2002 Mean intensity	Total N	Total Prevalence
Leptotila verreauxi	White-tipped Dove	3	0.33	0.67	2.00					3	0.33
Campylopterus hemileucurus	Violet Sobering	3	0.00	0.00		2	0.00	0.00		5	0.00
Abeillia abeillei	Emerald-chinned Hummingbird	2	0.00	0.00						2	0.00
Amazilia candida	White-bellied Emerald	22	0.00	0.00						22	0.00
Amazilia cyanura	Blue-tailed Hummingbird	42	0.00	0.00		13	0.08	0.08	1.00	55	0.02
Amazilia rutila	Cinnamon Hummingbird	3	0.00	0.00						3	0.00
Atthis ellioti	Wine-throated Hummingbird	1	0.00	0.00						1	0.00
Momotus momota	Blue-crowned Motmot	2	0.50	1.00	2.00					2	0.50
Synallaxis erythrothorax	Rufous-breasted Spinetail	2	0.00	0.00						2	0.00
Dendrocincla homocroa	Ruddy Woodcreeper					1	0.00	0.00		1	0.00
Grallaria guatemalensis	Scaled Antpitta					1	1.00	4.00	4.00	1	1.00
Myiopagis viridicata	Greenish Elaenia	1	0.00	0.00						1	0.00
Mionectes oleagineus	Ochre-bellied Flycatcher	4	0.00	0.00		6	0.00	0.00		10	0.00
Zimmerius vilissimus	Paltry Tyrannulet	1	0.00	0.00						1	0.00
Oncostoma cinereigulare	Northern Bentbill	1	1.00	2.00	2.00					1	1.00
Rhynchocyclus brevirostris	Eye-ringed Flatbill	1	0.00	0.00		1	1.00	1.00	1.00	2	0.50
Tolmomyias sulphurescens	Yellow-olive Flycatcher	4	0.25	0.25	1.00	2	0.50	0.50	1.00	6	0.33
Contopus pertinax	Greater Pewee	2	0.00	0.00						2	0.00
Empidonax flavescens	Yellowish Flycatcher					2	1.00	1.00	1.00	2	1.00
Myiarchus tuberculifer	Dusky-capped Flycatcher	4	0.00	0.00						4	0.00
Chiroxiphia linearis	Long-tailed Manakin					2	0.00	0.00		2	0.00
Hylophilus decurtatus	Lesser Greenlet	4	0.00	0.00						4	0.00
Thryothorus maculipectus	Spot-breasted Wren	2	1.00	2.00	2.00					2	1.00
Thryothorus rufalbus	Rufous-and-White Wren	4	0.75	2.25	3.00	4	1.00	3.50	3.50	8	0.88
Thryothorus pleurostictus	Banded Wren	1	0.00	0.00						1	0.00
Thryothorus modestus	Plain Wren	5	0.40	0.80	2.00	2	1.00	3.00	3.00	7	0.57
Troglodytes aedon	House Wren	10	0.80	1.60	2.00					10	0.80
Henicorhina leucosticta	White-breasted Wood-Wren					1	1.00	3.00	3.00	1	1.00

Appendix 1— continued.

Scientific name	English name	Winter 2001 N	Winter 2001 Prevalence	Winter 2001 Mean abundance	Winter 2001 Mean intensity	Winter 2002 N	Winter 2002 Prevalence	Winter 2002 Mean abundance	Winter 2002 Mean intensity	Total N	Total Prevalence
Catharus aurantiirostris	Orange-billed Nightingale-Thrush	4	1.00	2.25	2.25	3	0.67	1.67	2.50	7	0.86
Turdus assimilis	White-throated Robin					7	1.00	2.86	2.86	7	1.00
Turdus grayi	Clay-colored Robin	11	0.27	0.45	1.67	6	0.33	0.33	1.00	17	0.29
Myioborus miniatus	Slate-throated Redstart	3	0.33	0.33	1.00					3	0.33
Basileuterus lachrymosa	Fan-tailed Warbler					3	0.33	0.33	1.00	3	0.33
Basileuterus culicivorus	Golden-crowned Warbler	1	0.00	0.00		3	0.33	0.33	1.00	4	0.25
Basileuterus rufifrons	Rufous-capped Warbler	23	0.09	0.13	1.50	7	0.14	0.14	1.00	30	0.10
Habia rubica	Red-crowned Ant-Tanager	1	0.00	0.00		5	0.00	0.00		6	0.00
Piranga leucoptera	White-winged Tanager	5	0.20	0.20	1.00					5	0.20
Euphonia hirundinacea	Yellow-throated Euphonia					1	0.00	0.00		1	0.00
Cyanerpes cyaneus	Red-legged Honeycreeper	6	0.17	0.17	1.00					6	0.17
Diglossa baritula montana	Cinnamon-bellied Flowerpiercer	1	0.00	0.00						1	0.00
Melozone biarcuatum	Prevost's Ground-Sparrow	3	0.00	0.00		1	1.00	1.00	1.00	4	0.25
Melozone leucotis	White-eared Ground-Sparrow					2	0.50	1.00	2.00	2	0.50
Resident Total/Average		182	0.17	0.33	1.94	75	0.39	0.87	2.24	257	0.23
Grand Total/Average		721	0.12	0.20	1.75	169	0.45	0.98	2.18	890	0.18
		14 of 33 species				15 of 23 species				24 of 44 species	

A New Conservation Partnership: Conserving the Migratory Birds of the Americas[1]

Jack C. Capp[2] and David Mehlman[3]

Introduction

Over five billion birds move each year across the Americas, flying great distances over almost every location and habitat on the continents (Weidensaul 1999). Over 350 of the over 800 bird species in the United States migrate each year to Latin America and the Caribbean (Degraaf and Rappole 1995). Some fly each way over 4000 miles, chasing the seasons across oceans and continents (Weidensaul 1999). In addition, migratory birds are very important to Americans. Over 75 million Americans participate in bird watching, photography, hunting, nature study, and feeding. These Americans support businesses and communities by spending over $28 billion each year on these activities (U.S. Department of Interior 1997). Bird watching is the fastest growing outdoor activity currently in the United States (Cordell and Herbert 2002). Migratory birds are also critical in sustaining cultures (Jorgensen 1995).

Migratory bird species and their habitats are declining worldwide (Birdlife International 2000) Over half of the 350 plus migratory species in North America show a declining trend, such as the Cerulean Warbler (*Dendroica cerulea*), which has declined at a rate of 4.2 percent/ year during the period 1966-2000 (Hamel 2000, Sauer et al. 2001). Only about 54 percent of the original forest of Central America and the Caribbean remain today (World Resources Institute 2000). The human population of Latin America and the Caribbean likely will increase by at least 50 percent by the year 2050 (United Nations 1992).

For many of these species that are declining in numbers, habitat loss outside of the United States is a significant cause of population decline. For these species, conservation efforts in the United States may not be enough to sustain the species. It is increasingly clear we must pay much more attention to bird conservation in Latin America and the Caribbean if we are to conserve those migratory birds so important to Americans. If we do not invest in conservation outside the United States, we likely will lose the millions of dollars we have invested in bird conservation here at home.

The Nature Conservancy (TNC) and the USDA Forest Service International Programs (IP) formed a new conservation partnership to help conserve the migratory birds of the Americas. TNC's Migratory Bird Program was already well established as a very successful bird conservation program in the Americas, with projects throughout North America, Latin America and the Caribbean. The IP was building its migratory bird conservation program using the diverse conservation experience and partnership skills found throughout the USDA Forest Service (Watson and Capp 2001). This includes staff from State and Private Forestry, Research and Development, National Forest Systems, and IP branches of the Forest Service. IP leverages these skills around the world for conservation work and partnered with TNC for international bird conservation work.

The partnership has eight goals:

1. **Conserve and sustain the migratory birds of the Americas.** Part of this goal, as a working principle, is that our migratory bird conservation will help conserve the biodiversity of the Americas.

2. **Prioritize our work on species most at risk.** There is urgency for conservation of migratory birds and little time to waste on lower priorities.

3. **Apply the research and management skills and experience of our two organizations.** We have highly skilled and experienced conservationists with diverse inter-disciplinary skills in science, management, education, community relationships, and partnership building.

4. **Be engaged on the ground and in the field.** Funding for field personnel and field projects are very important.

5. **Encourage and form new partnerships.** We will emphasize collaboration with conservation organizations and local communities in other countries.

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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6. **Emphasize building stronger conservation capacity in other nations.** This is accomplished through training, education, and interactions with United States conservationists.

7. **Maintain a strong science base for all of our work.** We will continue to strengthen our science base through the application of the best applicable techniques in research and monitoring.

8. **Work where bird conservation is needed most.** We will link our work in other countries with bird conservation work in the United States based on the shared migratory species and habitats of highest concern.

Prioritizing Our Work

We reviewed species lists from established North American bird conservation plans and initiatives. These included species listed under the U.S. Endangered Species Act, the List of Species at Risk in Canada, high priority species on the Partners in Flight Watch List (Pashley et al. 2000), North American Waterfowl Management Plan, North American Waterbird Conservation Plan (Kushlan et al. 2002), and the U.S. Shorebird Conservation Plan (Brown et al. 2001). The latter four plans identified species of most concern or most in need of conservation attention.

Next, we needed to identify areas of Latin America and the Caribbean where our bird conservation work could be focused for the greatest conservation benefit. To do this, we utilized the end products of TNC's ecoregional planning process (Groves et al. 2000), which provides extremely valuable information for prioritizing our work by identifying priority conservation areas based on species and biodiversity richness, occurrence of migratory and endemic species, and critical bird migration concentration points. Using the list of critically important conservation areas determined by the process, we identified which of our priority bird species utilized which of the priority conservation areas.

Conservation Themes and Strategies

We established four conservation themes to guide our partnership: restricted range neotropical migrants, high priority migrant corridors, shortgrass prairie birds, and migratory shorebirds. These themes represent combinations of species and sites that share common threats and conservation concerns. For each theme, we identified a set of priority migratory bird species that enabled us to focus on critical habitats where our conservation work would be accomplished.

We then conceptualized practicable conservation strategies to plan and deliver migratory bird conservation work at these priority conservation areas. To accomplish this, we began by identifying important factors in successful bird conservation in Latin America and the Caribbean. We identified seven factors: ecoregional planning, avitourism, invasive species, community-based conservation, sustainable agriculture, ecological fire management, and monitoring.

Ecoregional planning forms the scientific, landscape, and priority setting foundation. Avitourism can be a powerful economic force for bird conservation. Invasive species often degrade migratory bird habitats. Community-based conservation that generates support for conservation is a well-understood, effective, and often-used conservation strategy in much of Latin America and Caribbean. Agriculture greatly affects bird habitats. Fire is a major habitat determinant in most of Latin American and the Caribbean and must be understood ecologically. Monitoring of bird populations and habitats is critical to measuring the success of conservation projects.

To target our work for years 2002 and 2003, we decided to focus on three strategies (ecoregional planning, ecological fire management, monitoring) and three themes (restricted range migrants, high priority migrant corridors, shortgrass prairie birds) for our partnership. For each combination of theme and strategy, we developed a conservation project to implement bird conservation at one or more sites or geographic regions to benefit one or more high priority species. These conservation projects are described below, along with their theme, strategy, focal species, and geographic scope.

A Research and Training Program for the Conservation of Wintering Kirtland's Warbler and Associated Species in the Bahamas

- Bird Conservation Theme: Restricted Range Migrants
- Bird Conservation Strategy: Monitoring
- Focal Species: Kirtland's Warbler
- Geographic Scope: Bahamas archipelago

The Kirtland's Warbler (*Dendroica kirtlandii*) is listed as Endangered under the U.S. Endangered Species Act. Millions of dollars have been spent on its recovery in the United States. It spends the breeding season in a small area of northern Michigan and the non-breeding season in the Bahamas. The Kirtland's Warbler Recovery Plan lists new information on the non-breeding range as the number one priority information

need. Our partnership project in the Bahamas will build skills of Bahamian scientists and managers in bird census and habitat measurement techniques. The project will also determine a variety of demographic and condition information for the warbler, including: site fidelity, body condition, over-winter survival, habitat use, and foraging behavior. In the spring of 2002, project personnel sighted and banded multiple Kirtland's Warblers on the island of Eleuthera. Preliminary data were obtained on habitat types, food resources, and co-occurring migrant birds on the island of Andros.

Establishment of an International Partnership as a Conservation Strategy for the Bicknell's Thrush and other Neotropical Migrants in the Dominican Republic

- Bird Conservation Theme: Restricted Range Migrants
- Bird Conservation Strategy: Monitoring
- Focal Species: Bicknell's Thrush
- Geographic Scope: Dominican Republic

The Bicknell's Thrush (*Catharus bicknelli*) may be declining in numbers, has a restricted breeding range, occurs in habitat that is threatened in both breeding and wintering seasons (Rimmer et al. 2001), and is listed as Extremely High Priority on the Partners in Flight Watch List (Pashley et al. 2000). Very little is known about the non-breeding range of this species on the island of Hispaniola, except for some high quality research from the Dominican Republic (DR). Studies are in progress on the breeding and non-breeding range by the Vermont Institute of Natural Science (Rimmer et al. 2001).

Our partnership project in the DR will train Dominicans in bird census, monitoring, and habitat mapping as well as determine a variety of thrush demographic attributes. A partnership agreement and an action plan have been completed among the Dominican government, IP, U.S. Agency for International Development, Dominican non-governmental conservation organizations, and TNC. Dominican conservationists have visited breeding season habitats and study sites in Vermont. USDA Forest Service and TNC conservationists have visited non-breeding season habitats in the DR. TNC and its partners in the DR have mapped the locations and density of migratory birds and protected areas in the DR. It is clear that protected areas will play the key role in conservation of the Bicknell's Thrush and other birds in the DR.

Conserving Grassland Bird and Prairie Dog Habitat in Northern Mexico

- Bird Conservation Theme: Shortgrass Prairie Birds
- Bird Conservation Strategy: Monitoring
- Focal Species: North American Great Plains grassland endemic birds
- Geographic Scope: Northern Mexico

North America's Prairie, the continent's largest biome, is arguably the most threatened. The shortgrass prairie has been severely altered with comparable impacts on the migratory birds that spend the breeding season there. Many shortgrass prairie bird species are in decline in all or parts of their ranges, including the Ferruginous hawk (*Buteo regalis*), Mountain Plover (*Charadrius montanus*), Sprague's Pipit (*Anthus spragueii*), and Burrowing Owl (*Speotyto cunicularia*) (Degraaf and Rappole 1995). Conservationists have been addressing these declines in the United States and Canada, but much less work is occurring in the arid grasslands of Mexico where most of these species spend the winter.

Our partnership, through the Prairie Wings Program of TNC, is helping design and implement conservation projects in two of the most critical grassland bird wintering areas in Mexico: the Saltillo Grasslands in the States of Nuevo Leon and Coahuila, and the Janos Grasslands in the State of Chihuahua. To accomplish the conservation goals at this site, we are assisting our conservation partner Pronatura Noreste in developing a management plan for the Saltillo Grasslands Protected Area, conducting bird inventories and monitoring in the Janos Grassland, and linking United States and Mexican field bird conservationists and their field projects.

Developing Ecological Fire Management Plans for Mexico

- Bird Conservation Theme: High Priority Migrant Corridors
- Bird Conservation Strategy: Ecological Fire Management
- Focal Species: Characteristic birds of fire-maintained habitats
- Geographic Scope: Mexico

Many conservation areas in Mexico have identified inappropriate fire regimes as a critical threat to the ecological integrity of their protected ecosystems. Wildland fires have always been part of the cultural

and ecological landscape of Mexico, resulting in biota that is dependent on fire, and land uses where fire is an indispensable tool. Wildfire, however, has been accepted as a serious threat to local communities. As a result, aggressive fire prevention and suppression campaigns have been developed reflecting strong public opinion that all wildfires are undesirable and detrimental. At the same time, natural resource managers recognize the ecological role of fire and the need to plan for and manage, rather than suppress all fires. It is imperative that this expertise is developed soon to enable Mexico to maintain and restore natural fire regimes and assess policies that call for suppression of all fires.

Fire plays a critical role in shaping migratory bird habitats in Mexico. Much of montane Mexico consists of forests and woodlands that are maintained by fire regimes that are poorly understood. Currently, in Mexico, no fire management plans for protected areas have completed or implemented although a few plans for protected areas have been drafted. Bird conservationists in Mexico have a strong interest in understanding the role of fire in vegetation dynamics and getting sites under effective fire management and natural disturbance regimes. Working together, and with Mexican partners, we are addressing:

- Negative impacts of aggressive fire suppression on bird habitats;
- Low public appreciation of ecological role of fire;
- Solutions to threats of wildfire on bird habitats;
- Strengthening Mexico's fire ecology science base;
- Producing practicable/effective fire management plans; and
- Building fire ecology and management capacity in Mexico.

Ecological Blueprints

- Bird Conservation Theme: All
- Bird Conservation Strategy: Ecoregional Planning
- Focal Species: All migrants
- Geographic Scope: Central America, Baja California (Mexico)

A critical product of ecoregional planning is an ecological blueprint. The blueprint serves as a portfolio of sites to conserve the full array of biodiversity, including species, natural communities, and ecological systems of conservation priority. It is initially developed by prioritizing communities and ecological systems, which serve as a "coarse filter" to capture all biodiversity. However, we know that through this process, some species may still not be captured in the portfolio. Therefore, our work plans to add species-level data, with an emphasis on migratory birds, to the base portfolio built on knowledge of communities and systems. Once completed, ecological blueprints guide conservation work throughout a region and help ensure the protection of biodiversity at a large geographic scale. Ecological blueprints thus serve as a foundation for bird conservation planning and targeting.

We are developing two ecological blueprints: one for Central America and one for Baja California, Mexico. While Central America represents only one-half percent of the world's landmass, it contains seven percent of the world's biodiversity. It serves as a major migratory bird migration corridor and habitat during the non-breeding season for migrants from the United States and Canada. Almost 70 species of migratory birds depend on Central America for their existence. For the Central America blueprint, we are constructing a GIS database of species-level biodiversity; providing a data system for future conservation planning and partnerships; incorporating Belize into the Central America portfolio of conservation sites; and including species-level data focusing on endemics, endangered species, and birds.

Scientists and environmental organizations consider Baja California, the Gulf of California, and the near-shore Pacific marine system of Mexico one of the most important regions of the world for conservation efforts. The unique geology, climate and vegetation of Baja California harbor many species and natural communities found nowhere else on earth. Few marine areas in the world have the combination of ecological productivity and biological richness of the Gulf of California and near-shore Pacific Ocean. This region contains extensive and intact coastal and marine ecosystems, including sea grass beds and mangroves, the nurseries of the sea, beaches used by sea turtles for nesting, an archipelago with plants and animals unique in the world, and marine habitat used by many species of whales for breeding and rearing.

During the initial phase of the project, a Conservancy team will review existing conservation priority setting exercises in the region developed by other conservation organizations and academic institutions. The team will analyze this data to identify information gaps and to establish compatibility with the Conservancy's standard planning methodology. Then, in collaboration with academic institutions and other conservation organizations in the region, we will establish conservation targets for the ecoregion, set conservation goals for each target, and select priority conservation areas that will ensure the long-term viability of each target. We

will generate an ecoregional map that highlights the functional conservation areas necessary to protect the biodiversity of the Gulf of California. We will also map current conservation projects in the region to determine gaps in conservation capacity.

Developing Consistent Ecological System Targets to Protect Migratory Bird Habitat in Latin America and the Caribbean

- Bird Conservation Theme: All
- Bird Conservation Strategy: Ecoregional Planning
- Focal Species: All migrants
- Geographic Scope: Latin America and the Caribbean

A critical foundation for ecoregional planning is a standard list and classification hierarchy of ecological systems. To expand ecoregional planning into additional countries in Latin America and the Caribbean where migratory birds spend the non-breeding season, more ecological information must be obtained. At this time, Latin America and the Caribbean do not have a standard classification of ecosystems that allows for comprehensive biodiversity conservation planning at the continental, regional, and local scales. Because the conservation of ecosystem diversity also protects the diverse array of constituent species and the ecological processes that they depend on, ecosystem or vegetation classification units have been often used as targets for conservation. In order to conserve migratory birds and biodiversity, we need a better understanding of how the landscapes can be divided into ecosystems, and not just vegetation types.

For all of Latin America and the Caribbean, we will produce a list of ecological systems, create written system descriptions, and store the resulting data in an information management system. The ecological systems will be mapped from satellite imagery by TNC. This base map will guide TNC's ecological blueprint development in Latin America and the Caribbean. Each ecosystem type will be assessed for importance to migratory birds and biodiversity to help establish conservation targets in each TNC ecoregion and help ensure that needs of birds are incorporated into the selection of ecoregional planning portfolio of conservation sites.

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Current Threats to the Lake Texcoco Globally Important Bird Area[1]

José L. Alcántara[2] and Patricia Escalante Pliego[3]

Abstract

Lake Texcoco was reported as almost dry in the late 1960s, and as a consequence the aquatic life has been considered gone since then. However, the government undertook a reclamation/restoration project in the area beginning in 1971 to help alleviate some of the environmental problems of Mexico City. Although Lake Texcoco was not completely dry in that period, the basin containing the lake had already lost the local forms of the Clapper Rail (*Rallus longirostris*), American Bittern (*Botaurus lentiginosus*) and Black-polled Yellowthroat (*Geothlypis speciosa*). With the restoration project an artificial lake was created (called Nabor Carrillo) with an area of 1,000 ha. The wetlands in total occupy approximately 8,000 ha in the wet season, and half that in the dry season. Both government agencies and students have studied the avifauna of this area for decades but the results are not available. We compiled data from theses and government agencies to establish the importance of the current avifauna of Lake Texcoco and provide an accurate picture of the effect of restoration to the bird populations. This information is of prime importance to evaluate the consequences of constructing a new airport within the boundaries of this area, both in terms of conservation and in terms of the security concerns for the airport operations. With the data presented, we will show that Lake Texcoco deserves to be considered as a Globally Important Bird Area because it maintains approximately 100,000 birds that occupy this area every year, among them significant populations of Wilson's Phalarope (*Phalaropus tricolor*), Northern Shoveler (*Anas clypeata*), Ruddy Duck (*Oxyura jamaicensis*), Snowy Plover (*Charadrius alexandrinus*), Killdeer (*Charadrius vociferus*), American Avocet (*Recurvirostra americana*), Black-necked Stilt (*Himantopus mexicanus*), and Solitary Sandpiper (*Tringa solitaria*).

Key words: airport, IBA, Lake Texcoco, multi-species conservation, restoration, waterfowl.

Introduction

Lake Texcoco is located in central Mexico, approximately 23 km east of Mexico City, between 19° 25' and 19° 35' North latitude and 98° 55' and 99° 03' West longitude, with an average altitude of 2,200 m. This body of water is a remnant of an ancient lake that covered most of the Valley of Mexico, a large, elevated valley (a closed hydrologic basin) surrounded by high mountains in the Central Mexican Plateau. Because the basin lies on the 19º parallel, it intersects with the Transversal Volcanic Axis, also called the Neo-Volcanic Axis (a line of volcanoes that extends across Mexico in an east-west direction.) The basin has the approximate form of an irregular rectangle inclined in NE-SW direction, with length over 120 km and less than 80 km in average, it has an approximate surface of 7,500 km² (Alvarez 1977).

Lake Texcoco is located in the central flyway for migratory waterfowl. The myriad of small lakes spread through the highlands of central Mexico were and still are important stopover and wintering grounds for several species of waterfowl and wading birds, as well as the breeding ground for several permanent residents. Pollution, desiccation, and urban sprawl are just some of the factors that have caused severe habitat degradation, a process in practically all of the Mexican highland lakes. Unfortunately, there is no assessment of how such habitat degradation has affected avian populations, but there is strong evidence that a serious loss of avian diversity is still under way, at least in Lake Texcoco. Our objectives are to outline the main characteristics and the current condition of Lake Texcoco, as the most important refuge left for migratory and resident waterfowl in the Valley of Mexico, and to point out current threats.

Lake History and Current Situation

During pre-Hispanic times, the Valley of Mexico was a huge marshy zone surrounded by extensive pine and oak forests (Lorenzo and Mirambell 1986). Transformation of the ancient lake started with natural climatic

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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changes (Espinosa 1996). On the other hand, human-made changes probably started with the first civilizations in the area, around 100 B. C. In the late 1300s the Aztec empire was the climax of the pre-Hispanic alterations of the lake through the building of a complex system of aqueducts, bridges and dams, and the practice of intensive wetland agriculture. Finally, the basin has suffered its most radical transformation since the sixteenth century, after the fall of the Aztec empire, with the Spanish Colonial period and culminating in modern Mexico, with the construction of complex hydraulic structures (Alvarez 1977). The ultimate goal of those hydraulic constructions was flood control and drying out of the lakes in order to gain land for human habitation.

It has been assessed that the original lake of the Valley of Mexico had an area of approximately 1,575 km² (Alvarez 1977). The limits of Lake Texcoco never have been fixed. With the arrival of the Europeans, the largest lake in the Valley of Mexico at that time (the so called Lake Mexico-Texcoco) was still more than 10 meters deep in some places and had a surface area greater than 700 km². By 1864, only 15 percent (approximately 230 km²) remained of the original surface, and by 1891 only 95 km² (6 percent) remained. Towards the end of the 1950s, the lake could reach a surface area of up to 100 km² when there were abundant rains; but in the dry season it was reduced to a few ponds, although it is said that the lake covered some 270 km² at that time (Rzedowski 1957). Recently, of the former extensive lacustrine zone, there are just three vestiges. In order of importance they are: (1) Lake Texcoco, of very salty and alkaline water, whose size varies largely according to the season and from year to year, (2) Lake Zumpango, with a maximum surface of approximately 15 km² of moderate salinity, and (3) a network of canals of fresh water in Xochimilco, and a smaller one near Mixquic (both neighborhoods of Mexico City), that are kept artificially filled for tourism.

Plan Lake Texcoco

By the end of the 1960s and beginning of the 1970s, Lake Texcoco had practically disappeared. Because of the extreme salinity of the soil, for the most part no terrestrial vegetation grew. Additionally, urban wastewaters were poured into the area. Thus, during the dry season winds carried out dust from the desolate old dried lakebed all over Mexico City; such dust storms caused serious gastrointestinal diseases among the city's population. On the other hand, attempts to control flooding, changes in watershed land uses, and increased water use resulted in drastic changes in the hydrology of the basin. Thus, during the rainy seasons there were no adequate control of local water flows, and floods occurred in the nearby city. As a consequence, in 1971 the Mexican government started a restoration project for the Lake Texcoco zone in order to ameliorate the environmental problems of Mexico City caused by the degraded area (Cruickshank 1994).

Plan Lake Texcoco was a set of programs to diminish the effects of erosion, water pollution, etc. This program represents the first successful environmental restoration model in Mexico and, in the words of its main architect, Gerardo Cruikshank (1994); Lake Texcoco has become again the most important refuge for wintering migratory aquatic birds in the Valley of Mexico.

The total area that currently encompasses the Lake Texcoco restoration plan is 11,600 ha. The project included the hydrologic management of the area and resulted in the building of a complex system that included the creation or restoration of a dozen artificial or semi-natural lakes. The most important of those is Nabor Carrillo, with an area of 1,000 ha and a maximum depth of 3.5 m.

Avian Diversity in the Valley of Mexico

Loss and Gain of Diversity

There are numerous historical accounts and archeological evidence of the importance of the birds of Lake Texcoco for the local cultures. In fact, the lake was a representative example of what some authors have called an 'inextricable link' between biological and cultural diversity (Espinosa 1996, Posey 1998). Nevertheless, scientific accounts of the avifauna of the Valley of Mexico did not start until the end of the 19th and beginning of the 20th centuries.

One of the main consequences of the implementation of the lake reclamation project was the remarkable increase of diversity of both resident and migratory bird species. The return of numerous bird species (previously common and widespread on the area) was, of course, the direct consequence of changes in habitat availability; that is, the re-establishment of permanent water bodies, temporary pools, cattail, marshes, and patches of woods.

More than 30 studies have been done on the avifauna of Lake Texcoco, but most are unpublished, mainly as research theses or governmental reports (Villada 1883, Herrera 1888, Villada 1897, Madrigal and Hernández 1968, Halfter and Reyes 1975, Leopold 1977, Babb et al. 1982, Chávez and Huerta 1985, Chávez et al. 1986, Wilson and Ceballos-Lascurain 1993, González 1995, Bojorges 1997, González et al. 2000.) Our review of most of those documents allows us to determine that more than 200 bird species have been recorded for the lake or nearby areas. Of these, two species have been

recorded only as fossils, and are already extinct, and 24 can by now be considered as historical records (i.e., species not seen on the area since 1970). Of all species recorded, 57 percent are aquatic and 43 percent terrestrial, although some of the latter are species associated with wetlands. Of the total, 21 species have been recorded only as accidental or occasional for the area. Currently, 178 species of birds corresponding to 16 orders and 46 families can be found in the Lake Texcoco area (*table 1*). In a recent study of only Lake Nabor Carrilo, Meza (2000) found fewer species.

Table 1— *Number and status of bird species recorded in Lake Texcoco area. Consejo Internacional para la Preservación de las Aves, Sección México's (CIPAMEX) literature review includes records from various wetlands within the Valley of Mexico but outside the Lake. Meza (2000) includes records only from Lake Nabor Carrillo.*

Status	CIPAMEX	Meza (2000)
Permanent resident	37	45
Winter resident	64	37
Summer resident	2	2
Transient	19	11
Accidental/escaped	23	2
No data	33	n/a
TOTAL	178	97

Most of the species recorded at Lake Texcoco are rare, and less than 15 percent are either very abundant or abundant (*fig. 1*). Nevertheless, the desiccation of the lake with its severe habitat reduction and alterations has resulted in a big loss of biological diversity in general and of birds in particular. Almost 20 bird species have been extirpated from the Valley of Mexico before 1970 because of habitat alterations (*table 2*). In addition, local forms of two species (i.e., Clapper Rail [*Rallus longirsotris tenuirostris*] and Black-polled Yellowthroat [*Geothlypis speciosa*]) and a breeding population of American Bittern (*Botaurus lentiginosus*) had been wiped out from the area as well.

Waterfowl Population Trends

U.S. Fish and Wildlife Service Aerial Surveys

In the 19th century, more than half a million ducks were killed annually by hunters in the Valley of Mexico in the lakes of the area (Herrera 1890). Then, since the first decade of the 20th century, particularly between 1911 and 1945, the attempts to dry out Lake Texcoco increased (Arellano and Rojas 1956, Rzedowski 1957). In the 1950s, nevertheless, several ponds still existed in the Eastern portion of ex-Lake Texcoco, that, in spite of fluctuations in their degrees of dryness through the year, remained sufficiently wet to allow the existence of aquatic vegetation and its associated fauna.

The first significant attempt to study the birds of the lacustrine zones of the Valley of Mexico during the first half of the 20th century was 1948, when the U.S. Fish and Wildlife Service began winter aerial censuses of the aquatic birds of Mexico, including Lake Texcoco (Smith and Jensen 1955, cited in Arellano and Rojas 1956; Smith et al. 1960; Smith et al. 1962; Hanson and Pospichal 1965; Hanson and Smith 1970; Benning and Hanson 1977; Leopold 1977).

Table 2— *Bird species extirpated from the Valley of Mexico before 1970.*

Common name	Scientific name
Common Loon	*Gavia immer*
Horned Grebe	*Podiceps auritus*
Double-crested Cormorant	*Phalacrocorax auritus*
Anhinga	*Anhinga anhinga*
Roseate Spoonbill	*Ajaia ajaja*
Wood Stork	*Mycteria americana*
Greater White-fronted Goose	*Anser albifrons*
Canada Goose	*Branta canadensis*
Wood Duck	*Aix sponsa*
Ring-necked Duck	*Aythya collaris*
Bufflehead	*Bucephala albeola*
Hooded Merganser	*Lophodytes cucullatus*
Cooper's Hawk	*Accipiter cooperii*
Great Black-Hawk	*Buteogallus urubitinga*
Swainson's Hawk	*Buteo swainsoni*
Gray-necked Wood-Rail	*Aramides cajanea*
Sandhill Crane	*Grus canadensis*
Ringed Kingfisher	*Ceryle torquata*
Common Raven	*Corvus corax*

An inspection of the censuses conducted between 1951 and 1965 (*fig. 2*) indicates an enormous fluctuation in the number of waterfowl from approximately 63,000 individuals in 1955 to only three Northern Shovelers (*Anas clypeata*) in 1963. According to Saunders and Saunders (1981), the average number in the period was around 39,000 waterfowl. According to these authors, that represented 7.3 percent of the total average of waterfowl over all the Mexican Plateau. The maximum number of individuals for a species in a given year was for Green-winged Teal (*A. crecca carolinensis*) with 30,500 individuals in 1955.

Total numbers of waterfowl counted on each winter census were 57,540 individuals in 1952, 62,850 during 1955 (both years with eight species), 57,800 for the 1959 winter, 29,645 in 1960, whereas during the 1962 only three Northern Shoveler were seen, a year that severe drought made the Lake practically disappear. In 1965 the winter census gave a count of only 525 individuals, later reduced to 400 in 1970, the last year in which these censuses took place in Lake Texcoco.

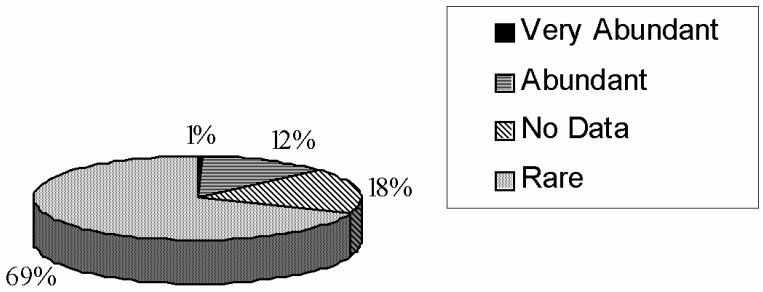

Figure 1— Lake Texcoco bird species by abundance categories. [Note: relative abundances were determined from CNA censuses, abundance categories based on Robbins et al. 1983. A guide to field identification, birds of North America (L. Gonzalez, pers. comm.)].

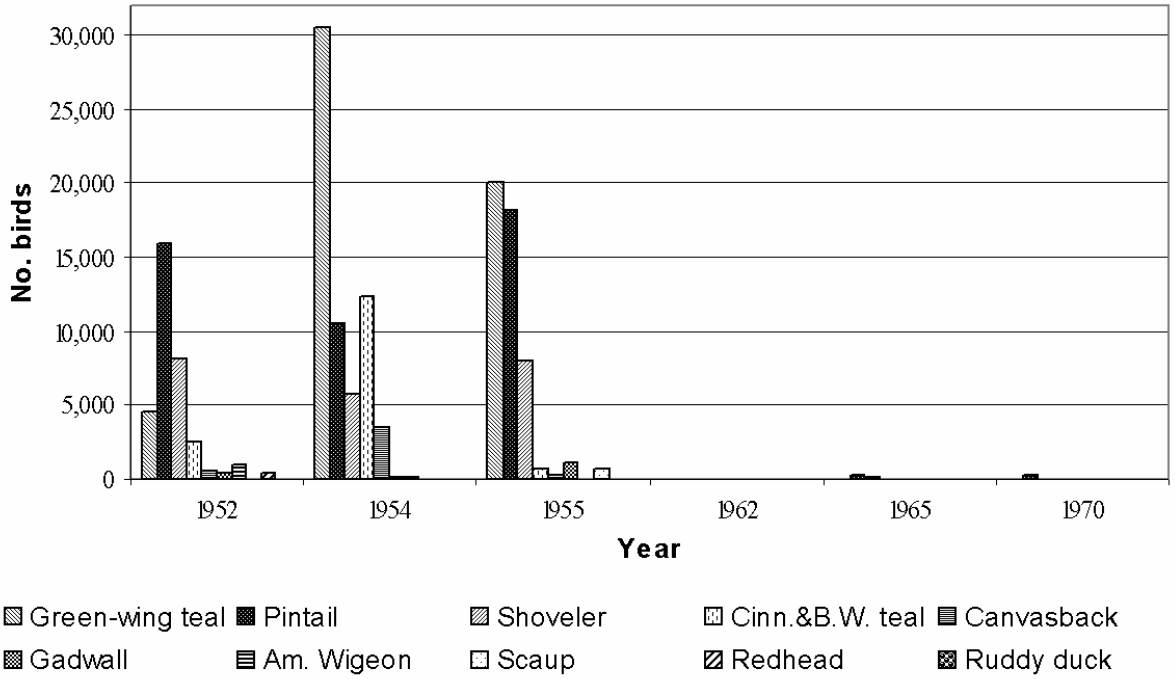

Figure 2— U.S. Fish and Wildlife Service - Lake Texcoco aerial surveys.

National Water Commission aquatic bird surveys

The recovery of the Lake resulted in a mosaic of different environments and the reestablishment of diverse populations of birds, characteristic of the old lacustrine zone of the Basin of Mexico (Cruickshank 1994). The censuses made by personnel of the Lake Texcoco Program (now under the Mexican National Water Commission, CNA by its Spanish acronym) during the last 16 years, document the presence in the zone of more than 150 species of birds. Considered as a whole, the population numbers including all the individuals of all the aquatic species have fluctuated between 100,000 and 150,000, reaching a maximum of 350,000 (*fig. 3*).

Consequently, the importance of this area for biodiversity in general, and for birds in particular, has been widely recognized. For example, in 1971 the Mexican Secretary of Environment and Natural Resources (SEMARNAT) has considered Lake Texcoco as a "special region" which led to the implementation of Plan Texcoco. The Mexican ornithological and conservationist organization, Consejo Internacional para la Preservación de las Aves, Sección México (CIPAMEX), declared the lake in 1996 as an Important Bird Area (IBA) (Arizmendi and Márquez 2000). The World Wildlife Fund has also identified Lake Texcoco as one of the Mexican highland lakes in need of urgent conservation. Finally, the Mexican National Commission for Awareness and Use of Biodiversity (CONABIO) recognizes the designation of Lake Texcoco as an IBA and considers it as part of its program High-priority Hydrologic Region under the category of threatened region (see http://conabioweb.conabio.gob.mx/aicas/doctos/aicas.html).

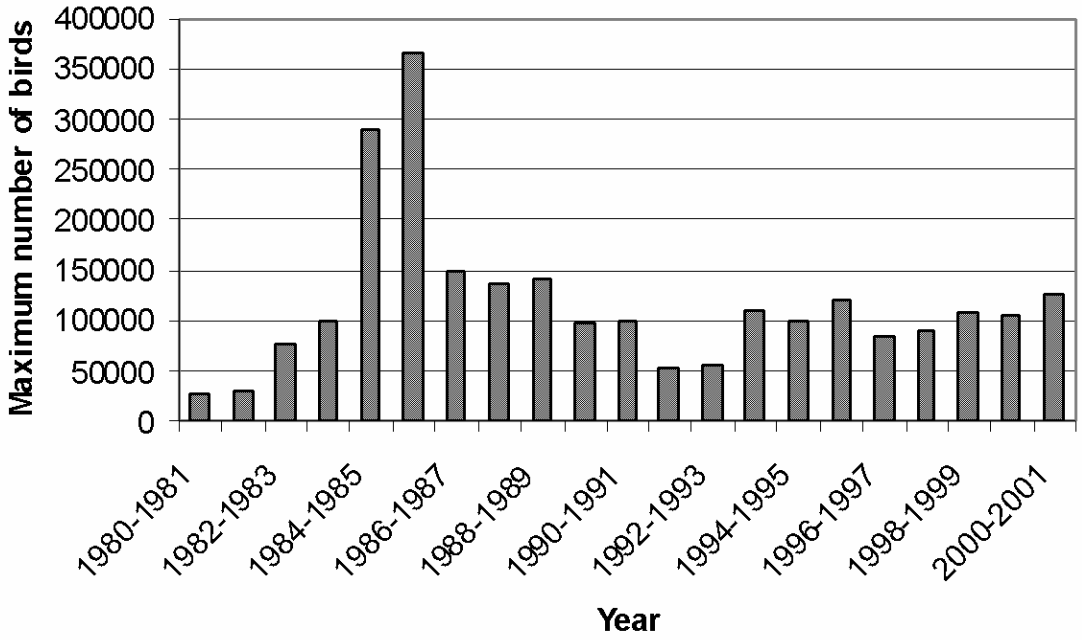

Figure 3— Comisión Nacional del Agua (CNA) aquatic bird censuses.

Table 3— *Population numbers that qualify Lake Texcoco as a Continental and Globally Important Bird Area.*

Scientific name	Common name	Maximum number of individuals registered in year 2000	1% population in the Americas (D. Wege[1] and A. Estrada, pers. comm.)	1% population Central flyway (Morrison 2001)
Phalaropus tricolor	Wilson's Phalarope	66,271	15,000	8,271
Anas clypeata	Northern Shoveler	56,300	20,000	
Oxyura jamaicensis	Ruddy Duck	17,796	6,800	
Charadrius alexandrinus	Snowy Plover	122	160	71
Charadrius vociferus	Killdeer	676	10,000	394
Recurvirostra americana	American Avocet	4,479	4,500	3,253
Himantopus mexicanus	Black-necked Stilt	1,673	1,500	1,200
Tringa solitaria	Solitary Sandpiper	235	250	56

[1]Numbers from Wege for shorebirds were also taken from Morrison (2001); those for waterfowl from Rose and Scott (1997).

More recently, the compilation of unpublished census bird data led to the realization that there are population levels of several bird species that qualify Lake Texcoco as a Continental and Globally Important Bird Area (*table 3*). Lake Texcoco deserves to be preserved as a wildlife refuge because it maintains regularly approximately 100,000 aquatic birds, among them significant proportions of Wilson's Phalarope (*Phalaropus tricolor*), Northern Shoveler, Ruddy Duck (*Oxyura jamaicensis*), Snowy Plover (*Charadrius alexandrinus*), Killdeer (*Charadrius vociferus*), American Avocet (*Recurvirostra americana*), Black-necked Stilt (*Himantopus mexicanus*), and Solitary Sandpiper (*Tringa solitaria*).

Current Threats

Being part of a city that has the largest urban population in the world living in a closed hydrologic basin, Lake Texcoco and its avifauna are in constant threat. The most important of those are:

- Feral dogs: a number of feral dogs proliferate in the area. There is no control or study of the impact of these animals on the avifauna. Most likely dogs have an effect on breeding birds.

- Pollution: Lake Texcoco still receives urban sewage and although most of the artificial lakes are filled with treated water (i.e., primary and secondary-treatment water), some

areas still have untreated water with unknown impact on the health of birds that feed in them.

- Hunting: although hunting is not allowed in the Valley of Mexico, poaching is still a common practice in the most remote areas of the lake, where there is little control. Trapping of live birds also seems to be a regular practice. The magnitude and effect of these activities on the conservation of waterfowl are unknown.

- Urban sprawl: there are constant attempts to establish irregular slums. The area encompassing the Lake Texcoco project is surrounded by inner city neighborhoods and ghettos and some semi-rural small towns (in total about 50 townships).

- A Sanitary Garbage Burial Field was established within Lake Texcoco that receives 11,000 tons of garbage from the metropolitan area and a proposal to extend it has been launched recently.

- International Airport: Mexican authorities announced that the Texcoco lakebed would be the site for construction of a new airport for Mexico City.

A New Airport, the Greatest Threat

In October 2001, Mexican authorities announced that Mexico city's new international airport would be build on the dry lakebed of Lake Texcoco, at a distance of 16 km (straight line) and 18 km by terrestrial routes from the present airport. This new terminal would meet the needs of a growing air traffic, which is expected to increase from 21 million passengers in 2000 to 29 million annually by 2005. The $2.5 billion dollar project is expected to be completed in about six or seven years.

Proponents of establishing the new airport in Lake Texcoco argue that the effect on bird populations would be small because:

- The area represents a degraded ecosystem.

- The area has no status as a Natural Protected Area.

- It is not recognized as a Ramsar international important wetland.

- It is proposed that the project increase the protected area for waterfowl by 3,500 ha (including the construction of two new artificial lakes).

- There are no endemic species that will be affected, only eight are threatened, six under special protection, and just one is considered rare (and not found in their census).

- They allege that Lake Texcoco harbors only 11 percent of the total number of birds that arrive to the Valley of Mexico.

Conservation, the Best Option

Data gathered through more than 30 years by biologists and ornithologists working in Lake Texcoco are of prime importance to evaluate the consequences of constructing a new airport within the boundaries of this area, both in terms of conservation and in terms of the security concerns for the airport operations.

Such information suggests that the construction of the airport in the lake would be adverse because:

- A restored ecosystem has conservation value both for humans and wildlife, and Lake Texcoco is a clear example.

- The current national network of natural protected areas (Sistema Nacional de Áreas Naturales Protegidas) does not meet even at minimum the conservation needs of Mexican biodiversity.

- In fact, the lake meets Ramsar standards, as their norms are that any area that contains at least 1 percent, or 20,000 individuals, of a species' regional population could be considered an international important wetland (Owen and Black 1990), Lake Texcoco meets such criteria for several bird species.

- The conservation value of an area goes beyond the number of endemics or single-species considerations.

- Monitoring of the area for more than 15 years has given figures of 100,000-150,000 aquatic birds wintering each year in Lake Texcoco, far more than the 11 percent of the birds wintering in the Valley of Mexico (the latter is based on 10 one- or two-day census carried out in five years). In addition, there are no population data for more than 60 bird species.

- The claim of a 3,500 ha increase in the restored area of Lake Texcoco is flawed because there is no land available in the region for such a purpose. Lately, governmental con-

fiscation of agricultural land has produced local social unrest.

- Three parallel runways will be built in the middle of the shorebirds' breeding area, which will have a detrimental effect on resident populations. So far, there has not been any mention of any mitigation or translocation programs.

- Aircraft safety will likely be jeopardized because of the large numbers of waterfowl; a vast literature supports the principle that "birds and aircraft do not get along."

Acknowledgments

We are grateful to V. Nequiz Castillo and E. Diaz who facilitated the work and for their assistance with the literature search for this paper. We would also like to thank L. A. González Olvera and G. López Santiago for sharing their unpublished data on Lake Texcoco, and to E. Cortes for guiding the senior author within the area of study.

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Two Species in One Ecosystem: Management of Northern Bobwhite and Red-cockaded Woodpecker in the Red Hills[1]

R. Todd Engstrom[2, 3] and William E. Palmer[2]

Abstract

Sport hunting for Northern Bobwhites (*Colinus virginianus*) is the reason that approximately 300,000 acres of semi-wild lands still exist in the Red Hills region of north Florida and south Georgia. Use of fire for management and relatively large (400 to 4,000 ha), contiguous land ownerships permitted populations of bobwhite and Red-cockaded Woodpecker (*Picoides borealis*) to persist in the Red Hills as regional populations of these two species declined precipitously. Three factors play important roles in the habitat shared by these species: canopy cover, canopy tree species composition, and ground cover composition. These factors affect quality of fuel, which influences the occurrence of fire (ecological stability) and the costs of land management (economic stability). We used simple habitat models for these species to examine tradeoffs that optimize habitat conditions for each species. Maintaining conditions that enable healthy populations of both species to co-exist into the 21st century will require innovative management tools, including habitat restoration, and serious interest in conservation within the community of landowners.

Introduction

Hunting estates have protected some of the finest examples of relatively undisturbed ecosystems in the world. For example, Bialowieza National Park, hunting grounds of the czar of Russia in eastern Poland, has extremely rare European old-growth deciduous and pine forests (Agrawal 2000). Likewise, the Hluhluwe-Umfolozi National Park in northeastern South Africa was the personal hunting area for Shaka, king of the Zulus (MacKenzie 1997). Protection from heavy exploitation of timber resources and development of agricultural systems for the purpose of hunting is the reason that these regions were preserved. The Red Hills physiographic region of north Florida and south Georgia in the United States has the potential to be another such ecological preserve, albeit one that will likely continue to be privately owned.

Several studies have shown that bird species common to open-structured, upland pinelands in the Southeast, including the Northern Bobwhite, benefit from restoration efforts to improve habitat for the endangered Red-cockaded Woodpecker (Askins 1993, Brennan et al. 1995, Wilson et al. 1995, Plentovich et al. 1998, Masters et al. 2002). The most important habitat restoration technique is removal of mid- and over-story hardwood trees, which permits more light to reach the ground and increases growth of herbaceous groundcover plant species, and facilitates use of prescribed fire. However, no two species have exactly the same habitat requirements. It is possible to maintain good habitat for Red-cockaded Woodpeckers that supports relatively few Northern Bobwhites, while excellent habitat for bobwhite may be completely unsuitable for the woodpecker. The current reason for existence of many of the plantations in the Red Hills is production of populations of Northern Bobwhites for hunting. We explore the point at which habitat that is suitable or excellent for bobwhite is no longer suitable for Red-cockaded Woodpeckers. We propose that management for both species is better than management for bobwhites alone, because Red-cockaded Woodpecker life history characteristics introduce ecological features that enhance ecosystem resilience and stability.

The Red Hills

Hunting estates comprise approximately 1,220 km^2 within the 2,400 km^2 Red Hills physiographic region (*fig. 1a*) (Cox et al. 2001, Ambrose 2001). The pattern of vegetation composition and structure in the Red Hills is a product of natural variation in life history traits of each plant species (Gleason 1926), the history of land use, and natural disturbances, such as hurricanes and fire. Briefly, the history of land use within the Florida portion of the Red Hills is one of agriculture by the native Apalachee farmers and subsequent American settlers. In the decades after the Civil War, Northern industrialists converted many of these properties into hunting preserves (Paisley 1989; pg. 210-211).

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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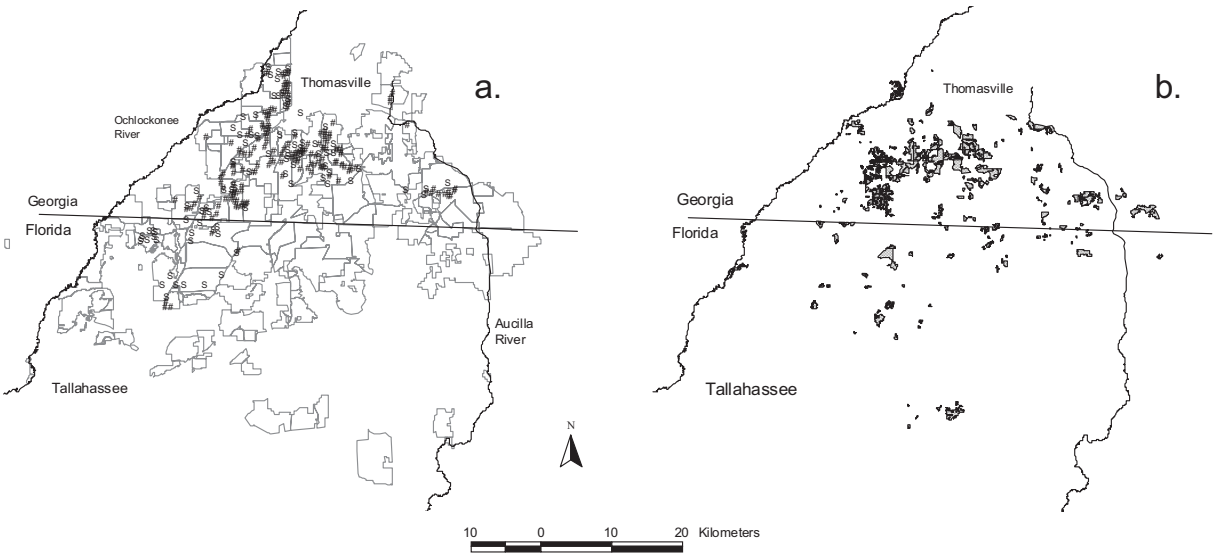

Figure 1— The Red Hills physiographic region between Tallahassee, Florida, and Thomasville, Georgia, is bounded by the Ochlockonee and Aucilla rivers. The Cody escarpment (an ancient shoreline) is the boundary that we use as the southern edge of the Red Hills. Although it is not indicated in this figure, it runs diagonally between the mapped southern endpoints of the rivers. (a) Quail hunting estates are indicated in outline and active Red-cockaded Woodpecker clusters are indicated by solid dots and inactive clusters indicated by open circles. Note: 98 percent of the Red-cockaded Woodpecker population is located in the Georgia portion of the Red Hills. (b) Blocks of relatively undisturbed ground cover within the Red Hills are indicated as polygons (Ambrose 2001).

Patterns of vegetation in northern Florida at the time of early Anglo-European settlement indicate that the Red Hills region was one of the few areas of north Florida in which pinelands were less abundant in relation to upland oaks (*Quercus* sp.) (Schwartz 1994). This may reflect the fact that many of the largest cotton plantations were located in Leon County, Florida, while the largest areas of unplowed land occurred between the Florida-Georgia state line and Thomasville, Georgia (Ambrose 2001). The relatively intact longleaf pine (*Pinus palustris*) wiregrass communities in Thomas County, Georgia, are some of the best remaining examples of mesic longleaf pine woodlands (Means and Grow 1985, Platt et al. 1988, Means 1996, Platt 1999).

Pine-dominated upland vegetation in the Red Hills physiographic area ranges from virtual monocultures of longleaf pine (Platt et al. 1988) to mixtures of "old field" pines, such as shortleaf (*Pinus echinata*), loblolly (*Pinus taeda*), lesser numbers of slash (*Pinus elliotii*) and longleaf pines (Clewell 1980, 1986). One hypothesis that accounts for the distribution of old field pines on sites that are typically dominated by longleaf is that longleaf pine trees were largely eliminated by American Indian and subsequent European settlers' agriculture. Loblolly and shortleaf pines, which are typically found in mesic or transitional dry slopes respectively (Landers 1991), colonized and essentially replaced longleaf as the dominant pine species (*fig. 2*).

Ground cover composition within the pine woodlands also varies from a relatively undisturbed plant community dominated by perennials (Peet and Allard 1995) to a plant community dominated by annuals (Clewell 1986). Ambrose (2001) found that approximately 12,000 ha (5.3 percent) of the least disturbed (i.e., not plowed) patches of vegetation remain within a hypothesized 225,000 ha of pre-agricultural upland forest in a recent inventory of the Red Hills.

Northern Bobwhites and Red-cockaded Woodpeckers

Populations of Northern Bobwhites have declined 70 to 90 percent across much of their range since Breeding Bird Surveys began in the 1960s (Church et al. 1993). Regional loss of habitat from land use changes is considered the main reason for the decline (Brennan 1991). State wildlife agencies in the Southeast have developed a regional plan (Dimmick et al. 2001) to help address long-term habitat declines. In the Red Hills, where populations have been actively managed on a landscape scale, populations are at least stable if not at historical highs on some properties (Brennan et al. 2000).

The Northern Bobwhite is adapted to grassland-shrub vegetation that is periodically disturbed. Suitable habitats for bobwhites in the southeast are diverse and

range from agricultural landscapes to open pine or pine-hardwood forests. Adults and juveniles form mixed family groups from October to April at which time they are largely seedeaters. During breeding season hens and young chicks require an arthropod-rich diet. Bobwhites show ambisexual polygamy and in good habitats individual hens can raise >1 brood per year (Curtis et al. 1993). Despite high productivity rates, population growth can be limited by low seasonal or annual survival rates, and this may be directly related to coverage and quality of the ground cover vegetation in relation to the predator community on an area (W.E. Palmer, pers. obs.).

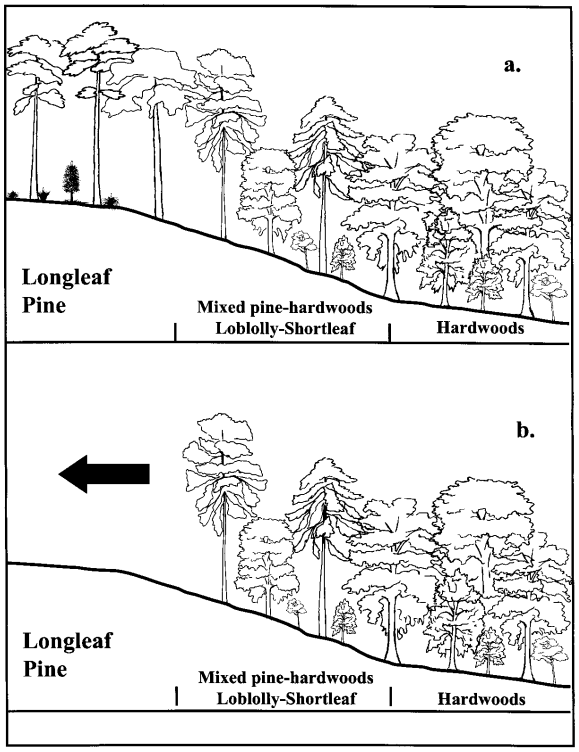

Figure 2— Hypothetical changes in forest composition as a result of clearing for agriculture in the Red Hills physiographic region. Longleaf pine dominated uplands, because it had superior adaptations to frequent fire, but it had relatively poor dispersal ability and was not an effective colonizing species. Loblolly and shortleaf pines are less fire tolerant during the first 5 years after establishment and were largely restricted to ecotones. Following widespread clearing of the uplands for agriculture, loblolly and shortleaf pines rapidly colonized the uplands and effectively replaced longleaf in the uplands.

Bobwhite management in the Red Hills has been refined from a century of research and management (Stoddard 1931). On forested areas typical of the Red Hills, fall densities are greatest (4 to 7 bobwhites/ha) on areas with low timber stocking, typically <14 m^2/ha. While bobwhites persist at low densities (0.25 to 1 bobwhites/ha) in timber stands with greater densities, their populations greatly diminish as ground cover disappears due to shading. Annual and biennial use of prescribed fire is the most important management tool to maintain a grass-shrub ground cover although mechanical and herbicidal treatment of hardwoods is equally important on old-field lands.

The Red-cockaded Woodpecker is a relatively sedentary, cooperative breeding species that lives in upland pine forests in the southeastern United States (Jackson 1994, Conner et al. 2001). Life history requisites are living, old pine trees that are used for nesting and roosting cavities and foraging, widely spaced stems with few hardwoods that provide an open structure, and spatial proximity to other groups within a population to ensure demographic exchange. Recommendations for maintaining an adequate forest structure for Red-cockaded Woodpecker foraging and nesting include: maintaining a minimum of 50 ha of good quality habitat (within 0.8 km of the cavity trees) that is defined as having (1) $\geq$45 pines/ha that are at least 35 cm diameter breast height (DBH) and $\geq$60 years old, (2) a basal area of pines $\geq$10 cm DBH between 9.2 to 18.4 m^2/ha, (3) 40 percent herbaceous ground cover, and (4) a minimal number of hardwoods in the midstory and canopy (U.S. Fish and Wildlife Service 2000). The upper end of the basal area found in recommendation 2 for trees >10 cm DBH may be an underestimate of good habitat conditions (R.T. Engstrom pers. obs.).

The Red Hills has the largest population of Red-cockaded Woodpeckers on private lands, and the sixth largest population overall (James 1995). This is a result of unusual historical factors (i.e., relatively contiguous forested habitat, conservative application of single-tree selection harvest, and regular use of prescribed fire to maintain open habitat conditions), but it also should be seen as an indicator of the intact longleaf pine ecosystem. The woodpecker population has been relatively stable to slightly declining within the past 10 years (Cox et al. 2001). The intact ecosystem can be economically managed for populations of bobwhite, limited timber production, and populations of Red-cockaded Woodpeckers.

Land Management Trends in the Red Hills

Prescribed fire is the most cost-effective way of controlling ground cover composition and structure. Reduction of overstory and disruption of groundcover may interfere with the efficacy of use of fire for management. The relative stability of upland pine ecosystems is strongly dependent on fire to control hardwood competition that will eventually shade pine seedlings and groundcover. The ability to burn the vegetation is

linked to the quality of the fuels. Pine needles and grasses are the principal fuels that sustain fire in this region. Removing pine overstory that provides pine needles and elimination of the most pyrogenic ground cover species will eventually increase the cost of maintaining the open structured forest that both bird species—bobwhite and Red-cockaded Woodpeckers—depend upon.

Canopy Cover

Two principal land management goals—elevating Northern Bobwhite populations and deriving income from timber--drive vegetation manipulation on hunting estates in the Red Hills. These two factors can act synergistically to justify reduction of overstory basal area. Ground-cover vegetation growth and vigor are inversely related to overstory cover because the overstory acts to shade understory plants (*fig. 3*). Therefore, land managers are interested in providing sunlight on the ground to enhance maximal growth of understory plants. Understory vegetation density and composition are critical for Northern Bobwhite because they provide food (e.g., seeds, insects, fruits) and cover from predation. Revenue from timber harvest is typically needed to offset the expenses of maintaining the estates for hunting. Current cost estimates for hunting estate land management range from 1 dollar to 10 dollars per acre per year, depending on ground cover conditions (Moser 2001). These costs cover prescribed fire, use of herbicides, tractor work (mowing, roller chopping, etc.), provision of supplemental foods, and predator control. Another periodic land management activity is removing hardwoods. The net result of hardwood removal can range from a loss to a gain for the landowner depending on the quality, quantity, and market value of trees removed. Habitat quality on the single axis of overstory pine basal area for Northern Bobwhite and Red-cockaded Woodpecker overlaps across a range of overstory basal area from approximately 7 to 18 m^2/ha (*fig. 4*). Red-cockaded Woodpeckers obviously need some trees and Northern Bobwhite habitat quality is diminished as the overstory of large trees shades understory plants. Variation in management costs, particularly use of prescribed fire, is driven, in part, by the ecological condition of the land. Management costs will rise when the overstory is significantly reduced (*fig. 4*). Ground cover and overstory composition also affect the quality of the fuels and hence the costs of management.

Ground Cover Composition

A common Red Hills management practice to improve habitat for bobwhite is to disturb the soil, which creates patches of desirable food plants (Buckner et al. 1979) and important structural characteristics for young bobwhite. Soil disturbance is typically accomplished by harrowing and roller drum chopping. In the remaining patches of relatively undisturbed native ground cover, this can result in elimination or severe disruption of some of the long-lived perennial ground cover plants characteristic of the longleaf ecosystem. Some of these plants, particularly wiregrass, are strongly pyrogenic and highly flammable (Clewell 1989). Loss of these plants can reduce flammability of the vegetation by shifting herbaceous composition to less pyrogenic species and by increasing invasion by hardwoods. In addition, disking previously undisturbed vegetation in longleaf systems may result in poorer quality habitats for bobwhites (Olinde 2000, Hammond 2001).

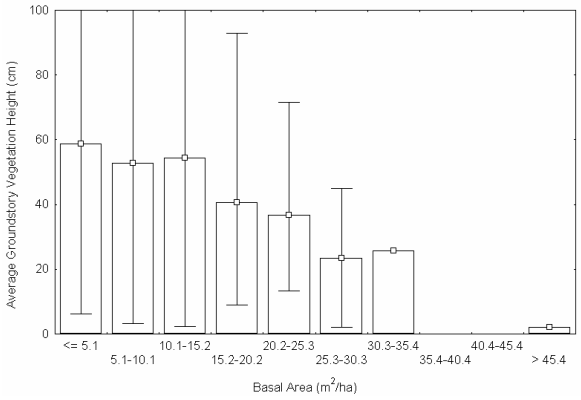

Figure 3— Relationship between basal area of trees in the overstory and height of ground cover vegetation on Tall Timbers Research Station.

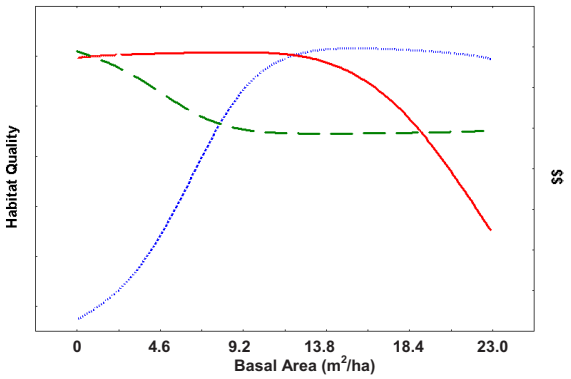

Figure 4— Hypothetical relationship between basal area (m^2/ha), habitat quality for bobwhite (solid line), habitat quality for red-cockaded woodpeckers (dotted line), and management costs (dashed line).

As noted earlier, much of the southern part of the Red Hills in Florida was used extensively for agriculture (Clewell 1980). In some places, successional replacement of pyrogenic ground cover plant species occurred decades or even a century or more previously. The effects of continually re-disturbing old-field vegetation, regardless how long that vegetation has been resident are unknown.

Canopy Cover Composition

Longleaf pine likely dominated uplands throughout the Red Hills before Native American and European settler agriculture (Clewell 1980). Longleaf has many physical (e.g., thin canopy, long, resinous needles, high resin production, and thick bark) and life history (e.g., growth in phases, shade intolerance) traits that are beneficial within a regime of frequent (1 to 5 year fire interval), low to intensity fires (Landers 1991). Besides widespread harvest, relatively poor dispersal ability, long mast intervals, and modification of the historic fire regime are likely the key reasons that longleaf pine has been displaced in favor of loblolly and shortleaf pines within the Red Hills. Resistance to insects and disease, tolerance of fire in the youngest age classes, and tolerance of wind and drought make longleaf pine a superior tree species for conditions in the uplands of the southeastern coastal plain (Wahlenberg 1946). In addition, density of its wood and other characteristics makes it one of the most valuable timber species in the region.

Red-cockaded Woodpeckers use several species of southern pines for its roosting and nesting cavities (Baker 1971, Jackson 1994), but longleaf has long been identified as the preferred tree species (Conner et al. 2001). Longleaf pine has certain qualities (e.g., resin flow, longevity, and wood strength) that may make it a better tree for use by the woodpecker. For example, the percentage of longleaf pine trees within a Red-cockaded Woodpecker cluster was the best predictor of whether a particular cluster was going to remain active or become abandoned by the woodpecker in a recent study within the Red Hills (Cox et al. 2001). It is no coincidence that active Red-cockaded Woodpecker clusters occur within the most intact stands of longleaf pine and the least disturbed ground cover within the Red Hills (Ambrose 2001) (*figs. 1a, b*).

Social Trends

A seemingly inevitable reduction in estate size is taking place within the Red Hills, because each property has tended to be subdivided among heirs during estate inheritance. Inheritance produces new challenges and opportunities for conservation. First, landowners must modify their expectations for the hunting experience because the land bases of the subdivided estates are smaller. Second, the same management functions (e.g., application of prescribed fire, road maintenance, food plots, etc.) that occurred on large estates must take place on smaller estates to maintain populations of bobwhites for hunting. This reduces economies of scale for bobwhite management at some point. Third, divergence of land uses among the subdivided estates could result in habitat fragmentation, increased suburbanization, increased opposition to the use of prescribed fire, and splintering of the hunting social community. At the same time, heirs of large estates are often interested in tax benefits available through conservation easements that can be structured to balance personal interests and values with regional conservation needs.

Conclusions

The key issue that we have chosen to examine is the functional interaction between pine canopy cover (using basal area as an index), habitat quality for the Northern Bobwhite and Red-cockaded Woodpecker, and the economics of land management (*fig. 4*). Clearly, good habitat for both species and lower management costs exists when overstory basal area is at an intermediate level. This observation is consistent with what is almost a truism in wildlife management: manipulations to maximize any one species will be both expensive and ecologically unstable.

Red Hills hunting estates, because they have been managed for similar purposes and are largely contiguous, can be viewed as a single functional landscape. The trajectory of the Red Hills landscape will be determined by economics, ecological relationships, and human social systems, as in all issues of conservation of natural resources (Gunderson and Holling 2002). Economic issues include wealth of individual landowners, costs of land management for hunting, and revenues generated by timber harvest. Management of the Northern Bobwhite—the primary species of interest for hunting—is the reason that these estates exist. The strength of hunting as a social phenomenon that provides the essential cohesion to the Red Hills must also be considered. How these factors can be shaped to permit change is the fundamental challenge for conservation of the unusual wildland character of the region.

We draw three conclusions from this preliminary exploration of ecological use of fire for vegetation management of the Northern Bobwhite and the Red-cockaded Woodpecker within the Red Hills:

(1) Loss of longleaf as the overstory dominant through agricultural conversion of vegetation has resulted in the ecological replacement on upland sites of longleaf by loblolly and shortleaf pines—species that are not as tolerant of fire in the earliest stages of development and provide inferior fine fuels from their needles. Shortleaf and loblolly, probably because of reduced resin flow and longevity in comparison to longleaf, are inferior cavity trees for the Red-cockaded Woodpecker (Cox et al. 2001).

(2) Maintenance of a basal area of older age class pine trees within a range of 9.2 to 18.4m^2/ha would provide ecological and economic benefits by providing excellent habitat for bobwhite and Red-cockaded Woodpeckers and needles that are an important source of fine fuel for using prescribed fire to manage vegetation.

(3) Strategic restoration of longleaf pine and wiregrass to sites that are currently dominated by post-agricultural plant species. This would increase the flammability of the vegetation, thereby decreasing the cost of controlling hardwoods within upland pine systems by methods other than fire.

Acknowledgments

D. Mehlman, L. Brennan, J. Cox, W. Baker, and D. Conner provided helpful comments on a draft of this paper. K. Gainey generously provided the artwork for *Figure 2*. C. Ambrose generously shared GIS layers from her report on ground cover conditions within the Red Hills region, and provided very helpful suggestions for making figures from ArcView.

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The Nature Conservancy's Prairie Wings Project: A Conservation Strategy for the Grassland Birds of the Western Great Plains[1]

Bob McCready,[2] David Mehlman,[3] Danny Kwan,[4] and Becky Abel[5]

In the second half of the nineteenth century, driven by the cultural mandate of manifest destiny and economic expansion, the North American west was rapidly settled and permanently altered by hundreds of thousands of residents from the eastern United States, Canada, Central Mexico and Europe. The first region to fill up with new arrivals was the Great Plains, a "sea of grass" that stretched uninterruptedly, from the prairies of southern Canada across the middle of the United States, to the arid grasslands of Northern Mexico – an area of both stunning continuity and biological complexity that is the largest biome on the continent. Although it is widely accepted that native peoples purposefully altered the prairie landscape primarily through the use of fire, in the last 150 years conversion to agriculture, fragmentation from urban development, degradation of wetlands, groundwater depletion, fire suppression, and incompatible grazing practices have been and will be among the most serious threats to prairies and many of the grassland obligate bird species that rely on the varied habitat types of the plains.

The impact of these human pressures on grassland birds has nowhere been more acute than in the western Great Plains – essentially the area bounded by the eastern slope of the Rocky Mountains in the west and the 100th meridian in the east. It is here that a relatively small number of avian species evolved and may be considered narrow endemics of the short and mixed-grass prairies. These include Ferruginous Hawk, Mountain Plover, Long-billed Curlew, Sprague's Pipit, Cassin's Sparrow, Baird's Sparrow, Lark Bunting, McCown's Longspur, and Chestnut-collared Longspur among others (Mengel 1970, Knopf 1996). Based upon North American Breeding Bird Survey (BBS) data, a majority of these have been experiencing disturbing declines (*table 1*) during the last four decades. Indeed, the endemic grassland birds of the short and mixed-grass prairies, have shown steeper, more consistent, and more geographically widespread declines than any other behavioral or ecological guild of North American species (Knopf 1994).

In response, The Nature Conservancy's Migratory Bird Program created the Prairie Wings project in 2000 with the goal of identifying and protecting critical grassland bird habitat across ten ecoregions (*fig. 1*) across the prairies of Canada, the United States and Mexico. There is an almost complete congruence between these ten ecoregions and the five western Great Plains bird conservation regions (Prairie Potholes, Badlands and Prairies, Shortgrass Prairie, Central Mixed-grass Prairie, and Chihuahuan Desert) as adopted by the North American Bird Conservation Initiative (U.S. NABCI Committee 2000). Ecoregions are the basic planning unit used by the Conservancy and are a modified version of Bailey's (1995) ecoregions, defined as large areas that have similarities in faunal and floral composition and are normally based on criteria such as climate, soils, geology, and vegetation cover types (Bailey 1998).

Figure 1— Project area boundary of The Nature Conservancy's Prairie Wings project.

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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Table 1— *Annual Rates of change in continental populations of selected endemic grassland bird species, 1966-2000. Trends statistically significant with a p-value <0.01 are boldfaced. Data from North American Breeding Bird Survey (Sauer et al. 2001). Scientific names are listed in table 2.*

Species	No. of BBS routes	Population trend	P value
Ferruginous Hawk	**216**	**+4.3%**	**0.00**
Mountain Plover	38	-1.2%	0.51
Long-billed Curlew	227	-1.2%	0.11
Sprague's Pipit	**126**	**-4.7%**	**0.00**
Cassin's Sparrow	**232**	**-2.3%**	**0.00**
Baird's Sparrow	124	-2.9%	0.02
Lark Bunting	346	-1.4%	0.03
McCown's Longspur	62	-3.6%	0.39
Chestnut-collared Longspur	148	-1.7%	0.04

Within each of these ecoregions, The Nature Conservancy identifies a portfolio of conservation areas that collectively represent the native species and ecosystems of the ecoregion and the underlying ecological processes that sustain them (Groves et al. 2002). Although the Conservancy's ecoregional planning efforts have been effective tools for guiding our conservation efforts at the ecoregional scale, there is concern that the sites identified in these plans may not adequately provide for the conservation of migratory birds or other wide-ranging species. As a result, The Nature Conservancy's Prairie Wings conservation planning team is analyzing existing data to identify those large landscapes that need to be protected across the entire short- and mixed-grass prairie ecosystem if viable populations of grassland birds are to be maintained into the future. The resultant map will be the basis for developing range-wide conservation strategies across ten ecoregions to protect the endemic birds of the western Great Plains.

The process we are using to identify the portfolio of important grassland bird conservation areas begins with the selection of what the Conservancy calls "conservation targets" or those elements of biological diversity that will be the focus of the planning efforts (Groves et al. 2000). Unlike most species of migratory birds, a majority of the narrow endemics of the western Great Plains spend all or at least a majority of their entire life cycle (i.e., breeding, migration, and wintering) within the short- and mixed-grass prairies and arid grasslands of Canada, the United States, and Mexico. The relatively small range of this group of birds offers unique opportunities to design and implement comprehensive conservation strategies that can be easily integrated with existing Conservancy and partner organization site-level work. Consequently, Prairie Wings staff has identified those birds that are considered to be endemics or those with a very strong affinity for the short- and mixed-grass prairie system as the primary conservation targets. These species are all also generally considered to be of great conservation concern by the bird conservation community (*table 2*). There are, in addition, species of great conservation concern in the Prairie Wings project area that spend only a small portion of their lifecycle in the Western Great Plains, have only a small portion of their range in the Great Plains, and/or are dependent on wetland habitat. The most threatened of these have been identified as either secondary or wetland associated target species (*table 2*).

Although planning is a critical step in the conservation process, it is the implementation of strategies to abate the threats that are causing the decline of the targets that will ultimately lead to conservation success. Given the paucity of data available on these conservation targets, an analysis to determine the most deleterious threats is rather coarse but includes:

- Habitat destruction from agricultural conversion and urbanization;
- Habitat fragmentation from the subdivision of large tracts near urban centers;
- Habitat disturbance from exotic species introductions and incompatible grazing practices;
- Alteration of the natural fire regime; and
- Changes in flow patterns of rivers, excessive groundwater depletion, and water quality degradation from inappropriate agricultural practices and development.

In an effort to mitigate these range-wide threats, Prairie Wings staff are working with The Nature Conservancy's programs in the United States, Mexico, and Canada as well as other conservation organizations, state and federal agencies, and researchers across the three countries to develop and implement conservation

Table 2-- *Prairie Wings grassland bird conservation targets. Species are divided into three categories; global conservation priority rank is from NatureServe (2001) and Partners in Flight (Pashley et al. 2000).*

Target type Common name	Scientific name	Global rank	Global PIF score
Primary			
Ferruginous Hawk	*Buteo regalis*	G4	17
Greater Prairie-Chicken	*Tympanuchus cupido*	G4	24
Lesser Prairie-Chicken	*Tympanuchus pallidicinctus*	G3	24
Scaled Quail	*Callipepla squamata*	G5	20
Mountain Plover	*Charadrius montanus*	G2	26
Long-billed Curlew	*Numenius americanus*	G5	20
Burrowing Owl	*Athene cunicularia*	G4	17
Sprague's Pipit	*Anthus spragueii*	G4	22
Cassin's Sparrow	*Aimophila cassinii*	G5	19
Lark Bunting	*Calamospiza melanocorys*	G5	19
Baird's Sparrow	*Ammodramus bairdii*	G4	23
McCown's Longspur	*Calcarius mccownii*	G5	23
Chestnut-collared Longspur	*Calcarius ornatus*	G5	20
Secondary			
Greater Sage-Grouse	*Centrocercus urophasianus*	G4	20
Short-eared Owl	*Asio flammeus*	G5	19
Clay-colored Sparrow	*Spizella pallida*	G5	18
Brewer's Sparrow	*Spizella breweri*	G5	19
Henslow's Sparrow	*Ammodramus henslowii*	G4	24
Smith's Longspur	*Calcarius pictus*	G5	23
Dickcissel	*Spiza americana*	G5	21
Bobolink	*Dolichonyx oryzivorus*	G5	19
Wetland Associated			
Trumpeter Swan	*Cygnus buccinator*	G4	21
Sandhill Crane	*Grus canadensis*	G5	18
Whooping Crane	*Grus americana*	G1	30
Yellow Rail	*Coturnicops noveboracensis*	G4	22
Black Rail	*Laterallus jamaicensis*	G4	25
Snowy Plover	*Charadrius alexandrinus*	G4	24
Piping Plover	*Charadrius melodus*	G3	27
Marbled Godwit	*Limosa fedoa*	G5	21
Least Tern	*Sterna antillarum*	G4	15

strategies at important grassland bird conservation areas in each of the ten ecoregions in the project area. Conservation strategies generated by our planning process include, among others, the permanent protection of critical habitat areas through acquisition and conservation easements, the creation of protected areas, collaboration with land management agencies to begin adopting management approaches that improve grassland bird habitat, and the creation of novel financial private landowner incentive programs that will protect native prairie habitat.

For instance, Prairie Wings staff worked closely with the Mexican non-governmental organization Pronatura Noreste in an effort that led to the decree of a new 20,000 hectare protected area in the El Tokio region in the state of Nuevo Leon in the Chihuahuan Desert Ecoregion. This globally significant area harbors the last remaining colonies of the Mexican Black-tailed Prairie Dog (*Cynomys mexicanus*), and provides critical wintering habitat for Ferruginous Hawk, Mountain Plover, Long-billed Curlew, Burrowing Owl, Sprague's Pipit, Lark Bunting, McCown's Longspur, and other grassland birds of concern. Our support for this project included financial and technical assistance to Pronatura Noreste in the design and implementation of an ongoing multi-year grassland bird inventory project as well as the identification and protection of additional key areas in the El Tokio region.

Another example of our approach can be seen in The Nature Conservancy's goal of developing a federally funded native grassland conservation easement program in the US. Thanks to the dedication of a strong coalition of conservation organizations, the Conservancy played a major role in the passage of the Grassland

Reserve Program (GRP) as a component of the 2002 Farm Bill. The GRP is an innovative program that will provide 254 million dollars for the enrollment of up to 2 million acres of grasslands or shrublands in the US in 10, 15, or 20-year rental agreements, or 30-year permanent conservation easements from interested landowners in regions determined to include high-quality native grassland habitat.

Our assumption is that if the threats presently degrading or destroying critical grassland habitat are abated, we will see a subsequent increase in those populations of grassland birds that are presently declining. The key to program success will be the degree to which a wide assortment of organizations collaborate on conservation efforts across all of the priority grassland bird conservation areas. It is our hope that if our range-wide approach to migratory bird conservation is successful, Prairie Wings will serve as a model for the development and implementation of other range-wide bird conservation efforts elsewhere in the Americas and beyond.

Acknowledgments

Mike Carter provided a helpful review of an earlier draft of this manuscript.

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Multi-Species Benefits of the Proposed North American Sage-Grouse Management Plan[1]

Clait E. Braun[2]

Abstract

The population size and distribution of the two species of sage-grouse (Greater – *Centrocercus urophasianus* and Gunnison – *C. minimus*) populations have become greatly reduced throughout western North America because of habitat changes. Threats are ongoing to the remaining sagebrush (*Artemisia* spp.) shrub steppe areas due to current land-use patterns. The proposed North American Sage-Grouse Management Plan, if implemented, could help manage existing sagebrush habitats used by sage-grouse and other sagebrush-dependent avifauna, restore degraded habitats, and re-habilitate habitats no longer capable of sustaining sage-grouse within the sagebrush habitat type in western North America. The long-term goal would be to restore sagebrush habitats capable of sustaining sage-grouse distribution and abundance at pre-1960 levels. The proposed North American Sage-Grouse Management Plan would have important benefits to other sagebrush obligate species such as Sage Sparrow (*Amphispiza belli*), Sage Thrasher (*Oreoscoptes montanus*), and Brewer's Sparrow (*Spizella breweri*) as well as other avian species that seasonally use shrub-steppe habitats for important life processes.

Introduction

Many avian species seasonally use habitats dominated by sagebrush (*Artemisia* spp.) for portions of their seasonal needs (Braun et al. 1976, Paige and Ritter 1999). Of the sagebrush obligate species, Sage-grouse (*Centrocercus urophasianus, C. minimus*) have been repeatedly demonstrated to depend upon sagebrush habitats for all of their life processes throughout the year (summarized by Schroeder et al. 1999, Connelly et al. 2000). The distribution and abundance of this species has declined dramatically, especially since about 1980 (Connelly and Braun 1997, Braun 1998) with extirpation of local populations (Braun 1995). Multiple factors have been implicated in the decline in distribution and abundance of sage-grouse with most relating to habitat loss, degradation, and fragmentation (Braun 1998). Because of the demonstrated declines in population size (Connelly and Braun 1997, Braun 1998), concern has been expressed about the long-term viability of distinct population segments and species. A petition was filed in 1999 to list sage-grouse in the State of Washington as threatened or endangered under the Endangered Species Act of 1973, a second petition was filed in 2000 to list the Gunnison Sage-grouse as threatened or endangered, and a third petition was filed in 2001 to list the Mono-Lyon population in California-Nevada as threatened or endangered. The U. S. Fish and Wildlife Service has since designated the Gunnison Sage-grouse as a "candidate" species and sage-grouse in the State of Washington as being "warranted but precluded" (by higher priority species) for federal listing. In Canada, where sage-grouse still persist in small numbers in Alberta and Saskatchewan, they are classified as endangered. Clearly, sage-grouse are perceived as needing attention throughout their range.

The status of other sagebrush obligate species is less well known (Paige and Ritter 1999). However, since they too depend upon sagebrush communities for breeding and rearing of young, it is likely their overall distribution has been reduced with concomitant decreases in local population size. It has been estimated that historical habitats of sage-grouse overlapped those of sagebrush obligates such as Sage Sparrow (*Amphispiza belli*) by 99 percent, and Sage Thrasher (*Oreoscoptes montanus*) and Brewer's Sparrow (*Spizella breweri*) by 94 percent (Rich and Altman 2001). Braun et al. (1976 and references cited within) noted that over 100 species of birds forage and nest in sagebrush communities. Concern has since been expressed about the population status of some of these species (i.e., Ferruginous Hawk [*Buteo regalis*], Columbian Sharp-tailed Grouse [*Tympanuchus phasianellus columbianus*], Mountain Plover [*Char-adrius montanus*], and Burrowing Owl [*Athene cunicu-laria*]) and petitions for federal listing as threatened or endangered have been filed for both Columbian Sharp-tailed Grouse and Mountain Plover. While sage-grouse may be the most widespread and charismatic of this group of species, there is an obvious need for a coordinated, well-developed, and funded habitat management plan that will benefit all avifauna that seasonally depend upon sagebrush steppe.

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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Proposed North American Sage-Grouse Management Plan

There is a need for a basic policy document to benefit sage-grouse (as well as other sagebrush-dependent species) that can be supported by individuals and public and private agencies across the International boundary with Canada in western North America. The goals of such a plan would be to: 1) enhance sage-grouse distribution and abundance through management of sagebrush-steppe habitats, and 2) restore sage-grouse distribution and abundance to pre 1960 levels within 25 years. Initial objectives would be to:

1. Develop an International framework (committee) to guide overall efforts for maintaining, restoring, and rehabilitating sagebrush-steppe habitats so that sage-grouse populations can increase.

2. Identify priority regional sagebrush-steppe habitat areas irrespective of political boundaries encompassing most present sage-grouse populations.

3. Develop International-funding mechanisms between Federal (Canadian Wildlife Service, U.S. Fish and Wildlife Service) and State and Provincial wildlife agencies as well as public land management agencies (Bureau of Land Management, U. S. Forest Service, U. S. National Park Service, etc.) on a proportional basis.

4. Develop and implement regional conservation plans (Joint Initiatives) using feasible conservation strategies to enhance sage-grouse habitats and populations.

5. Measure sage-grouse population response to habitat treatments.

6. Serve as a catalyst for major joint, coordinated activities by Federal and State/Provincial agencies.

The proposed North American Sage-Grouse Management Plan has been patterned after the highly successful North American Waterfowl Management Plan as described by Clarke (1987) and Patterson and Nelson (1988). However, no funding has been identified for the proposed North American Sage-Grouse Management Plan, other than a suggested proportional division of costs, and organization of the International committee has not been established. Further no commitments by any Federal or State/Provincial wildlife agency have been made to the concept of such a plan for sage-grouse. Some State and Provincial wildlife agencies historically have been reluctant to work cooperatively with Federal agencies and, at times, with adjacent States and or Provinces to manage "resident" bird species. Sage-grouse are not classified as "migratory" birds even though populations are known to move between states (i.e., Colorado into Utah and Wyoming, Idaho into Montana, Oregon into Nevada, etc.). The proposed North American Sage-Grouse Management Plan also differs in that a 25-year schedule is suggested (instead of the initial 15-year horizon suggested by Patterson and Nelson [1988] for the North American Waterfowl Plan). Twenty-five years appears more realistic given the slow response expected from habitat treatments in the sagebrush steppe.

Multi-Species Benefits

Maintaining existing occupied habitats, restoring degraded habitats, and rehabilitating former shrub-steppe habitats should benefit sage-grouse and all other sagebrush avian obligate species as well as other species known to use sagebrush habitats. Increases in distribution and abundance can be expected for sage-grouse, Sage Sparrows, Sage Thrashers, and Brewer's Sparrows as well as some other species that nest and rear young in sagebrush-dominated habitats. However, species such as Horned Lark (*Eremophila alpestris*) and Western Meadowlark (*Sturnella neglecta*) that have benefited from establishment of monocultures of exotic grasses may decrease. Enlightened management of shrub-steppe habitats should lead to improved management of riparian areas and other wet sites (ponds, springs, seeps). Management of these sites has the potential to benefit many other avian species.

The goals of the proposed North American Sage-grouse Management Plan are intended to benefit sage-grouse. However, sage-grouse can be viewed as "umbrella" species (Rich and Altman 2001) as they are charismatic because of their elaborate breeding displays which are familiar to many people in North America. Ensuring the health of habitats useful to maintaining and enhancing sage-grouse populations should also ensure the health of many other sagebrush-dependent species.

Acknowledgments

A proposed North American Sage-grouse Management Plan has been informally discussed with many biologists and managers involved with sage-grouse and sagebrush habitats. While the plan has not been popular with some, most individuals and agencies agree that uniform, coordinated approaches are needed not only within States and Provinces but also throughout specific regionally important areas for sage-grouse. I thank all who have listened and offered comments. Preparation

of this paper was encouraged by D. Mehlman of The Nature Conservancy. This is a contribution from Grouse Inc.

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The Conservation and Management of Migratory and Resident Birds and their Habitats on Department of Defense Lands[1]

Joe Hautzenroder[2]

Managing over 25 million acres of land on hundreds of installations, the United States Department of Defense (DoD) plays a key role in Partners in Flight (PIF). Department of Defense lands represent a critical network of habitats for neotropical migratory birds, offering these birds migratory stopover areas for resting and feeding, and suitable sites for nesting and rearing their young.

While DoD is a large federal landholder, we are not recognized as a land management agency. Unlike most of the agencies represented here whose primary mission is to accomplish basic conserve natural resources management, our mission is inherently destructive. The use of air-to-ground ordnance, tracked vehicles, ship-to-shore ordnance, underwater testing and amphibious assault maneuvers tend to take a toll on the environment. No one would argue that we must provide these training opportunities for our nation's armed forces. I think we would all agree that we want those who go in harm's way to have every advantage, and that requires realistic training. At the same time, though, the general public, government regulators, and many non-governmental organizations expect us to accomplish this mission with as little impact to the environment as possible.

Conservation and military readiness are not mutually exclusive. Indeed, we must identify define, understand, and manage the relationship between the two. To do this we must have up-to-date information on the natural resources under our control. Fortunately, the DoD has a small, dedicated, well-leveraged group of natural resources managers to help us acquire and use the data necessary to blend these two seemingly opposed issues. It is these professionals who acquire and manage the information needed to develop each installation's Integrated Natural Resources Management Plan (INRMP). A network of DoD PIF representatives ensure the habitat needs of birds are adequately incorporated in these plans.

There are a whole host of public laws and regulations to which we are bound. However, the Sikes Act, which can be thought of as our Organic Act, requires the Secretary of Defense to carry out a program to provide for the conservation and rehabilitation of natural resources on military installations. The Sikes Act was originally established in the 1940s to authorize a hunting program on Eglin Air Force Base in Florida. Since that time it has been amended many times, and is now the basic statutory requirement for DoD to manage natural resources.

While the act Sikes Act has long promoted the development of natural resources management plans and the cultivation of a working relationship with the U.S. Fish and Wildlife Service (USFWS) and State Fish and Game Departments, the Sikes Act Improvement Amendments of 1997 now make the development of an INRMP mandatory and the relationship with the USFWS and states more formal.

As of 17 November 2001, we (DoD) completed our first wave of "required" INRMPs. We are also now required to regularly report to Congress on the status of these plans and their updates. Each INRMP will must be updated on a 5-year cycle.

The Sikes Act states that, "Consistent with the use of military installations to ensure the preparedness of the armed forces, the secretaries of the military departments shall provide for:

1. The conservation and rehabilitation of natural resources on military installations;

2. The sustainable multipurpose use of the resources, which shall include hunting, fishing, trapping, and non-consumptive uses; and

3. Subject to safety requirements and military security, public access to military installations to facilitate the use."

In addition, the Sikes Act addresses specific components of the INRMP to be included: "Consistent with the use of military installations to ensure the preparedness of the armed forces, each INRMP shall, to the extent appropriate and applicable, provide for:

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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1. Fish and wildlife management, land management, forest management, and fish- and wildlife-oriented recreation;
2. Fish and wildlife habitat enhancement or modifications;
3. Wetland protection, enhancement, and restoration, where necessary for support of fish, wildlife, or plants;
4. Integration of, and consistency among, the various activities conducted under the plan;
5. Establishment of specific natural resource management goals and objectives and time frames for proposed action;
6. Sustainable use by the public of natural resources to the extent that the use is not inconsistent with the needs of fish and wildlife resources;
7. Public access to the military installation that is necessary or appropriate, subject to requirements necessary to ensure safety and military security;
8. Enforcement of applicable natural resource laws (including regulations);
9. No net loss in the capability of military installation lands to support the military mission of the installation; and
10. Such other activities as the secretary of the military department determines appropriate."

Of course, one of the most critical elements of the INRMP is the conservation of birds and their habitats. In an effort to provide our installation natural resources managers the information and direction they need to support PIF, we developed and implemented a specific DoD PIF Strategic Plan in 1994. This Plan detailed our goals and objectives and established a network of biologists and land managers to implement measures to conserve birds and their habitats. This Plan has served us well over the last several years.

As we move into another era of bird conservation, we will be guided by the newly revised published 2002 DoD PIF Strategic Plan (DoD PIF 2002), which has been endorsed by the Assistant Deputy Under Secretary of Defense (Environment), John Paul Woodley, Jr. Written primarily by our DoD PIF Program Manager with input from the all DoD PIF representatives, this revised Plan reflects the growth of the DoD PIF initiative over the last 10 years, and will help us to better address the conservation of all birds. The best way to do this is to ensure that every installation natural resources manager is aware and on board with the goals and objectives of the Strategic Plan, and that these goals and objectives are reflected in their installation INRMPs. Like the original, this revised Plan will be promulgated through the chain of command to each of the services and from there, to the installation level, where the INRMPs are developed and implemented.

We have gone to great lengths to ensure that local and relevant bird conservation information is made available to our installation natural resources managers for their use in the development and implementation of their INRMPs. In addition to participation at our annual DoD conservation meeting, where we promote the PIF initiative, we have developed a DoD PIF website (http://www.dodpif.org). One part of the website links the installation natural resources manager with the Partners in Flight bird conservation strategy – the "Flight Plan", as well as the specific bird conservation plan for the physiographic area or state where the installation is located. We also provide a link to the Rocky Mountain Bird Observatory for the species priority list for the subject installation. Our objective here was to provide our natural resources managers with the relevant data they need to properly address bird conservation in their INRMPs.

We have accomplished much over the last 10 years in support of bird conservation initiatives. One of our primary objectives will continue to be the cultivation of a better working relationship with conservation agencies and organizations through the efforts of our DoD PIF Program Manager to ensure that we are on the right course. One of the best things we have done, though, is to find and hire Chris Eberly as the DoD PIF Program Manager. Chris has done much to cultivate a working relationship with many of you in this audience to help ensure that we maintain the right course. Chris, together with Rich Fischer, will give a follow up to this presentation later this morning with some detailed examples of just how we integrate bird conservation objectives into our natural resources programs. Wherever possible, we will strive to implement cooperative projects and programs on DoD lands to benefit the health and well being of birds and their habitats.

Acknowledgments

I thank A. Dalsimer, DoD Legacy Program and C. Eberly, DoD PIF for helpful comments on this manuscript.

Literature Cited

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Figure 1— The Department of Defense recently unveiled its new Partners in Flight Strategic Plan, which provides the framework for incorporating bird conservation efforts into installation Integrated Natural Resources Management Plans. Over $15 million has been invested in hundreds of bird conservation projects over the last ten years.

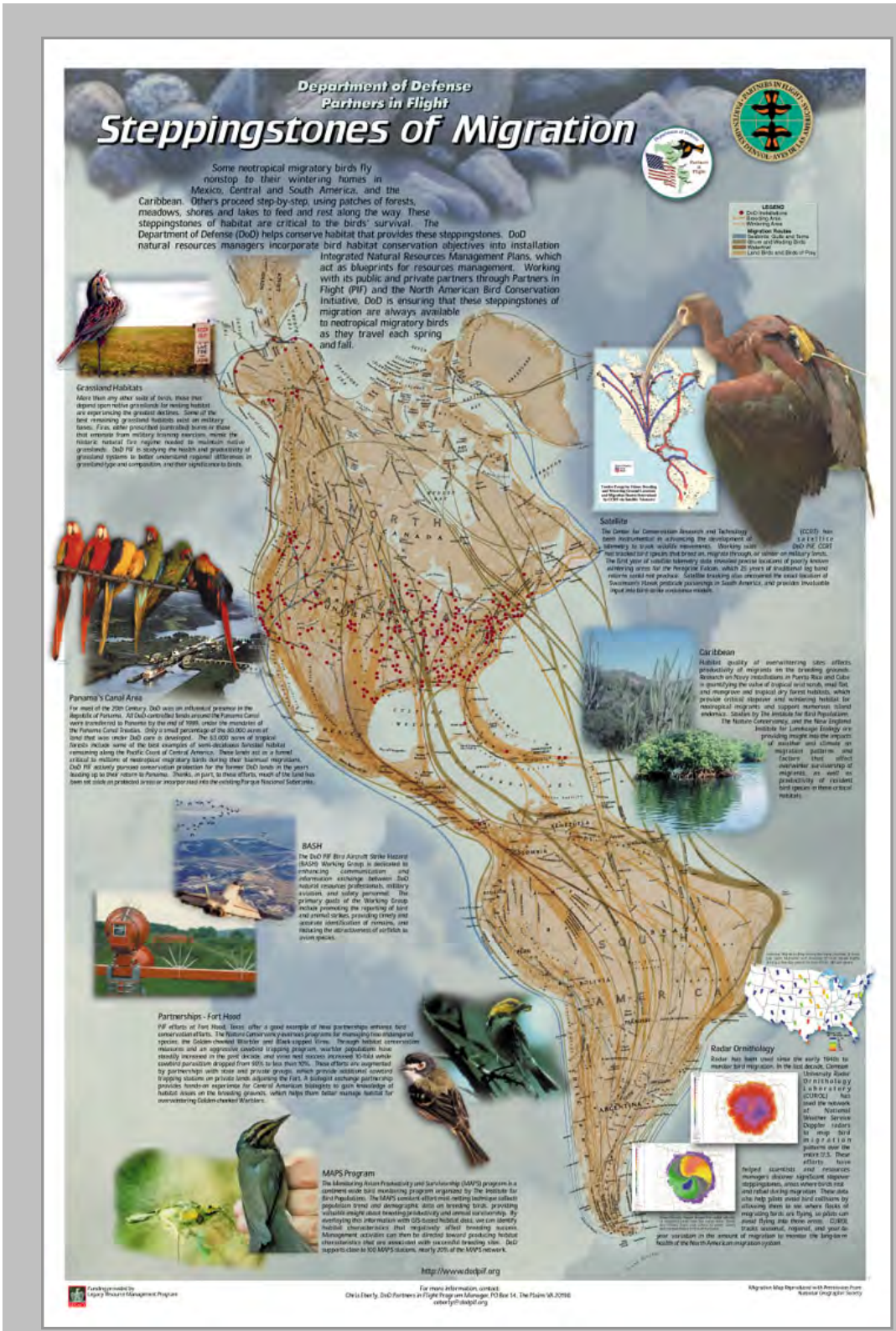

Figure 2— Integrated Natural Resources Management Plans have been prepared and implemented for over 380 Department of Defense installations covering millions of acres throughout the country. These DoD landholdings provide critical stopover sites for numerous migratory birds.

Integration of the North American Bird Conservation Initiative (NABCI) into Southeast National Park Service Planning and Operations[1]

J. Keith Watson[2]

Abstract

To encourage the involvement of southeastern National Park units in bird conservation efforts, the Southeast Region (Florida, Georgia, South Carolina, North Carolina, Tennessee, Alabama, Mississippi, Louisiana, Kentucky, Puerto Rico, and U.S. Virgin Islands) of the National Park Service (NPS) entered into an Interagency Agreement with the US Fish and Wildlife Service. Funds were provided for a two-year cost share program that provides a wide range of bird conservation guidance and support to the Southeast National Park Service. The means by which NPS units will increase their participation in southeastern bird conservation are 1) implementation of Avian Conservation Implementation Plans, 2) coordination between the National Park Service Inventory and Monitoring Program and established inventory and monitoring needs and priorities for southeastern bird conservation, 3) providing technical advice and expertise, and 4) development of a web site to facilitate communication among bird conservationists and National Park Service personnel.

Introduction

Since the creation of the now defunct National Biological Survey (a.k.a. National Biological Service - NBS), the National Park Service (NPS) has had limited participation in regional, national, and international bird conservation planning efforts. The NPS personnel responsible for coordinating bird conservation before creation of the NBS were all essentially removed from this duty when the NBS was created, reducing NPS participation in regional, national, and international bird conservation planning. However, individual efforts to promote bird conservation did continue and today, existing bird conservation efforts are largely attributed to individual park units and individuals in park units who have had support of the park superintendent or supervisor. A significant recent NPS contribution to bird conservation has been the development of the Park Flight Program, a partnership between the NPS, the National Park Foundation, the National Fish and Wildlife Foundation, American Airlines, and the U.S. Agency for International Development to facilitate bird conservation between United States national parks and Mesoamerican national parks. Park Flight is a great step forward in promotion of bird conservation in the NPS.

Another significant NPS bird conservation initiative is the effort to coordinate and integrate the strategies and goals of the North American Bird Conservation Initiative (NABCI) into the Southeast Region of the NPS.

Some bird conservationists ask why involve the NPS? Simply stated, the NPS is the fourth largest landowner in the United States, consisting of over 380 national park units covering 83 million acres of land and water. The 64 units in the Southeast Region of the NPS represent 16 percent of the total number of park units in the national park system and cover approximately 5 percent of the land base (*fig. 1*). Park Service units in the Southeast Region include national seashores (Canaveral National Seashore, Cape Hatteras National Seashore), national parks (Great Smoky Mountains National Park, Everglades National Park), national recreation areas (Big South Fork National River and Recreation Area), national preserves (Big Cypress National Preserve), national battlefields (Cowpens National Battlefield, Fort Donelson National Battlefield), national monuments (Fort Matanzas National Monument, Ocmulgee National Monument), and others such as the Blue Ridge Parkway, Obed Wild and Scenic River, and Timicuan Ecological and Historic Preserve. The Southeast NPS units provide habitat for over 400 species of migrating, breeding, and wintering birds as well as a wide range of Federally and State listed threatened and endangered species. There is further potential for contributions to bird conservation, through bird or habitat conservation, research, education, or a combination of these. Additionally, the NPS attracts over 280 million visitors to the parks each year, 120 million of these in the Southeast Region, affording excellent recreational bird watching, opportunities for bird conservation interpretation, outreach, and education programs.

In 1999, the Southeast Region of the NPS recognized the importance of coordinating existing bird conservation goals into planning and operations of national

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California**.

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park units in the southeast. To support this recognition, the Southeast Regional Office approved and allocated funding for a two-year project to coordinate and implement NABCI strategies into the NPS Southeast Region. The NPS allocated eighty-eight thousand dollars for a two year period to support the project, cost-sharing with the U.S. Fish and Wildlife Service (FWS) Region 4 (Southeast Region) to hire a bird biologist to conduct the project. Additionally, the NPS wrote the Interagency Agreement which provides for technological assistance when needed. This project is unique in the NPS and represents a potential model for regional bird conservation programs and activities in the NPS.

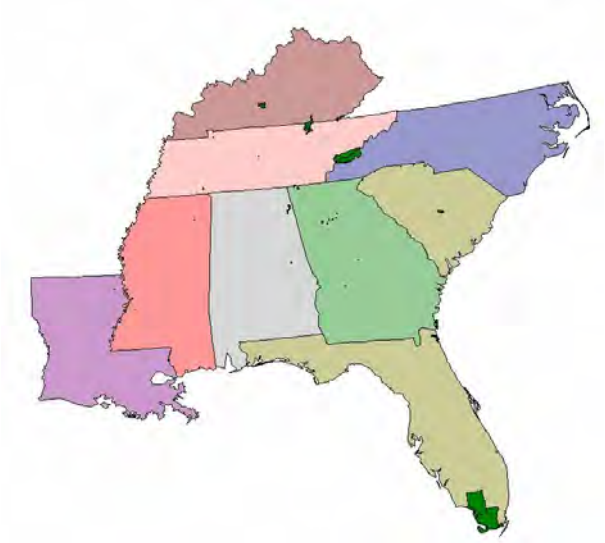

Figure 1— National Park Service, Southeastern Region.

What does "implementation of NABCI strategies" mean in the NPS? As envisioned, the coordination and implementation of NABCI strategies into the Southeastern NPS involves:

1. Develop and deliver Avian Conservation Implementation Plans (ACIP),
2. Coordinate with NPS Inventory and Monitoring Program,
3. Develop a web based project tracking site,
4. Establish bird conservation partnerships,
5. Identify and explore potential funding opportunities, and
6. Provide technical expertise to parks as needed or requested.

Avian Conservation Implementation Plans

The ACIP's will be concise documents that describe the parks avian resources, ongoing bird conservation efforts, identified bird conservation projects and priorities, if any, and how the landscape of the park unit fits into greater landscape bird conservation efforts, regionally, nationally, and perhaps, internationally. These documents will serve to guide the park for almost any desired bird conservation effort. The preparation of these documents will require site visits to each of the southeastern national park units and information will be gathered following a standard format. The plans will be delivered to the park units based on the NPS Inventory and Monitoring network (see following section). The general content of each ACIP will include: (1) Introduction; (2) Background; (3) Role of NPS in Avian Conservation; (4) Park Description; (5) Avian Resources of the Physiographic Area; (6) Avian Conservation of Park Unit; (7) Park Identified Needs for Avian Conservation; (8) Coordination with Regional Conservation Initiatives; (9) Integration of NABCI Objectives and Recommendations; (10) Literature Cited; and (11) Appendices.

NPS Inventory and Monitoring Programs

In the early 1990s, the NPS embarked on a nationwide project to develop and implement an inventory and monitoring program in all parks with significant natural resources. The program was initiated in developmental phases using pilot parks. The program has been expanded to over 250 national park units, organized into networks of parks with similar resources and resource management issues. For instance, because South Florida and the Caribbean have similar natural resources, the national park units in these areas have been selected to comprise the South Florida/Caribbean Inventory and Monitoring Network. The NPS has developed a single plan to identify the basic inventory and monitoring needs of these parks.

The Southeast Region of the NPS is comprised of five inventory and monitoring networks; the Appalachian Highlands, Southeast Coast, South Florida/Caribbean, Cumberland/Piedmont, and Gulf Coast Networks (*fig 2*). To develop plans, the networks have established scoping meetings where resources indicators of park health or ecosystem health are identified and considered for monitoring purposes. The project coordinator attends each network's scoping meetings to present relevant information on bird and habitat conservation priorities for the park, region, or bird conservation planning area of interest.

Web Site Development

A web site will be developed and administered through the FWS field office in Manteo, North Carolina. The web site will describe this project and provide links to: 1) existing bird conservation initiatives and plans, 2) NPS home pages (including inventory and monitoring pages), 3) FWS bird conservation web sites, 4) ACIP's, and 5) agency contact information. Access to agency contact information assists with the development and maintenance of partnerships between NPS, other agencies, and bird conservationists. This link will provide a database of nationwide NPS personnel contact information as well as key bird conservation specialists, biologists, and bird conservation coordinators. Agency contact information will be provided at five planning levels; NABCI BCR regions, PIF physiographic areas, NPS Regions, NPS Inventory and Monitoring Networks, and States. Each planning level will have an associated map with associated designations, i.e. BCRs, physiographic areas, regions, networks, and states. Each map designation will link to a database that provides personnel contact information. For instance, the PIF level map will show a map of the United States and Canada, Alaska, and Hawaii, and show all designated PIF physiographic areas. Each physiographic area will have an associated link to the contact database. For example, if the Southern Blue Ridge physiographic area is selected, the viewer is directed to the database table of associated NPS units in the Southern Blue Ridge physiographic area, individual unit information, including personnel information, and other primary bird conservation contact information. The web site will also have links to potential funding sources, the Park Flight Program, NPS bird checklists, and other relevant bird conservation web sites.

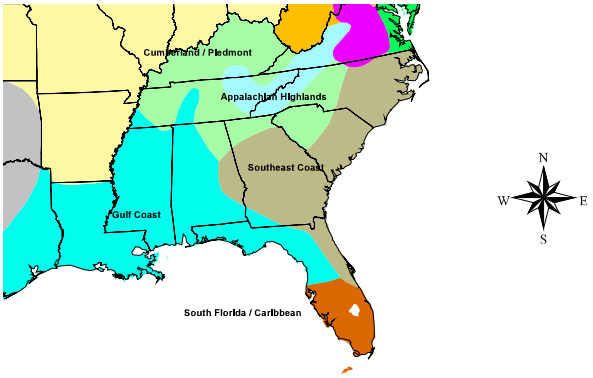

Figure 2— National Park Service, Southeastern Region Inventory and Monitoring Networks.

Established Partnerships

The project coordinator will work with the NPS and other bird conservation partners to develop and encourage partnerships that will facilitate cooperative bird conservation efforts and projects. NPS participation in the Appalachian Yellow-bellied Sapsucker (*Sphyrapicus varius*) Working Group is one example.

Funding Opportunities

The project coordinator will work with the NPS and bird conservation partners within the existing framework of funding mechanisms to obtain funding for high priority bird conservation projects in the southeastern United States. Funding to conduct research on American Oystercatcher (*Haematopus palliates*) in three national seashores on the Atlantic Coast has been obtained through this coordination.

Technical Expertise

The project coordinator will provide technical assistance upon request and assist park personnel in making the appropriate contacts with bird conservationists, partners, or other personnel to obtain the technical advice sought.

Results

Avian Conservation Implementation Plans

To date, 64 NPS units in the Southeast Region have been visited. Interviews have been conducted with staff at each of these units and information necessary to develop each ACIP has been obtained.

All plans are presently in preparation and over thirty are in review by parks or are final drafts. Draft ACIP's for the parks will be reviewed by park staff and their bird conservation associates to provide for an integrated implementation plan. Final copies of each ACIP will be available on the web site and usually on the particular parks internet home page.

NPS Inventory and Monitoring Programs

The project coordinator has participated in scoping meetings for the Appalachian Highlands, the South Florida/Caribbean and Cumberland/Piedmont Networks in the Southeast NPS. Bird and habitat conservation priorities for the park, region, and inventory and monitoring network landscape, were presented to the network teams for consideration in their monitoring plan development. This presentation also provides the opportunity for the network, or parks within the network to consider and potentially integrate NABCI bird conservation into their plans.

For example, in the NPS Cumberland/Piedmont Inventory and Monitoring Network, three PIF physiographic areas occur; the East Gulf Coastal Plan, the Southern Ridge and Valley, and the Northern Cumberland Plateau. Bird and habitat conservation measures identified in a draft PIF bird conservation plan were presented to the scoping meeting participants, including staff at these parks. A similar presentation was made to the South Florida/ Caribbean Inventory and Monitoring Network meeting participants.

Web Site Development

Development of the web site was contracted to a local individual. The web site address is: http://southeast.fws.gov/birds/npsbirds.htm and was launched in mid-July 2002.

Established Partnerships

Partnerships were established between:

- the NPS, FWS, US Geological Survey - Biological Resources Division, and North Carolina State University to conduct research on American Oystercatchers at Cape Hatteras, Cape Lookout, and Cumberland Island National Seashores
- the NPS, FWS, US Forest Service, Eastern Band of the Cherokee, and several academic institutions to conduct surveys for Appalachian Yellow-bellied Sapsuckers in the Southern Appalachians
- the NPS and the Atlantic Coast Joint Venture (NPS became an official member)
- Cape Hatteras and Cape Lookout National Seashores as participants in the International Shorebird Survey and web site entry into the South Atlantic Migratory Bird Initiative (SAMBI)
- the Great Smoky Mountains National Park and FWS to manage landscape at "The Purchase" to improve habitat for the Golden-winged Warbler (*Vermivora chrysoptera*)
- Canaveral National Seashore and Merritt Island National Wildlife Refuge to share resources to accomplish management and protection of two federally listed species.

Funding Opportunities

The FWS submitted a proposal and received funding for research for American Oystercatcher on Cape Hatteras and Cape Lookout National Seashores. A summary of funding opportunities outside the normal annual funding call of the NPS has been prepared and will be available on the web site. North American Wetlands Conservation Act (NAWCA) grant program information was submitted to NPS Southeast Regional Associate Regional Director of Resource Stewardship and Science for transmission to park units.

Technical Expertise

Technical support and guidance is an ongoing activity.

Discussion

The integration and coordination of the NABCI goals into the Southeast NPS represents a unique approach to incorporation of bird conservation goals into an agency's planning and operations. Approximately mid-way through this project, significant and enthusiastic cooperation has been given by the NPS. From the regional directorship down to the park resource manager and volunteer, the NPS has welcomed and encouraged this project and is excited to become a more active participant in southeastern bird conservation. Following completion and delivery of the ACIP's to southeastern parks, the next phase will be transferring the conceptual and tactical strategies described in the ACIP's into partnerships, funding opportunities, and projects that will translate to bird and habitat conservation in the NPS. Once fully embraced and incorporated into agency operations and planning, the ACIP's for parks in the Southeast Region will enable the NPS to "deliver the full spectrum of bird conservation through regionally-based, biologically driven, landscape-oriented partnerships under the North American Bird Conservation Initiative."

Acknowledgments

Special thanks is given to the Southeast Region of the National Park Service, especially Ms. Sheila Colwell and Mr. Jerry Belson. In the FWS, thanks to Mr. Chuck Hunter and Frank Bowers for promoting this concept of shared bird conservation visions between Department of Interior agencies and seeing that the opportunity became a reality.

Integrating Bird-Habitat Modeling into National Forest Planning for Bird Conservation in the Southern Appalachians[1]

David A. Buehler,[2] Eric T. Linder,[3] Kathleen E. Franzreb,[4] Nathan A. Klaus,[5] Randy Dettmers,[6] and John G. Bartlett[7]

Abstract

We developed spatially-explicit bird-habitat models with a variety of site-specific and landscape parameters to predict avian species distributions on southern Appalachian National Forests to aid National Forests with bird conservation planning. These models can be used to assess the effects of different forest management alternatives on long-term population viability for a variety of avian species. Unlike past planning efforts on National Forests which were based on qualitative attempts at interpreting changes in forest type and age class distributions on avian species, use of spatially-explicit habitat models can provide quantitative estimates of how habitat availability is changing for a given species and also evaluate the significance of management decisions on spatial configurations of avian habitats. Using the Chestnut-sided Warbler (*Dendroica pensylvanica*) as an example, we demonstrate how these models work and how different forest management alternatives may affect Chestnut-sided Warbler habitat in the future.

Key words: bird, Chestnut-sided Warbler, conservation, *Dendroica pensylvanica*, habitat, model, National Forest, planning, population viability.

Introduction

Bird conservation planning on U. S. National Forests is driven in part by the planning regulations enacted under the National Forest Management Act of 1976 (NFMA). These regulations require that National Forests periodically review conditions on the forest and assess the likelihood that various management alternatives will meet long-term management goals. These goals, to a certain extent, have been based on bird management goals identified through the Partners in Flight planning process, but also are based on other goals, such as timber production, recreation, and protection of endangered species.

The 1982 Planning Rules designed to implement the planning process under NFMA require that on individual U. S. National Forests "...fish and wildlife habitat shall be managed to maintain viable populations of existing native and desired non-native vertebrate species in the planning area" (Federal Register Vol. 47:43037, 30 Sep 1982). A viable population is defined for planning purposes as "...one which has the estimated numbers and distribution of reproductive individuals to insure its continued existence is well distributed in the planning area." The planning rules recognize that habitat is critical to supporting viable populations and further recognize a spatial component in that "...habitat must be well distributed so that those individuals can interact with others in the planning area." The southern Appalachian National Forests are undergoing a plan revision process following the 1982 standards and guidelines.

In December 1997, a Committee of Scientists was formed under the Secretary of Agriculture's directive to reexamine the planning process under NFMA. The committee recommended maintenance of long-term ecological sustainability as the foundation for development of National Forest management plans. In 2000, new planning rules were developed that guide the National Forests in achieving this goal. In terms of specific provisions related to fish and wildlife habitat, the new rules stipulated that the National Forests should "….provide for ecological conditions that provide a high likelihood of supporting the viability of native and desired non-native species well distributed throughout their ranges in the plan area" (Federal Register Vol. 65, No. 218:67574, 9 Nov 2000). So, in

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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spite of the new emphasis on ecological sustainability in the 2000 planning rules, there still remains the need to evaluate species viability on individual National Forests and to ensure those species are "well-distributed" across individual National Forests.

There have been several different approaches to evaluation of population viability including genetic, demographic, and habitat-based methods (Soulé 1987, Shaffer 1990, Roloff and Haufler 1997, White et al. 1997, White 2000; for review see Young and Clark 2000). Because the U.S. Forest Service is legally mandated to provide habitat capable of supporting viable populations under NFMA, we have chosen to use a habitat-based modeling approach. In this paper, we describe our approach used to develop spatially-explicit bird-habitat models from standard 10-min point-count data and then develop an example of how these models can be used to evaluate different forest management alternatives. Finally, we discuss the difficulties in following such an approach in the plan revision process currently being undertaken by southern Appalachian National Forests.

Methods

Developing Spatially Explicit Avian-Habitat Models

Our goal in model development has been to develop spatially-explicit models that predict the likelihood that a given forest stand on a National Forest will be occupied by a breeding pair for a suite of 25 avian species regularly occurring in the region. The models were developed based on 10-min point-counts conducted by various individuals from southern Appalachian National Forests (Cherokee National Forest, Tennessee; Chattahoochee National Forest, Georgia; George Washington-Jefferson National Forest, Virginia; Francis Marion-Sumter National Forest, South Carolina; and Nantahala and Pisgah National Forests, North Carolina). Avian census methods utilized were those that have been standardized for the Southeast (Hamel et al. 1996). Data used in this example were part of the U. S. Forest Service Region 8 bird monitoring database (R8bird) and included point-counts from Virginia, Tennessee, and Georgia covering the period of 1992-1996. Sample sizes differed among individual forests; >1500 individual point-count sites were included in the analysis. We developed one set of models for forests in the "northern" part of the southern Appalachians (northern Cherokee, North Carolina National Forests, and George Washington-Jefferson) and one set of models for the "southern" part of the southern Appalachians (southern Cherokee, Francis Marion-Sumter, Chattahoochee) because classification and regression tree analysis showed differences from north to south in bird-habitat relationships.

Habitat variables were derived from the Southern Appalachian Assessment (SAA; SAMAB 1996), compiled by Hermann (1996) and U.S. Forest Service CISC (Continuous Inventory of Stand Condition) databases. The SAA database was derived from remotely sensed data and covered both private and public land in the region whereas the CISC database was comprised of information assigned to the forest stand by U.S. Forest Service district silviculturists (forest type, stand age, condition class, site index). Forest stand characteristics and landscape metrics were assigned to individual bird-habitat sampling points.

Both habitat databases existed in a geographic information system (GIS) and our analysis was conducted at a 30 m x 30 m resolution, which was a spatial scale pertinent to our target species. We used stepwise logistic regression with $P < 0.10$ level to stay in the model (SAS 1990) to build habitat models to predict the likelihood of occurrence of a given species based on 17 explanatory variables (*table 1*). Logistic regression has proven to be an effective approach for developing bird-habitat models with high predictive power from point-count data (Dettmers et al. 2002). Final model selection was determined by a combination of the lowest Akaike Information Criterion value (Burnham and Anderson 1998) and the Hosmer-Lemeshow goodness-of-fit statistic (Hosmer and Lemeshow 1989). We assessed model performance for each species based upon changes in concordance and the max-rescaled R^2-value. Concordance measured the overall predictability of the model and the R^2-value was indicative of the variation explained by the model.

Applying Models to Southern Appalachian National Forests

Bird-habitat models (logistic regression equations) developed for each avian species were applied using ArcView (ESRI, Redlands, California) back across each individual 30 m x 30 m pixel on each individual National Forest to create a coverage of suitable habitat for that species (*fig. 1*). Initially, a species coverage represented a probability surface that depicted the likelihood that a singing male of a given species occurred in given pixels, with possible values ranging from 0 to 1. We determined the cutoff point at which pixels were deemed as suitable or unsuitable habitat based on two criteria. First, we used a threshold for sensitivity of 0.75 (probability of occurrence). If sensitivity was always greater than 0.75, we used a 'false positive' rate of 0.25 (probability of occurrence). Based on this approach, the overall correct classification was typically high and the false positive rate was relatively low, thereby making this cutoff point

Table 1—*Habitat variables derived from the Southern Appalachian Assessment (Hermann 1996) and U. S. Forest Service Continuous Inventory Stand Condition (CISC) databases used to construct avian habitat-models in the southern Appalachians.*

Variable Description	Range	Source
Elevation (m)	294 – 1,554	Hermann (1996)
Distance to nearest stream (m)	0 – 257	Hermann (1996)
Slope (%)	1 – 31	Calculated from elevation SLOPE command Arc/Info
Relative slope position	0 –98	Calculated from elevation based on Wilds (1996)
Average solar exposure	91- 454	Calculated from elevation HILLSHADE command Arc/Info
Aspect (Beers et al. 1996)	0.0 – 2.0	Hermann (1996)
Terrain Relative Moisture Index	0 – 60	Parker (1982)
Terrain Shape Index	-37 – 44	Hermann (1996)
Planiform Curvature	-2.1 – 1.8	Calculated from elevation CURVATURE command Arc/Info
Forest cover within 1 km (%)	0 – 100	SAA land cover map
Forest cover within 5 km (%)	0 – 100	SAA land cover map
Forest cover within 10 km (%)	0 – 100	SAA land cover map
Tree species diversity within 1 km	1 – 6	Hermann (1996)
Tree species diversity within 5 km	3 – 8	Hermann (1996)
Tree species diversity within 10 km	4 – 8	Hermann (1996)
Hardwood dominant forest type at 1 km	1 or 0	Hermann (1996)
Pine dominant forest type at 1 km	1 or 0	Hermann (1996)
Mixed pine-hardwood forest at 1 km	1 or 0	Hermann (1996)
Land cover-type diversity within 5 km	5 – 14	Hermann (1996)
Land cover-type diversity within 10 km	10 -15	Hermann (1996)
Cove hardwood forest type	1 or 0	U.S.F.S CISC database
Hemlock-White Pine forest type	1 or 0	U.S.F.S CISC database
Mixed Pine-Hardwood forest type	1 or 0	U.S.F.S CISC database
Northern Hardwoods forest type	1 or 0	U.S.F.S CISC database
Oak-Hickory forest type	1 or 0	U.S.F.S CISC database
Yellow Pine forest type	1 or 0	U.S.F.S CISC database
Forest stand age	0 – 150	U.S.F.S CISC database
Forest stand site index	40 – 110	U.S.F.S CISC database

relatively conservative. Using spatial-analyst tools in ArcView, we aggregated pixels that were deemed suitable into patches, better reflecting the continuous nature of the habitat. Aggregation only occurred for those pixels that were adjacent.

We converted these pixels of suitable habitat into an estimate of the potential to support a given breeding population. We summed the total suitable acreage for a given species across each National Forest and multiplied the total by the average breeding density of that species from Hamel (1992). Habitat patches that were less than one territory in size were not counted as occupied because they may not have supported a breeding pair. Habitat patches that could have supported a fraction of a breeding pair (e.g., 2.3 pairs) were rounded down to the nearest whole number (e.g., 2 pairs).

Creating a Virtual Forest

For this example, we created a virtual National Forest by taking current forest conditions in a GIS coverage and projecting these conditions across a sixty-year time horizon. This was done using a SAS-based forest model developed by Klaus (1998) that simulated both even-aged and uneven-aged timber harvests and aged the forest for unharvested stands. We developed hypothetical management alternatives that differed across forest type, total area harvested per 10-yr interval, the relative proportions of even-aged to uneven-aged harvests, group sizes, and percents of

stands harvested. Ideally, we could have used actual alternatives for a given forest for this analysis but those alternatives had not been specified for southern Appalachian National Forests at the time of the development of this example. Specific variations on intensities and harvest method were based upon past harvest practices and expert opinion of the district silviculturists for this example. Because our target species was associated with early succession habitat, we also needed to model natural disturbance regimes. Consequently, we modeled five natural disturbance types based upon existing literature and historical averages for this region. Natural disturbances including fire, ice storms, wind, southern pine beetle, and hemlock wooly adelgid were assigned randomly to forest stands that plausibly could be affected by that type of disturbance (e.g., southern pine beetle did not impact northern hardwood stands). For each simulation, virtual forests were updated every 10 years.

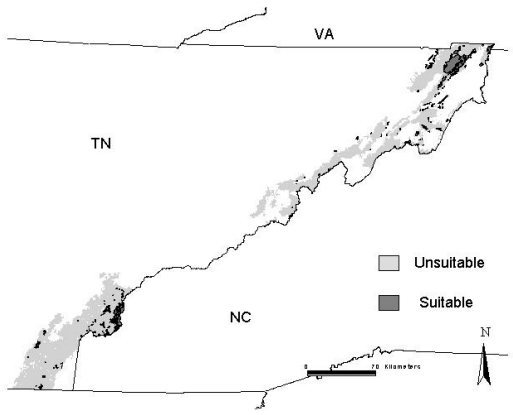

Figure 1—Predicted distribution of potential habitat for Chestnut-sided Warbler on the Cherokee National Forest, Tennessee.

Five scenarios were simulated, each with a different intensity of disturbance: 1) no timber harvest or natural disturbance, 2) no harvest but natural disturbance included, 3) expected level of harvest plus natural disturbance, 4) 200 percent of expected harvest plus natural disturbance, and 5) 300 percent of expected harvest plus natural disturbance. These scenarios offered a range of disturbance intensities and also allowed us to assess the relative significance of management compared to natural disturbances. Using the spatial analyst extension of ArcView, we calculated the area of each habitat patch for each simulation. The size of the potential population was calculated for each simulation at each 10-yr interval and graphed to compare the habitat potential under each disturbance scenario.

Modeling Results

The current distribution of Chestnut-sided Warblers (*Dendroica pensylvanica*) from the modeling illustrated that on the Cherokee National Forest, habitat for this species was currently well-distributed across the forest (*fig. 1*). We estimated that this habitat had the potential to support 1,400 breeding pairs, which would probably be considered a viable population by most population viability standards (Soulé 1987). In addition, this particular analysis did not take into account the opportunities for Chestnut-sided Warblers to occupy roadsides that provided additional habitat. So considering within-stand habitat and roadside edges, this species appears to have sufficient potential habitat currently to support viable populations.

Evaluation of the effect of disturbance on future habitat potential showed that this species was likely to be sustained under all management alternatives evaluated (*fig. 2*). With little disturbance in the form of management or natural disturbance, this species would decrease in the number of pairs supported whereas with forest management, it was likely to increase. In all cases, viable populations were likely to be sustained for this species, especially if breeding pairs along roadside edges were included in the analysis.

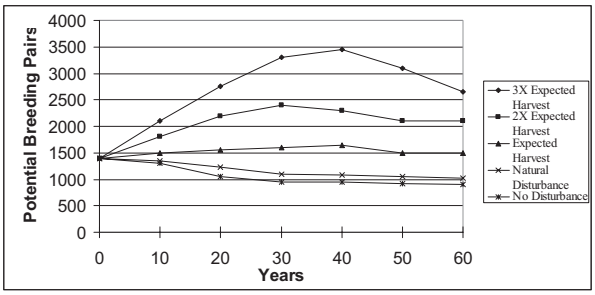

Figure 2—Predicted number of breeding pairs of Chestnut-sided Warblers supported on the Cherokee National Forest, Tennessee under various management scenarios.

Discussion

Chestnut-sided Warblers require early successional habitats, including second growth hardwood forests, and old fields with scattered saplings (Hamel 1992). Given the legal mandates under NFMA, our modeling approach demonstrated that Chestnut-sided Warblers were likely to be sustained under any management alternative we evaluated. It is important to note that the level of timber harvest evaluated in this example (expected harvest and two-three times expected), represented relatively long rotations (e.g., >100 years) and relatively small area disturbed for each 10-yr interval. Some concern about the isolation of these populations

might be expressed because this species typically was found at higher elevations (i.e., >1000 m) in the southern Appalachians that were isolated across the landscape. This modeling approach allowed forest managers to quantify how various management alternatives may ultimately affect habitat potential and hence population viability for wildlife species inhabiting the National Forest.

We have encountered limitations with this modeling approach in several important areas that are worth mentioning. Although we were able to create a virtual forest to model current conditions and identified plausible forest management alternatives, we were unable to simulate actual forest management alternatives under the southern Appalachian National Forest plan revision process. The problem arose because of the inability to tie forest growth models to specific stands in a spatially explicit environment on the forest so we could model the spatial configuration of habitat, an important part of our modeling process. We also had difficulty modeling habitat potential for rare species based on the R8bird database. For example, Cerulean Warblers (*Dendroica cerulea*) and Golden-winged Warblers (*Vermivora chrysoptera*) are high-priority species that occur rarely across the region. These species were not recorded with enough frequency (<5 records) on standard point-counts to allow for development of reliable habitat models. The problem lies in the R8 bird monitoring approach, however, rather than in the actual modeling approach we have demonstrated here.

Acknowledgments

We thank the various people that have contributed point-count data to the R8 bird database in the southern Appalachians. We thank C. Hardy, U.S. Forest Service, and T. Ettel, Tennessee Wildlife Resources Agency for reviewing earlier versions of this manuscript. Support for this work was provided by the U.S. Forest Service Region 8 and Southern Research Station, The University of Tennessee, and Mississippi State University.

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Supporting Habitat Management for Bird Conservation Planning on Fort Belvoir, Virginia[1]

Richard A. Fischer,[2, 3] Chris Eberly,[4] and Dorothy Keough[5]

Abstract

The U.S. Army Corps of Engineers, Engineer Research and Development Center (ERDC), Environmental Laboratory has conducted seasonal avian surveys (winter, spring, summer, fall) from Spring 1998 through Summer 2002 at approximately 127 permanent point-count locations on Fort Belvoir, VA. This work has resulted in a data-rich baseline understanding of the distribution and abundance of birds, as well as the relative importance of different habitats on the installation. Our investigation identified opportunities to enhance or create improved early-successional habitat on Fort Belvoir for Partners in Flight (PIF) priority birds within the Mid-Atlantic Coastal Plain physiographic area (MACP). This document describes the development of a site-specific plan, in support of the MACP Bird Conservation Plan (BCP), for improving habitats of early-successional bird species at Fort Belvoir, VA.

Key words: Partners in Flight, early-successional habitat, Mid-Atlantic Coastal Plain, priority species, Fort Belvoir.

Introduction

The Department of Defense (DoD) manages approximately 10 million ha of land on over 400 military installations in the United States. In addition, the U.S. Army Corps of Engineers administers approximately 5 million ha of project lands on over 450 man-made lakes and an additional 38,600 km of inland navigation streams in the continental United States (Fischer and Hamilton 2001). DoD lands represent a wide diversity of habitats, from mountain forests and meadows to coastal beaches and cliffs, and abundant lake, river, and stream riparian ecosystems throughout the nation. These ecosystems often occur as oases of habitat in the midst of fragmented and developed landscapes. Throughout the Americas, habitats that host high priority and federally listed species are becoming increasingly threatened by development. However, much of the land administered by DoD is relatively undeveloped, providing large habitat blocks for numerous threatened, endangered, and Partners in Flight (PIF) High Priority species (Boice 2000).

In 1991, DoD joined the PIF initiative through each of the military service branches. By participating in this partnership, DoD actively has pursued a sound conservation ethic in managing its public lands for the benefit of bird species throughout the Americas. The Sikes Act (P.L. 106-580) requires military installations to develop and implement Integrated Natural Resources Management Plans (INRMP) addressing fish and wildlife conservation. The DoD PIF program offers a coordinated framework for incorporating bird habitat management into an installation's INRMP, consistent with the military mission. The goals of the PIF effort within DoD must support the military mission, both overall for DoD and at each installation. For installations with an active (and sometimes destructive) training mission, maintaining lands in a condition that permits ongoing training activities is imperative. If lands degrade beyond the point where troops can train, the lands are lost for training activities.

Following the intent of the national PIF bird conservation strategy, known as the Flight Plan (Pashley et al. 2000), as well as regional approaches to migratory bird conservation, DoD's strategy focuses on inventory, on-the-ground management practices, education, and long-term monitoring to determine changes in populations of birds on DoD installations. In addition, the DoD PIF program focuses on protecting biodiversity using the best available science, working at a landscape level, and using partnerships to maximize the effectiveness of management efforts. The goals and objectives of the Flight Plan many times can provide the necessary guidance to support the military training mission, while

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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at the same time providing a benefit to bird habitat conservation.

Importance of Early-Successional Habitats in the Mid-Atlantic Coastal Plain

The Mid-Atlantic Coastal Plain (MACP) occupies approximately 56,451 square km covering all of Delaware, eastern Virginia and Maryland, southeastern Pennsylvania, and southern New Jersey. Within this area are approximately 1,000 perennial rivers and streams and nearly 1 million ha of wetlands (primarily forested wetlands and salt marsh). Vegetation within the region is closely associated with the Southeastern Coastal Plain. The avifauna within the MACP is comprised of both northeastern and southeastern species, which contributes to high species richness (> 180 species that regularly breed) (Watts 1999). Although populations of most species of breeding birds within the region appear to be secure, 30 species (16.7 percent) have declined significantly (Watts 1999).

Early successional grasslands/shrublands are designated as priority habitats within the PIF Bird Conservation Plan for the MACP (Watts 1999). Early-successional habitats are represented by a range of habitat characteristics, varying from open grasslands with little or no woody vegetation, to areas having varying densities of woody shrubs and small trees (i.e., "oldfields"). Grassland and oldfield habitats support a large number of PIF priority species, including five species of high continental priority - Henslow's Sparrow (*Ammodramus henslowii*), Bachman's Sparrow (*Aimophila aestivalis*), Prairie Warbler (*Dendroica discolor*), Blue-winged Warbler (*Vermivora pinus*), and Field Sparrow (*Spizella pusilla*) -; and eight species of high regional priority (Northern Bobwhite (*Colinus virginianus*), Brown Thrasher (*Toxostoma rufum*), Eastern Towhee (*Pipilo erythrophthalmus*), Grasshopper Sparrow (*Ammodramus savannarum*), Gray Catbird (*Dumetella carolinensis*), Upland Sandpiper (*Bartramia longicauda*), Yellow-breasted Chat (*Icteria virens*), and White-eyed Vireo (*Vireo griseus*).

Since the mid-1900s, agricultural practices in the MACP have greatly diminished the availability of idle lands for grassland-obligate and shrubland species. The introduction and widespread use of cool-season grasses such as tall fescue (*Festuca arundinacea*) and other herbaceous plant species (e.g., sericea lespedeza [*Lespedeza cuneata*]) have greatly reduced habitat quality for many grassland species. Although early-successional shrubland bird communities have not been as affected, the quantity and quality of shrubland habitats within the region are lacking. More than 50 percent of bird species within the MACP with a declining trend are associated with early successional grassland/shrubland habitats (Watts 1999). In the eastern United States, native grassland bird species populations have declined by almost 90 percent (Vickery et al. 1999).

According to Watts (1999), military installations provide some of the most significant forested and early successional habitats within the MACP. As such, it is important that these lands be identified, inventoried, and integrated into conservation planning processes to maximize their contribution to regional habitat and population goals. Natural resource managers charged with decision-making on these lands must be well informed of the priority habitats that they control and how appropriate management strategies can assist with meeting regional conservation objectives (Watts 1999).

The Fort Belvoir, Virginia, Environmental and Natural Resources Division is proactive in its approach to incorporating PIF objectives into their natural resources management strategy. The installation began its involvement with PIF in the mid-1990s by supporting the Monitoring Avian Productivity and Survivorship (MAPS) Program. A MAPS station has been operated on the installation every year since 1995. In 1998, Fort Belvoir initiated an installation-wide multi-year, multi-season bird survey to develop a comprehensive inventory of bird species, and evaluate habitat conditions and develop recommendations for habitat conservation and improvement. Fort Belvoir incorporated the preliminary results of this survey work, together with information gained through other survey efforts including Christmas Bird Counts, Breeding Bird Surveys and Jackson Miles Abbott's Fort Belvoir bird surveys, into their INRMP (U.S. Army Garrison, Fort Belvoir, 2001). Fort Belvoir expressed the installation's commitment to the PIF regional conservation objectives by including management actions for long-term monitoring and habitat conservation and enhancement, along with regional coordination of the PIF Program in their INRMP. Fort Belvoir used PIF Mid-Atlantic priority bird species and their associated habitats to designate sensitive wildlife habitat areas and identify potential areas for habitat improvement. For the latter, Fort Belvoir selected several PIF MACP priority bird species that 1) could reasonably be expected to maintain a viable population at Fort Belvoir, and 2) have habitat needs compatible with the habitat needs of other wildlife species of management interest on Fort Belvoir.

In 2000, the authors developed and hosted a Mid-Atlantic PIF conference at Fort Belvoir. Key attendees included representatives from PIF, other bird management programs (e.g., North American Waterfowl Management Program), regional land managers, and federal and state wildlife biologists. As a result of this conference, and using the conservation objectives expressed in Fort Belvoir's INRMP, we initiated development of the Fort Belvoir Bird Conservation Plan. In developing

this plan we synthesized data from several sources, including the PIF MACP Bird Conservation Plan (BCP) (Watts 1999), the Fort Belvoir INRMP (U.S. Army Garrison Fort Belvoir 2001), Fort Belvoir's multi-season bird survey data, MAPS data, Christmas Bird Count data and other inventory data and management plans. The objective of this paper is to describe the development of an implementation plan for managing PIF priority habitats on an eastern military installation to promote regional habitat and bird conservation planning goals.

Methods

Study Area

Fort Belvoir is located in southeastern Fairfax County, Virginia, approximately 32 km southwest of Washington, DC. The installation, which occupies 3,434 ha, is located within the MACP physiographic area identified by PIF (*fig. 1*). Fort Belvoir supports a diversity of habitats important to a wide variety of birds, including bottomland hardwood and upland mixed forests, freshwater and brackish emergent wetlands, riparian areas, and early-successional shrublands.

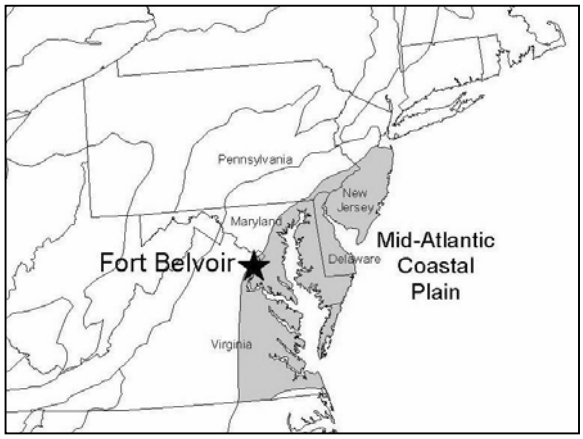

Figure 1— Location of Fort Belvoir, VA, in the Mid-Atlantic Coastal Plain.

Avian Sampling

From April 1998 to June 2002, we established and sampled 127 permanent sampling points in representative forested and non-forested habitats. We used standardized, unlimited distance point-count surveys to census birds during all seasons. Observers counted birds for 10 minutes during Spring and Fall migration, and 5 minutes during Summer and Winter; all species and individuals detected by sight and sound were recorded. Observers began recording data when they reached a point that was <50 m from the point-count station, which enabled the recording of individuals that were initially present but stopped vocalizing or flushed upon approach by the observer. The methodology used in this investigation is a standardized protocol for censusing breeding birds in the Southeast (Hamel et al. 1996).

Results and Discussion

During the monitoring period, early-successional habitats consistently had the highest mean bird species richness and abundance during the spring migration and summer breeding seasons (*figs. 2, 3*). Numerous PIF priority species breed in early-successional habitats and the presence of these species in Fort Belvoir oldfield habitats confirms the importance of this habitat type on post. Such species include the Prairie Warbler, White-eyed Vireo, Field Sparrow and Yellow-breasted Chat. Based on our investigation, although early-successional habitat represents only a small percentage of the total available habitat on the installation, it is one of the most important breeding habitats for PIF Priority species. Therefore, we suggest that management to increase the quantity and quality of early-successional habitat on Fort Belvoir should be a conservation priority. Our goal is to develop a plan for converting low-quality open areas on Fort Belvoir to higher-quality shrubland and grassland communities. Our intention is to use a combination of management techniques to achieve habitat enhancement, including (1) selected tree harvests to improve the quality of existing shrublands and early-successional habitats, and (2) manipulations of soil conditions and enhancement of vegetation cover to improve plant species composition and structural diversity of these stands.

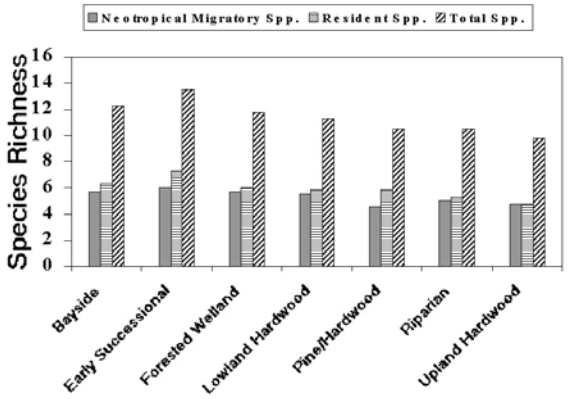

Figure 2— Mean species richness by habitat type during spring migration on Fort Belvoir, VA. May 1998-2002.

Decision-Support for Habitat Management

Grassland-obligate bird species within the MACP reach their highest density and probability of occurrence within patches >10 ha in size (Watts 1999). Open

lands <10 ha that are managed as "grasslands" are often considered suboptimal because they are not large enough for "area-sensitive" grassland birds and do not have adequate woody vegetation for shrubland bird species. Watts (1999) reported that the most abundant and widespread patches of open land within the MACP are <10 ha in size, meaning that a significant amount of open land within the region would be suboptimal as grassland. Therefore, instead of managing these small-sized areas as grasslands, greater conservation benefit would be realized through the conversion and subsequent management of these patches as shrublands.

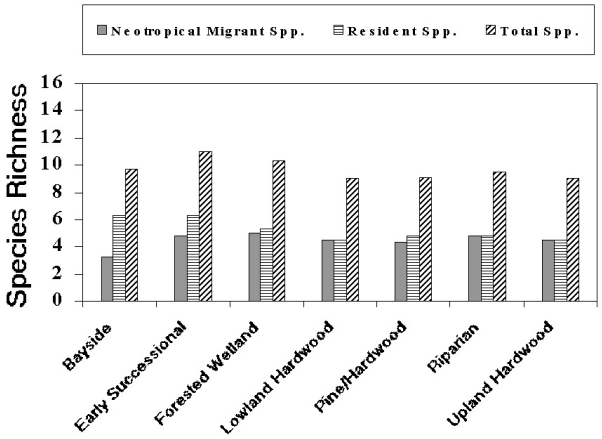

Figure 3— Mean species richness by habitat type during the breeding season on Fort Belvoir, VA, June 1998-2002.

All early-successional patch sizes on Fort Belvoir under consideration for bird habitat management fall below the 10-ha threshold. Moreover, the results of our intensive seasonal bird surveys indicated that these areas support a variety of early-successional habitats with a range of vegetation composition and habitat quality, each comprised of varying densities of several priority early-successional shrubland bird species. For example, scattered shrubland communities on the installation contained a mixture of grasses, herbaceous plants, and small trees that provide significant habitat for several priority species (e.g., Prairie Warbler, Field Sparrow, White-eyed Vireo). Thus, shifting the management focus of small early-successional patches on Fort Belvoir to shrublands would increase the availability of habitat for shrub-dependent birds on the installation as well as contribute to the overall goals of the MACP plan.

We identified three potential options for management of open areas on Fort Belvoir that had potential for providing habitat for PIF priority bird species: (1) enlarge existing open areas to rise above the 10-ha threshold and attempt to convert them to warm-season grasslands, (2) manage and maintain open areas as shrublands for early-successional bird species, or (3) allow habitat patches that are either too small for shrubland management, or would assist in closing up gaps and reduce forest fragmentation, to undergo succession into mature forest.

Option 1

An initial assessment identified two potential sites, a closed landfill and a former impact area, that could be connected via tree clearing, to create a 24 ha patch that could be managed for grassland birds. However, given logistical and political constraints associated with this conversion, we suggested that Fort Belvoir continue to manage the landfill as a grassland, and attempt to convert the vegetation cover from lespedeza to vegetation with better wildlife habitat value. Although the site is < 25 ac in size, some habitat benefits may be created for breeding Eastern Meadowlarks (*Sturnella magna*) and, possibly, Grasshopper Sparrows. The site also likely would provide suitable wintering habitat for numerous species (very few species currently use the site during any season).

Option 2

Open areas too small for grassland management but large enough for shrubland management were identified for potential habitat manipulations. We recommend maintaining a mixture of early- and late-successional stages of oldfield succession. All priority shrubland bird species within the MACP show a positive response to the density of shrub cover within oldfields, but differ somewhat in their preference for various levels of woody intrusion (Watts et al. 1997). For example, Prairie Warblers and Field Sparrows use a range of relatively young oldfields, from those having scattered shrubs and trees to older fields with moderate shrub cover. Neither of these species will readily use later successional stages where shrub and sapling cover becomes very dense (Watts 1999). Field sparrows generally decline in numbers as woody vegetation cover becomes continuous (Carey et al. 1994). Conversely, Yellow-breasted Chats prefer later successional stages of oldfields having moderate to dense shrub cover (Eckerle and Thompson 2001); other shrubland species like Brown Thrasher, Eastern Towhee, and White-eyed Vireo also prefer later successional oldfields having dense thickets of shrubs and saplings (Watts 1999).

Many open areas on Fort Belvoir are deficient in either vegetation composition or structure, and contain several highly invasive non-native tree and herbaceous species. For example, sericea lespedeza and tall fescue currently dominate nearly all open areas on the installation, significantly reducing habitat quality and quantity. In areas suitable for shrubland management, we are investigating the potential for conversion or enhancement of vegetation from low-quality plants to a

mixture of native warm-season grasses and other herbaceous and woody species beneficial to shrubland birds in the eastern U.S. (i.e., plant species that provide food and cover during all seasons). We plan to attempt various management techniques (e.g., tree removal; soil fertilization and amendment; application of herbicides followed by plantings of native grass, herb, and shrub species) to maintain or enhance these early-successional habitats in support of regional PIF goals. In the absence of regular maintenance (e.g., fire, mowing, tree harvest) to maintain early succession, open fields will progress through successional stages from a mixed stand of grasses and forbs with little woody vegetation to a shrubland dominated by woody shrubs and saplings, and eventually to forest. This is occurring rapidly at several open shrubby areas on the installation. Most early-successional bird species, while initially present, will eventually cease to use these areas.

Because of safety concerns, prescribed fire as a management tool is not a feasible option on Fort Belvoir for assisting the conversion and maintenance of early-successional habitats. However, the recent release of several highly effective herbicides has revolutionized the eradication of cool-season grasses and other invasive or non-native herbaceous and woody species, and enhanced success for the subsequent establishment of native warm-season grasses (e.g., Washburn et al. 1999, Washburn and Barnes 2000). Either a rigorous mowing regime or prudent application of herbicides followed by reseeding and replanting techniques offers the best hope for converting vegetation cover. At Fort Belvoir, such conversion is complicated by poor soil conditions. All of the open areas addressed in this study have little to no topsoil, most of which is of poor quality. These poor soil conditions have promoted establishment of opportunistic species such as sericea lespedeza. Soil conditions will need to be amended before attempting vegetation conversions.

Most shrubland bird species would benefit from the establishment of native warm-season grasses (e.g., big bluestem [*Andropogon gerardii*], little bluestem [*Schizachrium scoparium*], and indiangrass [*Sorghastrum nutans*]), shrubs (e.g., blackberry and raspberry [*Rubus* spp.], hawthorn [*Crataegus* spp.], sumac [*Rhus* spp.]), and trees (e.g., American holly [*Ilex opaca*], black cherry [*Prunus serotina*], hackberry [*Celtis occidentalis*], flowering dogwood [*Cornus florida*], red mulberry [*Morus rubra*], and oak [*Quercus* spp.]). Recommendations and guidelines for the conversion of 10 ha and smaller patches to shrublands have not been developed for the region (Watts 1999), thus the Fort Belvoir effort can assist in providing recommendations for other sites within the MACP.

Option 3

Allow small habitat blocks to succeed to forest habitat. These include areas deemed too small for effective habitat conversion, or those areas identified as habitat patches that, if allowed to succeed into forest, would increase patch size of forest blocks. None of the open areas assessed at Fort Belvoir were determined to benefit from conversion to forest habitat. Moreover the areas we evaluated all have operational requirements to be maintained in some type of open condition (e.g., landfill closure requirements prohibit establishment of woody vegetation).

As with most habitat management programs, there are some factors that hinder plan formulation and development. Funding tends to be the largest limiting factor; as budgets get tighter, funding for elective activities such as bird conservation becomes more difficult. Fort Belvoir has a contract workforce, and requires funds to hire contract staff and equipment to perform field projects for installation-wide surveys of birds, plant communities, invasive/exotic vegetation, and other taxonomic species groups, to manage data (e.g., GIS specialists), and to execute the habitat enhancement projects in the field. Second, resistance from the hunting community can be a problem, especially when they view any efforts toward "non-game species" management as in direct conflict with "game species" management. However, the proposed habitat enhancements will likely also benefit game species like white-tailed deer (*Odocoileus virginianus*) and eastern wild turkey (*Meleagris gallapavo*), allaying some of these concerns. Third, unprecedented development pressure is contributing to habitat loss and degradation on the installation. Because there are no regulatory requirements for the conservation of most PIF priority bird species, it can be difficult to convince the development community to consider them when making decisions on designing and siting new facilities. Finally, the largest grasslands on Fort Belvoir occur on closed landfills and at the installation airfield. Any habitat manipulation must make landfill closure and airfield operation requirements a priority.

The success of bird conservation and the DoD PIF program on military lands, like the larger natural resources management framework, is due largely to two key factors: dedicated professionals and successful partnerships. Natural resources professionals at Fort Belvoir and throughout DoD embody the thinking of Aldo Leopold (1949): "A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise." Balancing the needs of the military mission with those of protecting biodiversity requires the institutional memory, expertise, and dedication exhibited by these civilian employees. The research and recommendations

presented in this paper were completed over the course of several years with the close cooperation of the Fort Belvoir staff. Successful implementation and monitoring will require institutional dedication over many years.

Acknowledgments

The authors wish to thank G. Fleming and M. Guilfoyle for extensive data collection efforts, and M. Hudson for helpful comments on this manuscript.

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Resource Management Planning Efforts on the Bureau of Land Management's Snake River Birds of Prey National Conservation Area[1]

John Sullivan[2]

In 1993, Congress passed Public Law 103-64, which established the Snake River Birds of Prey National Conservation Area (NCA) for the purpose of conserving, protecting, and enhancing raptor populations and habitats. The NCA encompasses over 485,000 acres of public land along 130 km of the Snake River in southwest Idaho, and is located within a 30-minute drive of Boise and about half of Idaho's population. The area supports one of the highest densities of non-colonial nesting raptors in the world (USDI 1979b, Olendorff et al. 1989), and has been popular with raptor enthusiasts since the 1940s. Over 700 raptor pairs representing 16 species nest in the NCA each spring, with an additional eight species migrating through the area during various seasons. The increasing human population in the area has caused a number of recreation-related impacts to the NCA. The greatest impacts, however, have been caused by natural and human-caused wildfires.

Since 1980, about 280,000 acres of Wyoming Big Sagebrush (*Artemisia tridentata wyomingensis*)/ bunchgrass habitat have burned at least once (*fig. 1*). About 60,000 of these acres have burned as many as four times during that period. Most of the burned areas have been replaced with exotic annual grasses and weeds, particularly cheatgrass (*Bromus tectorum*) (USDI 1996). Because cheatgrass forms a continuous carpet of fine fuel that ignites easily and burns rapidly (Pyke 2000), the widespread conversion to this annual grass type has resulted in larger and more frequent wildfires (USDI 1996). The increase in the fire cycle keeps native shrubs from reestablishing and promotes the spread and persistence of cheatgrass and other exotics. Wildfire-related shrub loss in the NCA may have adversely affected Golden Eagles (*Aquila chrysaetos*) by reducing the NCA's carrying capacity for Golden Eagles (Kochert et al. 1999). The number of Golden Eagle pairs occupying nesting territories in the NCA declined significantly from 1971 to 1994 (Steenhof et al. 1997). The number of Prairie Falcon (*Falco mexicanus*) pairs found on long-term survey segments within the NCA also declined significantly from 1976 to 1997 (Steenhof et al. 1999).

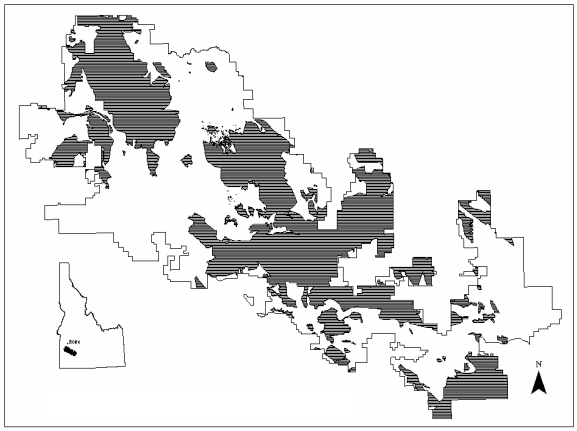

Figure 1— Snake River Birds of Prey Fire History 1980 through 2001.

Golden Eagles prefer to eat jackrabbits (Steenhof and Kochert 1988), and Knick and Dyer (1997) documented a decline in Black-tailed Jackrabbit (*Lepus californicus*) abundance in the NCA from 1971-1992. As a result, some of the Golden Eagle pairs have enlarged the size of their home ranges to accommodate different foraging needs (Kochert et al. 1999), which has reduced the NCA's ability to support numbers of Golden Eagle nesting pairs by about 15 percent over the past 30 years. Numbers of Prairie Falcon nesting pairs have also shown significant declines in some areas of the Snake River Canyon, but have remained fairly stable in other areas. Steenhof et al. (1999) showed that declines in Prairie Falcon nesting pairs from 1976-1997 occurred mainly in the west-central area of the canyon (*fig. 2*). However, the only area that showed a decline in 2002 was the area around the Simplot Grandview feedlot (*fig. 2*) (K. Steenhof, pers. comm.). The NCA's Prairie Falcons, which may have represented up to 5 percent of the world's population (USDI 1979a), feed primarily on Piute (formerly Townsend's) Ground Squirrels (*Spermophilus mollis idahoensis*). The broadscale change to an annual grassland has caused ground squirrel populations to become less stable (Yensen et al. 1992, Van Horne et al. 1997), and population numbers annually fluctuate much more than before. Other land uses in the NCA, such as livestock grazing, military training, and off-road vehicle use, also are suspected of affecting raptor populations because of their impacts on vegetation, but the escalating fire cycle, the associated loss of native plant

[1]A version of this paper was presented at **the Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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communities, and spread of annual weeds is believed to have had the most significant and profound influence.

In August, 2001, the NCA initiated the development of a Resource Management Plan (RMP), which is expected to take about four years to complete. The RMP is the BLM's umbrella planning document that will outline the desired future resource conditions that BLM hopes to attain over the next 20 years. Issues that will be addressed in the plan have been finalized, and BLM will now begin development of various management alternatives that will allow the agency to move towards the desired future resource conditions. BLM will use scientific data gathered from a number of research and monitoring projects over the past 20 years to analyze the impacts of the alternatives. Based on the analyses, BLM will determine which combinations of future uses are most consistent and compatible with the purposes for which the NCA was established. The most significant issues to be addressed are the conservation and protection of raptor and prey species, management of hazardous fuels, reduction in numbers and acreage of wildfires, and restoration of raptor prey habitat.

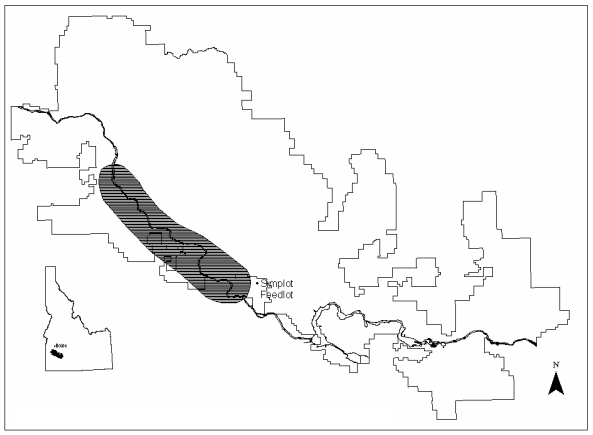

Figure 2— Shaded areas show the West/Central area of the Snake River Canyon.

The RMP will identify improved wildfire protection measures for remaining shrublands; establish viable, long-term, landscape-level habitat objectives; identify and prioritize the areas where habitat restoration projects will occur; and define a scientific approach for conducting habitat restoration. The plan also will include an adaptive management strategy to continuously evaluate and provide timely feedback from ongoing activities. This information will be used to increase the effectiveness of subsequent management actions and investments, and will hopefully allow BLM to continue to conserve, protect, and enhance the raptor populations and habitats for which the NCA was established, as required by the enabling legislation.

Acknowledgments

The author wishes to thank the Bureau of Land Management and the Idaho Army National Guard for their support of the various research and monitoring projects leading up to this land use planning effort, as well as their support of the planning effort itself. I also wish to thank M. Kochert, K. Steenhof, and T. Rich for their kind assistance in reviewing this document.

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Using Birds to Guide Management[1]

Bob Budd[2]

Most years, bluebirds come home to Wyoming on the 23rd day of March. I know this date because I have watched the birds for decades. It is not a date of great ornithological importance. The 23rd of March is my mother's birthday, and my mother loves bluebirds. As a son, you tend to remember things like mothers and bluebirds.

For a land manager, these things become fact, irrefutable correlations of centuries of observation. Scientists may show data to refute such and land managers may be impressed, but data will not change the fact that bluebirds come home to Wyoming on or around the 23rd of March. If those bluebirds aren't there around the 23rd of March, something is wrong. And, when bluebirds return, it snows. That's just the way it is. Of course, some may choose to "pick nits" about whether these blue birds are Lazuli Buntings (*Passerina amoena*), Mountain Bluebirds (*Sialia currucoides*), Eastern Bluebirds (*S. sialis*), Indigo Buntings (*Passerina cyanea*), or Blue Grosbeaks (*P. caerulea*). This is ridiculous trivia. These are birds, and they are, in fact, blue.

Lately I have learned that the first returnees are usually Lazuli Buntings and Mountain Bluebirds. On the eastern slope of the Wind River Mountains where I live, these species usually arrive earlier than the other blue birds. Over in the Wyoming range, there aren't so many buntings, and the blue birds there are Mountain Bluebirds. Perhaps they are so important to residents because they are harbingers of spring; and after long winter months of nothing but snow and brown grasses, they mean color again will become part of life.

It may surprise some to learn that I am not an ornithologist. Some may be dismayed to find that I am not even a qualified birder, though I can name many birds by their calls, including meadowlarks, geese, ducks, and Sandhill Cranes (*Grus canadensis*). I've just always liked birds. I grew up with wonderful, powerful women who loved birds. They were not well-educated in avian ecology. They just loved birds. When I was a little boy, my great-aunt would "sit" me at the window of her cabin and shush me, then tell me about each of the birds that fed on her handmade feeders or that nested in the cracks or boxes she had built for them to make a home. Mountain bluebirds and wrens were her favorites, but she did not care if the bird was brown or indigo. When we fished, she pointed to dippers, mergansers, and teal. And when she died, the birds she loved were in another part of the world, another continent, another ecosystem.

No matter. She always seemed to be happy to provide for birds in the world in which she lived, a summer place and a place where birds came and went as the snow and the cold moved in and out. She was very content with her world and with her part in the life of "her" birds. She had no control over the fate of birds that left her ranch when they departed in the fall; and while she cared deeply, she understood she had no control. There is nothing so disheartening as the feeling you have staring into a cage in Central America, suddenly able to buy a songbird with a band on its leg that has your own "return address."

When that return address is a patch of willow you nurtured, a bird in a cage makes the willows and the water and the changes in management seem small, but it does put your role in context. All I can do as a land manager is give the birds a place to breed and, hopefully, fledge more of their own.

The men in my life also connected with birds as much as they connected to plants and big animals. My grandfather called goldfinches "canaries," and I still do, just to aggravate ornithologists. He graduated from high school without much teaching in avian science, but he knew a "black-winged canary" from a "yellow canary," and he loved them both. One was a finch, the other a warbler. Some would hasten to point that out to him, I suppose, to keep him in his place. But few could manage willow thickets as he did, and none could care more. Nor could any of them take all of the willows away, as he could have done on any given day, by dropping a dozer blade, selling lots, or just quitting to care.

We will not make the world a better place for birds by simply showing graphs and data to each other. We will not make more habitats for birds by making those who feed birds feel insignificant or inferior to supreme intellect. We will make the world a better place for birds by engaging the innate sense of affection people have for bright creatures in their lives, and by telling a story of what these creatures need and like. Show a

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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rancher a flycatcher and tell him what they need. Love knows no boundaries. Thickets will abound.

Nor will any amount of law, order, arrogance, or education replace the simplicity of intimacy with a single piece of land. Leopold (Tanner 1987) said it most elegantly....."There is no conceivable way by which the general public can legislate crabapples, or grape tangles, or plum thickets....nor will the resolutions or prayers of the city change the depth of next winter's snow nor cause corn shocks to be left in the fields to feed the birds. All the non-farming public can do is to provide information and build incentives on which farmers may act."

In order to care for the long-term welfare of birds, we must understand the land and know where birds live. But we must also understand and appreciate the economic realities that place pressure on others. Until we can seek mutually beneficial outcomes for birds and those who raise them, we cannot even speak the same language. As in nearly all cases of natural resource conflict, the greatest barrier to getting the job done on the land is communication.

I am a land manager and a rancher. I like cows and I raise cattle, but I really love other things about ranching and what it offers the world. My "favorites" list is pretty simple: green grass, river otters, rain, weasels, sedges, bobcats, mule deer, willows, lizards, frogs, wrens, sagebrush, hummingbirds, fish, bears, falcons, fire, blue grama, wolverines, bighorn sheep, and bluebunch wheatgrass.

I like rain and hate drought, though both have always been part of my world. I am allergic to sagebrush but cannot live without it. I like big systems, big process, and all the little things that make time and space meaningful. I like diversity, and I like chaos. I like to see systems in various states of degradation and repair. One really hard rain can ruin my life's work on the land, and someday a hard rain will take my work away. I try to think in geologic time. I hope to act in my own time. I fully understand the paradox.

In recent years, I have come to the realization that birds offer land managers much more than color and sound. They are not just background or soundtrack to our work. Birds offer insight and feedback to management of natural resources. Making that information available and usable to landowners is key to more enlightened choices of how large landscapes may be managed. In most cases, there is no need for detailed analysis or statistical integrity. Mere presence or absence is often the indicator necessary to guide management. The need is great for simple identification of key species as indicators. Land managers will quickly pick up on those needs and make adjustments, just as my predecessors have done. A positive message will generate positive feedback. Instead of bemoaning missing species, we will be best served by using species that are strong indicators of particular habitats.

The presence of American Dippers (*Cinclus mexicanus*) on our creeks is a credible indicator of water quality and forage base for a species that is fairly picky about where it lives and eats. Likewise, abundant kingfishers, Great Blue Herons (*Ardea herodias*), and other fishing birds speak to the health of the aquatic system. Flashes of yellow, whether American Goldfinch (*Carduelis tristis*) or Yellow Warbler (*Dendrocia petechia*), tell me we are maintaining structure and density of woody species that house and feed those birds and others. Willow (*Empidonax traillii*) and Dusky (*Empidonax oberholseri*) flycatchers are great indicators of habitat in riparian areas, while Sage Thrashers (*Oreoscoptes montanus*) and Brewer's Sparrows (*Spizella breweri*) offer testimony to the quality of open sagebrush habitats. Newcomers like Bullock's Oriole (*Icterus bullockii*) and Blue Grosbeaks indicate we are maintaining structure for species that are perhaps slightly out of their normal range.

And sightings of birds less common often help me to remember the need for chaos that leads to a diversity of habitat types. For instance, as we have increased the scale and frequency of fire, we see Clark's Nutcracker (*Nucifraga columbiana*) and other species that thrive in a dynamic system. Absence of some species may help us understand deficiencies of the system, or remind us that we need to maintain specific habitats because it is difficult to take joy in something that is missing. For landowners, the real, the here and the now, will tell more than the maybe. As a result, indicators keyed to required habitats for many species are most desirable.

At Red Canyon Ranch, we are fortunate to have a banding station (MAPS) that is operating in its seventh year. From that meadow site, my learning curve has heightened and feedback to management is stronger and more constant. Andrea Cerovski has been able to teach me in the field, at my pace. She and her helpers have captured 96 species of birds on that small 60-acre site, mostly Neotropical migrants. Those species and their habitat requirements guide management of the area.

The meadow is small, and rather than cut hay, we normally graze the area in early spring and late fall to allow ground-nesting birds a full season without disturbance. By moving cattle keyed to birds' reproductive needs, we have been able to reduce the number of captures of cowbirds which indicates less potential for parasitism. We still remove the same amount of forage, but do so at times when we benefit by not feeding hay, or at times where the nutritional value of the grass is optimal to put on weight or improve condition

of cattle. We have been able to expand willow and shrub habitat by reducing mechanical harvest of forage. By knowing our bird clientele, we have been able to develop a mix of grasses and forbs that best provides seeds of the size most beneficial to those species. When we do cut the meadow, we time it to allow fledging. These are all management options that will work, not guided by all 96 species but by a handful of key residents that speaks for the whole.

A Yellow Warbler was captured on the ranch last year that had been banded 6 years earlier. This year, a bird estimated to be 6 years old was recaptured. The fact that these birds have migrated successfully back to this ranch for 6 to 8 years is astounding, but also an indicator that our management should not be altered greatly in the near future.

The next step for avian biologists and ranchers is to develop simple, abbreviated guides to different ecosystems and types, based on the birds we see. While most ranchers do not discuss warblers at peer meetings, they are universally drawn to birds and are truly curious about what birds tell them about the sustainability of their own ranches. Bird books are impressive, but intimidating. Song guides are helpful, but only if there are not too many notes in the tune. By making identification simple and correlating color and song with habitat and management, we will quickly see results on the ground. Results will be even more prevalent where mandate and regulation are absent.

The issues facing birds are the same issues facing land managers. Large habitat bases are being lost to rural subdivision and other alternative uses of the landscape. Habitat fragmentation and loss of large, open ranching landscapes are real and prevalent threats for many species. By using the responses of birds to guide our management of habitats, we will be able to sustain many species, and provide color and sound for those who love “bluebirds” and “canaries.”

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Wetlands Reserve Program: A Partnership to Restore Wetlands and Associated Habitat[1]

Randall L. Gray[2]

Key words: easement, migratory birds, waterfowl, Wetlands Reserve Program.

The 1990 Farm Bill created the Wetlands Reserve Program (WRP) to restore and protect wetland, which as of 2002 has enrolled over 1.4 million acres of wetland and upland habitat in 49 states and Puerto Rico. The program is administered by the U. S. Department of Agriculture Natural Resource Conservation Service and delivered in cooperation with many partners from the private and government sector. The program targets converted or degraded wetlands, primarily cropland, with a high probability of successful restoration. It authorizes permanent and 30-year easements as well as 10-year agreements. Restoration costs from 75% to 100% are provided, depending on the length of the easement. Most of the acreage is enrolled with permanent easements, and the remaining are 30-year easements or 10-year contracts.

The primary emphasis of the program is conservation of migratory birds, threatened and endangered species, and wetland-dependent wildlife. This is a wetlands program and is perceived to benefit primarily waterfowl, shorebirds, and wading birds. However, approximately half of the acreage is in existing or restored forest and grassland that provides habitat for a variety of non-wetland species. In selecting projects, priority is given to expanding the effective size of existing habitats such as private, state, or federal wildlife areas to decrease fragmentation as well as threatened and endangered species. In addition, sites that are potential habitat for threatened and endangered species or within bird conservation areas receive higher priority. Existing easements range in size from 1 ha to 4,000 ha, with even larger blocks of habitat consisting of multiple contiguous easements.

Although it is intuitive that converting cropland to wetlands, forest, and grasslands is good for birds and other wildlife, there are presently no quantitative studies on wildlife response to WRP restoration to validate this assumption. However, qualitative observations throughout the nation indicate the program is having major impacts upon birds. For example, in southeastern Oklahoma unusual or first time observations and nesting records for Wood Storks (*Mycteria americana*), White Ibis (*Eudocimus albus*), Willow Flycatchers (*Empidonax traillii*), Roseate Spoonbills (*Ajaia ajaja*), and Black-necked Stilts (*Himantopus mexicanus*) were made on the 7,500-acre Red Slough project (Steve Tully pers. comm). In Arkansas, over a half million waterfowl and 20,000 shorebirds were counted on the 7,000-acre Raft Creek Bottoms project following restoration (Jody Pagan, pers. comm.). In the lower Mississippi Valley, the program is restoring over 500,000 acres of bottomland hardwood forests and wetlands that are providing habitat for an array of songbirds, waterfowl, and wading birds. In Hawaii, the endangered Nene Goose (*Anser sandvicensis*) and Koloa Duck (*Anas wyvilliana*) are using WRP restoration projects (Terrell Kelley, pers. comm.).

Conservationists concerned with migratory bird habitat may play a significant role in establishing priority areas where the program will have the greatest impact and meet habitat restoration goals. The program allows landowners to conduct compatible uses such as haying, grazing, and timber harvesting when such activities further the long-term protection and enhancement of the wetland and do not adversely affect migratory birds. Each of these harvest practices can be a useful tool in specific situations to achieve habitat objectives if applied properly.

The 2002 Farm Security and Rural Investment Act extended the WRP and authorized the enrollment of another 1.2 million acres. When completed, this will double the habitat restored and protected by the program and will potentially have a great impact upon migratory birds.

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California**.

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The Prairie Partners' Approach to Landowner Outreach[1]

Tammy VerCauteren[2]

Abstract

With 70 percent of Great Plains habitat in private ownership, private landowners are the key to conservation of the prairie. Prairie Partners, developed by Rocky Mountain Bird Observatory, is a cooperative and voluntary effort to work with landowners, leaseholders, and land managers to conserve shortgrass prairie birds and their habitats. The ultimate goal of Prairie Partners is to build a coalition of landowners and land managers across the Great Plains who are actively involved in the conservation of lands important to prairie birds. Outreach is imperative to raise the awareness of prairie birds with private landowners. Landowner awareness is the first step toward conservation because it creates an appreciation for, and pride in, the birds and their habitats supported by the private landowners. We thank landowners for their stewardship, and we encourage their continued efforts. Prairie Partners also strives to work with landowners and managers to incorporate birds into management practices through incentive programs. Most landowners are already good stewards of the land, and they can serve as mentors for their peers. The success of our program largely is contingent on our partnerships with state, federal, and private organizations. State agencies, including Nebraska Game and Parks Commission and Colorado Division of Wildlife, help make our monitoring and outreach efforts possible. Other partnerships with entities like Natural Resources Conservation Service and Soil Conservation Districts, who work with private landowners on a daily basis, are critical also.

Key words: shortgrass prairie, private landowners, outreach, partnerships, birds, habitat.

Introduction

Prairie Partners, a program developed by the Rocky Mountain Bird Observatory (RMBO), was designed to address shortgrass prairie conservation issues and declining avian species by seeking cooperative and voluntary working partnerships with landowners and managers. The mission of Prairie Partners is to build a coalition of landowners and managers across the Great Plains who are actively involved in the conservation of lands important to prairie birds. The majority of shortgrass prairie (*fig. 1*) is privately owned, so the foundation of Prairie Partners is working with private landowners. We thank landowners for the habitat they provide and raise awareness of birds on their land. Awareness is the first step toward conservation because one cannot conserve where awareness and/or familiarity are absent.

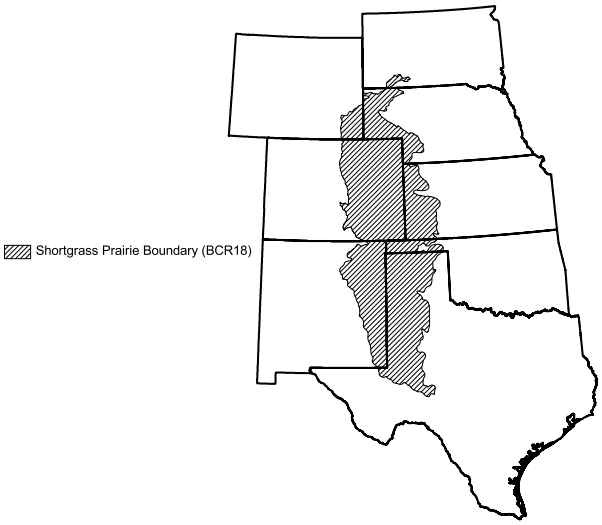

Figure 1— Shortgrass Prairie Conservation Region Boundary as delineated by the North American Bird Conservation Initiative.

Grassland birds rank high in conservation priorities among North American birds because they have shown the steepest population declines of any group (Knopf 1996). Sixty percent of the shortgrass region remains in grassland habitats (Weaver et al. 1996) with the majority of it managed by grazing (Beidleman 2000). According to the Partners in Flight Assessment and Prioritization database (Rocky Mountain Bird Observatory 2002), 11 percent of shortgrass prairie bird species are declining in the Great Plains, including Long-billed Curlew (*Numenius americanus*) and Lark Bunting (*Calamospiza melanocorys*). Data are insufficient to determine trends for 66 percent of Great Plains breeding bird species (including Burrowing Owl [*Athene*

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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cunicularia] and Chestnut-collared Longspur [*Calcarius ornatus*]). Twenty species have been identified as conservation priorities in one or more Bird Conservation Plans (BCP) within the shortgrass region (*table 1*). Prairie Partners is needed because the remaining shortgrass prairies are of conservation concern and are privately owned.

Outreach

Prairie Partners is at work in Bird Conservation Regions (U.S. NABCI Committee 2000) 17 (Badlands and Prairies) and 18 (Shortgrass Prairie). On-the-ground efforts by Prairie Partners began in 1999 when we initiated a four-state Burrowing Owl survey in Montana, Wyoming, Colorado, and New Mexico. Along with Burrowing Owl surveys, we had personal conversations with private landowners and had them respond to an attitudinal survey that was developed by a consulting firm. A sample of results for Wyoming and Colorado (*table 2*) represents over 60 private landowners. The survey results aided our efforts to work with private landowners because it gave us a better understanding of their opinion on issues important to Prairie Partners and helped us establish working relationships.

Outreach efforts include personal one-on-one conversations with private landowners, presentations, and information booths at meetings. Knocking on individual doors is time consuming; booths and presentations at meetings are efficient ways to meet multiple landowners. Attending agricultural meetings provides a comfortable, relaxed atmosphere for landowners and our presence at these meetings helps create credibility and trust. A relationship starts to build when landowners see us year after year at the meetings. Landowners feel comfortable and begin talking with us about their wildlife and ways we can work together. It is also a great atmosphere to introduce upcoming events and get feedback from landowners regarding programs or projects.

Through personal conversations with landowners, we get to know each other and landowners start introducing us to friends and neighbors. This provides us with an introduction by someone they know, trust, and respect. We also meet with representatives of different landowner-based organizations to learn more about landowner issues and to receive feedback on materials we provide. We make presentations to Natural Resources Conservation Service, Soil Conservation District, and Cooperative Extension personnel. These entities are great resources to reach people and to spread the word about our program and upcoming activities. Some of these governmental entities provide cost-share and assistance programs to help with habitat enhancement projects on private land.

We keep relationships positive when talking with landowners and, first and foremost, we thank them for the habitats they provide. As trust and mutual respect develops, we stay in touch through mailings, phone calls,

Table 1-- *Priority Grassland Bird Species by Bird Conservation Plan (BCP), within the Shortgrass Prairie BCR, for Wyoming, Colorado, and New Mexico (www.partnersinflight.org/pifbcps.htm).*

Species	Wyoming BCP	Colorado BCP	New Mexico BCP
Swainson's Hawk		X	
Ferruginous Hawk	X	X	X
Prairie Falcon		X	
Plains Sharp-tailed Grouse		X	
Greater Prairie-Chicken		X	
Lesser Prairie-Chicken		X	X
Scaled Quail			X
Mountain Plover	X	X	X
Upland Sandpiper	X	X	
Long-billed Curlew	X	X	X
Burrowing Owl	X	X	X
Short-eared Owl	X		
Cassin's Sparrow		X	X
Lark Bunting	X	X	
Baird's Sparrow	X		
Grasshopper Sparrow	X	X	
McCown's Longspur	X	X	
Chestnut-collared Longspur	X		
Bobolink	X		
Dickcissel	X		

Table 2— *Selected results from the landowner attitudinal survey for Colorado and Wyoming, 1999.*

Question	Percent Wyoming	Percent Colorado
Are very or somewhat familiar with Burrowing Owls	50	57
Dislike having prairie dogs on their land	78	77
Prairie dog management should take the well being of Burrowing Owls into account	25	38
Federal protection of endangered species is a threat to your way of life	47	50
Would consider receiving assistance to maintain a prairie dog colony	25	38

and visits. We proceed slowly, at a relaxed pace that is comfortable so landowners do not feel pressured or that they are being forced into programs. A key element in our interactions is to understand their way of life and includes offering to help with feeding, branding, fence mending, and calving. Our interest and respect enhances relationships and stirs interest in talking about the birds on their land.

We provide a manual (Gillihan et al. 2001) to landowners during our visits. The manual provides information about the prairie, basic bird biology, and specifics about different prairie birds that include identification, range maps, and management practices that benefit each species. Information in the back of the manual includes assistance programs that are available to landowners.

While visiting with landowners, we ask for permission to inventory their land for birds. Landowners are invited along, and we talk with them about the species we observe including what habitats they frequent and why. We talk about visiting next year and get a feel for what, if any, programs may be suitable for the ranch.

Habitat incentives have become an integral part of Prairie Partners. We offer a list of alternatives that fits the diverse needs of private landowners. For example, our Ferruginous Hawk (*Buteo regalis*) conservation program provides information on Ferruginous Hawk nesting sites and raises awareness of these birds with private landowners. We identify nest sites that may be impacted by cattle concentrating around nest trees, causing debarking and soil compaction. We provide landowners with information about economic diversification and specific references on a variety of programs and opportunities. We help develop management plans with the landowners that enhance habitat for prairie bird species, and we help get these projects funded through state, federal, and other sources.

We plan to develop and implement workshops during the summer of 2002. Workshops will have two objectives. The first is to get urban residents on a working ranch and have them learn about and talk with agricultural producers. We want them to see the benefits of keeping producers on the land and to learn first hand of their societal value in providing food, fiber, open space, and wildlife habitat. The second objective is for private landowners to establish the link between wildlife habitat, good range management, and opportunities for economic diversification. We will visit with landowners about the different habitats within the prairie ecosystem, explain how birds can be used as indicators of land health, and introduce programs that are available to conserve or enhance habitats through state and federal agencies and other organizations. The workshop will end with a discussion of economics that tie together range health, wildlife habitat, and opportunities through nature tourism. To provide a comfortable atmosphere, landowners will host all workshops, with support from Prairie Partners.

Prairie Partners has a positive image with conservation organizations, agencies, and private landowners. We encourage proactive, voluntary relationships, and we work to get landowners to step forward and show their existing contributions to prairie bird conservation. When we plan with landowners, we must recognize the importance of ranch economics. We are striving to enhance the social, cultural, and economic conditions of the landowner. We want to keep landowners on the land and the heritage of the West intact. Human and wildlife communities will be healthier with the incorporation of birds into management practices. Birds are good indicators of land health. If the system is healthy for wildlife, it is also healthy and sustainable for people and cattle.

Program success can be measured by the annual ratio of privately owned acres to the number of acres owned by landowners enrolled in conservation easements, among others. Another measure of success is by the number of landowners more familiar with bird ecology on their land following our involvement. To date, we have had personal conversations with over 300 private landowners and have permission to inventory birds on over 160,000 ha. Landowners are inviting us to cattle brandings and to local meetings, and they are calling us about the different birds they see. Landowners have commented on how the birds used to be "background noise," but now they are aware of birds and have identified the different species. Some have altered their management practices to enhance bird populations. Once

key members of the community are involved, neighbors become more willing to get involved.

Monitoring is a critical element of the Prairie Partners program. Over time, trends obtained by the monitoring of shortgrass prairie bird species will help guide and evaluate the effectiveness of our conservation efforts. We are collecting monitoring data on sites where we have established relationships with landowners as well as random sites across the prairie. With time, we can compare trends across the region to trends on our Prairie Partners' lands. Furthermore, monitoring locates hot spots of species richness and identifies key landowners important to our outreach efforts.

Discussion

The next steps involve better coordination of efforts among existing entities because we share the common goal of native prairie conservation. The way to truly affect species conservation is to conserve habitat throughout the breeding, wintering, and stopover range of our migratory prairie birds. The best way to accomplish that is by improving coordination with agencies and non-governmental entities in the United States, Mexico, and Canada, supporting and contributing to conservation work in these areas.

In the short term, we need to expand partnerships with Natural Resources Conservation Service to incorporate birds into their monitoring and management efforts on private lands through our United States Department of Agriculture Sustainable Agriculture Research and Education program grant. We have developed a pocket guide to prairie birds, to be distributed to resource managers and landowners throughout the Great Plains. This spring, we will implement on-the-ground conservation efforts for Mountain Plover through an informational video and field- clearing project in cooperation with the Colorado Division of Wildlife, Colorado Farm Bureau, United States Geological Survey-Biological Resources Division, Colorado Natural Heritage Program, Colorado State University, United States Fish and Wildlife Service, The Nature Conservancy Playa Lakes Joint Venture, and Nebraska Game and Parks Commission. The video will focus on Mountain Plover identification, behavior, habitat and conservation needs. The field-clearing project involves establishing a toll-free number that landowners can call in advance of cultivation activities so RMBO technicians can mark nests. Mountain Plovers are attracted to bare ground and are using cultivated land as nesting sites; marking nests will help reduce loss of nests due to cultivation activities and possibly assist with population recruitment.

In the long term, we need to build on the success of the Nebraska Prairie Partners Project, which is a partnership between RMBO and the Nebraska Game and Parks Commission. Building on this project will involve getting more staff working with the states and within the local communities to achieve the objectives of Prairie Partners, including monitoring, outreach, and habitat conservation throughout BCR's 17 and 18. We also need to build on the success of Colorado workshops and expand these outreach efforts to states within the Great Plains. Also, current monitoring efforts in BCR 18 need to be expanded to BCR 17.

Finally, we and our partners need to take a more proactive approach regarding spreading the word with landowners about economic diversification opportunities through nature tourism. Nature tourism provides the opportunity to keep our stewards on the land and helps them see their land as more than just grass for cattle or grain for feed. When landowners receive economic returns for the natural resources on their land, they are more likely to incorporate them into their ranch management plans, which positively benefit the habitat and associated species.

Acknowledgments

I thank S. Gillihan, T. Rich, T. Toombs, and G. Wallace for the critical review of this paper. I thank W. Gilgert for material reviews and the opportunity to be a part of the conference. Prairie Partners is made possible through our funders and partners: Colorado Division of Wildlife, Nebraska Game and Parks Commission, Natural Resources Conservation Service including the Wildlife Habitat Management Institute, Shortgrass Bird Conservation Region, Turner Foundation, American Birding Association, LaSalle Adams Fund, Intermountain West Joint Venture, Adams County Scientific and Cultural Facilities District, Texas Prairie Rivers Association, National Fish and Wildlife Foundation, U.S. Fish and Wildlife Service, U.S. Forest Service, Nebraska Environmental Trust, Colorado Farm Bureau, The Nature Conservancy, Soil Conservation Districts, Resource Conservation and Development Program, Wyoming Game and Fish, University Extension, Playa Lakes Joint Venture, RMBO members, and private landowners.

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California Partners for Fish and Wildlife Program: Conserving Birds Through Private Partnerships[1]

Debra Schlafmann[2] and Philip Morrison[2]

Introduction

The Partners for Fish and Wildlife Program, the U.S. Fish and Wildlife Service's (Service) habitat restoration assistance program for private landowners, was created primarily to improve habitat for waterfowl. Since its inception in 1987, however, the program has grown to include the restoration of all types of habitat. The purpose of this paper is to explain how the Partners for Fish and Wildlife Program has grown from an effort to benefit waterfowl to one that can benefit a wide variety of bird species.

The Partners for Fish and Wildlife Program arose from the recognition that privately owned lands, which make up approximately 2/3 of the Unite States. land base, represented an untapped resource and that, if the Service was to accomplish its mission - working with others to conserve, protect, and enhance fish, wildlife, and plants and their habitats for the continuing benefit of the American people - it needed the help of private landowners to maintain healthy populations of fish and wildlife. The program was designed to be a proactive, voluntary program to assist landowners in improving fish and wildlife habitat on private lands by providing technical and financial assistance.

The program was originally established primarily as a wetland restoration program. However, it has grown and changed significantly since its inception. The program has evolved into a broader, ecosystem- and landscape-based effort that emphasizes the restoration of historic ecological communities for the benefit of federal trust species, which include migratory birds, anadromous fish, and threatened and endangered species. Project designs strive to restore the greatest habitat diversity where possible. Today the program includes restoration and enhancement of a variety of Federal trust species' habitats, including riparian corridors, in-stream habitats, native grasslands, and other upland habitats, as well as wetlands. The program promotes building partnerships with other agencies and nonprofit organizations, who provide financial and/or technical support. Typical partners include U.S. Department of Agriculture, Bureau of Reclamation, California Department of Fish and Game, Ducks Unlimited, California Waterfowl Association, and Joint Ventures.

Nationally, the program has restored approximately 574,800 acres of wetlands, 884,800 acres of native grasslands and other uplands, and 4,190 miles of riparian and stream habitat. In California, the Service has developed partnerships with more than 560 landowners, restoring and enhancing approximately 71,000 acres of wetlands, 4,700 acres of uplands, and 170 miles of riparian and stream habitat. Over time, the projects completed under the program have focused on the restoration of riparian, grassland, and other upland habitats (*fig. 1*).

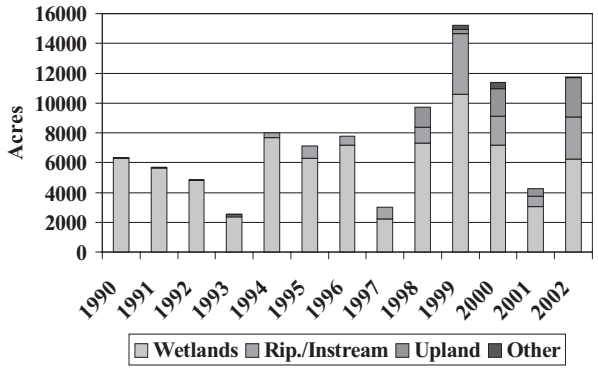

Figure 1—California Partners for Fish and Wildlife Program restoration accomplishments.

Habitat Improvement Strategies

The predominant wetland restoration activities in California are restoration of wetlands degraded as a result of agricultural activities to seasonal and semi-permanent emergent wetlands. These projects involve the use of bulldozers, excavators, and other earthmoving equipment to excavate historic swales and ponds to restore open water for waterfowl wintering habitat. Excavated material is used to build perimeter levees and nesting and loafing islands for waterfowl and shorebirds. Wetland restoration is also taking place in mountain meadow environments where downcutting and incised creeks cause wet meadows to dry. Instream structures are installed to stabilize the channel and col-

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California**.

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lect sediment to help raise channel bottoms and restore wetland hydrology to adjacent meadows.

Typical riparian restoration under this program involves installing livestock exclusion fence and planting cuttings or container stock, predominately composed of willow and cottonwood, but also including box elder, Oregon ash, buttonbush, elderberry, aspen, sycamore, and oaks. In addition, restoration may include the installation of drip irrigation systems, and the planting of native perennial grasses, sedges, and forbs in the riparian understory. Some projects include measures to stabilize banks and control erosion of the channel. Riparian habitats are also being restored by removing giant reed (*Arundo donax*), tamarisk (*Tamarix parviflora*) and other non-native invasive riparian plants from waterways.

Typical grassland restoration activities involve the removal of non-native invasive annual grasses and weedy forbs followed by the planting of native perennial grasses and forbs. Restoration begins by using farming techniques (disking, herbicide application), livestock, or fire to remove non-native plants from the project site. Native grasses and other upland plants are then planted through seed drilling, broadcasting, or plug planting. Follow-up applications of herbicide, mowing, livestock grazing, or other vegetation control methods are used to deter non-native plants while the native species become established.

Bird Conservation

Although wetland restoration continues to be the foundation of the Partners program, there is an increasing interest in riparian habitat restoration. Riparian habitats are extremely valuable for birds. Riparian ecosystems have the highest diversity and productivity of landbirds of any habitat type in the western United States. Over 135 species of birds in California depend upon riparian habitats or use them preferentially at some stage of their life history. Riparian habitat provides important breeding habitat, migration stopover areas, overwintering areas, and corridors for dispersal. However, over 95 percent of the historic streamside trees, shrubs, and ground vegetation in California has been lost as a result of urbanization, agricultural conversion, vegetation clearing for flood control, livestock grazing, and invasion of non-native plant species. The loss and degradation of riparian habitat are probably the greatest causes of the population decline occurring among bird species in western North America (RHJV 2000).

One of the goals of the Riparian Habitat Joint Venture is to double the extent of riparian habitat in California (RHJV 2000). The U.S. Fish and Wildlife Service, through the Partners for Fish and Wildlife Program, is striving to help meet that goal.

One example of riparian habitat restoration performed under this program can be found at Pete's Valley Ranch in northeastern California. Comprising 1,200 acres of wet meadows, wetlands, riparian habitat and sagebrush uplands, Pete's Creek has been managed since the 1940s as a cow/calf operation with season-long grazing that included intense use of the wetland and riparian areas. The loss of willows, sedges, and other streamside vegetation led to substantial erosion and down-cutting of the creek, lowering the water table in adjacent meadows. In turn, the meadows dried out earlier each year, allowing sagebrush to encroach. Two dams placed in Pete's Creek further degraded its value for fish (*fig. 2*).

Pete's Creek Partnership purchased the ranch in 1993 and the new owners realized that the existing grazing management system had a detrimental effect on the ranch's productivity and profitability. The new owners, disturbed by the decline of fish and wildlife habitats in the creek, wet meadows and uplands, sought financial and technical assistance to restore the damaged lands.

One of the owners contacted the Service about the Partners for Fish and Wildlife Program, and the Natural Resources Conservation Service (NRCS) to see if any of the Farm Bill conservation programs could fund their project. Service and NRCS staff met with the owners at the ranch in 1997 to discuss the proposed project. Because the anticipated benefits to fish, wildlife, wetlands, and water from the project would be so significant, both the Service, through the Partners program, and the NRCS contributed funds.

Biologists fenced and permanently excluded cattle from 1.25 miles of Pete's Creek, established a riparian buffer, and removed the dams to return historic flows to the creek. In addition, 120 acres of dense invasive sagebrush were removed, promoting the reestablishment of native perennial grasses and forbs.

Four years later, a dense riparian growth of sedges, forbs, grasses and willows provides feeding and breeding habitat for migratory songbirds (*fig. 3*). Mallards nest in dense cover along Pete's Creek. Pronghorn antelope are abundant and have access to the improved forage along the creek through the wildlife-friendly fence. A sage grouse "lek" (courting site) is located on the ranch and as many as 100 sage grouse have been seen on the property at one time. Sage grouse nest in the upland adjacent to the creek, and chicks and hens can be seen foraging among the forbs and perennial grasses in the riparian area.

The value of California's grasslands is also receiving increased attention by the Partners for Fish and Wildlife

Program. Native grasslands and other uplands provide important habitat for a wide variety of songbirds, foraging raptors, and nesting waterfowl. However, grassland birds face several problems here in California. The primary problems affecting grassland birds are the replacement of native perennial and annual grasses and forbs with exotics, the loss of grassland habitat, and the consequent reduction in the patch size of remaining grasslands (CPIF 2000). Grasslands around the Great Central Valley are becoming increasingly fragmented by urbanization and, in some areas, encroaching woody vegetation.

Again, the Pete's Valley Ranch project provides an example of how restoration through the Partners for Fish and Wildlife Program can benefit grassland bird species. As mentioned above, 120 acres of sagebrush were removed through brush-beating in order to allow for the reestablishment of native perennial grasses and forbs (*figs. 4* and *5*).

In summary, the Partners for Fish and Wildlife Program has evolved from a primarily wetland restoration program for the benefit of waterfowl, to one that is concerned with restoring or enhancing a wide variety of habitats for the benefit of all types of wildlife. Landowners enlist in the program for a variety of reasons such as restoring areas that have been difficult to farm because of flooding or soil type, planting trees to reduce wind erosion or stabilize an eroding stream, or increasing hunting and fishing opportunities. But most often landowners wish to participate in the Partners for Fish and Wildlife Program to provide habitat for those wildlife species they saw as a child. With more than two-thirds of California's land in private ownership, the future of wildlife habitat is heavily dependent on the conservation practices of the private landowner.

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Figure 2—Pete's Creek before partnership with Partners program.

Figure 3—Pete's Creek following restoration.

Figure 4—Pete's Valley Ranch uplands before restoration.

Figure 5—Pete's Valley Ranch uplands after restoration.

A Stewardship Approach to Grassland Bird Habitat Conservation in Saskatchewan, Canada[1]

Stephen K. Davis,[2, 3] Bob Springer,[2] Jennifer Lohmeyer,[2] Lesley Hall,[2] and Tom Harrison[2]

Introduction

Saskatchewan provides habitat for a number of grassland specialists that are of high conservation concern. For example, 10 of 12 "primary endemic," and 17 of 25 "secondary endemic" species of the Great Plains identified by Mengel (1970) regularly breed in Saskatchewan. In addition, each of the 30 species of high conservation concern currently identified in the Prairie Partners in Flight Bird Conservation Plan regularly breed in the province (Anderson et al., unpubl. data). Some species (e.g., Baird's Sparrow, *Ammodramus bairdii*), reach their greatest abundance in Saskatchewan (Sauer et al. 2002). While several species occur in seeded/introduced grassland (Davis and Duncan 2000), others such as Sprague's Pipit (*Anthus spragueii*) occur almost exclusively on native prairie (Owens and Myres 1973, Davis et al. 1999, McMaster and Davis 2001).

Nearly 162 million ha of native prairie was present on the Great Plains prior to European settlement. Land settlement and agricultural policies resulted in losses of 30-99.9 percent of the native prairie in North America, depending on the particular geographic area (Samson and Knopf 1994). In Saskatchewan, only 20 percent of the original native prairie remains, mostly in the southwestern portion of the province (Hammermeister et al. 2001). In some areas of the province where soils and landscapes are particularly suited for crop production, less than 0.1 percent of the original native prairie vegetation exists (Riemer et al. 1997). Existing native prairie continues to be threatened by cultivation, invasion by exotic plant species and woody vegetation, improper grazing management, and urban development (Riemer et al. 1997).

About 85 percent of Saskatchewan's 12.5 million acres of native prairie is privately managed with 45 percent under private ownership (Hammermeister et al. 2001). Therefore, it is important that any grassland bird conservation program include private land managers. In 1996, the Saskatchewan Wetland Conservation Corporation (SWCC; now Saskatchewan Watershed Authority) recognized this need and subsequently focused its activities on voluntary habitat stewardship programs with private landowners. SWCC's Native Prairie Stewardship Program is focused on private individuals that own and/or manage native prairie.

Since 1996, over 750 private landowners have participated in the program through Voluntary Stewardship Agreements. The Voluntary Stewardship Agreement is a verbal agreement whereby the producer agrees to maintain their native prairie to the best of their ability and to notify SWCC of major changes in management or change in ownership. Our primary objectives are to (1) discourage breaking of native prairie, (2) provide technical assistance to the producers if they are contemplating changes in management, and (3) contact new landowners to encourage them to conserve the native prairie.

Native Prairie Stewardship and Grassland Birds

SWCC's Native Prairie Stewardship Program comprises habitat enhancement, restoration, and securement. While the program is delivered throughout the grassland region of Saskatchewan, current emphasis is placed on key landscapes under the North American Waterfowl Management Plan. Within these regions, the focus is on native prairie because research has shown that many high priority grassland songbirds reach their greatest abundance/occurrence on native prairie rather than in cropland or seeded pastures and hayfields (Owens and Myres 1973, Wilson and Belcher 1989, Davis et al. 1999). In addition, the program does not concentrate only on large blocks of contiguous grassland as small patches of native prairie have been shown to be as productive as large patches for several grassland songbirds including Baird's Sparrow (Davis 2003).

Restoration and enhancement activities focus primarily on converting cropland to perennial cover (primarily for grazing) and promoting range management activities that improve range condition (Abouguendia 1990).

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[1]A version of this paper was presented at the **Third International Partners in flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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Converting cropland to seeded pasture provides habitat directly for grassland birds (Davis and Duncan 1999) and there is less chance of mortality due to management such as cutting hayfields (Bollinger and Gavin 1992, Dale et al. 1997). Converting cropland to pasture also helps to increase patch size and enhance existing native prairie by providing landowners the opportunity to defer grazing on their native prairie by grazing the seeded pasture earlier in the season. Improving range condition and increasing patch size can improve habitat quality for species of high conservation concern such as Sprague's Pipit (S.K. Davis, B.C. Dale and D.C. Duncan, unpubl. data; Davis 2003).

Native Prairie Stewardship and Private Landowners

In a survey of 148 landowners completed in January 2001, 36 percent said they joined our Native Prairie Stewardship Program because they wanted to preserve their prairie, 33 percent said it sounded like a good idea, 9 percent said they valued their native prairie, and 9 percent said they joined because it was something they were already doing. We also believe that many landowners have joined the program because it is non-threatening. The Voluntary Stewardship Agreements are not legally binding; no signature is required—only a handshake. Landowners maintain control of their land and are not worried about the "government coming in and taking it over."

The personal visit we make with the landowner also has contributed to the success of the program. In the first year of the program we determined the best methods to contact landowners. The methods involved:

1) Mail-out only: 100 landowners were sent an information package in the mail that included a postage-paid reply card. Landowners who did not respond were sent a second letter five weeks later.

2) Mail-out and phone call: 100 landowners were sent an information package in the mail that included a toll-free telephone number to reply to. Landowners who did not respond were phoned 2-3 weeks later to arrange a personal visit.

3) Unannounced visit: 100 landowners were "dropped-in" on without notice for a personal visit.

4) Arranged visit: 100 landowners were phoned and a personal visit was arranged.

Only 10 percent of landowners contacted through mail-outs alone (Method 1) responded, whereas 50 percent, 46 percent, and 48 percent of landowners contacted through Methods 2, 3, and 4, respectively, became voluntary stewards. All of these methods involved a personal visit. However, arranged visits (Method 4) have been determined to be most cost effective. Our personal visits let landowners know that our program is important enough for us to take the time to meet them in person. It also supplies the landowner with a face that they can associate with the organization, thus increasing their level of trust—an important factor in gaining participation.

Having joined the program, feedback from landowners indicated that frequent contact was required to maintain their interest. This was accomplished through information provided through a combination of personal visits, a monthly newsletter, and extension activities such as workshops. Extension activities are extremely important because they demonstrate why conserving prairie is important and how landowners can improve the condition of native prairie and economic viability at the same time. For example, workshops allow landowners to see economically and environmentally feasible management techniques that other landowners in their area are using. Seeing the benefits of these practices first-hand is more likely to inspire a landowner to adopt these practices than if an agency representative tells him about them or simply provides written information.

A preliminary evaluation indicated that the program is accomplishing our objectives but that more work is needed. We conducted a phone survey of stewards in 2001 to assess their attitudes toward the program and to learn how the program has affected their management of native prairie. Seventy percent of those interviewed said they had learned something new about native prairie, 33 percent said that they see their prairie in a new way, and 83 percent rated the program as "good" or "excellent." Although 95 percent of stewards contacted indicated they had not broken any native prairie since joining the program, eight (5 percent) landowners indicated that they had broken some native prairie. Reasons for breaking native prairie included, (1) seeding to tame pasture, (2) creating a trail, (3) establishing shelterbelts around homes, and (4) no longer had cattle and did not need some of the previously used grassland. Although these activities involved a small amount of native prairie (largest was 8 ha), our hope is to continue to gather more information about the effectiveness of the program so that we can further reduce the number of acres of native prairie lost.

Recommendations

Our advice to individuals and agencies interested in delivering similar programs with private landowners is that trust, continual contact, flexibility, and credibility are extremely important principles for successful program delivery. Meeting landowners in person helps to gain their trust, and if landowners are only available at lunchtime or in the evenings, then adhering to traditional workday hours will hamper success. Be flexible and adjust your schedule to fit your target audience. After initial contact, a regular newsletter and periodic workshops are effective in maintaining relationships. Workshops should be scheduled at times that are convenient for landowners, not during calving or seeding, for example.

Workshops should be held in a setting that your audience is comfortable in to improve attendance and increase the effectiveness of your message. For example, landowners may be intimidated by the thought of attending a workshop being held at a university, but they will attend one being held out of their local community center. Going to their communities further emphasizes the importance you place on your message. Lastly, terminology and activities should be constructed at a level of understanding that fits your audience. Overly academic or unfamiliar terms and concepts may only alienate a group of landowners.

Acknowledgments

The success of the Native Prairie Stewardship Program is due, in large part, to the partnerships formed with the following agencies to deliver and fund these activities:

Agriculture and Agri-food Canada through the Agriculture Institute of Management in Saskatchewan, Agriculture Environmental Stewardship Initiative, Canada-Saskatchewan Agricultural Green Plan Agreement, Canadian Adaptation and Rural Development in Saskatchewan, Canada Millennium Partnership Program, Government of Canada Habitat Stewardship Program for Species at Risk, TD-Canada Trust Friends of the Environment Foundation, Ducks Unlimited Canada, Canadian Wildlife Service & World Wildlife Fund (Endangered Species Recovery Fund), Nature Conservancy of Canada, Environment Canada through EcoACTION, National Fish and Wildlife Foundation, Saskatchewan Environment (Fish and Wildlife Development Fund), and Wildlife Habitat Canada.

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Ecological Niche Modeling as a New Paradigm for Large-Scale Investigations of Diversity and Distribution of Birds[1]

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Introduction

Large-scale assessments of the distribution and diversity of birds have been challenged by the need for a robust methodology for summarizing or predicting species' geographic distributions (e.g. Beard et al. 1999, Manel et al. 1999, Saveraid et al. 2001). Methodologies used in such studies have at times been inappropriate, or even more frequently limited in their analytical scope and predictive properties (Peterson et al. 2002c). A new set of methodologies focus on modeling the dimensions of species' ecological niches, and offer considerably improved analytical and predictive possibilities. The purpose of this brief contribution is to summarize these new methodologies, and to discuss several possible applications of this new approach.

Ecological Niche Modeling

Grinnell was first to propose an ecological niche concept (Grinnell 1917)—the range of ecological conditions within which a species can maintain populations. Later investigators focused niche concepts increasingly on the role of a species in an ecological community, and the two foci were eventually integrated and made more quantitative by MacArthur (1972). In the Grinnellian and MacArthurian views, the ecological niche is the quantity that governs the limits of geographic distributions of species.

To maximize applicability of these new techniques, we focus on techniques that relate point occurrence data to geographic information about the ecological and environmental characteristics of a landscape to produce a hypothesis of the dimensions of the species' niche. This ecological niche model can then be projected onto a landscape to identify geographic regions that have conditions inside and outside of the species' niche, producing a hypothesis of a potential geographic distribution for the species. It is important to distinguish this sort of approach (two steps: model the niche in ecological space, and project onto a landscape in geographic space) from other, simpler approaches that do not distinguish between ecological and geographic spaces (Peterson et al. 2002c): see e.g., Scott et al. (1996).

A particularly promising tool for ecological niche modeling is the Genetic Algorithm for Rule-set Prediction (GARP), a software application[4] that includes several inferential tools in an iterative, artificial-intelligence-based approach (Stockwell and Noble 1992, Stockwell 1999, Stockwell and Peters 1999). Occurrence points are divided evenly into training and test data sets. GARP works in an iterative process of rule selection, evaluation, testing, and incorporation or rejection: first, an inferential tool is chosen from a set of possibilities (e.g., logistic regression, bioclimatic rules), and then is applied to the training data and a rule developed; a rule is an IF…THEN statement that describes the conditions under which a species may be present (or absent). Rules are evolved by a number of means (e.g., truncation, point changes, crossing-over among rules) to maximize predictivity. Predictive accuracy is evaluated based on the test data and an equivalent number of points sampled randomly from the study region as a whole. The change in predictive accuracy from one iteration to the next is used to evaluate whether a particular rule should be incorporated into the model, and the algorithm runs either 1000 iterations or until convergence.

GARP models provide an efficient means of modeling species' ecological niches, and for projecting those models onto geography in the form of maps, which are testable hypotheses of distributional potential. The present implementation—for a stand-alone PC workstation—is able to process approximately 1000 models per 24 hr, and allows a rich environment for hypothesis-testing. The methodology has now seen numerous tests of predictive ability, including simple distributional prediction, prediction of community composition, and prediction of species invasions (Peterson et al. 1999; Peterson 2001; Peterson and Vieglais 2001; Anderson et al 2002a, 2002b; Feria and Peterson 2002; Peterson et al. 2002a, 2002c). The particulars of the method and its sensitivities have been tested and assessed with care (Peterson and Cohoon 1999; Stockwell and Peterson 2002a, 2002b; Anderson et al. 2003).

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California**.

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New Analytical Functionalities

Predicting and Summarizing Distributions

The principal focus of ecological niche modeling (e.g., GARP) is on predicting species' geographic distributions. GARP offers a highly predictive methodology to this end: limited numbers of known occurrence points (Stockwell and Peterson 2002) can be combined with limited numbers of ecological-environmental coverages (Peterson and Cohoon 1999) to produce models that are highly predictive of species' broader geographic distributions (Peterson et al. 1999; Peterson 2001; Feria and Peterson 2002; Peterson et al. 2002a, 2002c; Anderson et al. 2003).

One typical distribution-related challenge to which GARP models can speak powerfully is the vertebrate distributional models that are the core of Gap Analysis (Scott et al. 1996). The U.S. National Gap Analysis program and its proponents pioneered many of the early applications of distributional modeling and prediction, but too often stayed with earlier habitat-modeling techniques that offer considerably less predictive power. The essential difference between these older techniques and those being developed and explored presently is that the older approaches do not develop a quantitative model of an ecological niche. Too often, the distributional models used in Gap Analysis are static summaries of known distributions that cannot predict new knowledge. A head-to-head test of common Gap methodologies against ecological niche modeling techniques demonstrated considerably better predictive power in the latter approaches (Peterson and Kluza 2003).

Conservation Assessments

With the ability to predict species' distributions with statistical confidence, broader assessments of distributional patterns across entire biotas become feasible. For example, one study assessed the distributional patterns of endangered species in the United States (Godown and Peterson 2000), another examined threatened and endangered species in China (Chen and Peterson 2000, 2002), and another the distributions of endemic species in eastern Mexico (Egbert et al. 1998, Peterson et al. 2000).

The general approach in these studies is that of (1) identifying a universe of species to be examined, (2) modeling and predicting their distributions, and (3) prioritizing areas for conservation based on patterns of richness and complementarity among areas. In each case yet examined, the ecological niche modeling approach has been able to identify key additions to protected areas systems via addition of critical suites of species to the reserve system.

Invasions and Reintroductions

An early observation indicated that species' ecological niches are constraints on potential geographic distributions of species (Peterson et al. 2002c), and are often quite conservative over evolutionary time periods (Peterson et al. 1999). If such is the case, then niches can be good predictors of species' potential geographic distributions, even in completely different geographic scenarios. Application of this idea to the challenge of predicting the geographic dimensions of species' invasions revealed rich predictivity (Peterson and Vieglais 2001), now confirmed in a series of subsequent studies (Peterson et al. submitted).

Although invasive species may seem a topic relatively removed from conservation concerns for birds, such is not the case. For example, the Barred Owl (*Strix varia*), an invasive species in the Pacific Northwest, may pose a significant threat to the survival of its endangered congener, the Spotted Owl (*S. occidentalis*; Dark et al. 1998). Also, invasion of certain plant species can literally threaten entire ecosystems via conversion of landscapes into areas not as hospitable for bird species (Blossey et al. 2001).

Invasive potential and its prediction can also be turned to the positive. One frequent concern is that of where to attempt reintroduction programs for endangered species. Although for some species and regions the answer is straightforward (e.g., wherever there is forest!), in other cases it is not at all clear. A preliminary exploration of this functionality focused on the Mexican Wolf (*Canis lupus*; E. Martínez-Meyer et al. in prep.), and managed to identify areas both hospitable and not, the latter including the prime site that had previously been identified for reintroduction efforts.

Change Scenarios

Finally, ecological niche modeling has the special advantage of permitting prediction of distributional potential across scenarios of environmental change. Particularly relevant at present is the challenge of understanding the effects that ongoing human-caused global climate change will have on biodiversity. Application of ecological niche modeling techniques to this challenge produced a preliminary analysis (Peterson et al. 2001), and a broad survey over 1800+ species (Peterson et al. 2002b).

Completely unexplored, however, are the interactions between these climate change effects on biodiversity and conservation practice. Future applications must begin to evaluate which sorts of protected areas will be particularly vulnerable or particularly robust to climate change effects. Further development of scenarios of vegetation change and human land use change in

concert with climate change will also greatly enrich and educate these early-generation models.

Conclusions

The broadest result of this symposium should be the realization that new geographic tools have the potential to enable research in bird conservation biology greatly. GIS, in the first place, offers a first view of broad geographic patterns of geographic distribution. Ecological niche modeling then provides layers of interpolated distributional ecology (beyond just known occurrence points to likely occurrence across the landscape), as well as new capabilities of predictions across novel or changing conditions. Exploration of these tools and their potential applications is in its infancy, but already rich rewards are becoming apparent.

Acknowledgments

Thanks to T. Will for the invitation to participate in this symposium, and to B. Loiselle and C. Moore for their comments on the manuscript.

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Planning for Bird Conservation: A Tale of Two Models[1]

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Abstract

Planning for bird conservation has become increasingly reliant on remote sensing, geographical information systems, and, especially, models used to predict the occurrence of bird species as well as their density and demographics. We address the role of such tools by contrasting two models used in bird conservation. One, the Mallard (*Anas platyrhynchos*) productivity model, is very detailed, mechanistic, and based on an enormous body of research. The Mallard model has been extensively used with success to guide management efforts for Mallards and certain other species of ducks. The other model, the concept of Bird Conservation Areas, is simpler, less mechanistic, and less well-grounded in research. This concept proposes that large patches of suitable habitat in a proper landscape will be adequate to maintain populations of birds. The Bird Conservation Area concept recently has been evaluated in the northern tallgrass prairie, where its fundamental assumptions have been found not to hold consistently. We argue that a more comprehensive understanding of the biology of individual species, and how they respond to habitat features, will be essential before we can use remotely sensed information and geographic information system products with confidence.

Key words: *Anas platyrhynchos*, Bird Conservation Area, geographical information system, grassland bird, Mallard, model, remote sensing.

Introduction

Planning for bird conservation is currently in vogue. Although conservation planning has a long history, most plans focused on single species, typically threatened or endangered ones. The North American Waterfowl Management Plan led the way in multispecies planning. That Plan successfully brought together a wide variety of agencies and organizations from three nations, all with disparate missions, but with a common interest in waterfowl and their habitats. Later, Partners in Flight was formed to draw attention to birds that migrate from Canada and the United States to Latin America. It subsequently evolved to include landbirds in general. Other organizations coalesced to focus on waterbirds, shorebirds, and other groups of birds. Because birds from different groups often share the same habitats, conservation efforts to favor one group of birds often provide benefits to species in other groups. Recognition of this fact has led to more comprehensive, all-bird conservation planning under the North American Bird Conservation Initiative.

Central to each organization's efforts is the development of plans intended to achieve certain population or habitat objectives through a variety of mechanisms. The widespread availability of geospatial information about habitats, ownership, and other land features has resulted in GIS (geographic information systems) and remote sensing playing critical roles in the planning process. GIS gives planners ready views of many types of information, and particularly their spatial arrangement. Certain types of information (layers) are known with some exactitude; these include land ownership, locations of roads, long-term climatic patterns, and sites where particular bird species have been recorded. Other types of information derive from remote sensing and require either automated or manual interpretation; included here are land cover, identification of wetlands, and the like. The quality of these information layers is improved if on-the-ground verification of the interpretation is conducted. A third type of information often included in GIS reflects the output of models. For example, the suitability of a site for a particular bird species may be modeled in relation to the habitat type at the site, size of habitat patch, and location of the site relative to the range of the species. Graphical displays of information, especially spatial information, look very "real," lending an air of credibility to the information that may not be warranted.

Our purpose here is to address the role of models and the applicability of GIS and remote sensing in planning for bird conservation. We do that by contrasting two models currently in use, both of which use remotely sensed data and are amenable to GIS. One is the Mallard productivity model (Johnson et al. 1987), which has been widely used in planning for Mallards

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California**.

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on their breeding grounds (Cowardin et al. 1988). The Mallard productivity model is very detailed, mechanistic, and based on an enormous body of research. The other model is the concept of Bird Conservation Areas, which is included in several plans for breeding landbirds (e.g., Fitzgerald et al. 1998). The Bird Conservation Area concept is based on the observation that some bird species respond to the size of a habitat patch and to features of the landscape that surrounds the patch (e.g., Robinson et al. 1995). Unlike the Mallard productivity model, inputs to the Bird Conservation Area model can be derived solely from remotely sensed data. This is certainly an attractive feature for planners concerned about large land areas.

The Mallard Productivity Model

The Mallard model has been widely used, initially to guide research, but later for management applications. For example, it played a prominent role in developing the Mallard Management Plan for the Central Flyway (Cowardin et al. 1988). In that application, biologists evaluated the effects on Mallard recruitment of a variety of management practices, such as nest baskets, delayed cutting of alfalfa, no-till winter wheat, and predator-resistant fencing. Another early application was to compare various treatments for the U.S. Fish and Wildlife Service (Cowardin et al. 1988). Among the practices considered there were purchases of easements on wetlands and retirement of cropland. The model also has been used to evaluate mitigation plans for water development projects. More recently, it formed the basis for comparing management options for the Prairie Pothole Joint Venture, under the North American Waterfowl Management Plan. Lercel et al. (1999) used the Mallard model to estimate the effect of the loss of a mate in late winter on reproduction during the subsequent breeding season. Delta Waterfowl is applying the Mallard model to predict the efficacy of predator removal on Mallard recruitment.

The Mallard model is restricted to the breeding season, which has been demonstrated to be most influential in determining population dynamics of the species (Johnson et al. 1992, Johnson and Owyn 1992, Ankney 1996). The model comprises seven basic components: breeding population size, nest initiation, nest site selection, clutch size, nest success, brood and duckling survival, and survival of the female. Each of these components can be influenced by many variables, but the model incorporates only the most influential variables and those that either can be measured or can be generated internally within the model.

Breeding population size is determined for a prescribed site to which the model will be applied. The numbers of breeding pairs either can be defined by the user or can be determined as a function of the wetlands at the site. Each wetland is assigned an expected number of Mallard pairs, depending on its size and class (Cowardin et al. 1988). Those expected numbers are summed for all the wetlands at the site. Equations to generate these expected numbers were developed from analyses of counts of ducks on thousands of wetlands in the Prairie Pothole Region, and are specific to individual areas within that region. Further, the number of breeding pairs can vary in response to average nest success in the area. This added influence reflects the tendency of female Mallards to return to a breeding area (i.e., home) if they were reproductively successful the previous year (Johnson and Grier 1988, Lokemoen et al. 1990).

Arrival dates of simulated birds at the breeding site follow a random distribution that mimics arriving ducks during a typical year. After arrival, each female proceeds through the simulation on a day-by-day basis until it dies or leaves the site. On each day, a bird that is not already nesting can, with a specified probability, initiate a nest. That probability is a function of the date within the season, declining after mid June and falling to zero in mid July. The probability is higher when there are more wetlands containing water at the site (Krapu et al. 1979, 1983; Cowardin et al. 1985). The probability also is affected by the physical condition (expressed as body weight) of the hen (Cowardin et al. 1985, Eldridge and Krapu 1988), which in turn is a function of the number of eggs she has already laid during the season.

Once a simulated Mallard commences nesting, she selects a nest site from among the possible habitats at the site. The probability that she selects a particular habitat type is modeled as a function of the quality (height and density) of vegetation in that habitat type, multiplied by the proportional availability of that habitat type at the site. Again, because female Mallards are thought to return to habitats in which they were successful earlier, the model allows a heightened probability of selecting a habitat type with high nest success.

A large number of proximate and ultimate variables have been demonstrated to influence clutch size of birds (Godfray et al. 1991). The Mallard model incorporates two variables demonstrated to exert the most influence on clutch size in Mallards: date within season (reviewed by Rohwer 1992) and age of hen (Coulter and Miller 1968, Batt and Prince 1978, Krapu and Doty 1979). Simulated clutch sizes are large (mean about 11 eggs) early in the breeding season and decline linearly thereafter. Clutch sizes for yearling hens are about one egg smaller than for older birds.

The probability that a clutch is successful in hatching (nest success) is one of the two most influential

components of population size (Johnson and Owyn 1992). Predation is the most common cause of clutch failure in Mallards and most other waterfowl (Sargeant and Raveling 1992). While we might have modeled nest success as a function of the densities of various predator species, in reality those densities are almost never known and could not be usefully employed in applying the model. What has been determined in many areas of the Prairie Pothole Region are nest success rates in various habitats (e.g., Klett et al. 1988, Shaffer and Newton 1995). So the model can use either these estimates or site- and habitat-specific rates provided by the user.

The other most influential component of population size is brood and duckling survival. When the model was developed, information was not sufficient to model those rates in terms of variables that could be measured, so the probability that one or more members of a brood would fledge (brood survival rate) was set at 0.74, a typical value for the Prairie Pothole Region (Johnson et al. 1987, Sargeant and Raveling 1992). The probability that an individual duckling within a successful brood would survive to fledge (duckling survival rate) was fixed at 0.54. Subsequently, Cox and Johnson (in prep.) were able to use more-recent research findings to enhance the model by making brood and duckling survival rates vary in response to extrinsic variables or to variables simulated within the model. Brood survival rate in the enhanced model depends on hatch date (Krapu et al. 2000), wetland conditions (Krapu et al. 2000), and an index to the abundance of mink (*Mustela vison*), a key predator of Mallard ducklings (Talent et al. 1983). Survival rate is lower for nests hatching later the season; hatch date is generated from the nest initiation date internally within the model. The user can specify wetland conditions and one of three levels of mink abundance-low, medium, or high.

Rates of duckling survival (survival of individual ducklings within a successful brood) in the enhanced model depend on the weight of the bird at hatch (Cox et al. 1998), the abundance of invertebrate foods (Cox et al. 1998), and the occurrence of extreme weather events when birds are young (Cox and Johnson in prep.). The user can indicate whether invertebrates are abundant, about average, or uncommon. The other phenomena are simulated within the model.

Whether or not a female Mallard survives the breeding season is most strongly influenced by predation while she is on the nest. The model assigns a baseline daily mortality rate of 0.001 for days the hen is not nesting or she is nesting and her nest survives. If her nest is destroyed, the probability that she dies during that event is set at 0.06. This combination of rates has been found to yield realistic survival rates for the breeding season (Johnson and Sargeant 1977).

A variety of components in the model have been subjected to testing and evaluation procedures and have fared well (Johnson et al. 1986, Cowardin et al. 1988). In addition, biologists familiar with waterfowl ecology have found simulations made with the model to be consistent with their understanding of waterfowl nesting biology.

Because of interest in using the model in areas beyond that for which it was originally designed, a number of extensions have been made. The United States Fish and Wildlife Service and Minnesota Department of Natural Resources gathered data to modify the model for use in Minnesota (Zicus and Rave 1998). Ducks Unlimited, Canada, has conducted a number of studies to determine how the model applies to the Canadian Parklands and what modifications are necessary.

In sum, the Mallard productivity model illustrates what can be done to develop a tool to guide management of an avian species. It is mechanistic, incorporating known features of species behavior and basic population dynamics. The model is based on a tremendous number of research and management studies and reflects a considerable knowledge of biology. Nonetheless the model still is data-hungry for information on key variables such as nest success rates in available habitats and geographical areas that are being modeled.

The Bird Conservation Area Concept

We next turn to a much simpler, less mechanistic model, encompassed in the notion of a Bird Conservation Area (BCA). The fundamental idea of a BCA is that a large patch of suitable habitat, in a landscape that is not hostile, will maintain viable populations of breeding birds. This idea is based on three tenets: 1) A patch of suitable habitat is necessary. The habitat requirements of many species of grassland birds have been reviewed and summarized recently (Johnson et al. 1998). 2) In small patches of habitat, some species of birds often are absent or occur at low densities (Winter and Faaborg 1999, Johnson and Igl 2001), or they suffer low reproductive rates (Donovan et al. 1995, Porneluzi and Faaborg 1999). 3) Reductions in density and productivity with decreasing patch size (and corresponding increasing proportions of edge habitat) can be ameliorated if the surrounding landscape is favorable (Donovan et al. 1997). Patch size and landscape effects are at least partially mediated through edge effects, for example, lowered density and productivity close to a habitat edge (Faaborg et al. 1993). For grassland birds, woody vegetation is considered a hostile edge because certain grassland species avoid it (Johnson and Temple

1990, O'Leary and Nyberg 2000), and it provides travel lanes for various predators (Winter et al. 2000b) and perch sites for raptors and brood-parasitic Brown-headed Cowbirds (*Molothrus ater*; Chalfoun et al. 2002a, b). BCAs attempt to provide adequate habitat to ensure the long-term survival of bird species nesting at that site by designing reserves based on principles of both patch size and landscape structure.

Although the BCA concept has been proposed for grassland systems, most of the research that describes the patterns underlying BCAs was conducted in forest systems (Donovan et al. 1995). Only a few studies have investigated patch size and landscape effects on grassland birds, and the results of these studies vary widely among regions and years (Johnson and Winter 1999, Johnson 2001, Johnson and Igl 2001). The BCA model for grassland birds thus is based on a set of assumptions, most of which have not yet been tested in the appropriate habitat, or on the appropriate spatial and temporal scales.

The specific numbers for BCAs were suggested for a single grassland-nesting species, the Greater Prairie-Chicken (*Tympanuchus cupido*). The Wisconsin Department of Natural Resources proposed that grassland BCAs would maintain populations of Greater Prairie-Chickens and, under that umbrella species, other grassland-dependent birds, such as Grasshopper Sparrow (*Ammodramus savannarum*), as well (Henderson and Sample 1995). Specifically, in the northern tallgrass prairie region (Fitzgerald et al. 1998), each proposed Bird Conservation Area would consist of an 800-ha core of high-quality grassland embedded in a 4,000-ha buffer. This buffer would include an additional 800 ha of smaller patches of grassland. Partners in Flight suggested that such an area, if managed properly, would be sufficient to support Greater Prairie-Chickens and other grassland birds of concern (Fitzgerald et al. 1998).

Note that this conceptual model is ambiguous as to which species—other than Greater Prairie-Chicken—are likely to be favored by a BCA. Also, the model is without any explicit mechanism. Work on forest-nesting species has elucidated several mechanisms for patch size and landscape effects, such as differences in pairing success (Gibbs and Faaborg 1990, Villard et al. 1993, Bayne and Hobson 2001), differences in distribution of nest predators (Heske et al. 2001) and of brood-parasitic Brown-headed Cowbirds (Porneluzi and Faaborg 1999) and potentially differences in juvenile dispersion (Anders et al. 1997). But much less is known about such mechanisms in grassland species (Johnson 2001). The BCA concept thus is based on only general ideas that large patches and neutral landscapes are better than smaller patches and hostile landscapes, most of which were developed in forested systems. However, mechanisms in grasslands may differ from those described for forest systems due to differences in bird species assemblages and predator communities.

If a BCA would work, we therefore would not necessarily know how or why. Yet, the model is useful in guiding management, *based on the information currently available*. Further, that model may be all that is necessary. If it works, we may not need to know why. If the model fails to work, however, at least for some species or in some situations, then questions about mechanisms become more important.

For four years we have evaluated the BCA concept in the northern tallgrass prairie (Winter et al. 1998, 1999, 2000a, 2001). We examined the influences of patch size, landscape configuration, and their interaction on densities and nest success rates of breeding birds. We attempted to reduce the effect of proximate habitat features by selecting study sites with similar vegetation; most of them were native prairie. Absolute comparability was impossible, of course, so we recorded vegetation measurements to use as covariates during analysis.

Study sites were located in three regions, two in northwestern Minnesota and one in southeastern North Dakota. Within each of those regions we had both small (<40 ha) and large (>250 ha) grassland patches in both neutral (few trees in vicinity) and hostile (many trees in vicinity) landscapes. We compared breeding bird densities at 45 sites; on 30 of those we also gathered nest success information.

As will be shown elsewhere, the predicted patterns have not always materialized (Winter et al. 1998, 1999, 2000a, 2001). The effects of patch size and landscape on both density and nesting success were inconsistent, varying among years, regions, and species. For example, in the first year of study, Savannah Sparrows (*Passerculus sandwichensis*) were more common in plots in neutral landscapes than in hostile landscapes, and Bobolink (*Dolichonyx oryzivorus*) densities were positively associated with both neutral landscapes and large patches. Those patterns did not hold consistently in the subsequent years, however. It thus seems that at this time we cannot safely use patch size or simple landscape data (many versus few trees in the surrounding landscape) to predict grassland bird assemblages and habitat quality. The "black box" approach to planning for grassland bird conservation based on models that lack detailed mechanisms may be inadequate to the task, at least in the northern tallgrass prairie.

Discussion

Typically a model provides certain outputs, based on certain inputs. As an abstraction of a real system, a model incorporates the relevant knowledge we have of that system. Where we lack knowledge, we use assumptions to fill the void. If a model incorporates a lot of knowledge, and is dependent on few critical assumptions, the output from the model is likely to be trustworthy (*fig. 1*). In contrast, a model based on little knowledge and a lot of unsubstantiated assumptions will provide predictions with greater uncertainty and should be used only with caution.

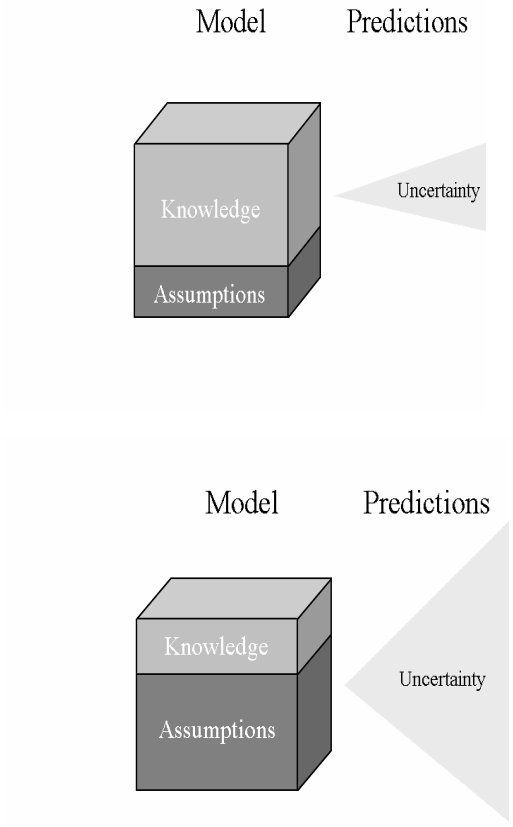

Figure 1— The quality of predictions from models depends on the amount of information incorporated in the model in comparison to the assumptions necessary to fill information voids. Less knowledge results in greater uncertainty in predictions from a model.

Birds respond, either in abundance, survival, or reproductive success, to numerous features of the breeding site. Among these are the geographical location relative to the species' range, gross (macro-) habitat characteristics-such as forest versus grassland, microhabitat features-such as litter cover, food resources for both adults and young, the abundance and composition of the predator community, and weather and other phenomena that act rather capriciously. Of these listed factors, remote sensing is realistically able to identify only the first two, location and gross habitat type. Therefore, any GIS or model based solely on remotely sensed data will be incomplete unless: 1) all the other features are unimportant; 2) long-term or large-scale averages of the other features are available and are adequate for planning purposes; or 3) cues to the other features can be identified and modeled themselves. We have serious doubts that the first option, disregarding the remaining factors, is prudent. The second option may be viable; we do think that modeling based on averages can be useful, but its value is limited. For example, one could base a model for Mallards on long-term average wetland conditions, but in most years on the prairies, wetlands are either markedly drier than average or wetter than average. And Mallard abundance and reproduction differ dramatically under those conditions.

We suggest that the third option holds the most promise. It is important to understand the processes that influence the abundance of birds and their reproductive performance. These processes no doubt will vary to some degree regionally and temporally, as well as among species. Understanding the behavior and ecology of the Mallard, for example, allowed biologists to appreciate when that species can be used as a proxy for other upland-nesting dabbling ducks and when modifications are necessary (Carlson et al. 1993). Further, careful monitoring of certain variables will be necessary to assess the accuracy of model predictions. The success of the Mallard model is in part due to on-the-ground collection of data on wetlands, Mallard abundance, and nest success by habitat. These data are very time- and site-specific, but are essential to the good performance of the model.

As modeling proceeds, we think it important to treat predictions from a model as hypotheses to be evaluated. That was done, for example, by Cowardin et al. (1985), who used the Mallard productivity model to guide their study and provide questions to address; in turn, results from that study were used to modify the model. This thinking is clearly in line with the adaptive resource management notion (Walters 1986). Under that philosophy, managing a system and learning about that system go hand in hand. Knowledge about the system is treated as one of the products of the system, which is managed in part to provide further information so that the system can be better managed in the future. As BCAs are established, they should be adequately monitored to determine how well they are meeting the objectives for which they were created.

Remote sensing, geographical information systems, and models are valuable tools. They can play important

roles in conservation planning for birds. But we must not lose sight of the importance of understanding the birds, their behavior, and how they use the habitats and other resources we intend to conserve and manage for their benefit. As Buckland et al. (2000: 6) observed, "It is an unfortunate fact of life that, if two pieces of software are available for a given task, most wildlife managers will select the one that is most impressive visually, irrespective of the relative merits of the methodologies underlying them. The inevitable consequence of this is that there will be an increasing trend toward a videogame mentality." Remote sensing and GIS data may have poor resolution and be error-prone, but they provide visually compelling products. We must be careful not to be seduced by the persuasive power of pixels.

Acknowledgments

We are grateful to R. R., Cox, Jr., M. A. Cunningham, S. J. Lewis, C A. Lively, R. E. Reynolds, and, especially, J. R. Faaborg for comments on earlier drafts of this manuscript, but we retain responsibility for any errors or misinterpretations.

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Natural Resource Assessment and Decision Support Tools for Bird Conservation Planning[1]

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Abstract

We have used a place-based decision support system for several years to identify bird conservation issues relating to the management and planning needs of resource managers. Public and private land managers are constantly seeking better ways to incorporate landscape, species, and habitat relationships into the conservation planning process. The U.S. Fish and Wildlife Service is engaged in long-term planning for federal lands under their jurisdiction as part of the Congressionally-mandated Comprehensive Conservation Planning process. The National Park Service is undertaking an inventory and monitoring program for a wide range of species. In addition, the North American Bird Conservation Initiative (NABCI) is a new international bird conservation effort seeking to "deliver the full spectrum of bird conservation through regionally-based, biologically-driven, landscape-oriented partnerships." These initiatives are driving efforts to plan and implement bird conservation at all spatial scales. Our system, developed in a geographic information system (GIS) framework, allows managers and planners to rapidly assess landscape attributes and link these attributes with species/habitat information. Users can pose questions about a species and obtain habitat information within a defined area, or pose questions about habitats within a defined area and receive information about the species that may use those habitats. Our decision support tool is not a 'black box'; it doesn't make decisions for managers, but it can facilitate the efficient use of historical and existing resource information. We describe examples of how these tools are being used on the Upper Mississippi River and in the Midwest to illustrate and define the spatial distribution, amount, and potential relative values of habitats. Once base layers that depict present conditions are added to the system, it is much easier for the managers to develop alternative management plans that consider type, size, and arrangement of habitat patches.

Key words: adaptive management, bird conservation, decision support, decision support tools, DSS, GIS, computer programs, habitat, species occurrence.

Natural Resource Assessment and Decision Support

Decision support systems (DSS) provide a process for organizing existing geographical, physical, and biological data for better management of natural resources (Daniel 1992, Prato 1999). They are interactive, computer-based tools using information and models to improve the process or outcome of decision-making through (a) analysis and visualization of management alternatives and their effects; (b) assimilation of available knowledge and data into the decision-making process; and (c) assessment of the level of certainty of different predictions (Siepel 1997). Decision support tools organize disparate data by linking the data layers and the geographical context of the data (Brown et al. 1994). Even very large databases can be organized and applied to the decision-making process (Kliskey 1995).

Decision support systems are gathering increased attention in natural resource management because three important trends are changing the way managers address natural resource issues. First and foremost, the stakes have gone up. Public land managers must respond to increasing demands for resource information from the public and policy-makers, as well as other government agencies. Natural resource decisions are frequently at the center of intense economic, political, legal, and value conflicts. Second, the complexity of managing animals, plants, and other natural resources is increasing and a massive volume of scientific information regarding species-habitat relationships is available. Natural resource decision-makers must examine and interpret this rich library of scientific data to balance demands placed on the natural resources under their care. They need efficient tools to summarize, analyze, and integrate this information. Third, technologies are now available to incorporate knowledge and expertise into ecological models. As we gain greater

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California**.

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understanding of ecological systems, the sheer complexity of ecological information makes it increasingly difficult to evaluate competing management options without models. Often, a key role of DSS is to help resource managers frame the relevant management questions.

Although high quality data may exist for many resource management areas, the decision process often suffers from the inability to effectively analyze, integrate, query, and synthesize these data (Rauscher 1999). Decision support systems are important tools in the adaptive management process (Johnson 1999, Crist et al. 2000). The U. S. Geological Survey and its partners have described recommended approaches to develop, evaluate, and apply DSS to natural resources management (D'Erchia et al. 2001). First, they believe it is essential to define the management goals, objectives, and procedures to determine what DSS spatial data layers are required for adaptive management.

A DSS should be targeted at the functional level needed to address the management goals. We define three functional levels of DSS, as determined by the goals and technical skills of the users (*fig. 1*). A Level 1 DSS is easy to use but has low functionality; it employs tools such as MapObjects[1]® (a stand-alone application; Environmental Systems Research Institute, Redlands, California, USA) or ArcIMS® (a web-based application; Environmental Systems Research Institute, Redlands, California, USA). Level 2 is the intermediate level and uses a general-purpose tool such as ArcView® (Environmental Systems Research Institute, Redlands, California, USA) that allows for some visual representation and querying of the data. The tools we describe in this paper are primarily in this intermediate category. Finally, if the management goals require high flexibility and model generation (Level 3) then we would recommend a suite of model development tools and spatial data layers that can be integrated with a program such as ModelBuilder® (Environmental Systems Research Institute, Redlands, California, USA). Simplified products or results from Levels 2 and 3 can be packaged for use in a Level 1 DSS as new information becomes available.

Decision support tools are used to assemble historical information, store new information for the future, and make both readily available for use in assessing environmental change. Resource managers can identify additional needed information and define options for the future state of the resource if historical and current information on the resource is available in a DSS. Standardized coding, accurate geo-referencing, and efficient transfer of data into electronic media enhances their use in a DSS system. Even recording raw data and general observations provides an important historical perspective on state of the resource and may form the baseline against which change is evaluated. As spatial data layers are compiled into a DSS framework, documenting the metadata using the Federal Geographic Data Committee (FGDC) terminology and definitions standards for geo-spatial data (http://www.fgdc.gov/metadata/csdgm/) is highly recommended. The standard establishes the names of data elements and compound elements (groups of data elements) to be used for documentation. In the ArcView® data layer list we record the name of provider, organization of provider, data layer title, year, links to metadata, etc. This docu-

[1]Any use of trade product, or firm names in this publication is for descriptive purposes only and does not imply endorsement by the U. S. Government.

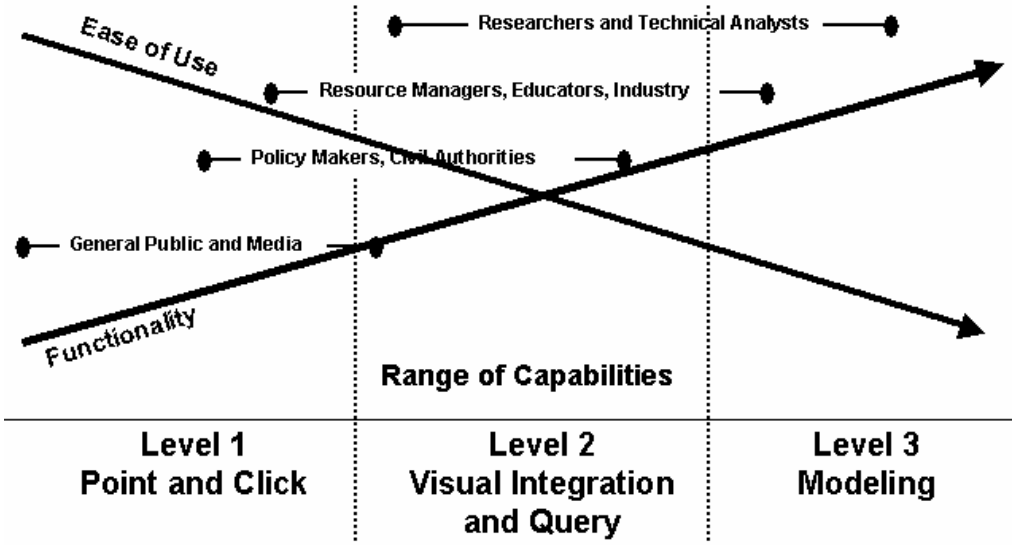


Figure 1—The goals and technical skills of the users determine what functional level of decision support is needed.

mentation adds credibility to the data and gives users information on the scale and quality control used to prepare data layers so that the reliability of the resulting products can be evaluated.

One of the key roles of a DSS team is to listen to the resource managers as they discuss their challenges and communicate with them to determine existing and needed information for designing a successful management plan. Data are generally available to answer resource management questions, but they may not be in the right format. We examine data sheets, reports, published literature, etc. and determine which data can be geo-referenced at an acceptable resolution or can be integrated into the DSS framework as background information. Then, the data are converted to spatial data layers. Also, more resources (*table 1*) are becoming available nationally that can be incorporated into a DSS framework. In our experience, the fundamental data layers are current true color or infrared geo-referenced photographs (scale between 1:12,000 and 1:24,000) and a digital land cover data layer derived from them.

Bird Conservation Planning

Several bird conservation planning efforts are underway across North America and they are likely to continue to evolve. These include the North American Waterfowl Management Plan and Joint Ventures (http://birdhabitat.fws.gov/nawmp/jv.htm), Partners in Flight (http://www.partnersinflight.org/default.htm), the North American Bird Conservation Initiative (http://www.nabci-us.org/), and the shorebird (http://www.manomet.org/USSCP/index.htm) and water bird (http://www.waterbirdconservation.org/) conservation plans. In addition, the U.S. Fish and Wildlife Service Comprehensive Conservation Plans for the National Wildlife Refuge System (http://library.fws.gov/ccps.htm) and the National Park Service's inventory and monitoring initiatives (http://www.nature.nps.gov/im/index.html) represent critical federal bird conservation planning opportunities. Many state and private agencies are also in various stages of planning for bird conservation on lands under their management. Ruth et al. (2003) outlines the U.S. Geological Survey's planning for research in support of bird conservation efforts and identifies five priority research areas: (1) avian life history, populations, and ecology; (2) habitat/environment; (3) integration of ecological information; (4) bird conservation planning; and (5) communication of ecological information. A DSS that combines research results, management activities, and monitoring into a coherent system facilitates an adaptive management system where lessons learned from past management activities help to improve future management. Such an operational framework could advance avian conservation efforts significantly.

Geographic Information System (GIS) Tools for Bird/Habitat Decision Support

We developed a GIS-based DSS that employs scripts within ArcView® to automate analyses of habitat data. Currently three tools (extensions) are available: the Matrix Wizard, the Query Tool, and the Edit Tool. Fox et al. (2003) provide software and describe details regarding functions and uses of these tools. A second-generation of ArcGIS DSS tools, LINK, is under development.

The Matrix Wizard

The Matrix Wizard enables managers and planners to define species/habitat associations based on land cover spatial data layers. Two data files are required - a spatial data layer (usually representing land cover) and a species/habitat matrix (spreadsheet). The spatial data layer (GIS shape file) is developed at a scale relevant to the bird habitat use within the study area (refuge, park, or region). It is important to use land cover classes relevant to the life cycle needs of the birds as well as the resource manager's ability to manipulate these habitats over time.

A spreadsheet file is constructed in which the columns represent attributes related to the nomenclature, status, etc. of the focal taxa and a column for each land cover class representing habitats (*fig. 2*). Scores are assigned using a zero-based numbering system (for example 0 to 3 or 0 to 10) to reflect the potential species occurrence within that habitat type. Higher values indicate a stronger association between the species and that habitat type. These scores can be obtained from quantitative data such as bird surveys or habitat studies. However, quantitative information regarding species habitat associations for the focal management unit is usually unavailable; the habitat portion of the matrix is then scored based on species/habitat information derived from standard references and the expert opinions of refuge or regional biologists. It may be necessary to construct more than one matrix if managers need to incorporate temporal (spring, summer, fall, or wintering) or life cycle stage (nesting, brood rearing, migration) shifts in habitat use or the presence/absence of birds during different times of the year. Taxa are usually defined as species, but guilds, families, genera, or any other defined grouping can also be used as the basic unit of analysis. The basic units (for example, species) can also be considered collectively (high priority species, Neotropical migrants, guilds, etc.) by adding

Table 1—*Data layers useful in a decision support system.*

Category	Data layer
Administrative	County boundaries
	Congressional district
	Study area boundary
	Cities and towns, points and polygons
	Weather stations
	Public land survey sections
	Topographic maps 1:24,000
	Railroads
	Roads
	Airports
	Infrastructure facilities such as dikes, levees, pumps, buildings, pipelines, management units, and special features.
Hydrology	USGS gauges
	Hydrologic unit boundaries
	Drainage area
	Stream order
	Stream bed elevation
Topography	Topographic maps at 1:24,000, 1:100,000, and 1:250,000 scales
	Shaded relief of North America
	Physiographic divisions
	Digital elevation models
Photography/Remote sensing	Digital orthophotos
	True color / color infrared photographs
	Satellite scenes
Land Cover / Use	Current and historical vegetation maps
	National Wetland Inventory maps
	Levees
	Flood zones
	Natural areas
	Public lands (summarizes all public land)
	Crop land
	Gap Analysis Program data
	Conservation Reserve Program Land
Geology/soils	State and county soil maps
	Total suspended solids
	Total wind and water erosion
Nutrients	Ammonia-N concentrations
	Nitrates
	Phosphorus
Biology	Plant and animal surveys

these descriptor columns to the matrix. A dialog box prompts the user to link the matrix file to the relevant spatial data layer (*fig. 3*). A single matrix can be linked to multiple spatial data layers (e.g., land cover, elevation, soils), and conversely, a data layer may link to many associated matrices (e.g., birds, mammals, reptiles). Sample habitat matrices supplied with the program or obtained from colleagues can be used as templates for defining a new matrix.

Query Tool

The Query Tool interface (*fig. 4*) allows the user to perform spatial analyses based on user-defined species

Common Name	Scientific Name	Abundance	FWS Region 3 Conservation Priority	Open Water	Submersed Aquatic Bed	Floating-Leafed Aquatic Bed	Semi-permanently Flooded Emergent Annual
Common Loon	*Gavia immer*	Uncommon	Yes	3	3	3	3
Pied-billed Grebe	*Podilymbus podiceps*	Common	No	3	3	3	3
Double-crested Cormorant	*Phalacrocorax auritus*	Common	No	3	3	2	0
Tundra Swan	*Cygnus columbianus*	Abundant	No	3	3	3	3
Snow Goose	*Chen caerulescens*	Common	No	3	3	3	3
Canada Goose	*Branta canadensis*	Abundant	No	3	3	3	3
Wood Duck	*Aix sponsa*	Abundant	No	3	3	3	3
Green-winged Teal	*Anas crecca*	Common	No	3	3	3	3
American Black Duck	*Anas rubripes*	Common	No	3	3	3	3
Mallard	*Anas platyrhynchos*	Abundant	No	3	3	3	3
Northern Pintail	*Anas acuta*	Common	Yes	3	3	3	3
Blue-winged Teal	*Anas discors*	Abundant	No	3	3	3	3
Northern Shoveler	*Anas clypeata*	Common	No	3	3	3	3
Gadwall	*Anas strepera*	Common	No	3	3	3	3
American Wigeon	*Anas americana*	Abundant	No	3	3	3	3
Red-breasted Merganser	*Mergus serrator*	Uncommon	No	3	3	3	2
Common Moorhen	*Gallinula chloropus*	Uncommon	No	3	3	3	3
American Coot	*Fulica americana*	Abundant	No	3	3	3	3
American White Pelican	*Pelecanus erythrothynchos*	Occasional	No	3	2	1	0
Franklin's Gull	*Larus pipixcan*	Uncommon	No	3	3	2	3
Black Tern	*Chlidonias niger*	Common	No	3	3	3	3
American Bittern	*Botaurus lentiginosus*	Uncommon	No	0	0	0	2
Least Bittern	*Ixobrychus exilis*	Uncommon	No	0	0	0	3
Great Blue Heron	*Ardea herodias*	Abundant	No	0	2	2	3
Great Egret	*Casmerodius albus*	Abundant	No	0	2	1	3
Snowy Egret	*Egretta thula*	Rare	No	0	2	1	3
Little Blue Heron	*Egretta caerulea*	Occasional	No	0	2	1	3
Cattle Egret	*Bubulcus ibis*	Not On Checklist	No	0	2	2	2
Green Heron	*Butorides striatus*	Common	No	0	0	0	2
Sandhill Crane	*Grus canadensis*	Uncommon	No	0	0	0	3
Yellow Rail	*Colurnicops noveboracensis*	Not On Checklist	No	0	0	1	3
King Rail	*Rallus elegans*	Uncommon	No	0	0	1	3
Virginia Rail	*Rallus limicola*	Uncommon	No	0	0	1	3
Sora	*Porzana carolina*	Common	No	0	0	1	3
Spotted Sandpiper	*Actitis macularia*	Common	No	0	0	0	1
Upland Sandpiper	*Bartramia longicauda*	Uncommon	Yes	0	0	0	0

Figure 2—A portion of a species/habitat matrix showing fields (columns) that contain descriptive information about the species and a potential species occurrence score for each habitat class. The first four columns represent information that can be incorporated into a query.

and location information. The program produces summary information in the form of tables, charts, reports, spatial data layers representing habitat associations, and a printable layout that combines all of the above (*fig. 5*).

The program calculates a wide range of metrics describing the landscape of interest and potential use by selected species. Metrics include the total area of each habitat type, potential species richness, and the proportion of the landscape representing potential habitat for target species. One of the most useful habitat metrics calculated by the program is the potential species occurrence score (PSO) for each habitat type. The PSO score is the mean of the habitat matrix values for all of the selected species that occur within a single habitat type; a PSO score is calculated for each habitat within the target landscape. The PSO scores can be mapped and compared to a larger landscape, an historical landscape, or a landscape representing projected future conditions. The potential occurrence data layer can also be superimposed on top of other digital spatial data layers to provide insight into ecological conditions that may influence bird selection of the habitat class. The area-weighted PSO score represents the mean value of selected habitat types found in the landscape for the species of interest and is calculated using this equation:

$$\text{Area - weighted PSO} \quad \sum = \frac{(\text{area of habitat} * \text{PSO score})}{\text{total area}} = \tag{1}$$

An Advanced Query function allows users to customize selection of species for analysis. For example, if the matrix contains a field which has the Partners in Flight (PIF) score for each bird species, the query builder enables the user to select all birds with PIF scores greater than 25, for example. The Query Tool will then use these species to calculate the PSO scores. Likewise, if the matrix contains a field in which a set of species are designated U. S. Fish and Wildlife Service regional conservation priorities, users can select these species for analysis.

The Edit Tool

Consideration of future habitat conditions is required under an adaptive management framework. Managers consider and map the most likely trajectory of habitat change in the absence of active management or evaluate the desirability of managed change under competing management options. The new scenarios are then quantified in terms of the changes in habitat areas and evaluated on how these habitat changes will affect different species. The Edit Tool allows planning groups to create spatially-explicit alternative spatial data layers, using existing conditions as a starting point.

Projected changes in habitat types are applied to existing spatial data layers and the resulting data layers are evaluated using the Query Tool and Matrix Wizard as described above. We have found this tool to be very effective in working with groups of planners and stakeholders when agreement on a set of management options is required. It is easier to get agreement on options and strategies when decisions are based upon objective 'rules' embodied in the DSS, and the results are visible to all stakeholders involved.

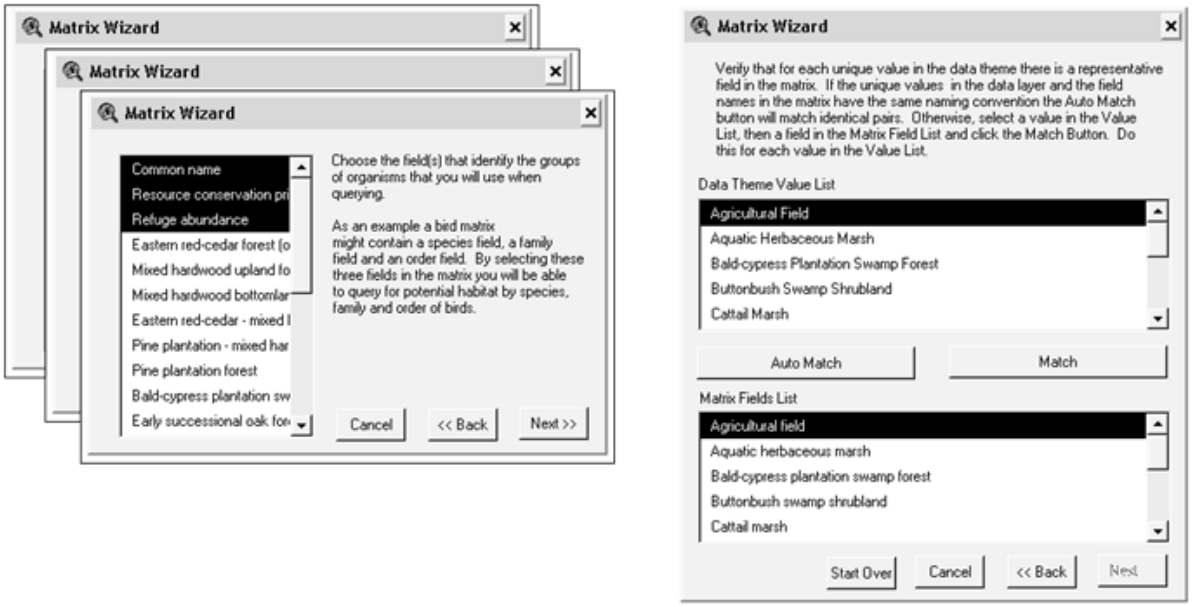


Figure 3—The Matrix Wizard enables managers and planners to define habitat classes from land cover maps and define species/habitat associations.

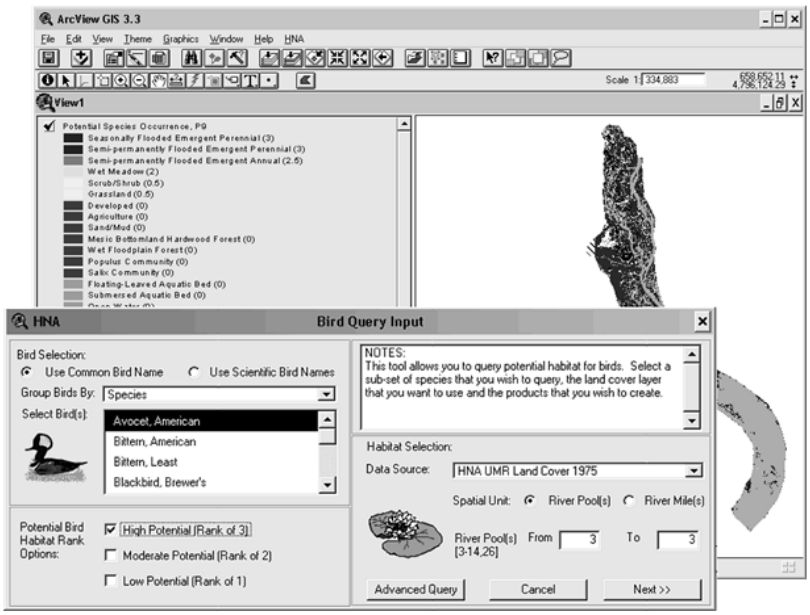


Figure 4—The Query Tool performs spatial analyses of habitat information based on user-defined species and location information.

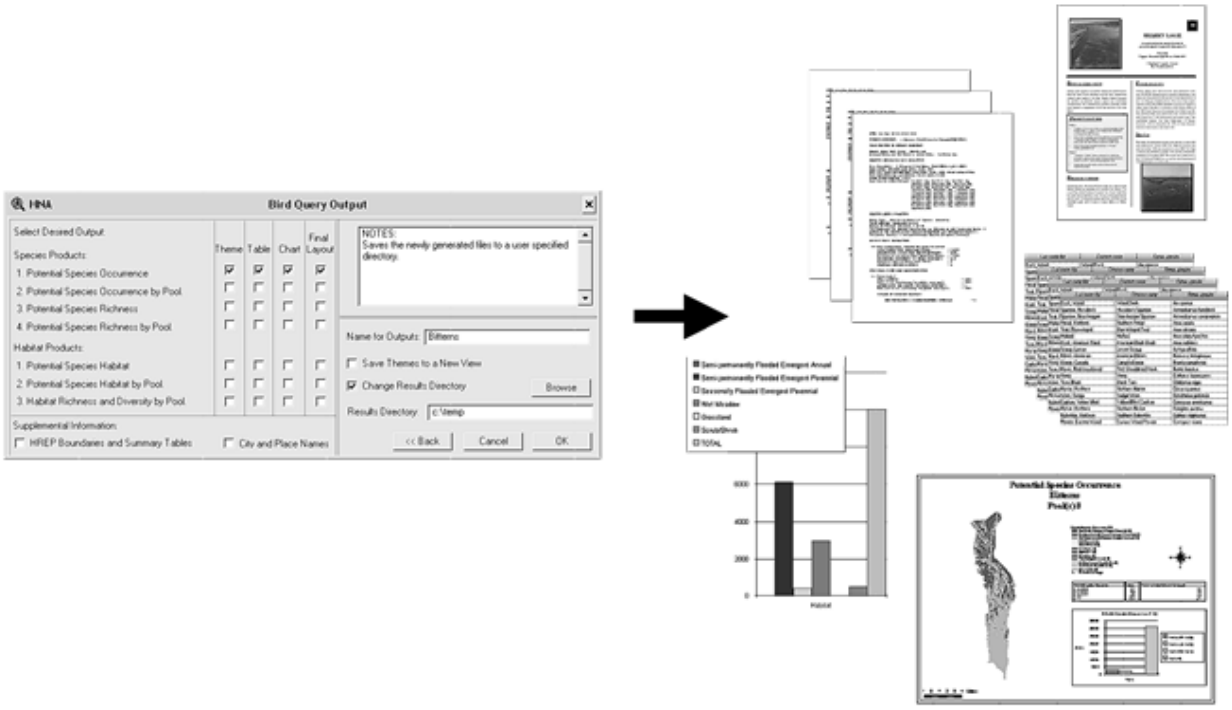


Figure 5—The Query Tool provides summaries of information in tables, charts, and maps of habitat associations.

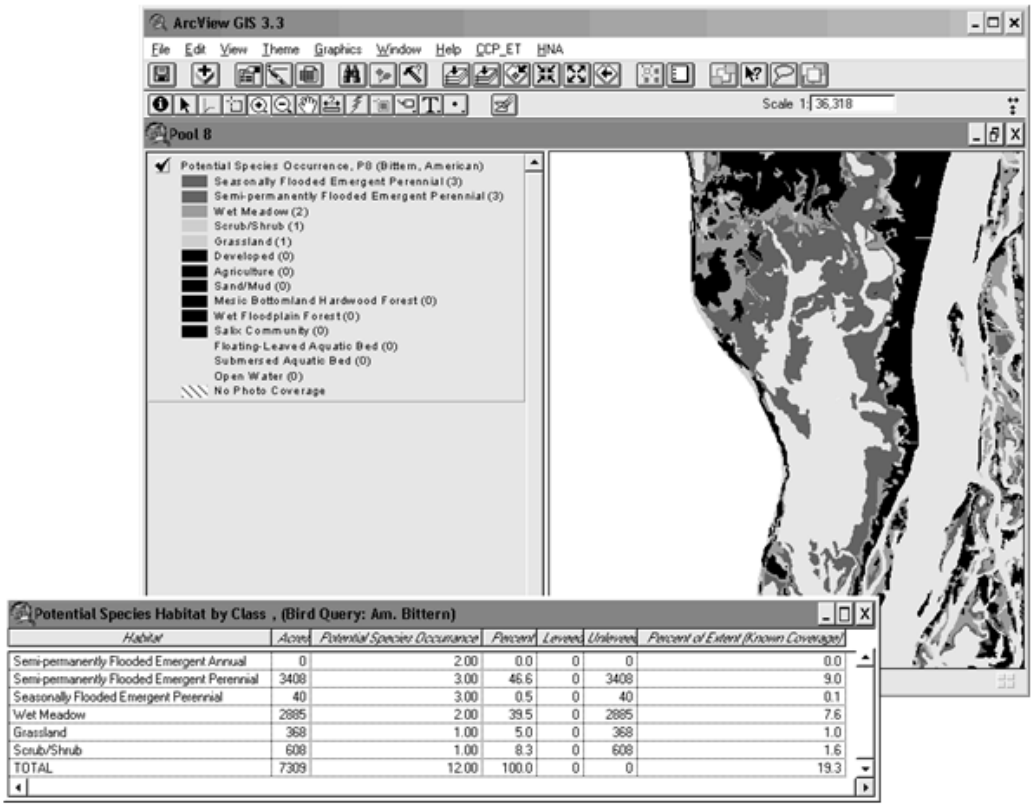
The Link Tool

The next generation of our DSS toolbox includes LINK, a VisualBasic for Applications program being developed in ArcGIS. The program will incorporate the functions previously described in a new GIS platform. We are currently applying the LINK tool to regional bird conservation planning in the Midwest (http://www.umesc.usgs.gov/terrestrial/migratory_birds/500911_bird_conservation.html). Resource managers will use the program to access data layers and habitat models for high priority bird species. The project is expanding our ability to evaluate terrestrial as well as aquatic habitats and function at regional as well as local scales. As part of the project, we are building statistical models of bird habitat associations at regional and local

scales and the LINK program will evolve to incorporate more advanced statistical species/ habitat models.

Case study: Habitat needs assessment for the Upper Mississippi River

The Upper Mississippi River and the Illinois River are valued by the nation as natural, historical, cultural, commercial, recreational, and transportation resources (Wiener et al. 1995, 1998). Collectively referred to as the Upper Mississippi River System (UMRS), it is the only U.S. waterway formally recognized by Congress as a nationally significant ecosystem and a commercial navigation system (U.S. Geological Survey 1999). Funds for monitoring and environmental management of the UMRS were authorized by Congress in 1986 and reauthorized in 1999. As part of the 1999 reauthorization, a Habitat Needs Assessment process was recommended to identify needs for habitat rehabilitation and enhancement projects. This recommendation initiated a large-scale case study in adaptive management of the UMRS and facilitated the development of a prototype of the ArcView® extensions described above, referred to as the Habitat Needs Assessment (HNA) Query Tool (DeHaan et al. 2000). The software, associated data, and user's manual for the HNA Query Tool are available from the U. S. Army Corps of Engineers in Rock Island, Illinois. This was the first attempt to conduct a system-wide analysis of historical and existing habitat conditions on the UMRS, a very large, complex regional ecosystem including portions of five states. The complexity of political, economic, and recreational issues on the UMRS makes resource decision-making subject to dispute (Hoops 1993; Sparks 1995; Knutson and Klaas 1998; Sparks et al. 1998). Agreement on what the system 'needs' to function better in all spheres of ecosystem services and how resources should be allocated is difficult to achieve (McLeod 1990).



Habitat	Acres	Potential Species Occurrence	Percent	Levees	Unleveed	Percent of Extent (Known Coverage)
Semi-permanently Flooded Emergent Annual	0	2.00	0.0	0	0	0.0
Semi-permanently Flooded Emergent Perennial	3408	3.00	46.6	0	3408	9.0
Seasonally Flooded Emergent Perennial	40	3.00	0.5	0	40	0.1
Wet Meadow	2885	2.00	39.5	0	2885	7.6
Grassland	368	1.00	5.0	0	368	1.0
Scrub/Shrub	608	1.00	8.3	0	608	1.6
TOTAL	7309	12.00	100.0	0	0	19.3

Figure 6—The Query Tool data layer, legend, and table output for the American Bittern in Pool 8 of the Upper Mississippi River.

The HNA Query Tool was central to the DSS process in that the tool was used to catalog historical and existing spatial data for the UMRS. Programmers, managers, and user groups worked together to collect and analyze information about the UMRS at multiple spatial scales, ranging from the entire system down to small river reaches (DeHaan et al. 2000). We developed and scored a matrix that contained 289 bird species (Theiling et al. 2000). In addition, habitat matrices for fish, amphibians, reptiles, and guilds of aquatic invertebrates were also developed to facilitate a comprehensive ecosystem assessment. Depending upon the

reach of the Mississippi or Illinois River, one to five spatial data layers containing from five to 18 land cover classes were processed by the Query Tool. The land cover data layer for 1989 was available for all 1,300 river miles (2,092 km) of the system. The data layers and tables generated by the Query Tool were useful in calculating potential habitat for bird species over broad geographic areas; locations where conservation values could be enhanced by vegetation (habitat) management in concert with needs of the bird were identified. The spatial data layer and table generated for the American Bittern (*Botaurus lentiginosus*) is an example of the Query Tool products (*Fig. 6*). The management goal was to illustrate the spatial distribution, amount, and potential relative values of different habitats used by bitterns.

The final product is a set of system-wide objectives for aquatic habitat protection and restoration in the UMRS. The Habitat Needs Assessment (HNA) tool was used to identify historical, existing, and desired future river conditions. Input from the public, land managers, and other stakeholders was solicited at public hearings. Through this process, a number of specific recommendations emerged. For example, the report to Congress recommends restoring 1,700 acres of main channel habitat, 27,000 acres of secondary channel habitat, 55,500 acres of contiguous backwater habitat, 24,000 acres of isolated backwater habitat, and 24,000 acres of island habitat. The report also targets the specific needs of different reaches of the UMRS and projects that these needs will double by 2050 if no action is taken. In addition, the HNA established a framework for incorporating new spatial data as it evolves from a multitude of agencies and partners working on the UMRS. River managers are now using the system to develop plans for the geomorphic reaches and pools of the UMRS, evaluate gaps in habitat distribution, and calculate the cost of maintaining, rehabilitating, or restoring habitats for migratory birds.

Case study: Development of management alternatives on Crab Orchard National Wildlife Refuge

We worked with staff of the Crab Orchard National Wildlife Refuge to evaluate the effects of future potential management alternatives on migratory birds. A land cover data layer was developed for the year 2000 using vegetation information and standard classification names as provided by NatureServe (2001, http://www.-natureserve.org). To explore several alternative management scenarios, we altered the existing land cover data layer to create a future condition data layer for the years 2015 and 2100. The first alternative was to manage for large blocks of forest, which should reduce edge effects and result in better nesting habitat for forest birds due to a reduction in predation and nest parasitism. The second alternative proposed conversion of pine plantations to hardwood tree species, considered more valuable to wildlife. The third plan focused on improving management of pastures and hay fields for grassland birds, e.g., delay mowing of hay until after the nesting season, convert fescue pastures to native warm- and cool-season grasses, and remove woody vegetation.

We used the bird/habitat matrix to examine relative effects of different alternatives on selected birds currently using the Refuge. For each target species, habitat potential for each land cover type was given a rank of 0, 1, 2 or 3 (no, low, medium, and high potential, respectively) by refuge biologists. We calculated Potential Species Occurrence (PSO) scores for each habitat and an area-weighted PSO scores for land cover type by each species or group of species for the year 2000 and for each alternative projected for 2015 and 2100.

The Query Tool was used to assess habitat for 31 species identified as regional conservation priority species (http://midwest.fws.gov/pdf/priority.pdf). Area-weighted PSO scores were calculated for the Bald Eagle (*Haliaeetus leucocephalus*; threatened) and five groups of species (all 31 species; nine forest birds, four grassland birds, five shrubland birds, and seven species of waterfowl). Scores for the year 2000 ranged from 0.14 for grassland birds to 1.39 for forest birds. The projected effects of the different alternatives varied. Bald Eagle and waterfowl area-weighted PSO scores remain nearly the same as 2000 scores under all alternatives. This is due to the fact that most of the habitats used by Bald Eagles and waterfowl will remain available in quantities similar to those found in 2000. Forest bird area-weighted PSO scores increase under all alternatives because of planned forest enhancement activities and the succession of young forests and fallow areas into more mature forest habitat. Grassland and shrubland bird area-weighted PSO scores decrease under all alternatives because of succession of open grass and shrub habitats to forest habitat. The amount of refuge habitat for grassland and shrubland birds is small, so losses of these habitats had larger effects on area-weighted PSO scores.

Area-weighted PSO scores are rough estimates of the effects of different alternatives and focus more on habitat quantity than quality. Other factors not considered in this modeling process may also influence the value of a given habitat for wildlife. For example, much of the refuge's forests are relatively young and their values will likely increase as they continue to mature. Also, the planned management activities may enhance habitats for other wildlife species, but the area-weighted PSO scores in this example only addressed bird habitat relationships.

The Roles of Simple Habitat-Association Models vs. Advanced Statistical Models in Bird Conservation Planning

Simple habitat-associations, translated into the species/habitat matrix, are useful as a first step in the decision-making process. These simple models can be generated for any species or group of species for which habitat associations are generally known. Simple models rely on general information available through standard references such as the Birds of North America series (http://www.birdsofna.org/) and expert opinion. However, simple species/habitat matrices can only generate information about potential habitat use. Validation of actual habitat use requires survey data collected from the target management units. Simple models are also useful for defining habitat strata, from which appropriate sampling designs can be derived. For example, defining habitats with the highest probability of detection can be helpful when designing survey strategies for rare species.

Because time is critical in most management settings, simple models can provide a framework for decisions that need to be made quickly or for regional planning when large-scale field data collection is impractical. The major advantage of simple habitat models is their ready application to habitats where general information about species associations is available. Their biggest disadvantage is their failure to provide information on actual habitat use, which can be influenced by many factors, including the range of the species of interest, quality of the habitat, trends in species abundance, metapopulation processes influencing extinction probabilities, historical factors, landscape context, and adjacency to risk factors such as contaminants, human disturbance, and invasive species.

Advanced empirical and statistical habitat models require appropriate data collected from the landscape of interest or other similar habitats in order to generate statistical or empirical models of habitat relationships. This is usually difficult, if not impossible, for many species, especially rare or otherwise at-risk species for which adequate sample sizes are difficult to obtain. Advanced modeling requires time and resources, and answers may not be forthcoming in the time frames decision-makers require, but it is nonetheless critical. Statistical models allow for refinement of habitat relationships and should be incorporated into the DSS process as new information becomes available. Thus, an evolving system of simple model development linked through adaptive information management to statistical models becomes the approach of choice in an effective DSS.

There is always a risk that user groups will misuse simple models, assuming that they represent actual habitat use without validation. Frameworks, tools, and models are only as robust as the information they contain. Research and monitoring efforts should be increased to fill data gaps in our knowledge of life history requirements, habitat use, and the identification of high priority species. The DSS process and the attendant spatial analyses will provide an impetus for posing new hypotheses related to the life history requirements of birds. Likewise, research and monitoring data, incorporated into a DSS framework, are keys to successful implementation of an adaptive management process.

Conclusion

Decision-makers need tools to efficiently organize information and analyze complex systems at a variety of spatial scales. Advances in computer technology now enable managers to assess information regarding management units and ecosystems without advanced training in GIS. This allows managers and biologists to focus on biology, ecosystem management, and setting quantitative, objective conservation goals without becoming distracted by the mechanics of operating the GIS. Our GIS tools allow resource managers to jointly consider both habitats and species during the planning process. The tools described here can be applied to any taxa for which information on habitat associations is available. A prototype of this program was used in a recent report to Congress on the status of the Upper Mississippi River System, possibly the largest, and most complex natural and economic multi-use resource in the United States. The DSS for the Upper Mississippi River System relied heavily on a GIS tool we developed to integrate information for all partners involved in the planning process and resulted in a list of specific habitat needs. The second-generation LINK tool holds promise for application to bird conservation planning at regional, national, or international scales. Because the program is a tool and not a 'black box' and relationships between species and habitats are relatively simple and subject to revision, no stakeholders are excluded from evaluating underlying assumptions of the models. However, more complex statistical models can be incorporated as they are validated and desired by the planning partners. While our DSS tools are currently applied to bird conservation planning at local, regional, and even continental scales, the tools are not limited to assessments of bird habitat. The tools can be applied to any taxa or set of taxa and any landscape, given that spatial data layers representing habitats are available and species/habitat relationships can be defined. A DSS that incorporates spatial habitat models can contribute to policy decisions that weigh

the habitat requirements of migratory birds against economic and political considerations.

Acknowledgments

We thank E. M. Kirsch, L. R. Hill, C. D. Lowenberg, and M. Brown for their contributions to the concepts and implementation of the decision support tools described. D. Olson, D. D. Diamond, J. A. Fitzgerald, L. R. Hill, and three anonymous reviewers provided constructive reviews.

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Use of Survey Data to Define Regional and Local Priorities for Management on National Wildlife Refuges[1]

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Abstract

National Wildlife Refuges must manage habitats to support a variety of species that often have conflicting needs. To make reasonable management decisions, managers must know what species are priorities for their refuges and the relative importance of the species. Unfortunately, species priorities are often set regionally, but refuges must develop local priorities that reconcile regional priorities with constraints imposed by refuge location and local management options. Some species cannot be managed on certain refuges, and the relative benefit of management to regional populations of species can vary greatly among refuges. We describe a process of "stepping down" regional priorities to local priorities for bird species of management interest. We define three primary scales of management interest: regional (at which overall priority species are set); "Sepik Blocks" (30 min blocks of latitude and longitude, which provide a landscape level context for a refuge); and the refuge. Regional surveys, such as the North American Breeding Bird Survey, provide information that can be summarized at regional and Sepik Block scales, permitting regional priorities to be focused to landscapes near refuges. However, refuges manage habitats, and managers need information about how the habitat management is likely to collectively influence the priority species. The value of the refuge for a species is also influenced by the availability of habitats within refuges and the relative amounts of those habitats at each scale. We use remotely-sensed data to assess proportions of habitats at the three geographic scales. These data provide many possible approaches for developing local priorities for management. Once these are defined, managers can use the priorities, in conjunction with predictions of the consequences of management for each species, to assess the overall benefit of alternative management actions for the priority species.

Introduction

National Wildlife Refuges are generally acquired for specific purposes. The legislative authorities that create them identify the primary wildlife management focus of the refuge. Historically, many refuges were acquired under authority of the Migratory Bird Treaty Act using "Duck Stamp" funds, and hence many refuges were dedicated to waterfowl and wetland habitat management. However, recent biodiversity and taxon-specific conservation initiatives have considerably broadened the number of species to be managed on refuges, and have created an interest in managing for those habitats that can best contribute toward wildlife resources within constraints of what is practically feasible. It is also the case that refuges can both achieve the stated purpose and still contribute toward other wildlife management goals. Identification of these other goals is often difficult, given the wide suite of potential wildlife species for which a refuge may manage. The broader perspectives associated with landscape ecology also influence goals of refuge management; refuges now consider the local and regional context of their habitats when defining management options.

In this complicated environment, refuge managers need information at several geographic scales to make reasonable management decisions. Among the relevant data for refuges could be: ecological mapping data, historical vegetative distribution, potential natural vegetation, current conservation status reports, national land cover data, and current animal species distribution and trend information, but often these data are summarized only at regional scales. Bird surveys such as the North American Breeding Bird Survey (BBS, Robbins et al. 1986) and habitat datasets such as the National Land Cover Data (NLCD, http://www.epa.gov/mrlc/nlcd.html) are convenient sources of information that can be summarized using geographic information systems (GIS) at geographic scales needed for management. We have been evaluating the use of these data in establishing priorities for refuge management, and in this paper we describe analyses of BBS and NLCD data at scales relevant to refuge management in Fish and

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California**.

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Wildlife Service (FWS) Region 5 (comprising the states of Maine, New Hampshire, Vermont, New York, Massachusetts, Rhode Island, Connecticut, New Jersey, Pennsylvania, Delaware, Maryland, Virginia, and West Virginia).

What Information is Needed for Management?

To make reasonable management decisions, the following types of information must be summarized at several geographic scales:

1. Priorities for species management are often defined at regional or national scales, and these regional species priorities provide a list of possible species of management interest on refuges, in addition to those species mandated by the refuges' purposes. For birds in FWS Region 5, priorities are defined from a variety of sources, including legislative mandates, species covered under the Endangered Species Act, species identified as declining by the Division of Migratory Bird Management, and by Partners in Flight (PIF) prioritization activities (Carter et al. 2000). Often, regional priorities are based on estimates of population change from the BBS or other surveys.

2. Regional priorities often contain many species that are not suitable for management on all refuges. Clearly, not all species occur at equal abundances throughout a region, and management needs at the edge of a species' range may differ from those in the center of the range. Patterns exist in population change for most species throughout a region. Consequently, the geographic location of the refuge will influence whether the species is a local priority, and population analyses at more local scales can focus the regional priorities on the refuge. For example, PIF prioritization results are presented by physiographic stratum, reflecting differing species pools and regional variation in population change at the stratum scale (*table 1*), and these priorities provide a local context within the larger region. For refuges, it is often of interest to consider patterns of abundance at scales even more local than physiographic strata, as refuges often are established to protect areas of specific conservation concern. One aspect of conservation planning in Region 5 has focused on 30-min blocks (Sepik Blocks, *fig. 1*) as a scale at which survey (e.g., from the BBS) information can be reasonably summarized to provide landscape-level survey data, but which also provides a context for refuges that is based on nearby habitats. Note that the block size permits a local context that includes several BBS routes (*fig. 1*). Other scales are also used for mapping of regional survey data (e.g., Sauer et al. 1995), and could be used as alternatives to the Sepik Blocks in analyses.

3. Additional information is needed on the actual and potential habitats on a refuge, as some species could not occur on a refuge regardless of management. The assessment of management potential for species on a refuge should influence the list of priority species. Because habitats are managed on refuges, the potential for the species to actually respond to habitat management actions is an important consideration in defining priorities. The land capability at a refuge to sustain the appropriate habitat or natural processes that create habitat for a species will influence refuge wildlife management objectives.

4. Landscape context (e.g., the presence of habitats within the Sepik Block containing the refuge) also can influence the relevance of management for a particular species on a refuge.

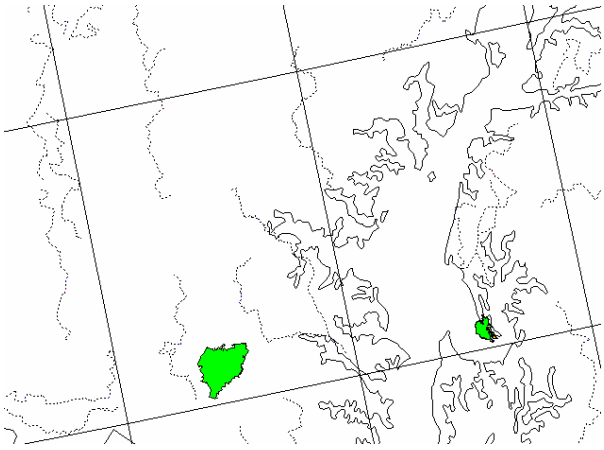

Figure 1– Map showing size of "Sepik" Blocks near the Patuxent Research Refuge (solid area) in Maryland. BBS routes in the region are also displayed as dashed lines.

Variation in these attributes among (or within) Sepik Blocks provides some idea of relative value of the refuge for each species. Ideally, then, biological information at these scales should provide refuge managers with both a list of priority species for management, and a relative ranking of the value of management on the refuge for each species. The list of priority species, weighted by a measure of importance of the species, can be used to calculate the overall effects of alternative management actions. It can be thought of as an "objective function" (e.g., Williams et al. 2002), from which the overall effects of alternative management actions can be tied to responses of priority species by summing up the predicted total populations of each species multiplied by the weights for the species. Although any such ranking of species in an objective

Table 1— *Listing of bird species identified as priorities in ≥1 of the Partners in Flight Physiographic Strata in FWS Region 5. N indicates the number of strata in which the species was listed as a priority for management.*

N	Species common name	Scientific name
4	American Black Duck	*Anas rubripes*
2	Black Rail	*Laterallus jamaicensis*
7	American Woodcock	*Scolopax minor*
4	Upland Sandpiper	*Bartramia longicauda*
1	Piping Plover	*Charadrius melodus*
1	Northern Bobwhite	*Colinus virginianus*
1	Spruce Grouse	*Falcipennis Canadensis*
1	Northern Saw-whet owl	*Aegolius acadicus*
2	Red-cockaded Woodpecker	*Picoides borealis*
1	Yellow-bellied Sapsucker	*Sphyrapicus varius*
2	Whip-poor-will	*Caprimulgus vociferus*
1	Olive-sided Flycatcher	*Contopus cooperi*
3	Acadian Flycatcher	*Empidonax virescens*
2	Bobolink	*Dolichonyx oryzivorus*
2	Red Crossbill	*Loxia curvirostra*
7	Henslow's Sparrow	*Ammodramus henslowii*
2	Nelson's Sharp-tailed Sparrow	*Ammodramus nelsoni*
2	Salt Marsh Sharp-tailed Sparrow	*Ammodramus canducutus*
2	Seaside Sparrow	*Ammodramus maritimus*
2	Field Sparrow	*Spizella pusilla*
2	Bachman's Sparrow	*Aimophila aestivalis*
1	Yellow-throated Vireo	*Vireo flavifrons*
1	Prothonotary Warbler	*Protonotaria citrea*
3	Swainson's Warbler	*Limnothlypis swainsoni*
8	Worm-eating Warbler	*Helmitheros vermivorus*
1	Blue-winged Warbler	*Vermivora pinus*
10	Golden-winged Warbler	*Vermivora chrysoptera*
1	Cape May Warbler	*Dendroica tigrina*
6	Black-throated Blue Warbler	*Dendroica caerulescens*
2	Chestnut-sided Warbler	*Dendroica pensylvanica*
2	Bay-breasted Warbler	*Dendroica castanea*
10	Cerulean Warbler	*Dendroica cerulea*
5	Blackburnian Warbler	*Dendroica fusca*
6	Prairie Warbler	*Dendroica discolor*
8	Louisiana Waterthrush	*Seiurus motacilla*
5	Kentucky Warbler	*Oporornis formosus*
5	Canada Warbler	*Wilsonia canadensis*
4	Bewick's Wren	*Thryomanes bewickii*
1	Winter Wren	*Troglodytes troglodyte*
1	Brown Creeper	*Certhia americana*
1	Red-breasted Nuthatch	*Sitta canadensis*
1	Black-capped Chickadee	*Poecile atricapillus*
1	Golden-crowned Kinglet	*Regulus satrapa*
1	Veery	*Catharus fuscescens*
3	Bicknell's Thrush	*Catharus bicknelli*
9	Wood Thrush	*Hylocichla mustelina*

function is likely to be controversial, use of biological information to define priorities at the local scale represents a significant advance from use of arbitrary methods of defining priorities.Our interests over the past few years have focused on use of data to inform all steps of this process. Our use of landscape-level survey data

and remotely-sensed habitat data to focus regional priorities for specific refuges involves evaluating regional differences in species abundance and habitat features at local scales. We assume that spatial patterns of species abundance are relevant to management, and use the information both to define relevant species for management and to establish relative priorities for management among species. We also use remotely-sensed habitat data to evaluate the uniqueness of refuges relative to nearby areas, providing further information for use in defining local priorities. We use information from a variety of surveys, but will provide examples based on bird populations as summarized by the BBS.

Providing Information at Several Geographic Scales

Biological Information from the BBS

For many taxa, no information exists on regional population status. However, a variety of surveys exist for bird species, and the BBS, the Christmas Bird Count, Mid-winter Waterfowl Surveys, International Shorebird Surveys, and waterfowl band recovery databases all provide information on bird populations (See Sauer and Droege [1990] and Martin et al. [1979] for information regarding these surveys). Here, we use the BBS as an example of estimation of population attributes at several geographic scales.

The BBS provides a unique source of information for multi-scale population analysis. The BBS is a roadside survey of birds that consists of >4,000 survey routes in North America. Each route consists of 50 count locations, which are surveyed once each year by a volunteer observer (Robbins et al. 1986). Initiated in 1966, the survey provides population relative abundance and change information for >400 bird species, and trends can be estimated at scales from local (individual survey routes) to continental. Although analyses of the BBS can be controversial due to its roadside sample frame and flaws in the count information (Bibby et al. 2000), it is our only source of information on population change for many species. Consequently, we must make some assumptions about consistency in population change and patterns of abundance between sampled and unsampled areas (Robbins et al. 1986).

Analyses of BBS Data at Regional and Sepik Block Scales

BBS results are commonly used to estimate population change at regional scales (e.g., Robbins et al. 1986). Population trend estimates (Link and Sauer 1994) are a primary resource for conservationists; the PIF prioritization process uses BBS information on population change by physiographic strata to identify priority species for conservation efforts. (http://www.blm.gov/wildlife/pifplans.htm). Abundance information also plays an important role in prioritization, by focusing conservation efforts on portions of a species range where it is most abundant (Carter et al. 2000). We extend that process by evaluating relative abundance and population change at the scale of the more-local Sepik Blocks. For each species on the BBS, we estimated relative abundance and population change for Sepik Blocks using Inverse Distancing, which provides a spatially-weighted average for the center point of the block (Sauer et al. 1995). For relative abundance, we estimated the average counts for each species on each route over the interval 1992–2001, then used a distance-weighted mean of data from the five BBS routes nearest the center of the block to characterize the abundance of the species in the block. For population trends, we used a Poisson regression (Link and Sauer 1994) to estimate change for each BBS route in the region, then calculated a weighted (by mean abundance and precision) average of the nearest five survey routes to characterize trend by Sepik Block.

Note that BBS data are not used to provide direct estimates of population attributes on refuges. Our simple spatial models rely on an assumption that the BBS information provides a summary of birds occurring on average landscapes in the regions. Refuges are often selected because they contain specific habitats, and are then managed for specific wildlife resources; we expect that the landscape level summaries provided by nearby BBS data will not reflect bird populations actually occurring on refuges.

Habitat Analysis

For our habitat analysis, we used the National Land Cover Data (NLCD, http://www.epa.gov/mrlc/nlcd.html) that is derived from images acquired by the Landsat Thematic Mapper sensor. NLCD is a GIS dataset in which 30 m cells (called “pixels” in GIS jargon) are classified into >20 habitat categories (http://www.epa.gov/mrlc/classification.html; actual number of groups varies among revisions). Although these classifications are made with error (Zhu et al. 2000), and classifications do not necessarily conform to vegetation types and structure most relevant to bird species, remotely-sensed data do provide general information on extent and location of habitats and has proven useful for habitat analysis at the landscape level (e.g., Flather and Sauer 1996). NLCD datasets from circa 1992 are available for all states in FWS Region 5, and can be used to summarize proportion of habitat types and other habitat and landscape features at any scale from refuge to region.

To be relevant to population analyses of priority species, some association must be made between habitat categories and their use by birds. For example, forested habitats presumably represent potential habitat for forest-nesting birds. However, the extent of these associations is unknown, as all bird species have unique habitat requirements and remotely-sensed habitat categories are generally not particularly sensitive to habitat considerations important to birds. In our habitat summaries, we have chosen to broadly aggregate habitat categories to provide general indications of habitats relevant to birds, such as aggregating forest categories or grassland categories to imply beneficial habitats for birds that nest in those habitats. These general relations appear to exist among groupings of birds at the landscape level (e.g., Flather and Sauer 1996). A variety of more complicated models can be used to develop more specific relationships between birds and habitats, and several efforts are underway to develop better models based on NLCD and use these models to predict bird abundance near refuges (M. Knutson, pers comm).

Summaries of BBS Data at the Scale of Sepik Blocks

Bird species can differ widely in abundances and trends over Sepik Blocks in FWS Region 5. Maps of relative abundance (*fig. 2*) and population change (*fig. 3*) for Wood Thrush (*Hylocichla mustelina*) and Canada Warbler (*Wilsonia canadensis*) clearly show regional patterns. Summaries by species groups such as forest-breeding (*fig. 4*) or grassland birds (Peterjohn and Sauer 1998) also show distinct regional patterns in mean abundance. These data provide basic information on (1) blocks where the species occur; (2) relative abundance among blocks; and (3) blocks in which species' populations are increasing or declining.

Summaries of Habitat Data

NLCD-based habitat summaries provide information at the refuge and Sepik Block scales, and can be summarized for single habitat categories, or for groups of habitats (all forested habitats, *fig. 5*). It is also possible to use this information to address explicit landscape attributes such as amount of edges and interior forests to provide more information on possible management issues for priority species. Finally, it is reasonable to summarize NLCD data to identify relative proportions of habitats on refuges relative to regions, in order to identify unique habitats on refuges.

Uses of this Information

Historically, the process of deciding local priorities has been based on expert opinions about areas of importance for regional priorities. The availability of actual data on relative abundance and population change for many bird species, in conjunction with information regarding both regional habitat distributions and habitat preferences of priority species, allows us to provide quantitative information on the relevance of local priorities. The mapping of trend and relative abundance at local scales reflects an extension of prioritization methods used at regional scales. By evaluating where the populations occur, where they have higher abundances, or where they are declining in a region, we can focus

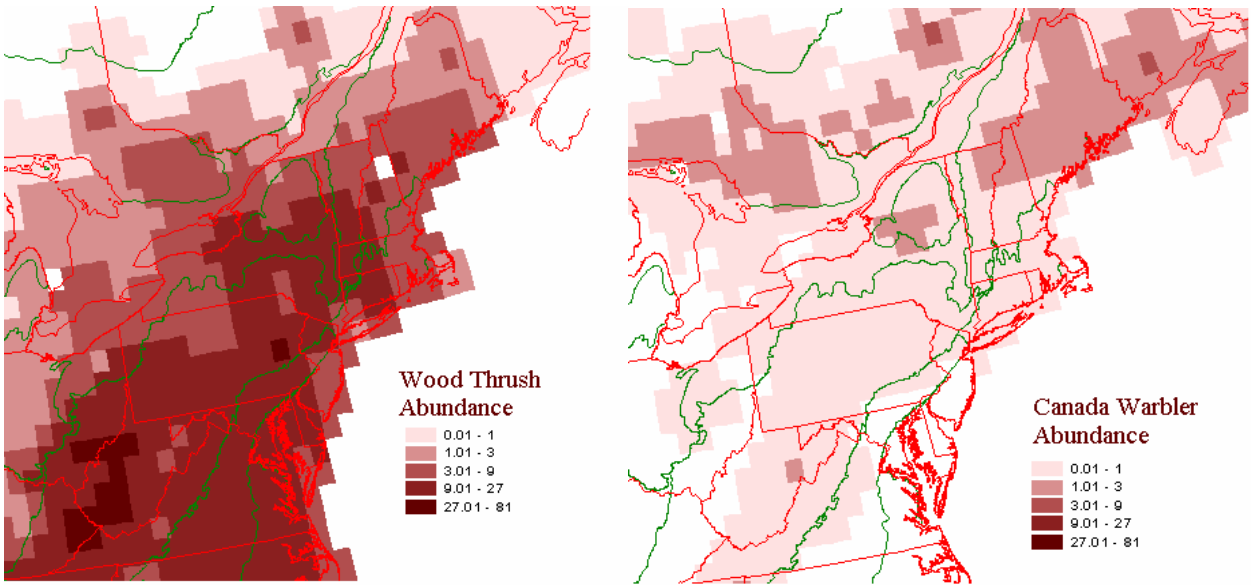

Figure 2—Estimated mean relative abundance of Wood Thrush and Canada Warbler for Sepik Blocks in FWS Region 5. Abundance in a block is estimated by inverse distancing of mean counts from nearby BBS routes. Abundance categories are in terms of birds/survey route.

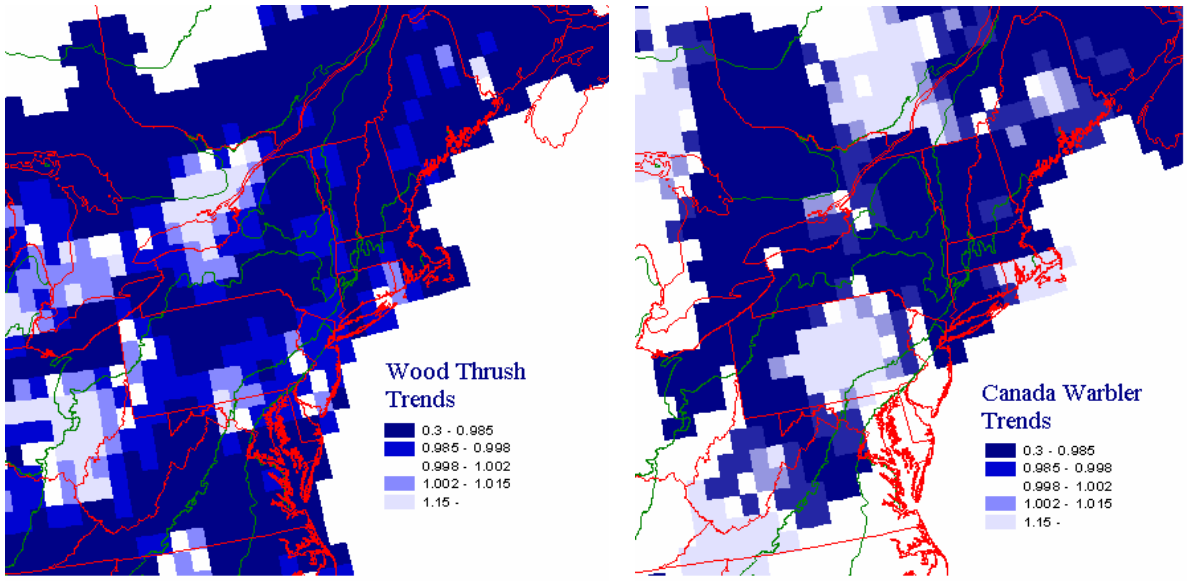

Figure 3—Estimated population change of Wood Thrush and Canada Warbler for Sepik Blocks in FWS Region 5. Proportional change estimates that are < 1 indicate declining populations, and estimates >1 indicate increasing populations.

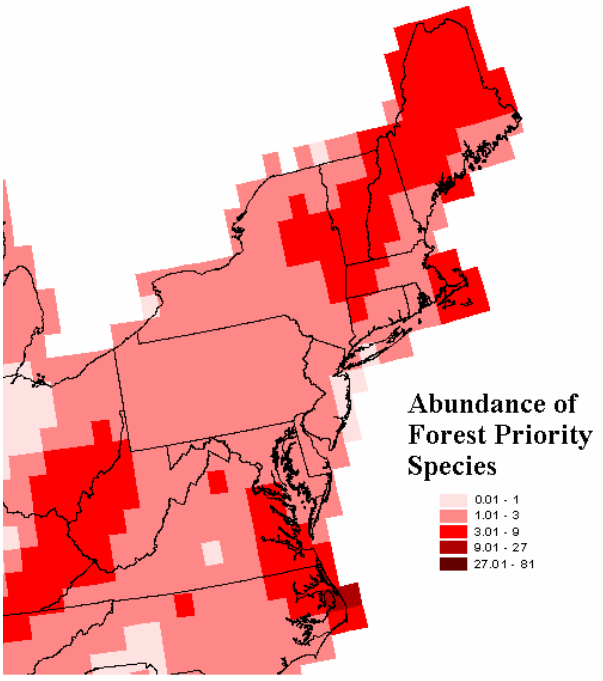

Figure 4—Estimated mean relative abundances of priority forest-breeding birds for Sepik Blocks in FWS Region 5. Abundance in a block is estimated by inverse distancing of mean counts of all forest-breeding priority bird species on nearby BBS routes. Abundance categories are in terms of birds/ survey route.

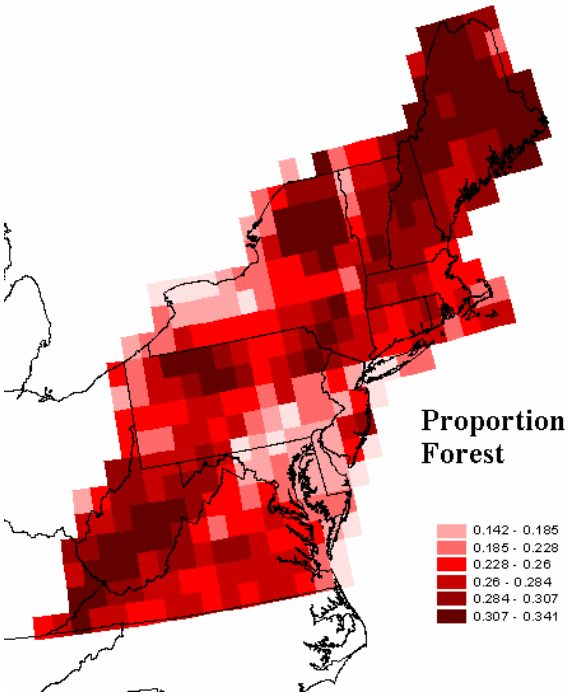

Figure 5—Proportion of land cover in Sepik Blocks classified as Forest, as summarized from remotely-sensed NLCD data.

possible value for management. It is beyond the scope of this paper to define these quantitative measures, as conversion of the biological information into a relative measure of value of management among Sepik Blocks requires that assumptions be specified about the consequences of management for a species. Refuge managers can take the summaries at the Sepik Block scale and use them in very general ways (e.g., to simply constrain regional priority lists to species that occur near their refuges) or in very specific ways (e.g.,

by combining abundance and trend measures, and assigning highest priorities for management to areas within the region of high abundance with most steeply declining populations). It may be that addition of a bird to the population through a management action will have the same effect on the population regardless of where it is added; viewing areas of high relative abundance to be of higher value to the population implicitly assumes that management in these areas produces more birds than would management in areas of lower abundance. Also, it must be assumed that management has more value in areas where populations are declining. Clearly, as in other prioritization activities, these assumptions must be carefully considered and evaluated to ensure that effort is properly allocated.

Habitat data provide measures of the relative proportions of habitats on refuges relative to the Sepik Blocks and the regions. Managers must assess the uniqueness of their habitats as well as the bird species priorities in making management decisions; the habitat data provide a critical specific context in terms of what habitats could potentially occur in refuges, and how these habitats interact with the nearby (Sepik Block scale) habitats. For example, a refuge that provides forested habitats in a nonforested landscape needs to consider this in their management. Consequently, the biological data permits a stepping down of the regional priorities to the Sepik Block scale, but the habitat data provides measures both of possible local impact (via assessment of the refuge habitats relative to the Sepik Block habitats) and of the potential for on-refuge management options by defining present habitats.

We note that additional information sources are also useful in assessing the relevance of existing vs. natural habitats on refuges and within regions. For example, understanding the historical and potential natural vegetation provides insights into possible priorities for conservation and management.

The Relative Roles of Predictive Modeling and Mapping in Refuge Management

The mapping methods we describe aid managers in deciding what to manage, and are effectively a repackaging of monitoring data at a relevant scale. Management of biological resources on refuges clearly also requires a predictive component, in which models of bird-habitat relationships are used to assess the consequences of alternative management scenarios on total bird populations on the refuges. If these models exist, they can be used in conjunction with the list of priority species (and their relative importances, as defined in the objective function described above) to provide an overall measure of how alternative management actions would influence the priority species on the refuges.

Predictive models also play a role in predicting abundances and trends at scales for which survey data do not exist. For example, predictive models provide the means to connect the bird populations on refuges to the populations at the scale of Sepik Blocks, through modeling of common habitat variables. In our view, these modeling exercises have great value, and represent an important innovation in management of refuges. Roles exist for both use of survey information to estimate relative abundance and population change and the use of predictive models to facilitate estimation at different scales and predict alternative management actions, and the direct connection between habitats and habitat-based predictive models is clearly very useful for refuge managers who can only manipulate habitats. However, general habitat information as presented here permit the initial steps in assessing opportunities for management on refuges, and many regional-scale modeling exercises are based on summaries of general habitat models applied to NLCD or similar habitat databases. When models that efficiently use the habitat information become available, they can be substituted for the general habitat information to provide better information on the exact relevance of habitats for birds.

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Pre-Euroamerican Distribution of Pine Warblers (*Dendroica pinus*) in Wisconsin: A Tool for Setting Regional Conservation Priorities[1]

Anna M. Pidgeon,[2] Lisa A. Schulte,[2,3] and David J. Mladenoff[2]

Introduction

A common goal of conservation and management plans is to maintain populations of species of conservation concern at some historic level that was a product of environmental conditions at a time when they were less influenced by humans than at present (e.g., Wade 1993, Reijnders 1994, Polacheck et al. 1999). Conservation planning also includes consideration of the distribution, abundance, and reproductive success of a species, all of which are affected by both the amount and spatial pattern of habitat (Donovan et al. 1995, Trzcinski et al. 1999, Pidgeon et al. 2003). However, in regions like Wisconsin, USA, where land use changes have been rapid and pronounced in the last 150 years (White and Mladenoff 1994, Radeloff et al. 1999), studying population demographics only in the recent period (1965 – present) for which most population trend data are available provides only a narrow view of species-habitat relationships. In this work, we have fused the fields of spatial and historical ecology to provide a perspective that includes an estimate of a bird species' distribution just prior to Euroamerican settlement (~1850).

Although humans had been active in the area covered by Wisconsin for thousands of years, studies have shown that the landscape changed far less during the 2,000 to 3,000 years prior to Euroamerican settlement than during the 150 years following it (Davis 1981, Webb 1986, Cole et al. 1998). The pre-Euroamerican landscape of northern Wisconsin was largely the product of long-term interactions between vegetation, physical factors, and natural disturbance (Cleland 1983, Webb 1986, Schulte and Mladenoff 2001). The influence of Native Americans on the distribution and amount of wildlife habitat was likely more limited here than elsewhere (Cleland 1983), and much less than the influence of the Euroamericans who followed them (Fries 1951, Cole et al. 1998).

Vegetation data for the pre-Euroamerican period are contained in the U.S. General Land Office's original Public Land Survey (PLS) records, collected between 1832 and 1866 in Wisconsin. From these data we have developed digital coverages of dominant land cover type, relative dominance of individual tree species, and overall tree density (Schulte et al. 2002). These maps form the basis of a model that depicts the potential distribution of a bird species, the Pine Warbler (*Dendroica pinus*), during the immediate pre-Euroamerican period.

We selected the Pine Warbler for two reasons. First, the species' preferred breeding habitat, mature pines, has undergone radical change in the last 150 years, making comparison of Pine Warbler potential distribution in the pre-Euroamerican settlement time period with its present distribution of particular interest. Secondly, modeling the species' habitat preferences is relatively straightforward due to its strong association with mature pines, and because the distribution of mature pines appears to have been captured well in the PLS data set.

Methods

We modeled the potential pre-Euroamerican and present day habitat of the Pine Warbler. Then a map of current Pine Warbler locations (Wisconsin Society for Ornithology 1995; *fig. 1*) was compared with the modeled present day habitat distribution to assess the robustness of the habitat modeling technique.

Our unit of analysis was the Land Type Association (LTA) polygon, one level of ecoregion patterning within the U.S. Forest Service Hierarchical Ecoregion Classification System (Keys et al. 1995, Cleland et al. 1997). Wisconsin LTA polygons are 0.1 to 3,847.3 km^2 in extent (WiDNR 1999). Criteria used in deriving the model were developed from modern sources (*table 1*), and applied to the pre-Euroamerican settlement vegetation data available in the PLS records and to present day vegetation data available from Forest Inventory and Analysis plots (1996; Miles et al. 2001). The resulting maps were then compared to assess changes in this species' potential distribution between the mid-1800s and the present (*fig. 1*).

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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Table 1— *Criteria used to map pre-Euroamerican settlement Pine Warbler habitat and data sources from which they were derived. Habitat meeting minimum tree density and pine dominance criteria was classified as Pine Warbler habitat, and was weighted according to tree composition and stand age criteria.*

Habitat category	Criteria	Citation
Tree Density	Forest (>47 trees/ha)	Niemi et al. 1997, Haney and Lydic 1999
Pine Dominance	>10% pine species	Robbins et al. 1989, Robbins 1991
Tree Composition	White pine = red pine >jack pine >all else	Howe and Roberts this volume, Hanowski and Niemi 1991a,b
Stand Age	Mature > Non-mature (≥50 cm dbh >40-49 cm >30-39 cm >all else)	Collins et al. 1982, Rodewald et al. 1999

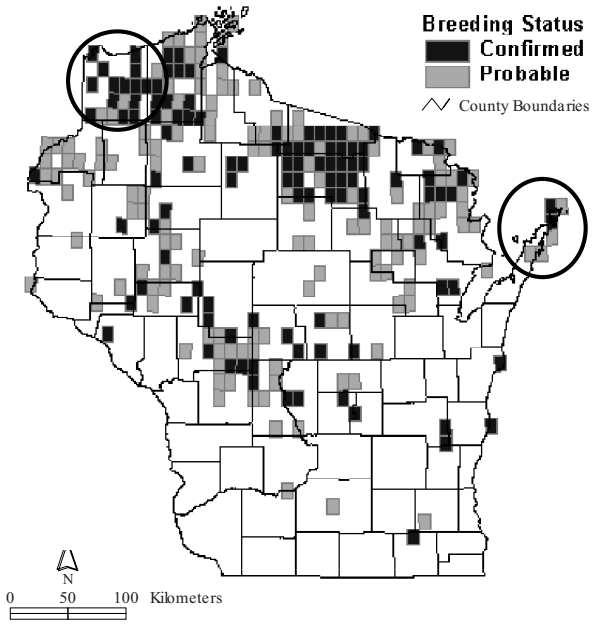

Figure 1— Current distribution of pine warbler habitat, as derived from the Wisconsin Breeding Bird Atlas (Wisconsin Society for Ornithology 1995). *Confirmed breeding status* is defined as one of the following: physiological evidence in adults, physical evidence of nest, nestlings, or fledglings. *Probable breeding status* is defined as specific behavior associated with breeding. Circles indicate areas where our model did not predict current Pine Warbler habitat.

Results and Discussion

The overlap in the present day distribution of Pine Warblers (*fig. 1*) and present day modeled habitat (*fig. 2b*) is strong. This concordance supports the robustness of the modeled pre-Euroamerican settlement potential habitat maps.

Our results suggest that potential Pine Warbler breeding habitat was patchily distributed within the northern portion of Wisconsin prior to Euroamerican settlement (*fig. 2a*), and that this pattern continues today (*figs. 1, 2b*). Historically, the best quality habitat was primarily located on or near sandy glacial outwash plains, where stands of old-growth white and red pine (*Pinus strobus* and *P. resinosa*) forest were common (*fig. 2a; all circled areas*). Overall, the estimated distribution of Pine Warbler habitat in the two time periods is strikingly similar; however habitat quality, and likely the Pine Warbler population, appears to have degraded since the pre-Euroamerican period. In virtually the entire the northern tier of counties, habitat suitability has declined. In this region, where large pines occurred during the pre-Euroamerican period on sandy outwash plains (*fig. 2a, areas 1a - 1c*), subsequent development (i.e., farming) ultimately failed due to poor soils and/or inadequate commodity distribution networks (Gough 1997), and red and white pines have become established once again (WiDNR 1998). Further south (*fig. 2b; area 2*) habitat has contracted since Euroamerican settlement, likely due to the permanent replacement of white pine forest by agriculture (WiDNR 1998).

However, Pine Warbler breeding habitat is currently more broadly distributed in portions of Wisconsin that were previously dominated by herbaceous vegetation (Bolliger et al. 2004), probably due the establishment of pine plantations and successional trends associated with the alteration of the historical fire regime (*fig. 2b, areas designated as 3*). Pine Warblers have also expanded into a localized site in the southeastern portion of the state (*fig. 1*), which is currently state forest, but was in a savanna condition in pre-European settlement times.

Our model failed to predict current Pine Warbler habitat in two northern areas where Breeding Bird Atlas data indicate that Pine Warblers do occur (*fig. 1, circled areas*). A likely reason for the incongruity relates to the scale at which the two maps were derived; our potential habitat map was derived using the LTA as the unit of analysis. LTAs can vary widely in size and can be much coarser than the resolution of Breeding Bird Atlas survey blocks (150 km^2; *fig. 1*). Analysis of large LTAs containing predominantly unsuitable habitat may

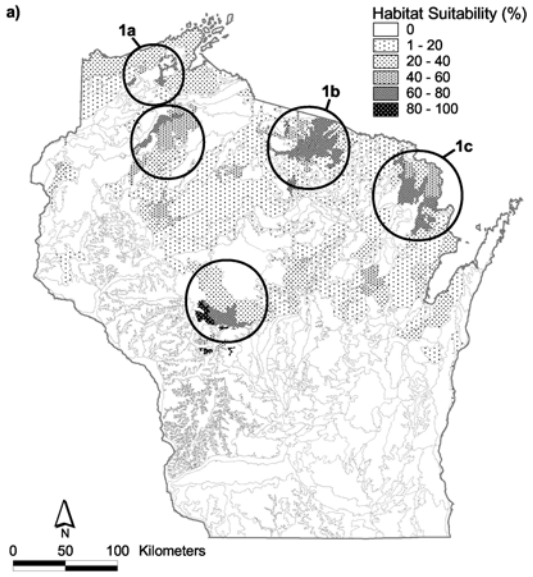

Figure 2a— Percent probability of suitable pine warbler habitat in the period just prior to Euroamerican settlement, as derived from vegetation data in the U.S. General Land Office original Public Land Survey records. Circles indicate sandy glacial outwash plains.

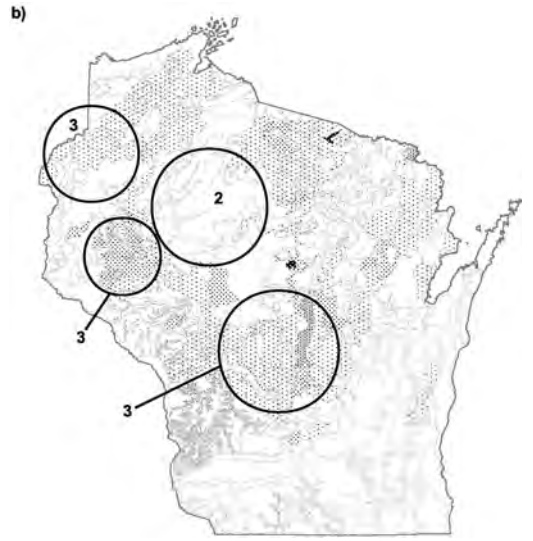

Figure 2b— Percent probability of suitable pine warbler habitat in the current period, as derived from Forest Inventory and Analysis (FIA; Miles et al. 2001) data. Circle designated as "2" indicates an area where Pine Warbler habitat has degraded since the pre-Euroamerican period. Circles designated as "3" indicate areas where Pine Warbler habitat has expanded since the pre-Euroamerican period.

camouflage small, suitable habitat patches that are detected with the Breeding Bird Atlas methodology. Analysis of PLS data at the section level would result in a finer scale map of potential habitat, which would reveal small habitat patches; however FIA data can be summarized only at coarser resolutions. Facing a tradeoff between the level of detail depicted and the transparency of the results, we decided to focus on determining the robustness of the model by being able to directly compare PLS and FIA data while sacrificing finer scale details of potential habitat distribution.

During model development we made two assumptions; that habitat preferences of the Pine Warbler have not changed between the two time periods, and that habitat was occupied during the pre-Euroamerican settlement period in patterns similar to those exhibited by modern Pine Warbler populations. The similarity of potential habitat distribution just prior to the Euroamerican period and current Pine Warbler distribution supports the validity of both the assumptions and the resulting pre-Euroamerican potential habitat map. Advantages of our method include its quantitative approach and replicability; limitations include the uneven availability of quantitative habitat data for various bird species (e.g., habitat criteria of grassland bird species are not captured in the PLS-derived data set) and the lack of additional data for validation of the pre-Euroamerican bird distributions.

Our method provides a spatially explicit assessment of probable changes in bird habitat over a broad temporal window. Such an assessment can provide valuable insight into historical patterns of avian distribution. Moreover, there is considerable interest in using birds as indicator species of both environmental change and habitat quality (e.g., Morrison 1986, Taper et al. 1995, Niemi et al. 1997). Inclusion of information about the historical distribution of indicator species in assessments of habitat conservation needs illuminates the extent of landcover change. Adoption of the probable historic distribution of avian indicator species as an approximate target can provide an ecologically rational approach for current conservation efforts.

Acknowledgments

Funding for this project was provided by the Department of Forest Ecology and Management UW-Madison, the Wisconsin Department of Natural Resources under the Pitmann-Robertson program, and U.S. Forest Service North Central Research Station. We thank G. Niemi, J. Hanowski, and R. Howe for sharing their habitat data, and the Wisconsin Breeding Bird Atlas for Pine Warbler atlas data. We are grateful to C. Lepczyk and G. Niemi for comments that improved the manuscript, and to V. Radeloff and T. Sickley for technical assistance.

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Important Bird Areas in the Neotropics: The Backbone of a Coordinated, On-the-ground Bird Conservation Initiative in the Western Hemisphere[1]

Angelica Estrada[2] and Ian Davidson[3]

Abstract

The Important Bird Areas (IBA) Program was developed by BirdLife International as an approach to conserving birds and associated biodiversity throughout the world. The IBA program seeks to identify and protect a network of sites, at a biogeographic scale, which are critical for the long-term viability of naturally occurring bird populations for which site-based conservation is appropriate. The IBA program, run by national organizations in each country, consists of four stages: site identification, site designation, advocacy and action, and assessment and monitoring. In the Americas the IBA program was launched in 1997 and since then 24 countries have launched IBA programs, with more than 3,381 IBAs identified across the region. Selected conservation actions are described from Brazil, Panama, Cuba and Argentina.

Key words: Caribbean, conservation action, Important Bird Areas, Latin America, national inventories, network, partnerships.

Background

The Americas are home to the greatest avian diversity on this planet. A total of 4,339 species or nearly 50 percent of all known bird species occupy every habitat type from Alaska to Argentina (BirdLife International 2002a). The neotropical region hosts the highest concentration of species with Brazil, Colombia, Peru, Ecuador and Bolivia recognized as "mega-diversity" countries, which alone account for 50 percent of all the species found in the Americas (BirdLife International 2002a). Nearly 350 bird species face an imminent threat of extinction largely brought about by habitat destruction (BirdLife International 2000). Of the 12 ecoregions with the highest aggregation of threatened species worldwide, seven are found in the Americas (Mittermeier et al. 1999).

Amongst the many innovative regional conservation initiatives, the Important Bird Areas (IBA) program, initiated in the Americas by BirdLife International in 1997, is not only helping to identify those critical areas for birds, but is also embarking on the conservation of the most critically threatened sites. The IBA program seeks to identify and protect a network of sites, at a biogeographic scale, which are critical for the long-term viability of naturally occurring bird populations across the distributional range of those bird species for which a sites-based approach is appropriate (Wege 1997). BirdLife works through a national Partner in each country. These Partners (or in some cases, "Associates" where BirdLife does not have an official Partner) are responsible for coordinating the IBA program and liaising with all necessary stakeholders who are willing to contribute to the process.

The objectives of the IBA program are to:

- Identify and document globally important places for bird conservation in the Americas using agreed to criteria for threatened birds, species with restricted distribution, range restricted species, and congregatory species. In addition, some countries have identified national and/or sub-regionally important areas based on a set of similar criteria developed for national and/or sub-regional areas.
- Publish and widely distribute IBA directories at the national, sub-regional or regional levels in the appropriate languages.
- Establish a database containing critical information about IBAs in a format that can be maintained, updated and made widely available.
- Highlight sites that are threatened or inadequately protected.
- Inform decision makers and pertinent national authorities at all levels about the existence and significance of IBAs, and promote the acceptance and official support of the program.

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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- Promote the conservation of critical sites and ensure their conservation and sustainable development.

- Ensure the involvement of local communities in the decision-making processes for the development and implementation of conservation activities.

- Incorporate and promote the work of international and national non-governmental agencies (NGOs), and help build national and regional networks of ornithologists and conservationists through training, capacity building, and network development.

- Establish the basis developing national conservation strategies, including national protected areas programs and bi-national, sub-regional, regional and global conservation agreements.

While global in scope, the IBA program promotes a comprehensive and extensive network of critical sites for birds in the Americas. Given that birds are generally accepted as indicators of the presence of broader biodiversity, IBAs also help identify critical areas for other taxa (e.g., reptiles, amphibians, and mammals; ICBP 1992).

IBAs are identified using a set of standardized criteria. The criteria used to identify sites of global significance are the same as those used in other regions throughout the world (*table 1*). These criteria were initially developed and later improved through a process of global consultation (Fishpool and Evans 2001). The application of these criteria to the identification of IBAs allows for a global comparison of sites (Estrada and Davidson 2001).

The implementation of the IBA Program usually follows a four-stage process. These stages consist of the following:

1. **Site Identification.** After completing a training session on the IBA Program, each Partner organization, through their volunteer network of experts, identifies and nominates potential IBA sites. The nominated sites are reviewed by an appointed National IBA Coordinator and/or a national IBA Technical Committee using internationally agreed upon criteria (*table 1*). Information on each potential IBA is compiled and added to the World Bird Database (WBDB). The WBDB is designed to manage data on IBAs and bird species. During the identification stage, data entered into the WBDB (generally collected by naturalists in each country) can be used to help generate information on the significance of each potential IBA with the purpose of identifying all sites within a country that fulfill the IBA global criteria. National IBA site inventories are published and distributed to local decision-makers in efforts to support future site designations.

2. **Site Designation.** The designation process is lead by the Partner organization in each country. This may involve organizing press conferences, lobbying local and national governments, producing and disseminating information, and other activities related to a site's formal designation. Public dedication ceremonies are usually coordinated by local groups at or adjacent to IBA sites. Support for these activities is provided by the national Partner. There are a variety of mechanisms for designating a site. Designations sometimes result in areas being added to formal legally protected areas managed by the government. Some sites remain in the hands of private groups while still others are purchased and declared private reserves. There are a variety of ways of publicly announcing and disseminating information about sites that have been designated. However, the designation of an IBA as a protected area is only the first step towards ensuring the long-term conservation of its birds and biodiversity in general.

3. **Advocacy and Action.** Interested local groups are encouraged to develop management plans for each site, either on their own or in cooperation with other relevant stakeholders. Working with local and national stakeholders, the Partner organization coordinates a priority setting exercise that helps identify key areas where conservation work is critically needed, feasible and achievable. Activities at the site level include the development of land use planning strategies, cooperative management agreements with the local landowners, acquisition of land for the creation of private reserves, establishment of sustainable development programs, and environmental education initiatives. National Partners also work with governmental agencies to help ensure that IBAs are considered for inclusion in the system of nationally protected areas. This latter initiative is attractive for governments and helps meet their obligations under the Convention on Biological Diversity (Viada 1998).

4. **Assessment and Monitoring.** BirdLife Partners work with local groups to monitor specific threats to IBAs. The WBDB is an important tool for tracking change at sites, and regular updates on the status of each IBA are critical for ensuring the stability of the network of globally important sites. Site monitoring is an excellent mechanism for evaluating the status of bird species, including those that are critically threatened, because in many cases (particularly in South America) an

IBA may be the only known site for a species (e.g, the Black-breasted Puffleg [*Eriocnemis nigrivestis*]) which is endemic to the Mindo IBA in Ecuador. Regular monitoring also provides an early warning signal for sites that are being impacted, which may provide time for addressing site degradation issues.

Table 1— *Summary of global Important Bird Area categories and criteria.*

Category	Criterion	Notes
A1. Globally threatened species	The site regularly holds significant numbers of a globally threatened species, or other species of global conservation concern.	The site qualifies if it is known, estimated or thought to hold a population of a species categorized as Critical or Endangered. Population-size thresholds for Vulnerable, Conservation Dependent, Data Deficient and Near Threatened species are set regionally, as appropriate, to help in site selection.
A2. Restricted-range species	The site is known or thought to hold a significant component of the restricted-range species whose breeding distributions define an Endemic Bird Area (EBA) or Secondary Area (SA).	The site also has to form one of a set selected to ensure that, as far as possible, all restricted-range species of an EBA or SA are present in significant numbers in at least one site and, preferably, more.
A3. Biome-restricted assemblage	The site is known or thought to hold a significant component of the group of species whose distributions are largely or wholly confined to one biome.	The site also has to form one of a set selected to ensure that, as far as possible, all species restricted to a biome are adequately represented.
A4. Congregations	(i) The site is known or thought to hold, on a regular basis, ≥1 percent of a biogeographic population of a congregatory waterbird species.	This applies to waterfowl species as defined by Rose & Scott (1997). Thresholds are generated in some instances by combining flyway populations within a biogeographic region, but for others lacking quantitative data, thresholds are set regionally or inter-regionally, as appropriate. In such cases, thresholds will be taken as estimates of 1 percent of the biogeographic population.
	Or	
	(ii) The site is known or thought to hold, on a regular basis, ≥ 1 percent of the global population of a congregatory seabird or terrestrial species.	This includes those seabirds not covered by Rose & Scott (1997). Where quantitative data are lacking, numerical thresholds for each species are set regionally. In such cases, thresholds will be taken as estimates of 1 percent of global population.
	Or	
	(iii) The site is known or thought to hold, on a regular basis, ≥ 20,000 waterbirds or ≥ 10,000 pairs of seabirds of one or more species.	This is the Ramsar criterion for waterbirds, the use of which is discouraged wherever data are good enough to permit the use of (i) or (ii).
	Or	
	(iv) The site is known or thought to exceed thresholds set for migratory species at bottleneck sites.	Thresholds are set regionally or inter-regionally, as appropriate.

Development of the IBA Program in the Americas Region

The IBA program in the Americas is an initiative coordinated by the BirdLife Secretariat based in Quito, Ecuador. The IBA program was officially launched at the annual BirdLife Americas Partnership Meeting held in Cayambe, Ecuador in 1997. Since then, two additional regional workshops were held in Santa Cruz, Bolivia in 1999 and Madrid, Spain in 2000 which aimed to strengthen a coordinated approach to the IBA program, ensure Partners understood the methodology being used globally, and share experiences amongst the many organizations who had begun to implement the program in their respective countries.

Given the varying capacities of each partner to implement conservation activities, the IBA program is evolving at different stages in each country. This creates a challenge for implementing a coherent IBA program following standards developed and in practice in over 100 countries worldwide (L. Fishpool, pers. comm.). Regional coordination is key to ensuring that the program is carried out in a standardized fashion and also helps facilitate the sharing of information and experiences.

Identifying critical sites is crucial for deciding where to best invest limited conservation resources to affect the greatest benefit for conserving birds. The IBA program provides a useful and simple tool for identifying priority areas at the national and regional levels. Currently, 20 partner organizations are actively advancing the IBA program in 24 countries in the Americas. Canada, Mexico and Panama have finished national IBA inventories and are initiating site conservation at critical sites. Argentina, Bahamas, Belize, Bolivia, Brazil, Chile, Cuba, Ecuador, El Salvador, Falklands, Jamaica, Paraguay, Uruguay, the United States of America, and Venezuela all have initiated IBAs through data compilation and, in some cases, are completing national inventories and/or are engaged in site conservation activities. In addition, "Associates" in six non-partner countries (Dominican Republic, Colombia, Costa Rica, Puerto Rico, Peru, and UK Territories) have been advancing their IBA programs. In 2003, the Royal Society for the Protection of Birds will publish the first Caribbean UK Territories IBA Inventory.

As of January of 2004, 3,381 IBAs were identified throughout the Americas (*table 2, fig. 1*, other IBA articles in this volume), most of which have been entered into the WBDB. This valuable tool was developed for managing and analyzing data and producing reports on a variety of topics, including the status of individual sites and their species. These reports can be generated in a simple way that can be used to inform stakeholders, decisions makers and conservationists about each IBA. The WBDB has also been used to:

- Generate national IBA directories describing important sites for birds, including an evaluation of their conservation status, threats and necessary priority actions.
- Identify key sites in each country for species conservation.
- Assist in developing maps, posters, drawings, summaries, articles that publicize and promote results from analyses of information on sites.
- Support the development of regional publications that combine the results from all the IBAs in each of the countries in the Americas (Estrada and Davidson 2001).

Table 2— *Number of IBAs identified in selected countries as of January 2002.*

Country	No. IBAs
Argentina	182
Bahamas	90
Bolivia	43
Brazil	161
Canada	597
Chile	14
Colombia	105
Cuba	54
Domincan Rep.	43
Ecuador	105
Jamaica	54
Falklands	28
Mexico	225
Panama	88
Paraguay	42
Peru	198
Puerto Rico	54
United States	1200
Uruguay	25
Venezuela	64
Total	3,381

Select Conservation Actions at Critical IBAs in the Americas

In some countries, BirdLife Partners have already embarked on conserving IBAs in globally important habitats. The following is a description of selected activities in critically threatened ecosystems that support species and site conservation.

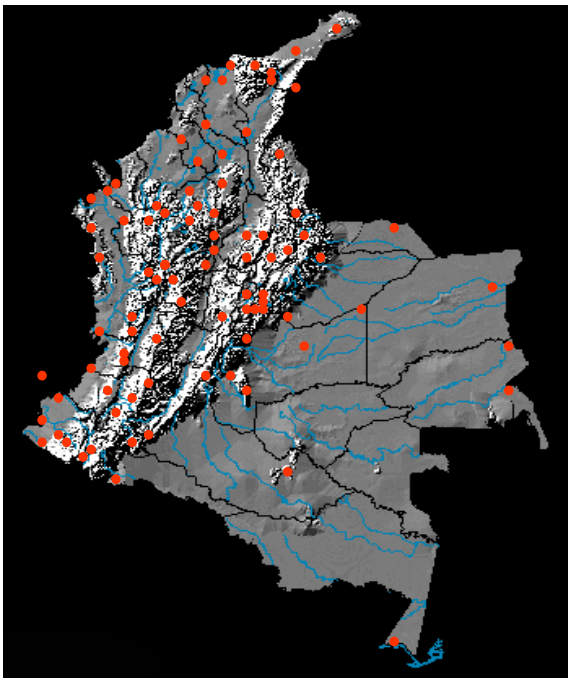

Figure 1— Map of Colombia showing 105 potential IBAs according to the results of Colombia's first National IBA Workshop, March 2002.

Brazil's Atlantic Forest

In 2002, BirdLife initiated its Brazil Program with a focus on helping to conserve the globally important and highly fragmented Atlantic Forest along the eastern coast of Brazil. While little more than 7 percent of the original forest cover remains, the habitat still supports an astonishing 103 globally threatened bird species (Bencke and Mauricio 2002). Relying on an expert network in Brazil, BirdLife identified Murici and Serra das Lontras; two critically threatened sites supporting over 13 globally threatened species of birds including the Alagoas Foliage Gleaner (*Philydor novaesi*; Bencke and Mauricio 2002). After initial fieldwork at each site, a concerted effort was mounted to ensure sites were nationally recognized for their globally unique collection of fauna found nowhere else on the planet. As a result, 6,616 ha of forest at Murici were officially declared by the President as a Scientific Station (the equivalent designation in other countries is "Ecological Reserve") and successful efforts at Serra das Lontras have resulted in increased public awareness and over $100,000 USD have been raised for private land purchase. Although the declaration of the Murici site as a protected area is significant, the site continues to suffer from habitat destruction and species loss. This highlights the need for maintaining pressure on governments to ensure a site's conservation while at the same time, working with communities to empower them to become custodians of IBAs. To date, 161 IBAs have been identified in the Atlantic Forest alone and efforts are currently underway to complete a preliminary list of IBAs for all of Brazil (Goerck and Wege, this volume).

Panama's Pacific Coastal Wetlands

Efforts to conserve the globally important Rio Bayano IBA in Panama provide an example of community involvement in conserving IBAs. Financed by the Canadian International Development Agency (CIDA) and the German Technical Agency (GTZ), the Panama Audubon Society is working with local villagers to develop a strategy for increasing revenues through ecotourism activities. Rio Bayano, one of the most important sites in the Western Hemisphere for shorebirds, attracts an enormous concentration of Western Sandpipers during the boreal winter months. Fishermen in the surrounding communities have been trained to guide ecotourists to areas rich in both shorebirds and other "exotic" resident species. This is helping to diversify and enhance local incomes. It is believed that in the long-term, the increased revenue will result in a greater awareness and appreciation for the importance of maintaining the mangrove forests upon which both birds and fish depend (BirdLife International 2002b).

Cuba's Extensive Eastern Forests

Through its government Affiliates in Cuba, BirdLife is embarking on a program to identify IBAs in the largest remaining tract of Caribbean pine and oak forests in the eastern end of the island. These forests support healthy populations of both Caribbean and Cuban endemics as well as exceptionally rare species, probably still including the Ivory-billed Woodpecker (*Campephilus principalis*) that was extirpated from the United States in the early 1900s (J. Wells, pers. comm.). Newly identified IBAs will be assessed and those identified as globally important will be submitted for consideration for legal protection. Additionally, several Cuban institutions are now working towards the designation of a critical wetland in the eastern forests of Cuba as a Ramsar site (BirdLife International 2002b).

Argentina's Pampas Grasslands

In Argentina, the IBA program is focusing on the identification of sites in the temperate grasslands that include the well-known Pampas. The Pampas support many endemic grassland-dependent birds and at one time hosted the now possibly extinct Eskimo Curlew (*Numerius borealis*; Di Giacomo 2001). To date, 26 global threatened bird species have been located in this ecosystem, which extends from south of Buenos Aires up into western Uruguay and eastern Paraguay. BirdLife's Partner, Aves Argentinas, has been communicating with the government to promote the use of alternative and less damaging land use practices which

currently include the planting of exotic species such as eucalyptus. More than 60 sites in the grassland region have been identified as IBAs. On-the-ground work with local landowners is underway to develop more sustainable land use practices at critical grassland sites that are compatible with biodiversity conservation (Di Giacomo 2002).

Conclusion

The IBA program, initiated in the neotropical region by BirdLife International, is beginning to demonstrate tangible conservation results. These include: site protection through both legal means and via the purchase of critical habitats; increased awareness of the impacts of habitat degradation on birds; improved data on species distribution and habitat requirements; new alliances among conservation groups; strengthened capacity of NGOs to lead on-site conservation projects; improved communication among the ornithological community; and an evolution of ornithological groups with greater focus on conservation action. The success of some of these initiatives depends on the collaborative nature of the IBA program, which encourages participation at all levels to deliver conservation results. It is also clear that the IBA program depends on its linkages with other regional initiatives including the North American Bird Conservation Initiative, the North American Waterbird Management Plan, Partners in Flight, the Convention on Migratory Species (the Bonn Convention), Conservation International's Hot Spots Program, National Audubon and Jocotoco's Land Securement Program, to name but a few. The IBA program is inclusive and unlike some of the successful species initiatives in North America, it addresses all species through a site-based conservation approach. The IBA conservation approach covers most species. Widely dispersed species in some cases are not, and strategies need to be developed to address these species. With many bird species on the brink of extinction in the Americas, the IBA approach is a proven method for helping conservationists and other interested stakeholders, determine those most important areas for immediate conservation action.

Acknowledgments

BirdLife wants to recognize the support several organizations have provided to the IBA Program in the Americas Region. The National Audubon Society, the International Program of the U.S. Forest Service, and Partners in Flight provided financial and logistical support to IBA coordinators from Latin American countries to facilitate their participation in the International Meeting of Partners in Flight at Asilomar, California. BirdLife also appreciates the numerous private donors who support bird conservation activities in the Americas Region.

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Conserving the Grassland Important Bird Areas (IBAs) of Southern South America: Argentina, Uruguay, Paraguay, and Brazil[1]

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Abstract

In the southern part of South America, knowledge about bird species distribution is still not used as a tool for land use planning and conservation priority-setting. BirdLife International's Important Bird Areas (IBA) Program is an appropriate vehicle for analyzing existing information about birds, and to generate new data where necessary. IBA inventories should provide input to urgent regional conservation issues, such as those relating to temperate and subtropical grasslands. There is a rich avifauna of grassland-specialist species in Argentina, of which approximately 25 are threatened or near-threatened at the global level. The grassland biome also serves as wintering grounds for neartic migrants, such as Bobolink (*Dolichonyx oryzivorus*), Upland Sandpiper (*Bartramia longicauda*) and Swainson's Hawk (*Buteo swainsoni*). The BirdLife network is represented in the region by the Brazil Program Office, Guyra Paraguay, Aves Uruguay and Aves Argentinas/AOP. These organizations are trying to start an international cooperative project focusing on grassland IBA identification and conservation.

Key words: Argentina, conservation, grasslands, Important Bird Areas.

Introduction

In the southern part of South America, where grazing and agriculture have severely impacted grassland habitat, knowledge about bird species distribution is still incomplete. As a result, this information is not used as a tool for land use planning and conservation priority-setting. BirdLife International's Important Bird Areas (IBA) Program is a useful way to analyze and to organize existing information about birds, and to generate new data where necessary. IBA inventories should provide an input to urgent regional conservation issues, such as those relating to temperate and subtropical grasslands.

The Grassland Biome

Southern South America contains an extensive grassland biome, a continuous habitat matrix of 700,000 km^2, comprising part of Southeast Brazil, Northeast and Central Argentina, Uruguay and Southeast Paraguay (*fig. 1*). Temperate grasslands are known as 'Pampas', and the subtropical ones as 'Campos' (Soriano 1991). Relief is almost flat, with a very slight slope towards the Atlantic Ocean, and a few hills and rocky outcrops in isolated sites. In the Pampas, mean annual temperature is about 15°C, with warm summers and cool winters. Campos are warmer and wetter. Rainfall decreases from 1,000 to 1,500 mm in the north and east to 400 mm in the south and west (Cabrera 1976, Soriano 1991). In the Pampas, rains are more frequent in spring and fall, slight in winter and least in summer (Cabrera 1976), while in the Campos winter rains increase markedly (Lemcoff 1991).

Grasses (Poaceae) dominate the vegetation in the Pampas and Campos. The flora of the Pampas subregion is comprised of about 1,000 species of vascular plants, mostly native (León 1991). Most of the plant taxa are shared with the Chaco biome, although there are several taxa of Andean origin (Cabrera 1976); endemic species are scarce. The number of grass species present in the Pampas is 230: 190 native and 40 introduced. The native grasslands are dominated by "flechillas" ("little darts"), of the genera *Stipa*, *Piptochaetium,* and *Aristida*. Other important plant families in addition to grasses are the Asteraceae and Fabaceae. In wet locations and years, vegetation structure corresponds to a prairie, and to a pseudo-steppe in drier conditions. We can distinguish some internal heterogeneity inside the Pampas, according to natural gradients and landscape features. The Campos is a gently rolling grassland; a subtropical savanna that constitutes the northern expression of the Pampas, with which it shares many plant taxa. Characteristic grass genera are *Andropogon*, *Aristida*, *Briza*, *Erianthus*, *Piptochaetium*, *Poa*, *Stipa*, *Paspalum,* and *Panicum* (León 1991). Trees appear in isolated patches or as riparian forests.

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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The grasslands provide fertile soils, mild climate and excellent locations for urban settlement, and are being modified by several human activities. Grazing by cattle, agriculture, urban and infrastructure development, and afforestation with exotic trees are among the main land uses (Krapovickas and Di Giacomo 1998).

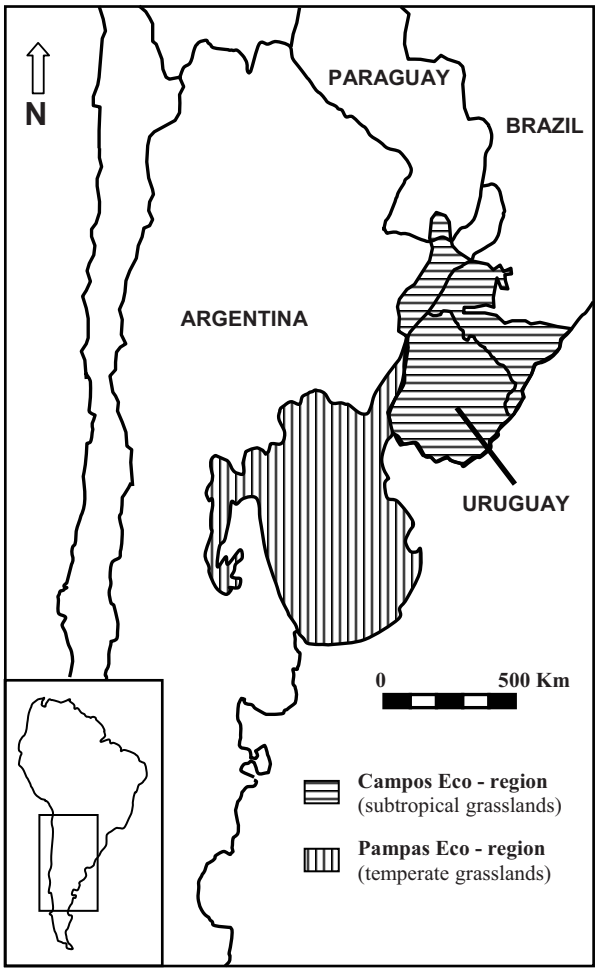

Figure 1— Distribution of two major grassland biomes, Pampas and Campos, in southern South America prior to European settlement. This map was adapted from Soriano (1991) and R. Fraga (pers. comm.).

The Grassland Birds

The avifauna of the grassland's biome is comprised of between 350 and 250 species in a northeast and southwest gradient (Narosky and Yzurieta 1987). There is a rich avifauna of grassland-specialist species, of which approximately 25 are threatened or near-threatened at the global level (*table 1*; BirdLife International 2000). Most grassland bird populations have declined markedly or are very fragmented (Krapovickas and Di Giacomo 1998). For example, the range of the Pampas Meadowlark (*Sturnella defilippi*) has contracted by >80 percent (Tubaro and Gabelli 1999). Populations of other species, such as the Saffron-cowled Blackbird (*Xanthopsar flavus*), the Strange-tailed Tyrant (*Alectrurus risora*), and the Black-and-White Monjita (*Heteroxolmis dominicana*) (Fraga et al. 1998, Fraga 2001, A. Di Giacomo unpubl. data) have diminished at least by >50 percent. Numerous other species, including some flycatchers, nighthawks, sandpipers and seedeaters are now rare and very local. As a result of range contraction, these species can only be found in small fractions of the areas that they previously occupied (BirdLife International 2000). The main causes of this decline include the massive conversion of natural grasslands into croplands, the drainage of wetlands, and the intensification of agriculture and forestry in the last decades.

This grassland biome serves as wintering grounds for nine neartic migrants (Vickery et al. 1999) such as Bobolink (*Dolichonyx oryzivorus*), Upland Sandpiper (*Bartramia longicauda*), Swainson's Hawk (*Buteo swainsoni*), and others (*table 2*). Populations of some of these species decreased in the US between 1966 and 1996 (Peterjohn and Sauer 1999) and it is suspected that winter survivorship may be contributing to these long-term declines (Herkert 1997, Vickery and Herkert 2001).

Argentina's IBA Experience

Pampas and Campos biodiversity is not well represented in existing protected areas of Argentina. Fewer than 150,000 ha are formally included in reserves, representing about 0.3 percent of the biome's surface (APN 1998). Existing protected areas are located mainly in the Flooding Pampa (Samborombón Bay, with salty *Spartina* grasslands), the Austral Pampa (Sierra de la Ventana), and several scattered wetlands. The most threatened birds of the grasslands, including Saffron-cowled Blackbird, Entre Ríos Seedeater (*Sporophila zelichi*) and Black-masked Finch (*Coryphaspiza melanotis*) are not protected in any area of the System of National Parks (Chebez et al. 1998).

In Argentina, grassland IBA identification started in 2000 with financial support provided by BirdLife International/Vogelbescherming Nederland. Aves Argentinas decided to initially focus on the grassland biome (one of 18 ecoregions of the country) because of its high-priority conservation status (Di Giacomo 2001). The IBA Program is based in the Department of Conservation and Aves Argentinas, and the IBA technical committee responsible for formally identifying the IBAs is composed of a National IBA Coordinator (an employee of Aves Argentinas) and a team of field

Table 1— *Globally threatened birds of the Pampas and Campos grasslands of Argentina, Brazil, Paraguay and Uruguay (BirdLife International 2000).*

Species scientific name	Species common name	Family name	Threat category[1]	Argentina	Brazil	Paraguay	Uruguay
Rhea Americana	Greater Rhea	Rheidae	LR/nt	X	X	X	X
Eleothreptus anomalus	Sickle-winged Nightjar	Caprimulgidae	LR/nt	X	X	X	
Porzana spiloptera	Dot-winged Crake	Rallidae	VU	X			X
Numenius borealis[2]	Eskimo Curlew	Scolopacidae	CR	X	X		X
Tryngites subruficollis	Buff-breasted Sandpiper	Scolopacidae	LR/nt	X		X	X
Harpyhaliaetus coronatus[3]	Crowned Eagle	Accipitridae	VU	X	X	X	
Spartonoica maluroides	Bay-capped Wren-Spinetail	Furnariidae	LR/nt	X	X		X
Limnoctites rectirostris	Straight-billed Reedhaunter	Furnariidae	LR/nt	X	X		X
Culicivora caudacuta	Sharp-tailed Grass-Tyrant	Tyrannidae	LR/nt	X	X	X	
Polystictus pectoralis	Bearded Tachuri	Tyrannidae	LR/nt	X	X	X	X
Pseudocolopteryx dinellianus	Dinelli's Doradito	Tyrannidae	LR/nt	X		X	
Heteroxolmis dominicana	Black-and-white Monjita	Tyrannidae	VU	X	X		X
Alectrurus tricolo)	Cock-tailed Tyrant	Tyrannidae	VU	X	X	X	
Alectrurus risora	Strange-tailed Tyrant	Tyrannidae	VU	X	X	X	X
Anthus nattereri	Ochre-breasted Pipit	Motacillidae	VU	X	X	X	
Gubernatrix cristata[3]	Yellow Cardinal	Emberizinae	EN	X	X		X
Coryphaspiza melanotis	Black-masked Finch	Emberizinae	VU	X	X	X	
Sporophila ruficollis	Dark-throated Seedeater	Emberizinae	LR/nt	X	X	X	X
Sporophila palustris	Marsh Seedeater	Emberizinae	EN	X	X	X	X
Sporophila hypochroma	Grey-and-chestnut Seedeater	Emberizinae	LR/nt	X	X	X	
Sporophila melanogaster	Black-bellied Seedeater	Emberizinae	LR/nt		X		
Sporophila cinnamomea	Chestnut Seedeater	Emberizinae	VU	X	X	X	X
Sporophila zelichi	Entre Ríos Seedeater	Emberizinae	CR	X		X	X
Sturnella defilippii	Pampas Meadowlark	Icteridae	VU	X	X		X
Xanthopsar flavus	Saffron-cowled Blackbird	Icteridae	VU	X	X	X	X
Total species by country				24	21	17	16

[1]CR= critically endangered, EN= endangered, VU= vulnerable, LR/nt= low risk/ near threatened
[2]Possibly extinct
[3]Woodland species often found in grassland habitats

Table 2— *Nearctic breeding birds that winter in Pampas and Campos grasslands (Stotz et al. 1996).*

Species name	Family name
Swainson's Hawk *(Buteo swainsoni)*	Accipitridae
American Golden Plover *(Pluvialis dominica)*	Charadriidae
Eskimo Curlew *(Numenius boreales)*[1, 2]	Scolopacidae
Upland Sandpiper *(Bartramia longicauda)*	Scolopacidae
Buff-breasted Sandpiper *(Tryngites subruficollis)*[2]	Scolopacidae
Sand Martin *(Riparia riparia)*	Hirundinidae
Cliff Swallow *(Petrochelidon pyrrhonota)*	Hirundinidae
Barn Swallow *(Hirundo rustica)*	Hirundinidae
Bobolink *(Dolichonyx oryzivorus)*	Icteridae

[1] Possibly extinct (BirdLife International 2000)
[2] Globally threatened (BirdLife International 2000)

ornithologists. A manual on how to identify IBAs has been produced in Spanish. This manual explains the basic data needed to complete the IBA nomination forms and at the same time it serves to advertise the project to the public. The manual includes complete up-to-date lists of all species and population thresholds that can trigger the four global IBA criteria. In this way all the necessary information needed to complete a nomination is found in the same publication.

A list has been produced of approximately 200 potential IBAs that contain recent records of globally threatened grassland bird species. Primary sources of data used to support the nomination of these sites as IBAs include: a) a database compiled by Dr. Rosendo Fraga (1995-1998), b) the Inventory of Key Areas - BirdLife International (Wege and Long 1995), c) recent literature and museum specimens, d) inventories from recent field surveys, and e) nomination forms filled out by individuals based on their own data. In addition to these sources of data, sites will be revisited to get more complete information about bird populations, habitat, boundaries, ownership, and threats.

The IBA database for this region (BirdLife's World Bird Database) is still being populated, but as of November 2002 there was sufficient information to complete nomination forms for 22 grassland sites. These sites are currently classified as 'candidate IBAs' (*table 3*). Each candidate IBA has viable populations of one to 14 threatened bird species. These sites contain a total of 24 threatened species and together constitute a significant proportion of the total remaining grassland habitat in the region.

Sites in the "Campos" grassland seem to have the highest numbers of threatened species (between 9 to 14 each). However, these sites are severely threatened by accelerating changes in land cover because the government is subsidizing afforestation with exotic pines and *Eucalyptus* (Di Giacomo and Krapovickas 2001). Another important region in which to identify IBAs is the Iberá Marshes Basin in the province of Corrientes. This region encompasses 1.3 million ha of a complex mosaic of habitats such as grasslands, patches of forests, marshes, lagoons, forestations and agricultural fields. There is still much information lacking in order to correctly assess the importance of each Iberá site and determine the boundaries. Threats to Ibera's sites appear to be the same as those mentioned for the subregion in the Campos. A third area with a high density of potential IBAs is in the southern region of the Entre Ríos province. This region is in the temperate grasslands habitat and it has four candidate IBAs that are threatened by changes in land cover, particularly agriculture and urbanization. All three of these regions are included in the Endemic Bird Area known as "Argentina's Mesopotamian Grasslands;" a region of high priority at global level for the conservation of three endemic bird species of genus *Sporophila* (Stattersfield et al. 1999). Other critical sites that have been identified as potential IBAs include populations of local birds such as the Straight-billed Reedhaunter (*Limnoctites rectirostris*) and the Pampas Meadowlark.

The 22 candidate IBAs include all the provinces in the grassland biome. This set of sites provides a starting point for official IBA designation, outreach, media coverage, stakeholder analysis and advocacy. Some of these candidate IBAs are currently protected by the Federal or Provincial Governments or by private landowners, and the remaining have several threats.

Initiating this IBA project provided Aves Argentinas with an increased opportunity to participate in the search for solutions for one of the most serious conservation problems in southern South America. Since this project began, Aves Argentinas has obtained more up-to-date information concerning problems encountered by populations of threatened grassland species and has also enhanced its ability to carry out new evaluations and to design action plans.

IBAs are a simple and cost-effective way to incorporate biodiversity issues in land-use plans. The IBA activities are aimed at helping to make sound decisions in land use planning and biodiversity conservation, as well as producing a valuable database. It is crucial that society become aware of and concerned about these

Table 3— Candidate Important Bird Areas in the Pampas and Campos grassland of Argentina.

IBA name	Province	Area (ha)	IBAs Criteria[1]	Threatened species	Level of protection
Reserva Natural Ing. R. Otamendi	Buenos Aires	3,000	A1, A3	5	National Nature Reserve
Reserva Natural Punta Lara	Buenos Aires	300	A1,A3	2	
San Cayetano	Buenos Aires	ca.30,000	A1, A3	2	
Puan - Tornquist	Buenos Aires	600,000	A1, A3	2	
Bañados del Río Dulce y Laguna de Mar Chiquita	Córdoba	ca.500,000	A1, A4	6	Múltiple–use Provincial Reserve
San Francisco	Córdoba	4,000	A1	3	
Bañados del río Saladillo	Córdoba	80,000	A1, A4	2	
Estancia Dos Hermanas – Fundación Raquel y Pamela Schiele	Córdoba	5,400	A1, A3, A4	3	Private Reserve
Estancia Puerto Valle	Corrientes	8,000	A1, A2, A3	8	Private Reserve
Estancia San Juan Poriahú	Corrientes	14,500	A1, A3, A4	9	Private Reserve
Parque Nacional Mburucuyá	Corrientes	17,680	A1, A2, A3	7	National Park
Albardón del río Aguapey	Corrientes	60,000	A1, A2, A3	7	
Concepción	Corrientes	200,000	A1, A2, A3	8	
Reserva Natural Iberá	Corrientes	1,300,000	A1, A2, A3, A4	14	Provincial Reserve
Bañado Mora Cué	Corrientes	ca.15,000	A1, A2, A3	6	
Parque Nacional El Palmar	Entre Ríos	8,500	A1, A3	9	National Park
Gualeguaychú	Entre Ríos	ca.3,000	A1, A3	10	
Ceibas	Entre Ríos	ca.20,000	A1, A3, A4	5	
Perdices	Entre Ríos	ca.10000	A1, A3	11	
Estancia Guaycolec	Formosa	25,000	A1, A3	3	Private Reserve
Reserva Ecológica El Bagual	Formosa	3,900	A1, A3	10	Private Reserve
Reserva Natural "Federico Wildermuth"	Santa Fé	1,300	A1, A3	4	Private Reserve

[1] IBA criteria: A1= globally threatened species, A2= globally endemic species, A3= biome indicator species, A4= congregatory species.

issues and it is important to enhance co-operation among institutions and researchers. It was these ideas that guided Aves Argentinas to promote a workshop for scientists and conservation institutions. Fortunately, there are several organizations that share the same objectives with whom the workshop was co-hosted. These organizations included: the National Institute for Agricultural Technology (INTA), the Foundation for Argentine Wildlife (FVSA), the National Parks Administration (APN), and the National Biodiversity Group supported by the South America Regional Office of the International Union for Conservation of Nature and Natural Resources (IUCN). As a result of the workshop the participating organizations decided to call the project "Interorganization Committee for the Conservation of Pampas Biodiversity (BIOPAMPA)." BIOPAMPA consists of a participatory and coordinated effort of an increasing number (>30) of official and private organizations that are oriented towards the evaluation, conservation and sustainable management of the biological diversity of the Pampas eco-region. The philosophy of this initiative is to build on the convergence of common interests, the ambitions of government and private institutions, public participation, solidarity, and a consensus of clear ideas. This is very important as the IBA program is starting to become known on a national scale, and as a concept it has already been adopted by several researchers, environmental consultants, and decision makers.

Researchers use the IBA program as a way to value different areas objectively, by assessing the bird life. Decision makers use the IBA program as a fundamental tool with which to discuss and make decisions about environmental issues. The number of potential sites that might be nominated as IBAs could increase to approximately 200. This could be a difficult number for the small conservation community in the region to manage in the limited time available, particularly considering the limitations of budget, personnel, and logistical difficulties such as inaccessibility and the great distances between sites. A goal is that Aves Argentinas, through the IBA program, can contribute to regional development by studying, valuing, and conserving the biological and cultural richness that the natural environment and its flora and fauna represent for Argentina.

Future Plans

The tools that are used currently in Argentina are also being utilized in neighboring countries. Besides Aves Argentinas, the Brazil Program Office, Guyra Paraguay, and Aves Uruguay represent the BirdLife network in the region. The Brazil BirdLife Program has identified ten IBAs in the state of Rio Grande do Sul with threatened birds of the grasslands. Guyra Paraguay has identified several parks and reserves in east of the country with important populations of grassland birds. Aves Uruguay has identified ten IBAs, with five of them identified for their relevance to grassland bird conservation.

Together these organizations are attempting to launch an international cooperative project focusing on grassland IBA identification and conservation from a regional perspective. The IBA approach allows for the integration of information regionally, and should increase the participation of ornithological institutions in the conservation of natural resources. The establishment of a regional legal framework to protect IBAs is an important goal for the BirdLife International Partnership in southern South America. Mercosur, the free trade agreement among Argentina, Brazil, Paraguay and Uruguay, could provide such a framework in the near future, as NAFTA is helping to integrate conservation action among the countries of North America.

Acknowledgments

The Vogelbescherming BirdLife/Nederland, SEO/BirdLife, BirdLife International, the Convention on Migratory Species (UNEP), and Alparamis S. A. provided funds to support this research. We are grateful to D. Niven, J. Cecil, P. D. Vickery, R. S. Ridgely and T. Rich for reviewing the manuscript.

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The Challenge of Implementing the Important Bird Area Program in a Megadiversity and Mega-threatened Country[1]

Jaqueline M. Goerck[2] and David C. Wege[3]

Abstract

Brazil is a megadiversity country but also has the highest number of threatened bird species in the neotropics. There are over 100 species of birds threatened with extinction in Brazil. Some of the most threatened birds occur in the highly threatened Atlantic Forest hotspot of Brazil. BirdLife International started an Important Bird Areas (IBA) program in Brazil by identifying 161 areas in 15 of the 26 Brazilian states. Two areas were selected as priorities for initial projects, and their case studies are presented here: Murici, in Alagoas, and Serra das Lontras, in the state of Bahia. In Brazil, BirdLife has been working with local non-governmental organizations (NGOs) to develop and implement conservation projects. Local NGOs, which are an integral part of the process, have easier access to first-hand knowledge and information about the real situation of the areas under study. A network of such NGOs, linked through BirdLife, can then exchange experiences and thereby enhance the chance of success of any individual initiative.

Key words: Atlantic forests, birds, Brazil, Important Bird Areas, Murici Serra das Lontras, threatened.

Introduction

Brazil is a megadiversity country and ranks first in the neotropics in richness for higher plants, freshwater fishes, and mammals, and in the top five for amphibians, reptiles, birds, and butterflies (Myers et al. 2000). Such high biodiversity combined with the continuing destruction of the country's natural resources has lead to an imminent threat of extinction for many species and, as a consequence, Brazil also ranks first in the Americas in numbers of threatened bird species; 114 species of the Brazilian avifauna are considered threatened with extinction, (BirdLife International 2000). In a country with continental dimensions, (ca.8,500,000 km^2), two hotspots have been identified, namely the Atlantic Forest (ca. 1 million km^2) and the Cerrado (ca. 2 million km^2) (Mittermeier et al. 1999). The hotspot concept was first proposed by Myers (1988). The main criterion to identify a hotspot is the level of species endemism (instead of the total biodiversity), particularly of vascular plants, in a biogeographic region. Although the hotspots are determined primarily based on plant endemism, animal data are also examined. Another important criterion to determine a hotspot is the degree of threat to the region, caused principally by humans. Many hotspots have had over 90 percent of their original vegetation cover altered, including the above-mentioned Atlantic Forest Region of Brazil (Mittermeier et al. 1999).

Some of the most threatened birds occur in the Atlantic Forest of Brazil, which spans the region from Piauí in the north-east to Rio Grande do Sul in the south, and includes portions of the interior states of Minas Gerais, Goiás and Mato Grosso do Sul (Federal Decree nº 750/93). The coastal states were the first to be colonized in Brazil, and as a consequence 70 percent of Brazilians live in this, the most developed region of the country (Conservation International et al. 2000). The exceptionally diverse forests here help protect watersheds that provide water for both urban and rural communities, help to regulate microclimate, and still are home to several traditional peoples. Within the states of the Atlantic Forest Domain, there are 103 globally threatened and 64 near threatened bird species.

Background

BirdLife International initiated a conservation program in Brazil in March 2000, with support from the British Birdwatching Fair and the Council of Agriculture of the Republic of China (Taiwan). The program was developed based on an initial assessment of needs, challenges and opportunities, reviewed by key ornithologists and conservationists.

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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The initial focus of the country program lies primarily in the Atlantic Forest region. Although much attention is now given to the Atlantic forests, its continuing destruction is apparent. Indeed, deforestation in this region has been rampant in the last 15 years - recent estimates suggest the rate is 2.5 times that of the Amazon for the same period. Paradoxically, as much as 410 million reais (equivalent to ca. US $160 million in May 2002) have been invested in conservation programs in the Atlantic Forest region in the past 10 years, as shown by a study lead by the Instituto Socioambiental (Rede de ONGs da Mata Atlântica 2002). According to this study, most implementing agencies were non-government organizations, but the majority of the funds came from the National Environment Fund (Fundo Nacional do Meio Ambiente), a fund from the Ministry of the Environment.

Although the legal protection of the Atlantic Forest is ensured by the Brazilian Federal Constitution through several articles, some laws, and a decree, its practical preservation remains a challenge. Recently, the national policy for the environment known as PPG-7 (Programa Piloto para a Proteção das Florestas Tropicais Brasileiras) expanded from the Amazon region to include the Atlantic Forest. A sub-program of the PPG-7, known as Ecological Corridors, predicts that protected areas will become the cornerstones of the ecological corridors. Land-use in the intervening areas will be regulated through sustainable development projects and other mechanisms that enhance and ensure that forested patches are connected. Three main corridors have been identified in the Atlantic forests:

- The Central Corridor, which includes areas in southern Bahia, northern *Espírito* Santo, and northeastern Minas Gerais
- The Serra do Mar Corridor, which follows this mountain range along the coast of Rio de Janeiro and São Paulo, and
- The Tri-national Corridor, which includes the interior Atlantic forests of Paraná towards Argentina (Misiones) and eastern Paraguay.

The Niche for the Important Bird Area Program in Brazil

The BirdLife International Brazil Program seeks to fill a major gap in the current conservation efforts, one that must be filled in the immediate or short term if we are to prevent numerous species extinctions. In the Brazilian Atlantic Forest, landscape level conservation (such as the Corridors initiative) is the ultimate long-term goal, but is not enough in the immediate short-term. The reason is that the remaining forest areas are fragmented (especially so in the north-east), and given the large number of very local endemic species that they support, it is essential to look at species and site-level conservation issues. Landscape approaches to conservation will succeed only if source populations exist to disperse into restored or corridor-connected areas. Many forest fragments contain multiple priority bird species and large numbers of other endemic taxa. Therefore, unless a site-oriented effort is undertaken immediately, many populations of threatened species will be lost forever.

By building on existing initiatives and working from previous priority setting exercises, e.g. by PROBIO (Pacheco and Bauer 2000), BirdLife's *Key Areas for threatened birds in the neotropics* (Wege and Long 1995), and the neotropical Wetlands Directory (Scott and Carbonell 1986), the Important Bird Area (IBA) program of BirdLife International seeks to ensure the sustainable conservation of a network of globally important biodiversity sites that combine to encompass, and thus help to maintain the integrity of, the entire Atlantic Forest region. This region was selected both for the high degree of threat to the ecosystems that form the Atlantic Forest Biome, and for a relatively greater knowledge of its avifauna available through the scientific literature and unpublished reports. The gathering and preliminary analysis of this information is an essential step in the process of IBA identification to avoid duplication of efforts. Thus, our initial objectives were to:

- Gather extant information on the priority areas for conservation of birds in 15 of the 17 states within the Atlantic Forest Domain
- Propose a network of IBAs following global criteria (sensu BirdLife International), based on information available from the literature, and
- Evaluate the protection status of the proposed IBAs.

These initial phases are being conducted in collaboration with Fundação Zoobotânica do Rio Grande do Sul. The ultimate goal of this phase of the IBA program is to ensure that each globally threatened species is effectively protected in at least one IBA in the Atlantic Forest Domain. The network of IBAs in the Atlantic forests will also ensure the protection of other endemic bird species, as well as diversity and other endemic taxa.

Proposed Network of IBAs in the Atlantic Forest Region

During the initial process, 161 areas were identified as IBAs (Bencke and Maurício 2002). Another 30 areas are considered potential IBAs, but more information is needed before they can be included in the proposed IBA network system. These 191 sites are distributed throughout the Atlantic Forest regions (*Fig. 1*). Some IBAs, regardless of their size, have large concentrations of threatened bird species, e.g., 20 threatened species at Parque Estadual do Desengano, 19 at Sooretama/Linhares, 15 at Estação Ecológica de Murici, 15 at Boa Nova/Serra da Ouricana, along with many other examples (Bencke and Maurício 2002). In contrast, five globally threatened species did not have confirmed records in any of the proposed IBAs. All may be extinct in eastern and southeastern Brazil (Sick 1997, BirdLife International 2000). Another 44 globally threatened species occur in fewer than five proposed IBAs and may be considered as priorities for the identification of new IBAs (Bencke and Maurício 2002).

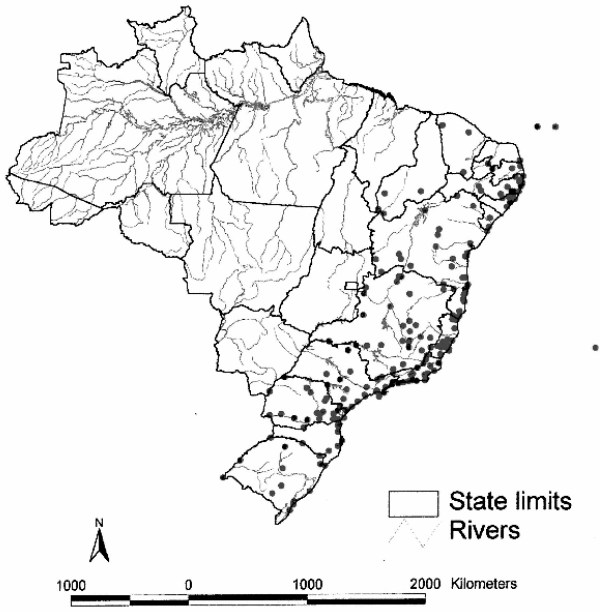

Figure 1— Location of 191 proposed and potential IBAs identified in the 15 Brazilian states that encompass the Atlantic Forest. The status of these areas is preliminary and currently under review.

Of the proposed and potential IBAs, 28 percent are legally protected as conservation units, and 22 percent have part of their areas protected. Thus, half of the areas considered IBAs are not currently protected. This analysis will be refined as more information becomes available, and some areas may gain or lose the status of IBAs once a more complete inventory is concluded. Nevertheless, as some areas have been identified as priorities being under severe threat (see below), immediate conservation action is imperative if we are to prevent the extinction of more avian species.

Case Studies: Murici and Serra das Lontras

Murici

Remnant forests on the mountains of northeastern Brazil have been seriously threatened in recent decades due to expanding agricultural programs in Brazil. The most dramatic example lies in a forested area in the Municipality of Murici in the state of Alagoas, where less than 2 percent of the original forest cover remains (Teixeira and Gonzaga 1985). During the 1970s, forests in Alagoas gave way to sugar cane plantations, largely due to fiscal incentives provided by the government under a development plan known as Pró-Álcool, where sugar cane was produced and processed to produce fuel (ethanol) for motor vehicles. There has been much discussion in the media about the government's intention to revive this program, which has not only helped to devastate north-eastern forests, but also interior forests in south-east Brazil. Conservation efforts in the Murici region date back to the 1980s, after an expedition discovered four species of birds new to science: *Philydor novaesi* (Alagoas Foliage-gleaner; Teixeira and Gonzaga 1983b), *Terenura sicki* (Orange-bellied Antwren; Teixeira and Gonzaga 1983a), *Myrmotherula snowi* (Alagoas Antwren; Teixeira and Gonzaga 1985), and *Phylloscartes ceciliae* (Long-tailed Tyrannulet; Teixeira 1987). Three of the above species have been recorded at other localities but, to date, there have been no confirmed records of the Alagoas Foliage-gleaner outside Murici.

Previous efforts to protect Murici include the declaration of an "Area of Relevant Ecological Interest (ARIE)", established in 1984 by the National Council for the Environment (CONAMA - Resolução 005-84). In 1992, the owner of the largest tract of forest in the region, the Usina Bititinga (a sugar cane processor plant) signed an agreement with a national NGO, which would be responsible for the management and protection of the forest. However, due to financial and administrative problems, and local politics, the NGO was unable to maintain the agreement. In 1997, Murici was encompassed by an "Area of Environmental Protection (APA)" of approximately 116,100 ha. The establishment of an APA, however, does not involve reimbursement to the landowners for their properties, and therefore, protection of forest is not ensured because it remains privately owned. Yet, in 1997 Murici was considered a priority area within the Biosphere

Reserve of the Atlantic Forest (RBMA), sponsored by the United Nations Educational, Scientific and Cultural Organization (UNESCO). Belonging to a Biosphere Reserve does not ensure legal protection of forests, but it raises the status of the area to a global level of importance. Thus, all initiatives up to that date raised Murici's profile, but did not ensure its effective conservation (Goerck 1999). BirdLife International, through its partnership, led a campaign with other NGOs that resulted, in May 2001, in the declaration of Murici as an "Ecological Station", i.e., a fully protected area, through a federal decree signed by the President of Brazil, Mr. Fernando Henrique Cardoso.

BirdLife International has worked closely with a national NGO, Sociedade Nordestina de Ecologia (SNE), and with the Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (IBAMA) in the design of a plan of action for the reserve (this study was partially funded by World Wildlife Fund). Little has been achieved after the new status of Murici was gained: inhabitants of nearby villages and camps continue to use forests as a source of firewood, wood for construction, and food (game and fruits). In addition, small-scale agriculture occurs in areas adjacent to the forest, and in some cases, plantations (e.g., bananas) are illegally placed within the forest. As a consequence, the remaining forest fragments continue to be degraded. Another immense threat for the avifauna in particular is the illegal capture and trade of birds with commercial appeal, among them the Seven-colored Tanager (*Tangara fastuosa*) and the Yellow-faced Siskin (*Carduelis yarrellii*). These birds are captured and sold not only by children along the roads, but also in local markets and fairs. Some species even reach the illegal, but well organized markets of Bahia, Rio de Janeiro, and São Paulo (Renctas 2001).

Much action on the ground is needed, including studies and inventories of the flora and fauna for the elaboration of a suitable management plan for the reserve. Indeed, an integrated management plan incorporating remaining forest tracts and recovering degraded areas is needed to maintain the integrity of the forest ecosystem and the long-term survival of species, particularly those threatened with extinction. The creation of the Murici Ecological Station is only the first, but decisive, step in the protection of these globally important forests (Goerck 2001). We have now a legal mechanism, through which we can effectively change the course, or curse, of destruction that has seemed to linger over Murici.

Serra das Lontras

Serra das Lontras belongs to a complex of small mountains that lie about 50 km away from the coast in the state of Bahia. Coastal forests in Bahia have recently received much conservation attention, and are now more effectively protected: several national and state parks have been created in the last few years (e.g. Parque Nacional do Descobrimento, Parque Estadual da Serra do Conduru, etc). Despite efforts that have taken place along the southern coast of Bahia, the adjacent mountains have been neglected, even though they comprise an essential portion within the Central Corridor initiative. These mountains reach up to 1,000 m in altitude, but are generally no more than 500-800 m in elevation, and continue west for more than 100 km. Humid forests on the plateau were ideal for the plantation of cacao, using an agro-forestry system known as '*cabruca*', where the canopy is thinned to about 40 percent cover (or exotic trees are planted to reach 40 percent cover), and cacao trees are planted under the shade. Most *cabruca* plantations are near the coast, and they have contributed in many ways to the preservation of forests there. Farther inland, forests gradually were replaced by pastureland, and very few forest remnants still exist.

The little known avifauna from Serra das Lontras contains 10 globally threatened species (Develey and Silveira 2001, Bencke and Maurício 2002), including two recently described species, *Acrobatornis fonsecai* (Pink-legged Graveteiro, Pacheco et al. 1996), a most unusual ovenbird (Furnariidae) that belongs to a monotypic genus, and *Phylloscartes beckeri* (Bahia Tyrannulet; Gonzaga and Pacheco 1995). Little is known about the distribution of either of these recently described taxa, and they may have broader ranges than previously thought. But the fact that the Graveteiro seemingly preferentially uses cacao plantations, *cabrucas*, indicates that this agro-forestry system needs to be considered in future conservation efforts.

Cacao producers have always recognized the many advantages of the *cabruca* system of cacao plantation (e.g., control of insect pests and weeds, microclimate stability, etc.; Johns 1999), not to mention the immense benefits to the preservation of adjacent forests along mountaintops. In the late 1980s, the Brazilian cacao sector was hit by sudden drops in world cacao prices and the onset of a major fungal disease, known as "witch's broom." This disease, caused by the fungus *Crinipellis perniciosa*, has devastated cacao plantations and resulted in c.60-70 percent declines in cacao production. This collapse of labor-intensive cacao plantations has left thousands of rural workers unemployed, unable to control their lives and without a political "voice." Looking for other options, owners of large properties converted their farms to alternative uses such as cattle ranching or sun coffee plantations. These practices are clearly not sustainable in the region (Radon and Barrett 2000), and through the felling of the *cabruca*, previously protected forests became vul-

nerable to the process of deforestation. While some alternative solutions are being tested (e.g., implementation of genetically modified cacao), it is impossible to predict the outcome of this crisis, and the conservation of this montane habitat needs to be seriously considered (Goerck 1999).

BirdLife has joined forces with a local NGO, the Instituto de Escudos Sócio-ambientais do Sul da Bahia, to create a private protected area in the region. Funds already have been secured to purchase an area of approximately 500 ha within the mountains. In addition, a proposal will be presented to the national government for the creation of a federal conservation unit, because the Serra das Lontras mountain complex is the largest tract of forest within the Central Corridor of the Atlantic Forest that links the coastal forests to the forests inland. BirdLife's presence in the region will both provide assistance and ensure that this unique area receives the protection it deserves.

Final Considerations

There are at least 100 sites in the Atlantic region of Brazil in need of increased protection. This is too many sites for any one conservation organization to address. However, the IBA program is designed to form a framework within which all concerned institutions and government agencies can work towards a common agenda. The program also provides a framework within which to monitor sites and evaluate conservation success. Thus, the IBA network of priority sites is anticipated to enhance the survival chances of several species, particularly those that have received little attention and are not currently within any of the existing protected areas. However, for some species that are affected by the pet trade, hunting, or that have specialized habitat needs or behaviors, like the Red-spectacled Parrot *Amazon pretrei*, the IBA program may not be the most efficient tool for protection, and species-specific efforts need to be undertaken in such cases.

While there may be opportunities for linking IBAs in North America with those in Brazil through the few North American migratory species that reach the area, the utmost necessity is to protect the globally threatened and endemic species. The global coverage of the IBA program provides opportunities to share conservation successes, experiences, and expertise, through a loose network of sites and institutions (whether local, national, or international), thus developing the overall capacity for achieving conservation successes. The emphasis of an alliance between North America and Brazil should be based on a common desire to prevent bird species extinctions. The Atlantic Forest region of Brazil is of critical importance for global conservation due to the presence of numerous highly threatened endemic birds. Many of the Atlantic Forest IBAs in Brazil have been neglected in the past, and creative mechanisms, such as site-based partnerships between North America and Brazil, are needed to raise their profiles and ensure effective long-term protection.

Acknowledgments

The authors would like to thank Dr. R. S. Ridgely and T. Rich for reviewing this paper and making some excellent suggestions for its improvement. We also thank G. A. Bencke and G. N. Maurício for compiling an enormous amount of information thoroughly, resulting in an invaluable report on the Atlantic Forest IBAs. This study was partially funded by the American Bird Conservancy. The area projects have been funded through various grants: Murici - Beneficia Foundation and BirdLife's Rare Bird Club; Serra das Lontras - Rainforest Action Fund, Garfield Foundation, and Clothworkers Association. Also, the generosity of several individuals has made this initiative possible, and we wish to thank Mr. K. Berlin, Mr. N. Simpson, and Mr. J. J. Childs.

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Priority Setting for Bird Conservation in Mexico: The Role of the Important Bird Areas Program[1]

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Abstract

Many species in Mexico are threatened and in need of protection. At least seventy species are considered to be globally threatened, yet conservation actions have been scarce and not coordinated. In 1996 BirdLife International's Important Bird Areas Program was initiated in Mexico to identify a network of the most important places in Mexico for birds, with the goal that if protected, these sites will support populations of all of Mexico's vulnerable bird species. A series of national and regional workshops were held, resulting in the identification of 230 Important Bird Areas (IBA). A second level of prioritization among IBAs, that included information about opportunities for action as well as bird population data, identified 35 IBAs as high priority areas for conservation action. Consejo Internacional para la Preservación de las Aves en Mexico (CIPAMEX), the BirdLife Partner in Mexico, and other local non-governmental organizations (NGOs) have subsequently developed conservation and management plans at two priority sites: El Carricito del Huichol and the Sian Ka'an Biosphere Reserve. It is hoped that trilateral projects with North American Bird Conservation Initiative (NABCI) will increase the success of the Mexican IBA program in the future.

Key words: bird, conservation, Important Bird Areas, Mexico, protected areas.

Introduction

Mexico ranks between tenth and twelfth place among countries throughout the world in terms of the number of bird species it supports, with 1,050 species in 468 genera, 79 families and 22 orders (AOU 1983, Escalante et al. 1993, Howell and Webb 1995). This avifauna represents 81 percent of the orders, 51 percent of the families, and 27 percent of the genera of the world. Mexico has 30 percent more bird species than the number regularly occurring in the United States and Canada combined, countries with a combined territory almost ten times larger than Mexico. Additionally, Mexico is the country where more than half of the migratory birds of North America spend between six and eight months of the year (Rappole et al. 1993).

Approximately 100 species, or 10 percent of the national avifauna, are endemic to the country. The regions of Mexico where the highest number endemic birds species occur are, in order of importance: 1) the tropical dry forest of the Pacific slope, 2) the arid and semi-arid areas of the north-central region of the country and 3) the temperate forests of the Sierra Madre del Sur and the Eje Neovolcánico Transversal (Escalante et al. 1993, Arizmendi and Ceballos, pers. obs.). Some species endemic to these ecosystems are West Mexican Chachalaca (*Ortalis poliocephala*) and San Blas Jay (*Cyanocorax sanblasianus*) of the Tropical dry forests, Boucard's Wren (*Campylorhynchus jocosus*) and Elegant Quail (*Callipepla douglasii*) of the arid areas, and Aztec Thrush (*Ridgwayia pinicola*) and Bumblebee Hummingbird (*Atthis heloisa*) of the temperate forests.

The birds in Mexico, as with other groups of vertebrates, are subject to strong pressures that threaten their survival. These pressures affect all bird species, but especially those that have a restricted distributional range. The main threat that species face today in Mexico is habitat loss. Populations of wild plants and animals depend on the habitats where they have evolved and where they can breed and survive under natural conditions. Therefore, one of the highest priority actions necessary to conserve Mexican biodiversity is the protection these areas.

Under legislation for the protection of Mexican flora and fauna (Sedesol 1994), 33.6 percent of the bird species occurring in Mexico are included in some threat category, with 56 species classified as being in danger of extinction, 121 as threatened, 144 as rare, and 17 subject to special protection. In a global analysis, BirdLife International (2000) categorized 70 species in Mexico to be globally threatened. This list includes one species that is considered to be extinct, and of the

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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remaining species, eight are critically threatened, 12 are in danger of extinction, 19 are vulnerable, 28 are near threatened, and two are potentially threatened but there is insufficient information to determine their status.

Despite the lack of detailed information about bird populations in many regions in the world, it has been documented that in the last four centuries approximately 105 bird species have gone extinct, which is equivalent to about 1 percent of the world total (Bibby 1995, IUCN 1996). In Mexico four species have gone extinct in recent times. The main causes of these extinctions have been the introduction of exotic species, hunting, and the destruction of critical habitat (Escalante et al. 1993, Ceballos and Marquez-Valdelamar 2000). Other factors such as pollution and the illegal traffic of species for the pet trade have been identified as severe threats for species already in danger of extinction. These factors may have contributed to the extinction of some species, but there is no detailed information available to confirm this.

The number of birds considered to be at risk of extinction in Mexico has increased in recent years. For example, Aguilar-Ortiz (1979) reported 31 species in danger of extinction. Soon after, the International Council for Bird Preservation (King 1981) included 35 Mexican species on its threatened species list. The availability of more detailed information allowed the Mexican partner of the former International Council for Bird Preservation (currently known as BirdLife International) to classify the threat status of 117 species, of which 35 were considered to be in danger of extinction, 27 were classified as threatened, and 55 were listed as prone to extinction (CIPAMEX 1989). More recently, BirdLife International (2000) identified 70 Mexican species as globally threatened, as detailed above.

However, in spite of the high diversity of Mexican birds and the multiple threats they face, conservation actions have been scarce and not coordinated. In 1996 the Important Bird Areas (IBA) Program was initiated in Mexico as part of a trilateral project between Mexico, USA and Canada within the framework of the North American free trade of commerce agreement (NAFTA).

The main objective of the Important Bird Areas Program (referred to in Spanish as AIAs - Areas Importantes para las Aves, or AICAs - Areas Importantes para la Conservaciòn de las Aves) is to identify a global network of places that are important for the long-term sustainability of the populations of birds they support. IBAs/AIAs/AICAs are:

- Places of international significance for the conservation of bird species.
- Practical tools for conservation.
- Chosen using standardized criteria.
- Not appropriate for the conservation of all species.

As general guidelines IBAs should:

- Be sufficiently large (wherever possible) to support viable populations of the species for which they are important.
- Be feasible to conserve
- Include, where appropriate, the existing network of protected natural areas.
- Be included in regional conservation and/or management plans.

By identifying the places of most importance for the conservation of the birds, the IBA Program serves as a useful tool for identifying gaps in a country's system of protected natural areas. In most cases IBAs are identified by using existing information that is compiled for this purpose. IBA data are then used to inform management plans and regional conservation strategies.

The IBA Identification Process

The first step of the Mexican IBA program was to form a steering committee, led by the IBA coordinator. This committee includes many stakeholders, including representatives of both academic and the government institutions (f*ig. 1*).

An initial IBA workshop was held in Oaxaca in 1996 to initiate the IBA identification process. Approximately 40 experts representing universities and non-governmental organizations from throughout Mexico met to propose areas of importance for the conservation of the birds (*fig. 2*). In this workshop 170 areas were nominated, using criteria initially developed by BirdLife International (Estrada and Davidson, this volume). During 1996-1997 those 170 areas were reviewed by the national coordinator, along with 23 additional sites subsequently nominated by other ornithologists. These nominations were revised as further information became available and information about each site was entered into the Mexican IBA database which is maintained by CONABIO. Maps of all nominated areas were digitized by the staff in the CONABIO office (National Commission for the Knowledge and Use of Biodiversity) and incorporated into a geographical information system (ARCHINFO scale 1: 250,000).

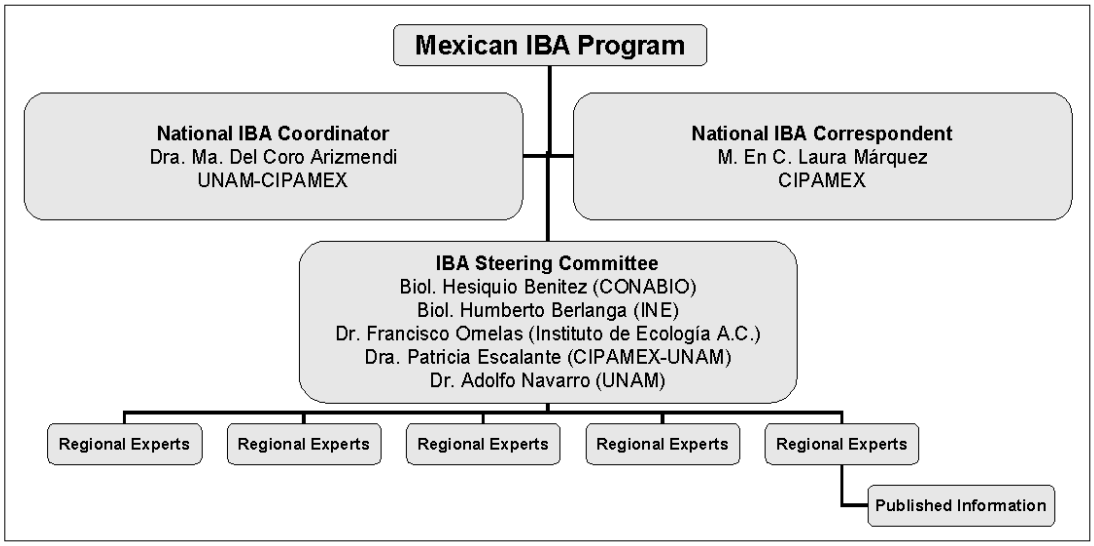

Figure 1— Structure and internal organization of the IBA Program in Mexico.

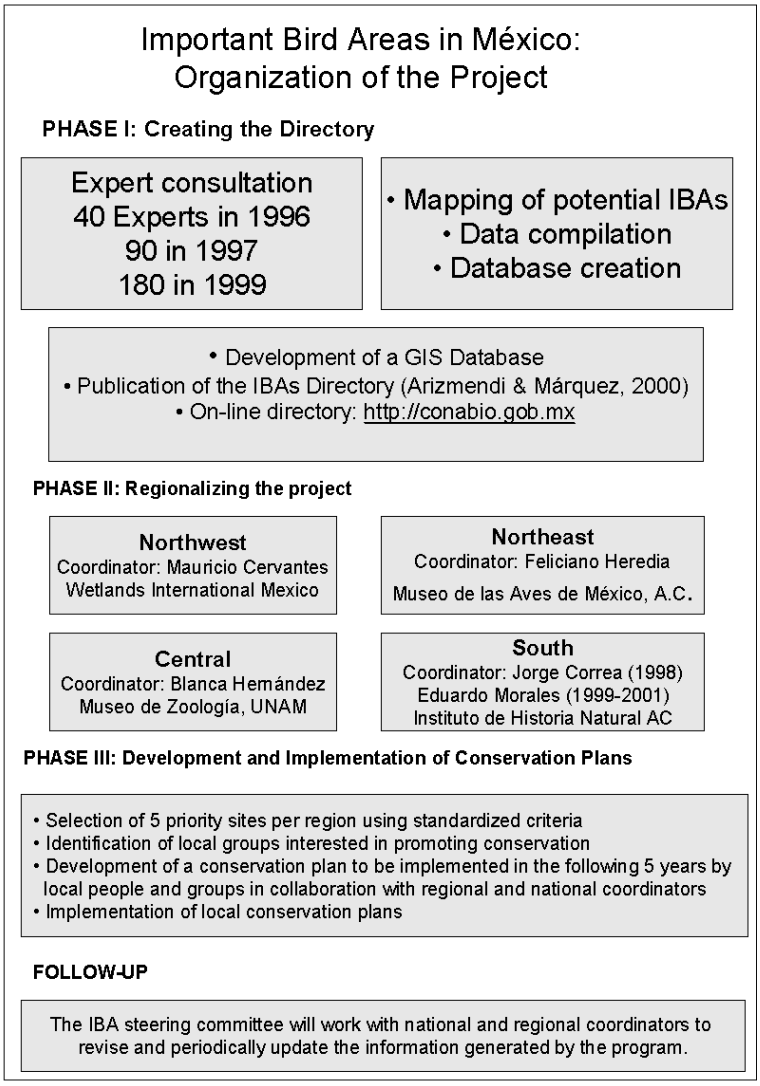

Figure 2— Flow chart of the development of the IBA Program in Mexico.

In a May 1997 meeting of the IBA Steering Committee, the national coordinator and technicians of CONABIO revised, with the support of maps of vegetation, topography and hydrography, the boundaries of the 193 proposed IBAs. We created a map which can be consulted in an electronic format at http://conabioweb.conabio.gob.mx/aicas/doctos/aicas.html, where all information about the IBAs is available.

In 1998 the IBA program entered a second phase during which the country was partitioned into four regions for planning purposes (Northeast, Northwest, South and Center). In each region two workshops were held to revise the list of IBAs, based on input from the larger number of regional experts that attended these meetings. IBAs were added, aggregated, or eliminated, resulting in a definitive list of 230 IBAs (*fig. 3*).

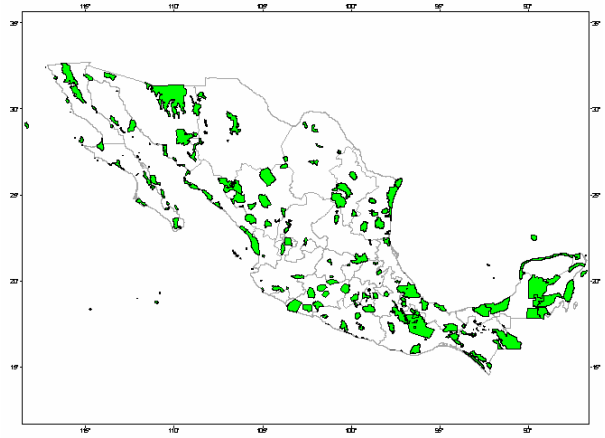

Figure 3— IBAs designated in Mexico (1996-2000).

Each IBA is documented in a technical description that includes biotic and abiotic information about the area, in addition to a bird list that includes the species, their abundance (categorically) and their seasonal occurrence in the area. The complete database of 230 IBAs includes more than 22,000 records of 1,038 species of birds (96.3 percent of the total species regularly occurring in Mexico according to the American Ornithologist Union 1983). Additionally, 90.2 percent (306 of 339 species) of the species listed as threatened according to Mexican law, and 100 percent of the species included in *Threatened Birds of the World* (BirdLife International 2000) occur in at least one IBA. Moreover, of the 100 species endemic to Mexico (Navarro and Benitez 1993) all occur in at least one IBA. Finally, all vegetation types recorded in Mexico (Rzedowski 1978) also are present in one or more IBAs.

All of Mexico's Biosphere Reserves, Special Reservations, and Biological Stations have been nominated as IBAs. Also, 121 Priority Regions for Conservation (Arriaga et al. 2000) are recognized as IBAs (63 percent of total regions). IBAs have been identified in all the states of the Mexican republic; nonetheless, some states appear to be over- or under-represented (*fig. 3*). This is partially a reflection of unequal ornithological knowledge among the states, and it therefore highlights an important agenda for future field work.

From Identification to Conservation Practice: The Prioritization Exercise

By definition, the IBA process identifies sites that are priorities for conservation action. However, implementing conservation plans in all the IBAs is likely to be impossible or at least impractical in the near future. Therefore, we decided to develop a set of national criteria for prioritizing which IBAs would be most important and practical to work in first. We scored each IBA based on eleven criteria (*table 1*), which included, for example, bird species richness, presence of endemic and/or threatened birds, and the presence of opportunities for implementing conservation measures (defined as the presence and local people and/or institutions with positive attitudes towards conservation). For each IBA, the scores for all eleven criteria were added to produce a site priority score, and all the IBAs were then ranked by these scores to determine priorities among the IBAs. Sixteen IBAs where classified as priority areas for bird conservation in Mexico (*fig. 4*).

If we succeed in sustaining the target bird populations in all 16 priority IBAs we will be conserving 805 species (75 percent of the Mexican avifauna), including 55 percent of Mexico's globally threatened species and 81 percent of Mexico's endemic species. This goal, however, is not sufficient. Our priority as a country is to preserve all the Mexican endemic bird species, as defined by Navarro and Benitez (1993), and ensure the conservation of all the Mexican bird species listed as globally threatened (BirdLife International 2000). Therefore, to further prioritize IBAs we queried the IBA database for sites supporting any endemic or globally threatened species. Sites supporting the largest component of these species were listed as priority sites. This list was supplemented by additional sites that supported other priority species that had been missed, until a subset of IBAs was identified that supported all priority species. This process generated a list of 19 additional priority sites (*table 2*).

Table 1— *Criteria used for prioritizing IBAs for conservation actions in Mexico. Each criterion was subjectively weighted by the associated score to reflect its perceived importance for ranking priorities. Priorities were obtained for each IBA by adding the scores for each criterion that was met at a site.*

Criteria	Score
Global importance based on IBA criteria (Presence of globally threatened species, range-restricted species, biome-restricted species, or populations of congregatory species exceeding 1% of global population)	5
Presence of opportunities to manage and conserve the IBA (Presence of local landowners who are actively working towards conservation and sustainable development)	5
Existence of a management and/or conservation plan for the IBA	4
Presence of an effective local conservation group	4
Presence of priority vegetation types	3
Size of the IBA (ha)	0-4,999 = 1
	5,000-10,000 = 2
	> 10,000 = 3
Presence of infrastructure (roads, communications, etc)	3
Biological richness (4) of birds (number of species)	0-50 = 0
	51-100 = 1
	101-250 = 2
	> 251 = 3
Presence of range-restricted (endemic) bird species	Endemic to México = 1
	Endemic to the region = 2
	Endemic to the state = 3
Site of migrant bird concentration	3
Site of breeding bird concentration	3

Table 2— *Priority IBAs for bird conservation in Mexico.*

A: Based on site criteria	
Center: Cuitzeo, Islas Revillagigedo, Tehuacán, Chamela-Cuitzmala and Omiltemi.	
North-East: Sierra de Arteaga, El Potosí, Peña Nevada, Pradera de Tokio and El Cielo.	
North-West: Marismas Nacionales, Isla Tiburón and Archipiélago Loreto.	
South: El Triunfo, Sian Ka'an and Río Lagartos.	
B: Based on species criteria	
Cañón de Lobos	Carricito del Huichol
Centro de Veracruz	Cerro de Oro
El Ocote	Estero San Jose
Isla Benitos	Isla Guadalupe
Islas Marías	La Sepultura
Lagos de Montebello	Las Bufas
Reserva El Pinacate y Gran desierto de Altar	Sur del Valle de México
Sierra de Atoyac	Sierra de Manantlán
Sierra de Miahuatlán	Sierra de Santa Martha
Sierra Norte	

First Steps Towards Implementing Conservation Actions

The first IBA for Mexico, El Carricito del Huichol, an old-growth pine forest, represents one of the few remnants of this vegetation type growing in the western coast of Mexico that still preserves its biological integrity. This area has been the focus of attention by CIPAMEX since 1997. The main goal here was to promote the development of a conservation and manage plan that will enable local landholders (private and indigenous) to make a living from their lands without damaging the environment. Some actions have been implemented,

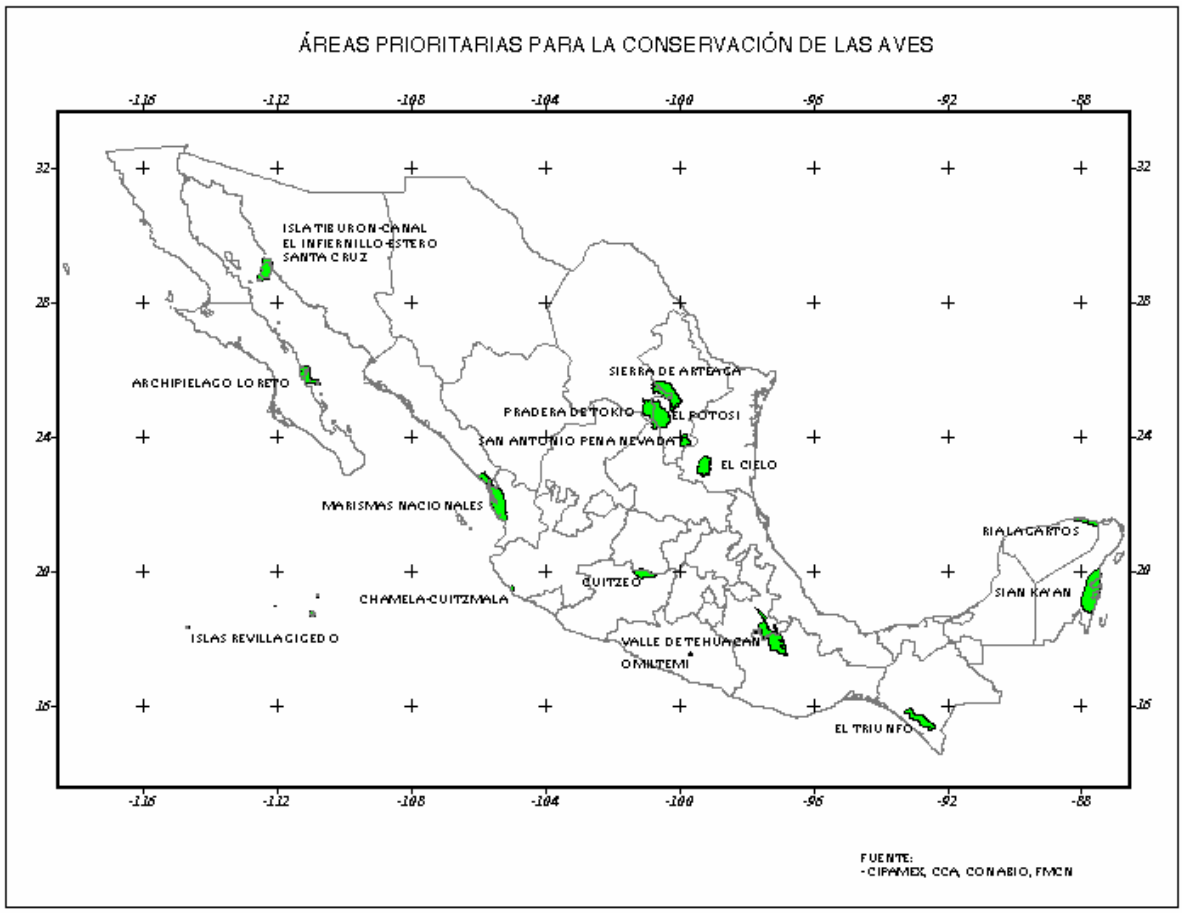

Figure 4— Priority IBAs for México.

such as the building of a field station where both scientists and tourists are welcome to conduct surveys or birdwatch. These activities benefit the huicholes who inhabit the land. This project grew so fast that in 1998, a new NGO (Bosque Antiguo AC) was formed to deal specifically with the conservation of this area.

More recently, a second area, the Sian Ka´an Biosphere Reserve in the Yucatan Peninsula, was adopted as a cooperative sister project by Panama, Mexico and Canada. This project, building on a long history of related projects in the area by Amigos de Sian Ka'an A.C., involves the development of ecotourism, based on birding tours, as an alternative for communal development in the area. In this way Amigos de Sian Ka´an A. C., along with the Director of the biosphere reserve and CIPAMEX, conducted workshops in two local communities to train nature guides. Trails for bird observation were built and promoted throughout Mexico by CIPAMEX, and at the international level by our Canadian partner, the Canadian Nature Federation. By the end of 2002 this initiative, along with efforts of many organizations and people working towards bird conservation in the Yucatan Peninsula, had grown into a NABCI pilot project.

In the near future management plans will be developed for four more IBAs, one in each of the four regions in Mexico, with the goal of quickly implementing conservation actions in those areas.

Opportunities for the Conservation of Birds in Mexico: The Role of the IBA Program

The publication of a directory of Mexico's Important Bird Areas in 2000 (Arizmendi and Marquez 2000) was truly a benchmark in the history of Mexican ornithology. However, the IBA Program also has provided Mexico with a unique opportunity for initiating new and exciting cooperative efforts among many people and organizations interested in the study and conservation of the Mexican birds.

The IBA Program, besides being a tool for the conservation community and the Mexican government, serves as a starting point for the formulation of conservation plans within NABCI: a trilateral initiative that is working towards the implementation of coordinated conservation actions throughout North America. In Mexico,

IBAs will be the primary implementation units for NABCI.

The successes that have been achieved by the IBA Program in Mexico have occurred within the context of recent changes in the government, non-governmental organizations, the private sector, and the overall social structure of the country, which have created a climate conducive to these achievements. The IBA Program therefore represents an important example of the positive impact a program can have when it has the consensus of many institutions and people working to achieve one common goal – the conservation of our birds.

Acknowledgments

We want to acknowledge the work of A. Estrada and D. Niven who provided excellent editorial comments that improved the present manuscript. We thank BirdLife International for their support in several phases of this work and especially the Americas office whose personnel helped a lot in the elaboration of the present work. We also thank Partners in Flight and the Mexican NABCI project for the financial support given to Ma. Del Coro Arizmendi for attending in the Asilomar Conference.

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American Bird Conservancy's Approach to the U.S. Important Bird Area Program – Identifying the Top 500 Global Sites[1]

Robert M. Chipley[2]

The idea for the Important Bird Area Program originated in a series of studies in the early 1980s conducted by BirdLife International. Recognizing that these studies could become a powerful tool for conservation, BirdLife International began an effort to identify and gather data regarding the most important areas for birds in Europe and to make this information available to conservationists and government agencies alike. The idea has spread throughout the world. In 1995 American Bird Conservancy began an Important Bird Areas Program for the United States.

As an important facet in our program, we have developed a list of the top 500 globally most significant Important Bird Areas (IBA) in the United States and are publishing a book with accounts describing them. We created the list by reviewing the extensive information from IBA nomination forms in our files, from the literature, and through contacting experts all over the country. We asked the latter not just for recommendations on what other sites might be added to the list but why the sites were important for bird conservation and what the management issues were. Using this information, we wrote accounts for each site and sent them to the experts for review. Over 600 scientists and interested lay people from all 50 states have contributed to our effort.

In choosing the top sites, we used a set of criteria based on those set forth by the North American IBA Technical Committee, a group of biologists from Canada, the United States and Mexico that met to adapt the criteria from Europe for use in North America (Commission for Environmental Cooperation 1999). American Bird Conservancy's (ABC) criteria are:

> Category 1: areas within the 50 states with habitat consistently used during breeding, migration or winter by a federally endangered or threatened species;
>
> Category 2: areas within the 50 states with habitat consistently used during breeding, migration or winter by a Partners in Flight
>
> Category 3: habitat for a species with a very restricted range, such as Tricolored Blackbird (*Agelaius tricolor*), Yellow-billed Magpie (*Pica nuttallii*), or Brown-capped and Black Rosy-Finches (*Leucosticte australis* and *L. atrata*);
>
> Category 4: areas with habitats supporting a large concentration of breeding, migrating or wintering birds, including waterfowl, seabirds, wading birds, raptors, or landbirds. For waterfowl, we have included primarily sites with 100,000 or more birds. For hawk-watches, we include primarily sites where over 25,000 birds are recorded annually.

Note that for the first three categories above, we include the sites which support the largest known numbers for these species.

Detailed descriptions of each site are provided, along with text on many of the current issues in bird conservation. The site accounts are arranged by the North American Bird Conservation Regions, as defined by Partners in Flight and the North American Bird Conservation Initiative (U.S. NABCI Committee 2000). Bird Conservation Regions (BCRs) provide a common geography for planning for bird conservation and are appropriate as a framework within which to list IBAs. The boundaries of BCRs were demarcated based on factors relevant to birds, including distribution of bird species, patterns of vegetative types relevant to birds, prevalent land use practices, and important conservation issues. Among the BCRs with the most identified IBAs are Northern Pacific Rainforest, Coastal California, Eastern Tallgrass Prairie, and Southeastern Coastal Plain. Accounts concentrate on population sizes and trends of the key bird species at each site, with a discussion of conservation and management issues. Where sites are open to the public, we also supply visitor information. American Bird Conservancy has also produced a map, in cooperation with the National Geographic Society, showing the top IBAs in the United States, overlaid on Bird Conservation Regions.

This book is the first to identify and describe the globally most significant Important Bird Areas throughout

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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the country. No single work to date has put the most important sites in the United States into the context of their global meaning to bird conservation. As such it serves both a conservation and educational function. Every birder knows how important Aransas National Wildlife Refuge is to the Whooping Crane (*Grus americana*) (Lewis 1995), and most know how important Delaware Bay and Grays Harbor (Harrington et al. 1989, MacRae 1995, U.S. Fish and Wildlife Service 1996) are to migrating shorebirds, but less well known is the fact that Apalachicola National Forest has the world's largest population of Red-cockaded Woodpecker (*Picoides borealis*) (Costa, pers. comm.), that Fort Hood is number one both for the endangered Golden-cheeked Warbler (*Dendroica chrysoparia*) and Black-capped Vireo (*Vireo atricapillus*) (Cornelius, pers. comm.), that Frozen Head State Natural Area in Tennessee has one of the largest known concentrations of Cerulean Warblers (*Dendroica cerulea*) (T. Ettel, pers. comm.), or that Superior National Forest, Minnesota has the greatest number of breeding species of any national forest, including 24 species of warblers (American Birding Association 1994).

Our goal in the program is to sharpen awareness of the public, managing agencies and landowners as to each site's exceptional value, and to use this heightened recognition to help mobilize the resources to ensure adequate protection. It is an inescapable conclusion that, while protecting more land and setting up more preserves for birds is important, proper management of the existing protected important areas also is critical. One benefit is that an IBA can become a point of pride to the local community. With funds from the Disney Foundation, ABC sent signs and certificates to the top IBAs, naming them of global importance for bird conservation. The signs and certificates have been very well received by the site managers and owners, several sites have held dedication ceremonies, and there are already indications that this increased recognition is helping to allocate more funds for management to benefit birds.

Most of the sites in this book are on protected lands. Of the 546 sites mentioned, some 60.4 percent are in federal ownership, 27.7 percent are owned by state governments, 6.2 percent are owned and managed by The Nature Conservancy, 3.1 percent by other conservation groups, 1 percent by municipalities, but only 1.6 percent are on private lands; among the sites with complete or part ownership by private landowners are Cross Bar Ranch, Florida, Upper St. John River Project, Maine, and Butterbredt Spring, California. Does this reflect the true situation in the United States—that for IBAs, public and conservation lands have everything and private lands next to nothing? This undoubtedly is not the case. Then why aren't private lands better represented?

The main reason is that, in general, far less information on birds—both species and numbers—is available on private than on public lands. Most private lands are not open to researchers, let alone the public, and often the level of their significance has not been evaluated. In addition, the rights of property owners are a sensitive issue, and many landowners might regard the naming of their holdings as IBAs with suspicion. We hope that in the future, more private lands might be identified as Important Bird Areas, and that landowners might come to regard this recognition as an object of pride. This is a top priority in the further development of the IBA concept.

We thank our two principal partners in the IBA program. The first is The Nature Conservancy, which provided financial support through its Wings of the Americas program, and which has been very helpful in supplying information about the more than 30 of its projects which are IBAs. The second is the Disney Foundation, which supported our project to send signs and certificates to the top 500 sites, naming them and dedicating them as global IBAs.

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The Important Bird Areas Program in the United States: Building a Network of Sites for Conservation, State by State[1]

Jeffrey V. Wells,[2,3] Daniel K. Niven,[2] and John Cecil[2]

Abstract

The Important Bird Area (IBA) program is an international effort to identify, conserve, and monitor a network of sites that provide essential habitat for bird populations. BirdLife International began the IBA program in Europe in 1985. Since that time, BirdLife partners in more than 100 countries have joined together to build the global IBA network. Audubon (BirdLife partner-designate for the United States) has been working since 1995 to identify and conserve hundreds of IBAs throughout the United States. There are 46 state IBA programs now underway in the United States with paid staff coordinators in 40 states. Ten states have completed documented IBA inventories totaling more than 1500 IBAs and encompassing more than 14.4 million hectares. The IBA program sets science-based conservation priorities and engages local action to safeguard the most essential sites for bird populations. More than 4,000 people have participated in the IBA nomination and conservation effort across the United States.

Key words: BirdLife, Bird conservation, IBA, Important Bird Area, National Audubon, site protection.

Background and Current Status

In order to implement broad-scale national and bio-regional bird conservation plans, sites must be identified across the landscape at which relevant actions are undertaken. These actions include site assessment, land acquisition, restoration, habitat management, resource monitoring, education, and outreach. To provide the most effective use of conservation dollars, these sites should be identified through a standardized and flexible approach that ensures that the most important sites are chosen and given priority for conservation actions. In addition, and perhaps most importantly, programs that identify these priority sites should engage a broad bird conservation constituency and build the infrastructure necessary to implement on-the-ground conservation.

The Important Bird Areas (IBA) program, as part of a global initiative of BirdLife International and its Partners (National Audubon is the U.S. Partner), was originally developed in order to meet these goals (Evans 1994, Wells 1998, Heath and Evans 2000, Fishpool and Evans 2001). IBA inventories are comprehensive, recognizing not only sites that support rare and endangered species, but also those that support globally important concentrations of non-endangered species – a proactive approach to ensure these species do not become endangered. These sites include breeding as well as non-breeding habitats and vital migratory stopover locations. IBAs may be publicly or privately owned and they may vary in size from a few hectares to tens or even hundreds of thousands of hectares.

IBA inventories are part of a global, all-bird conservation initiative that is implemented by in-country partners so that sites are put in a context that highlights their importance worldwide. In addition, IBA programs are unique in that they enlist grassroots citizen scientists in collecting the information needed for the IBA inventory. Investing this locally based constituency galvanizes them as advocates in the protection of birds and habitat at these sites.

The IBA Program was initiated in Europe by BirdLife International in the mid-1980s (Heath and Evans 2000). Since then, IBA programs have been initiated in over 100 countries throughout the world, including for example, the African continent (Fishpool and Evans 2001) and the Middle East (Evans 1994). IBA inventories for over 50 of these countries have been published (Fishpool pers. comm.). IBA programs are underway in many countries throughout the Americas including Mexico, Colombia, Cuba, Dominican Republic, Argentina, Brazil, and Ecuador (Estrada and Davidson this volume). Mexico (Arizmendi and Valdelamar 2000) and Panámá (Angehr 2003), already have published inventories of their IBAs and data from Canada are available at http://www.ibacanada.com/.

IBA programs have been responsible for safeguarding thousands of sites and millions of hectares around the

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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world. Long-standing programs in Europe, Japan, and Taiwan, for example, have prevented the destruction of key habitats protecting endangered endemic bird species through the direct engagement of local citizens in conservation action (Heath and Evans 2000, Fishpool pers. comm.).

In the US, Audubon and the American Bird Conservancy began identifying IBAs in the mid-1990s. The American Bird Conservancy's IBA efforts are summarized in another paper in this symposium (Chipley this volume). Audubon has carefully invested in developing the infrastructure to sustain long-term conservation initiatives for IBAs. This is done by establishing state-level IBA programs (through Audubon state offices where they exist and with other partners where they do not) that enlist state agency personnel and other state bird experts and empower state and local constituencies to be conservation leaders for IBAs.

The first state-based programs were established in Pennsylvania in 1995 and New York in 1996. Both of these states have published their IBA inventories (Wells 1998, Crossley 1999). Since these early successes, state-based IBA programs have been initiated in 46 states, and it is expected that programs will be launched in all 50 states by 2004. IBA inventories have been completed in ten additional states (Ritter 2000, Audubon Colorado 2001, Cooper 2001, Cullinan 2001, Audubon Maryland 2002, Lyon 2002, Audubon North Carolina 2003, Pranty 2003). With paid IBA staff in 40 states (mostly Audubon employees) and an annual budget of approximately $2,000,000, Audubon's IBA program constitutes the largest IBA effort in the world. Moreover, Audubon's commitment to the IBA program has grown, and, in fact, the IBA Program is now a central part of Audubon's "2020 Vision" for implementing the long-term conservation goals of the organization.

In addition, as the U.S. Partner Designate of BirdLife International, Audubon has established a U.S. National IBA Technical Committee to review all state IBAs and others for consideration as Global and National IBAs. This committee includes representatives from all four major bird conservation initiatives (waterfowl, waterbirds, Partners in Flight, and shorebirds). Audubon also is developing an online IBA database to serve as the central repository of all US IBA data and has entered into agreements with the North American Waterbird Conservation Plan and the U.S. Shorebird Conservation Plan to identify IBAs for colonial waterbirds and shorebirds.

Goals and Objectives

The development of state-level IBA Programs in the US has generally occurred in three stages: start-up, site identification, and conservation action and outreach.

Start-up

In the start-up phase a state coordinator is designated and, preferably, hired in full-time capacity and an IBA Technical Committee is established. Some states also have established a separate IBA Steering Committee, or Conservation and Outreach Committee, to assist in those initiatives. The IBA coordinator then works with the IBA Technical Committee to develop and finalize the IBA identification criteria for that state.

IBA committees play a crucial role in coalescing the many state agencies and conservation groups around the IBA Program and ensuring the greatest impact. The IBA Technical Committee usually numbers approximately 12 individuals and consists of the top ornithologists and bird distribution experts in the state. This committee establishes the state IBA criteria, assists in collecting data about sites, and reviews these data on potential IBAs to identify which sites qualify as Important Bird Areas. The IBA Steering Committee or Conservation and Outreach Committee function in an advisory capacity. Its members are drawn from state agencies and conservation organizations. This committee recommends the most appropriate conservation strategies for specific IBAs, in coordination with ongoing efforts of participating groups.

The IBA criteria are the benchmarks by which potential sites are deemed to qualify as official IBAs. The criteria provide a scientific, objective basis for determining the importance of a given area to bird populations. Criteria have been developed and refined over more than 10 years, first by BirdLife International for sites around the world, and then in the United States by the National Audubon Society. To qualify as an IBA a site must support threshold numbers for congregatory species, species of conservation concern, or range-restricted (endemic) species, or biome-restricted species. Global-level thresholds have been established by BirdLife International (Fishpool and Evans 2001) and Continental-level thresholds by Audubon's U.S. National IBA Technical Committee, in coordination with IBA coordinators from Canada, Mexico, and BirdLife. State-level thresholds are modeled after these standardized criteria but are sometimes modified in response to the particular biogeographical needs of that state.

Identification

Identification is the second phase of the IBA process. During this phase, birding experts, ornithologists, conservation biologists, and the public are invited to

nominate sites that they feel meet the established state IBA criteria. Site nominations must be supported by bird survey data and to achieve this, paper and online forms are made widely available. An outreach effort typically is mounted at the same time in order to ensure the broadest possible participation. Often Audubon chapters and bird clubs within the state work cooperatively with the state IBA coordinator to nominate sites within their areas. All of this is done in order to maximize the number of sites nominated and to increase the eventual grassroots capacity for conservation at sites that are identified as meeting IBA criteria. At the end of the nomination process (typically 6-9 months) the state IBA Technical Committee reviews the nominations and identifies sites that meet the IBA criteria. To ensure that this inventory is as complete as possible, state IBA coordinators usually draw upon available data from state wildlife agencies, state Natural Heritage Databases, and other conservation groups active in that state.

At the end of the identification phase, the state IBA coordinator produces an IBA report with detailed documentation on all of the state's IBAs. This information also is entered into a national database. These data include the location of each IBA, a description of the habitat, quantitative data on the species for which the site is important, and conservation threats and actions. The IBA report sometimes also includes an overall analysis of the IBAs and a set of preliminary recommendations for conservation. The IBA report is disseminated to decision-makers, land-use planners, conservationists, agency personnel, and other key stakeholders and its use encouraged as a blueprint for conserving vital habitats for birds throughout the state.

Conservation Action and Outreach

The conservation action and outreach phase of the IBA Program is ongoing and long-range in its goals. In the first year of a state program, often a small number of sites are selected that clearly meet the criteria as "model IBAs." These serve as keystone sites to demonstrate the IBA process, promote the concept, and implement conservation measures where they are needed. For example, one or more public IBA designation events may be held to recognize the landowner for stewardship of the site. Events like this across the United States and the world have generated media attention and helped focus the spotlight on birds and their habitats. For example, a binational IBA dedication ceremony in Niagara Falls was attended by United States and Canadian mayors and leaders of both countries' federal environmental agencies, resulting in extensive media coverage.

After the inventory and report of IBAs have been completed, a state's IBA Conservation and Outreach Committee may be asked to prioritize sites based on where the greatest unfulfilled needs are and to determine ways to best meet those needs. In some states a subset of IBAs may be chosen for focused attention. Plan development is carefully coordinated with the input of landowners, land managers, local land trusts, conservation groups, and other stakeholders. Finally, bird monitoring procedures are established in many states with state IBA Coordinators recruiting volunteers to conduct them. The resulting data can then be used to monitor the progress of the program as it is reflected in changes in bird populations.

The most important phase of IBA programs is that which follows site identification – the conservation action phase. For example, sites identified as IBAs can be integrated into Partners in Flight planning efforts as focus areas at which conservation activities can be undertaken. IBA programs in many states are already achieving successes in all-bird conservation in various ways from increasing rates of land acquisition for conservation by state wildlife agencies to changing land-use policies that are detrimental to birds. Other IBA programs have taken on outreach and education efforts and developed bird monitoring networks at IBAs. Some of the ongoing state IBA conservation successes are listed below.

Montana

- Audubon Montana signed a 10-year license to protect 175 hectares of cottonwood habitat that supports a host of neotropical migrant songbirds near Kalispell. Located at the confluence of the Stillwater and Flathead Rivers, this area serves as key open space for the Kalispell community, and it has been nominated as an Important Bird Area.

- Audubon Montana is developing and implementing a management plan for the Owen Sowerwine Natural Area IBA located in the Flathead Valley. This area is a magnet for wildlife because of its mix of wetland and upland habitats. In addition, this IBA contains important habitat for 10 Partners in Flight priority neotropical migrant songbird species.

North Carolina

- Audubon's IBA program has secured permanent protection for 30 percent of the 2,000-hectare Lea-Hutaff Island IBA, providing key habitat for neotropical migrant waterfowl, colonial waterbirds, shorebirds, and songbirds. Audubon expects to acquire the remaining area within the next 12 months.

- Bullhead Mountain, the key component of the Bullhead-Mahogany Rock IBA, has been purchased through a cooperative effort by the Conservation Trust for North Carolina, the Blue Ridge Rural Land Trust, and the North Carolina Division of State Parks, and Audubon North Carolina. Audubon will manage the site and plans to build a platform to allow visitors to view the many neotropical migrant raptors that pass over the area.

Mississippi

- Audubon Mississippi is assisting the Lower Mississippi Valley Joint Venture (http://www.lmvjv.org/) with a citizen-science effort to monitor neotropical migratory shorebirds (http://www.lmvjv.org/shorebird/) throughout the alluvial valley of the lower river states. Much of the monitoring in Mississippi will occur at nominated IBAs. This monitoring effort will assist researchers in estimating the number of shorebirds migrating through the valley (now estimated at 500,000 birds each fall) and help them learn more about the habitat needs of the birds.

- Audubon Mississippi, along with its partners, is developing a long-term conservation initiative involving the Pascagoula River and associated habitats. The Pascagoula is the largest free-flowing, essentially unfragmented river system in the lower 48 states. The river and the bottomland hardwood forest that borders it, much of which is public land, provide a protected corridor for neotropical migrant songbirds, nesting and roosting habitat for Swallow-tailed Kites (*Elanoides forficatus*), and habitat for a variety of wading birds. Several candidate IBAs have been nominated along the Pascagoula River.

New York

- Audubon New York increased the number of IBAs included in the state government's Open Space Plan from 40 to 83. These sites will be priorities for land acquisition over the next five years and will result in the protection of tens of thousands of acres of habitat supporting thousands of neotropical migrants.

- Audubon New York is working with several land trusts to increase their acquisition efforts on behalf of neotropical migrant songbirds. This includes a partnership with the Finger Lakes Land Trust to acquire an 80-hectare riparian IBA for Cerulean Warblers (*Dendroica cerulea*) and landowner outreach for eventual acquisition of a 160-ha grassland complex supporting breeding Henslow's Sparrows. An effort with Save the County land trust was initiated to begin acquiring parcels in the Whiskey Hollow IBA, which supports breeding Golden-winged Warblers (*Dendroica chrysoptera*) and Cerulean Warblers.

- At Sterling Forest State Park IBA, plans to manage hundreds of hectares for valuable successional habitats that support key populations of Golden-winged Warblers were included in the park's master plan through Audubon's efforts.

- At the Montezuma Wetlands Complex IBA, which hosts massive numbers of neotropical migrants including waterfowl, waterbirds, shorebirds, and songbirds, Audubon helped obtain $2.5 million of Lands and Water Conservation Funds for habitat acquisition and restoration affecting thousands of acres.

Pennsylvania

- Audubon Pennsylvania's IBA program has embarked on an ambitious IBA conservation planning initiative which will culminate in the completion of IBA conservation plans for all 78 of Pennsylvania's IBAs.

- Along the lower Susquehanna River, Audubon-Pennsylvania worked on the development of a cooperative agreement and 35-year FERC licensing agreement with Safe Harbor Power Company to maintain neotropical migrant shorebird habitat (mudflats) throughout the spring and fall migration season at the Conejohela Flats IBA above Safe Harbor Dam.

- Audubon Pennsylvania assisted The Conservation Fund to acquire 960 hectares of forested habitat supporting breeding neotropical migrant songbirds such as the Scarlet Tanager (*Piranga olivacea*) and Wood Thrush (*Hylocichla mustelina*) along Bald Eagle Ridge IBA.

- Audubon Pennsylvania acquired 30 hectares of forested habitat at Miller's Gap, along the Kittatinny Ridge IBA.

- Audubon Pennsylvania helped develop a rating system with the Pennsylvania Department of Conservation and Natural Resources that provides a 20-point advantage for all Com-

munity Conservation Partnership Grant requests that involve IBAs and that will result in more resources becoming focused on the needs of neotropical migrants.

- Audubon Pennsylvania created a broad community-based coalition of over 30 organizations working together to conserve the entire length of the Kittatinny Ridge, a 72,000-ha IBA spanning 11 counties and recently hired a conservation planner to work directly on the project. The IBA hosts exceptionally large numbers of migrating neotropical migrant raptors as well as breeding neotropical migrant songbirds characteristic of the Ridge and Valley PIF physiographic region like Worm-eating Warblers (*Helmitheros vermivorus*) and Louisiana Waterthrushes (*Seiurus motacilla*).

Conclusions

The IBA Program has gained momentum around the world because it provides a common sense quantitative way to set conservation priorities for protecting sites that support vulnerable bird populations. The long-term goal is to use this prioritization process to inform long-term conservation planning and actions. This will be done in cooperation with relevant stakeholders at all levels, from grassroots, locally concerned citizens, to state and federal agencies responsible for large scale land stewardship.

Acknowledgments

Our sincere thanks to the thousands of people from across the US who have volunteered their time and expertise to make IBA programs achieve conservation results. Thanks also to the 46 US state IBA coordinators and other Audubon staff who work to support the programs and to Ian Davidson, Lincoln Fishpool and other BirdLife International staff and partners from around the world who have provided advice and expertise. National IBA program work in the US has been funded through Canon U.S.A., Commission for Environmental Cooperation, General Electric Foundation, LaSalle Adams Fund, New York Community Foundation, and the Prospect Hill Foundation.

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Important Bird Areas as a Conservation Tool: Implementation at the State Level[1]

Michael F. Burger[2] and Jillian M. Liner[2]

Abstract

In the mid 1990s, Audubon New York initiated an Important Bird Areas (IBA) program that had two goals, 1) to identify sites most critical for the protection of birds and 2) to take positive and coordinated action to promote the conservation of those sites. The first goal was achieved in 1997 when 127 IBAs were identified across New York State. Since then, in order to achieve the second goal, Audubon New York has been implementing a broad program based on advocacy, conservation planning, research and monitoring, and education and outreach. Advocacy efforts include political lobbying, promotion of site protection through acquisition and easements, and passage of state legislation establishing a state bird conservation area program. Through conservation planning, Audubon staff advocate for proper management of sites and assist land managers with technical aspects of bird and habitat conservation. Research and monitoring projects at IBAs are undertaken to assess and track populations, identify priority habitats, and encourage advocacy among citizen-scientists who participate in the projects. Education and outreach efforts aim to increase the public's knowledge of the importance of quality habitats for birds and other wildlife and to encourage them to advocate for the protection and proper management of those habitats. Outreach tools include public presentations, media coverage of IBA events, and a website (http://ny.audubon.org/iba). In all aspects of the program, Audubon New York partners with federal and state governments, other environmental organizations, and local citizens.

Key words: citizen science, conservation planning, IBA, New York, site protection.

Introduction

The first Important Bird Areas (IBA) initiative was begun in Europe by BirdLife International in the early 1980s. The idea of using standardized avian criteria to identify sites that are important for the conservation of birds subsequently spread across the globe to the Mediterranean region, Africa, Asia, and to the Americas (e.g., Commission for Environmental Cooperation 1999, Arizmendi and Valdelamar 2000, Cullinan 2001, Fishpool and Evans 2001, Bird Studies Canada and the Canadian Nature Federation 2002). In the mid-1990s Audubon launched an IBA program in New York State. The goals of the program were 1) to identify sites most critical for the protection of birds and 2) to take positive and coordinated action to promote the conservation of those sites. More than 250 sites were nominated as IBAs, and after review by a technical committee composed of 22 bird experts from around the state, 127 sites were identified as IBAs in 1997 (*fig. 1*), making New York the first state in the United States to complete the site identification phase of its IBA program (Wells 1998).

Figure 1—Locations of 127 Important Bird Areas in New York State.

Many of these sites are distinct habitats that support birds of conservation concern (e.g. New York State endangered, threatened, or special concern species), locations where birds congregate during migration and at other times, or areas that support distinct avian communities that are rare or threatened or exemplar for the region or state (*table 1*). Though IBAs vary in size, they are limited in area and often delineated by

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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Table 1-- *Criteria used to identify Important Bird Areas (IBAs) in New York State.*

New York IBA criteria
1a - 2,000 waterfowl (loons, grebes, cormorants, geese, ducks, coots, moorhens)
1b - 100 pelagic seabirds (shearwaters, storm-petrels, fulmars, jaegers, alcids) or terns; 10,000 gulls
1c - 300 (inland) or 1,000 (coastal) shorebirds (plovers, sandpipers, snipe, woodcock, phalaropes)
1d - 100 wading birds (bitterns, herons, egrets, ibises)
1e - 8,000 raptors
1f - exceptional diversity of species (includes migrant traps for landbirds)
1g - significant number (>1% of state population) of a particular species
2 - NYS endangered, threatened, or special concern species
3a - assemblage of species of a rare, threatened, or unusual habitat within the state or region
3b - assemblage of species of an exceptional representative of a natural or near-natural habitat within the state or region

ecological boundaries, e.g. changes in habitat type. New York's IBAs include high elevation forests, lakes, bogs, other wetlands, habitat islands in urban landscapes, grasslands, early-successional habitats, and other avian habitat types. Partners in Flight (PIF) priority species were considered during the nomination process in two ways. First, many PIF priority species are state-listed in New York and thus were addressed through the birds of conservation concern criterion. Second, the distinct avian communities for which IBAs were sought were composed mostly of PIF priority species, for example birds of high regional priority as identified in the PIF physiographic area plans. For more information about the habitats and species covered by IBAs in New York, see Wells (1998).

In this paper, we summarize the approach Audubon New York has taken to implement the second phase of its IBA program, i.e. taking positive and coordinated action to promote conservation of IBA sites. There are currently 46 U.S. states with IBA programs in various stages. Approaches toward conservation taken by state IBA programs vary to suit the environmental, social, and political situations in each state. Many state IBA programs have demonstrated their effectiveness in protecting IBAs, and in no way do we intend to imply in this paper that New York's approach has been more effective than others. Rather, the intention is to give the reader a feeling for the scope of the endeavor and the value of IBAs as bird conservation tools based on the experience in one state.

Audubon New York is the state program of the National Audubon Society and has more than 40 employees stationed at offices in Albany, Ithaca, New York City, and at Audubon Centers (environmental education centers) across the state. Of these full-time employees, several frequently work directly with the IBA program, including the Executive Director, Director of Conservation, Director of Bird Conservation, IBA Program Coordinator, Forest and Wetlands Program Coordinator, Director of Education, and Director of Government Relations. Part-time Geographic Information Systems (GIS) technicians and conservation interns also routinely assist with the IBA program, as do seasonal field technicians. In addition, volunteers from 30 affiliated Audubon Chapters across the state as well as from other groups often play important roles in the conservation of IBAs.

Through a strategic planning process completed in 1998, Audubon New York determined that IBAs could be protected and conserved effectively by implementing a broad program based on advocacy, conservation planning, avian research and monitoring, and education and outreach. For the remainder of this paper, we will summarize how Audubon New York has pursued these four areas in our efforts to protect IBAs.

Advocacy

Many IBA-related activities fall under the category of advocacy. In general, our advocacy aims to accomplish three objectives: 1) promote the protection of IBAs through land acquisitions or conservation easements by federal or state government entities or private land trusts, 2) influence land management for bird conservation at IBAs, and 3) promote within the New York State government the Bird Conservation Area Program.

Audubon New York advocates for the protection of IBAs through property acquisition or easements in several ways. We work within the public input framework of the New York State Open Space Conservation Plan (OSCP) process to promote the inclusion of IBAs in the State's OSCP. Properties must be included in this plan for the state to pursue acquisition of or easements on them. Over the past several years, the state has acquired or otherwise protected more than 7,325 ha at more than 30 IBAs, including Black Creek Marsh, Sterling Forest, Montezuma Wetlands Complex, Braddock Bay, Fahnestock State Park, and Catharine Creek Marsh IBAs. In

the 2001 draft plan that was released in fall 2001, 73 out of the 127 IBAs were listed as priority projects, several others were identified as "other large projects," and the IBA program was mentioned in multiple places in the plan. Audubon accomplished this by sending all members of the regional Open Space committees across the state information about the IBAs in their regions that included discussion of why these sites were important for the conservation of birds. Staff from Audubon New York also attended regional hearings for public input on the draft OSCP.

Federal property acquisition at IBAs for conservation purposes has also been notable. With lobbying support from Audubon New York staff, Montezuma National Wildlife Refuge has received funding from the federal Land and Water Conservation Fund for habitat acquisition. In addition, Audubon New York was instrumental in the successful transfer of 223 ha of the former Galeville Airport to the USFWS as the new Shawangunk Grasslands National Wildlife Refuge.

Audubon New York also works with private land trusts that are in the process of protecting IBAs, either through acquisition or easement. For example, Audubon New York staff participated in site visits and landowner negotiations with the Finger Lakes Land Trust at Salmon Creek IBA, which led to the purchase of additional lands within the site. Similarly, we helped Save the County land trust contact landowners and set up a meeting to discuss habitat values of the Whisky Hollow IBA. This collaboration has led to the purchase of additional lands within the Salmon Creek IBA by the Finger Lakes Land Trust, with more acquisitions pending. Similarly, we helped Save the County Land Trust contact landowners and set up a meeting to discuss habitat values of the Whisky Hollow IBA.

In another example of how we advocated for the protection of an IBA, Audubon New York staff supported the Friends of the Great Swamp's efforts to protect the Great Swamp IBA by writing a letter of support for their North American Wetlands Conservation Act grant proposal, co-hosting an IBA designation ceremony, and lobbying state government for Environmental Protection Fund support for land acquisition.

Acquisition by a conservation organization or government entity, alone, does not always guarantee that an IBA will continue to support the birds for which it was identified. Therefore, Audubon New York also advocates for proper management at IBAs. Our actions generally are planned in advance; however, in many cases unforeseen threats to IBAs arise to which we must respond. Notably, Audubon New York and grassroots efforts contributed to the rejection of a golf course planned for an important bird habitat at Joseph Davis State Park within the Niagara River Corridor IBA. We continue to be involved in several ongoing advocacy efforts, such as opposing the development of a recreational pathway and instead promoting marsh restoration at Jamaica Bay National Wildlife Refuge, opposing private resort developments near the Bashakill Wildlife Management Area, and altering public access projects within the Niagara River Corridor. We led a successful grassroots campaign to support the staff of the Shawangunk Grasslands National Wildlife Refuge in their decision that the flying of model airplanes and associated activities were an incompatible use of the refuge's grasslands. In addition, we successfully advocated for the management of early successional forests and shrub lands within Sterling Forest State Park, which is an important site for Golden-winged Warblers (*Vermivora chrysoptera*) and other species that prefer early successional habitats. Other examples in which Audubon New York promoted conservation of IBAs include serving as a resource during the New York Power Authority land transfer along the St. Lawrence River in the Town of Lisbon, encouraging management of the Plattsburgh Airbase in a manner compatible with the habitat requirements of grassland birds, and providing information on the implications of oil and gas exploration on bird populations in the Finger Lakes National Forest.

An important accomplishment for the IBA program was the passage in 1997 of New York's Bird Conservation Area (BCA) Program law (Environment Conservation Law Section 11, Title 20). This law allows state-owned lands and waters that meet criteria similar to our IBA criteria to be designated as BCAs and requires that bird conservation needs be considered in the management of these sites. Due to lobbying efforts by Audubon New York, funding for the state BCA Program has increased from $200,000 in FY 1999-2000 to $300,000 in FY 2000-2001. Four full-time biologists have been hired by the New York State Department of Environmental Conservation for the BCA Program. As of March 2002, 18 BCAs have been designated in New York State, totaling nearly 61,000 ha (see Burger et al. this volume).

Conservation Planning

Audubon New York promotes conservation planning at IBAs on multiple levels including local, state, national, and international. For example, at the local level we assisted the citizens of the Town of Greece (Braddock Bay IBA) in the development of a document identifying priority wildlife habitat and open space, and the Town has since submitted a grant to acquire one of these identified sites. Similarly, we sent information on bird usage at the Fort Edwards IBA to Laberge Group and Town of Fort Edwards to incorporate into their updated Town Master Plan. We also have begun a conservation plan for the Constitution Marsh IBA to help guide

future management actions and set guidelines for recreational access.

At the state level, Audubon New York has promoted conservation planning through our continued collaboration with the BCA Program. In 2001 and early 2002 we assisted in the designation of seven new BCAs (Constitution Marsh, Sterling Forest, Harbor Herons, Perch River, Adirondack Sub-alpine Forest, Champlain Marshes, and High Tor) and contributed to the development of management guidance summaries for those sites. Audubon New York reviews and contributes to these management guidance summaries, which have been completed for all 18 BCAs.

At the national and international levels, Audubon New York promotes the inclusion of IBAs in the planning efforts of PIF and the North American Bird Conservation Initiative. This is being accomplished through regular participation by Audubon staff in PIF New York and Northeast Working Groups and planning meetings for the Lower Great Lakes–St. Lawrence Plain Bird Conservation Region (BCR 13). At these planning meetings, Audubon provides information on habitats of priority species (i.e. IBAs) in New York State. We also have participated in and made IBA information available to the planning efforts of other organizations including Wildlife Conservation Society, The Nature Conservancy, and Shawangunk Greenway Coalition.

To facilitate further conservation planning at IBAs, we have created a Geographic Information Systems (GIS) database for New York's IBAs. This database includes various GIS themes useful for land use planning, including digitized IBA boundaries, landuse/landcover, and bird distribution data from New York's Breeding Bird Atlas. In addition, we worked with BirdLife International and National Audubon in the development of a North American version of the World Bird Database by beta testing and critiquing the database. This database will serve to better organize New York IBA information and make it available to land managers and the general public throughout the world.

Avian Research and Monitoring

Several objectives were established with regard to research and monitoring. One objective is to increase volunteer-based monitoring of IBAs, both in general and for particular species. Another objective is to conduct research for site-specific purposes.

Avian Inventory and Monitoring Teams were established to conduct surveys for species of conservation priority at 15 IBAs in 1999 and at an additional 14 IBAs in 2000. A coordinator was hired for the 2000 surveys. In cooperation with Massachusetts Audubon, surveys were conducted on many sites across New York State for grassland bird species. In cooperation with the Cornell Laboratory of Ornithology, an assessment of where Golden-winged Warblers are found in New York State, both within and outside of IBAs, was initiated. Audubon New York continues to work with National Audubon's and the Cornell Laboratory of Ornithology's BirdSource (Audubon and Cornell Lab of Ornithology 2002a) and eBird (Audubon and Cornell Lab of Ornithology 2002b) projects to develop tools for online reporting of bird sightings at IBAs and elsewhere.

Audubon New York continues to develop volunteer-based research and monitoring programs at IBAs for specific purposes. Beginning in 2001, we partnered with the Vermont Institute of Natural Science in their Mountain Birdwatch program (Vermont Institute of Natural Science 2002), which uses volunteers to monitor Bicknell's Thrush (*Catharus bicknelli*) and other high elevation birds throughout the northeastern US. In 2001, we implemented a program to monitor shorebirds at the Montezuma Wetlands Complex to provide information to the Montezuma National Wildlife Refuge about shorebird habitat through the fall migration season. In 2002, we initiated a project to inventory Cerulean Warblers (*Dendroica cerulea*) at the Hemlock and Canadice Lakes IBA in central New York and to complete an assessment of part of this IBA that may undergo selective logging in the near future.

Education and Outreach

Education is a long-term strategy for the conservation of IBAs in New York. We continue to update our IBA website (http://ny.audubon.org/iba) with the latest information on the IBA program and sites, including site descriptions, data on bird usage, and information on conservation issues. The IBA website also has been incorporated into Audubon New York's newly revised, highly visited website. A 3-panel IBA display was designed and created and has been presented at numerous meetings and multiple local environmental fairs. In addition, we have supplied the text and photos for kiosks at several IBAs (Rochester Urban Parks, Montezuma Wetlands Complex, and Niagara River Corridor). IBA information has been integrated into the development of environmental education centers at the Montezuma Wetlands Complex IBA (completion expected fall 2003) and Prospect Park IBA (grand opening was held April 26, 2002). The establishment of a fall birding competition at the Montezuma Wetlands Complex IBA is another outreach effort of Audubon New York. The Montezuma Muckrace–a day-long birding event that raises money for and awareness of bird conservation at

the IBA–was held for the sixth straight year in September 2002.

Presentations at national conferences and to local groups also have been critical to our outreach efforts. Audubon New York staff regularly attend and give presentations at several state and national conferences each year. We also give numerous IBA presentations to local Audubon chapters, bird clubs, and other groups. In addition, we often lead bird walks for groups at various IBAs and field many requests for information from the public and the media.

In the spring of 2002, we launched the Adopt-an-IBA initiative (modeled after Audubon Pennsylvania's program) in conjunction with Audubon New York's education program to encourage local organizations and Audubon chapters to implement monitoring and education programs at IBAs. Audubon New York's IBA monitoring efforts are volunteer-based, citizen science projects that provide important outreach opportunities in addition to gathering valuable data (see Avian Research and Monitoring section). We are in the process of developing bird checklists for several IBAs, including Prospect Park, Great Swamp, Montezuma Wetlands Complex, and Rochester Urban Parks, as tools for public outreach and to encourage participation in monitoring.

Bird conservation staffs continue to work with Audubon New York education staff to integrate IBA avian monitoring needs with citizen-science education efforts. To date, citizen-science monitoring efforts have focused on Prospect Park, Moriches Bay, Edith G. Read Wildlife Sanctuary, and Rensselaer Forest Tract IBAs. Projects are designed to match the skill levels of the citizen scientists. The goal is to collect useful data for the IBA program, while at the same time teaching the participants about birds, their habitats, and science.

Conclusion

Audubon New York's strategy for implementing the conservation phase of its IBA program is based on advocacy, conservation planning, research and monitoring, and education and outreach. This strategy would not be effective without the partnerships we have formed with Audubon chapters across the state, federal and state governments, other environmental organizations, and local citizens. Cultivation of this support was and continues to be one of the most important factors contributing to the success and growth of our IBA program. Outreach through media and public events has been central to increasing statewide awareness of the IBA program. While working collaboratively with various partners on the identification and conservation of IBAs has generated support and encouraged involvement in IBA-related issues.

Equally as important to Audubon New York's IBA success has been the organization's continued commitment to the IBA concept. IBAs are more than a catalog of important bird habitats in the State; they have become an organizing principle for the conservation efforts of Audubon New York and have helped focus how we utilize our limited financial and personnel resources. By promoting protection and proper management of these sites, responding to threats that require immediate action, and educating the public and others about the importance of these sites, Audubon New York continues to demonstrate its commitment to the conservation of IBAs.

Our experiences in New York State have shown that IBAs can be an effective tool for achieving bird conservation. With the generation of partner and public support, combined with an organizational commitment to the IBA concept, implementation strategies similar to what we described could be developed elsewhere with equally successful results.

Acknowledgments

The authors thank a number of people for their continued support of New York's IBA program and for recognizing the value of IBAs as a bird conservation tool. In particular, we thank D. Miller and other Audubon New York staff; F. Gill, J. Wells, D. Niven, and J. Cecil of National Audubon's Science Department; Audubon chapters across New York; and the many birders and citizens of New York who nominated and continue to advocate for IBAs. Many people have helped to improve New York's IBA program through consultation and critique, including staff within the New York State Department of Environmental Conservation and Office of Parks, Recreation and Historic Preservation; Ken Rosenberg and other staff at the Cornell Lab of Ornithology; and Audubon IBA leaders from other states. Lastly, we thank those who supported New York's IBA program by providing funding, including the Commission for Environmental Cooperation, Ellsworth Kelly Foundation, North American Fund for Environmental Cooperation, the New York State Biodiversity Research Institute, Park Foundation, HSBC, Henry Luce Foundation, New York Community Trust, Canon U.S.A. Inc., and many individual donors.

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Important Bird Areas and International Migratory Bird Day – A Beneficial Convergence in 2002[1]

Jennifer Wheeler[2] and Susan Bonfield[3]

Coming Together

International Migratory Bird Day (IMBD) was created in 1993 to increase public awareness, education, and concern for migratory birds and their habitats. As a day of recognition, it serves as both a celebration and a call to conservation action.[4] Programmatically, IMBD offers resources to celebrants in the form of a suite of promotional and educational products as well as via communication networks such as listservs and web-pages. IMBD also can provide celebrants with a focus in the form of an annual, general theme. Themes have included the importance of wetlands, the recovery of the Peregrine Falcon (*Falco peregrinus*) from an endangered status, and the role of shade-grown coffee in preserving migratory bird habitat (USFWS 2002a). In 2002, the theme for IMBD was "Celebrating Special Places for Birds," with a particular focus on Important Bird Areas (IBAs).

The IBA program was first initiated by BirdLife International – a worldwide partnership of conservation organizations that work together to conserve all wild bird species and their habitats. Launched in Europe in 1985, the program has expanded to Africa, Asia, and the Middle East. BirdLife International explains in its promotional material that the IBA Program helps to build capacity within participating organizations and involves them in specific, site-based conservation actions. Likewise, the National Audubon Society – a Birdlife International partner – includes in the U.S. IBA Program goals that it involve local communities, conservation groups, landowners and the general public (National Audubon Society 2002). Recognition of IMBD, in the form of gatherings or publicity, is an excellent means by which proponents for a particular site can engage and inform local individuals and entities in a very positive way.

What IMBD Offers to IBA Programs

The IMBD program has progressed to a point where a catalog of products is offered each year (NFWF 2002). Promotional and educational products include posters and t-shirts (portraying artwork from a well-known wildlife artist), a press kit, conservation-related activity guides and booklets, music, banners, and more. These items can be of great assistance to site proponents in event planning and publicity.

In 2002, IMBD materials integrated specific information on IBAs with assistance from representatives from BirdLife International, National Audubon Society, and American Bird Conservancy. Specifically, IBAs were defined and described on the reverse of the poster, in the press kit, and in the colorful "Exploring Habitats" booklet. The IMBD products catalog also offered IBA directories for Mexico, the United States, and the states of New York, Washington, and Pennsylvania (Wells 1998 Crossley 1999, Arizmendi and Valdelamar 2000, Cullinan 2001, American Bird Conservancy in press).

In addition to material resources, IMBD provides IBA proponents with opportunities. IMBD is an ideal occasion to dedicate a new IBA or launch a State IBA program, because it puts these events into the context of an international celebration. IMBD is also an annual opportunity to attract birders and the public to IBAs, in order to strengthen and expand awareness and support. IMBD also has yielded a wealth of ideas for events and activities over its ten years. Coordinators can choose from any number of locally-focused activities to explain IBAs and their importance to birds, especially migrants, such as bird counts and walks, talks, open houses, classroom visits, written media and displays. Moreover, a variety of audiences can be reached, including local citizens (especially children), local advocates who can serve as citizen scientists, and local decision-makers who can be instrumental to site protection.

How IMBD Celebrants Can Draw on the IBA Theme

A primary goal of IMBD, and all conservation education endeavors, is to provide audiences with a means of acting on their newfound information and concern for the resource. The IBA theme is a powerful tool in that it allows educators to point to specific ways

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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[3]National Fish and Wildlife Foundation, P.O. Box 934, 998 Blue River Parkway, Silverthorne, CO 80498.

[4]Though technically a single-day observance on the second Saturday in May, IMBD should not be viewed as limiting for events; any successful IMBD events are held on alternative dates and over multiple days.

in which inspired, concerned people can take direct action in support of migratory birds. IBAs are discrete sites with identifiable management, monitoring, and advocacy needs. By steering audiences to local IBAs, IMBD celebrants can make conservation messages tangible.

The theme of "special places" meshes well with the basic ecological concepts often forwarded by natural resource educators. A presentation on IBAs easily can segue into discussions on the definition and elements of habitat, wildlife habitat needs, and the importance of habitat protection to wildlife protection. For migratory birds specifically, the IBA Program can illustrate concepts of seasonal habitat needs, critical habitat – including stopover habitats along the migration routes, as well as geographic and demographic patterns of migration.

Finally, the IBA Program exemplifies the value of recognition programs, an approach that conservationists can apply in many situations. "Special places" may vary from those of global biological significance to a local woodlot. Regardless, the formula of site or cause designation, associated collaborations of concerned individuals and organizations, and the subsequent promotion and stewardship has universal effectiveness.

Mutual Benefits

In the wake of IMBD 2002 it is possible to make some measure of the success of "Celebrating Special Places for Birds" as a theme.

It is likely that the theme was helpful in raising awareness and adding to the momentum of IBA Programs. The logos and websites for theme sponsors – BirdLife International, National Audubon Society, and American Bird Conservancy – appeared on 75,000 posters and 40,000 catalogs distributed across the United States, Canada, and Latin America. IMBD also served as a forum for coordinators and supporters to promote IBAs, such as in radio interviews and articles in honor of the day, and several coordinators scheduled site dedication ceremonies to fall on IMBD. Via IMBD materials and hundreds of events, it is believed that IMBD activities involved two to three hundred thousand people in 2002.

Likewise, veteran IMBD celebrants drew upon the "special places" theme in their activities. A review of the IMBD Events Registry yielded a number of incidences where sites were identified as official IBAs or as "special places" – e.g., a presentation on "Bodega Bay, A Globally Important Bird Area" (Bird Rescue Center, Santa Rosa, California); a field trip to Mann Lake, an Idaho Important Bird Area (Lewiston Wildlife Habitat Area, Lewiston, Idaho); nature tours of Forest Park's "special places" (Forest Park Nature Center, Peoria Heights, Illinois); and a festival at Eastern Neck National Wildlife Refuge, an IBA (Eastern Neck NWR, Rock Hall, Maryland) (USFWS 2002b). The IBA theme provided educators with an example of an ongoing, successful movement to protect bird habitats and a means of putting into context the role of their specific site in bird conservation.

Also, the IMBD program benefited from promotional efforts by BirdLife International, National Audubon Society, and American Bird Conservancy, and through these organizations, established additional contacts with chapters and branch offices. Finally, representatives from these organizations acted as sources of ideas and expert reviewers for IMBD materials.

The Future

Work has already begun in crafting a theme for IMBD 2003; however, "A Celebration of Special Places" is not consigned to the past. The concepts of critical habitat and IBAs will continue to appear in IMBD materials (e.g., "Exploring Habitats" will be offered in future catalogs) and be advanced at IMBD events, and IBA managers will continue to have IMBD as a vehicle for rallying public support. The convergence of IBAs and IMBD will continue to be a boon to migratory bird conservation efforts.

Acknowledgments

We wish to acknowledge the sponsorship and support of the National Fish and Wildlife Foundation, the U.S. Fish and Wildlife Service, National Audubon Society and BirdLife International. We give a special thanks to those individuals – Daniel Niven, John Cecil, and Peter Stangel – who provided review of the manuscript.

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Ten Years of International Migratory Bird Day[1]

Jennifer Wheeler[2] and Susan Bonfield[3]

Introduction

Public awareness and concern are crucial components of migratory bird conservation. Citizens who are enthusiastic about birds, informed about threats, and empowered to become involved in addressing those threats can make a tremendous contribution to maintaining healthy bird populations. One of the most successful vehicles for public education on migratory birds is International Migratory Bird Day (IMBD).

IMBD, held annually on the second Saturday in May, is an invitation to celebrate and support migratory bird conservation. Like any day of recognition, IMBD exists to focus attention on a valuable resource — the nearly 350 species of migratory birds that travel between nesting habitats in North America and wintering grounds in South and Central America, Mexico, the Caribbean, and the southern U.S. IMBD was created in response to disturbing findings in the late 1980s that many of these bird species were in decline, facing a growing number of threats on their migration routes and in both their summer and winter habitats. Thus, IMBD, in addition to being a day to foster appreciation, was created as a call to action.

This article describes how IMBD has grown from a good idea to a significant, annual occurrence. It provides a brief history of IMBD, the partnerships that sustain it, and a discussion of future directions for the event.

A Retrospective

The history of IMBD is one of growth – the event was launched with a tremendous amount of energy and has continued to gather momentum over time. Below are some of the highlights in the IMBD story:

1993

- Saturday, May 8th, 1993 marked the first annual IMBD. It was conceived to "provide a platform for the numerous conservation efforts already underway through the Partners in Flight – Aves de las Americas Program, as well as to inspire others into action."
- Smithsonian Migratory Bird Center compiled The Migratory Bird Handbook, providing activists and educators with strategies, ideas, and resources.
- Partners in Flight poster with art by Kendahl Jan Jubb created for distribution.
- Considered a glowing success with 130 events in 39 states, two Canadian provinces, and several locations in Guatemala and Mexico.

1994

- An Organizer's Information and Media Packet was coordinated by Cornell Lab of Ornithology, National Audubon Society, with a Latin American version produced by Smithsonian Migratory Bird Center.
- 2,300 packets were mailed by the IMBD date.
- IMBD 1994 poster art depicting a wide variety of birds created by Kendahl Jan Jubb.
- Events tallied at about 100, in at least 30 states and 3 provinces. Drop since 1993 was likely due to reporting, as those reports received indicated increases (e.g., events doubled in Alaska).

1995

- Coordination moved to U.S. Fish and Wildlife Service (USFWS) and National Fish and Wildlife Foundation (NFWF), with major sponsorship by Phillips Petroleum Company and others. First contractor hired as a coordinator.
- New annual Organizer's Packet and IMBD-specific t-shirt developed for distribution on an order basis, and over 30,000 free IMBD 1995 posters distributed, again featuring art by Kendahl Jan Jubb.
- Promotional material touted "more than 400 events."

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California**.

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[3]National Fish and Wildlife Foundation, P.O. Box 934, 998 Blue River Parkway, Silverthorne, CO 80498.

- Focus put on the economic values of nongame birds and non-consumptive bird-related recreation.

1996

- Two separate and expanded packets produced: Organizer's Packet and Educator's Packet.
- Sales of IMBD products were initiated, including banners, t-shirts, tote-bags, pins, and stickers, on top of distribution purely by sponsorship. Over 40,000 Partners in Flight posters distributed, featuring art by Margo McNight.
- Estimates of 250 to 500 local events and "tens of thousands" of people reached by IMBD activities.
- Focus on the production of the PIF Flight Plan.

1997

- First formal products catalog produced, including promotional banners, t-shirts, pins, patches and stickers. Products distributed by USFWS.
- IMBD 1997 poster features montage of bird profiles created by Keith Hanson.
- Theme switches from "Sharing A Passion for Birds" to "Join the Flock" – encouraging measurable steps towards conservation. Concerted effort is made to offer the media "solutions."
- Substantial supplements were created for the nearly 1,500 Organizer's and Educator's Packets distributed.

1998

- Catalog published in full-color; theme was "Catch the Migration Sensation," and highlights the importance of coastal beaches to neotropical migrants.
- Artist John Sill depicts migrants on a Gulf Shore beach for IMBD 1998 poster.
- IMBD went on-line via an American Birding Association website, which included data entry.
- Approximately 24,000 posters distributed; about 500 contacts compiled on the sales list.

1999

- IMBD highlighted the critical importance of wetlands to migratory birds.
- IMBD 1999 poster illustrates wetland diversity through art by Carol Decker.
- Product sales were handled out of American Birding Association Sales Office.
- Events continued to number in the hundreds.

2000

- Art by Roger Tory Peterson featured on products. Theme was the recovery of an Endangered Species, the Peregrine Falcon.
- USFWS website, including access to Events Registry, went online.
- First IMBD Distance Learning Program by the National Conservation Training Center.
- Focused effort to tally IMBD activities supported estimate of hundreds of thousands of people reached via at least 500 public events, countless private events, distance learning and media coverage.

2001

- Theme was the benefits of shade-grown coffee, resulting in many new connections and partnerships. Artist Terry Isaac is flown to Guatemala to produce original art for IMBD 2001 poster.
- Product distribution moved to NFWF contractor in Colorado Springs; on-line ordering via NFWF website established.
- 25,000 catalogs distributed.
- Poster and education piece translated into Spanish for the first time

2002

- IMBD turned 10 years old! Theme was "Celebrating Special Places for Birds," highlighting habitat conservation especially via the Important Bird Areas programs.
- IMBD 2002 poster features a popular print "Mystery of the Missing Migrants" by artist Charley Harper.
- Approximately 40,000 catalogs and 75,000 posters distributed; about 1,500+ contacts on the sales list.
- Data from Events Registry indicates that IMBD is reaching a growing audience.

Partnerships

From its beginnings, IMBD has drawn on the ideas, talents and energies of many individuals and organizations. The principal responsibility for coordination has been shouldered by a few parties, but IMBD is an event that belongs to all who celebrate it.

IMBD's first and lasting affiliation is with Partners in Flight (PIF), recognized by the PIF logo on IMBD products. When PIF formed in 1990, education was identified as a critical element of bird conservation. Members of the PIF Information and Education Working Group and associated Task Group on Education and Outreach produced the first IMBD materials. IMBD is now considered the hallmark outreach event for PIF, and continues to be supported by partners though sponsorship, creation and review of products, promotion, coordination, and celebration. It is particularly effective when a geographic working group or partnering agency takes on local coordination, as has occurred in Colorado, Georgia, Nebraska, Georgia, and Utah, among others.

IMBD also owes much of its success to individuals and organizations not directly affiliated with PIF. For example, sponsors over the years have included Birder's World Magazine, Birdlife International, Canon, Center for Conservation Research and Technology, Eagle Optics, Harcourt Brace, Mark Feldstein and Associates, Inc, Mill Pond Press, Phillips Corporation, Sanctuary Coffee, The Summit Foundation, Swift Optics, Thanksgiving Coffee, and the Wild Bird Feeding Institute/National Bird Feeding Society (apologies to any omitted).

The American Zoo and Aquarium Association and its members have promoted and celebrated IMBD; a formal campaign in 2000 resulted in 100 facilities hosting activities, most of which continue to do so. Via an arrangement with Eagle Optics, IMBD catalogs are sent out with every order and taken to trade shows and festivals. The non-profit Kids for Saving Earth mails out catalogs supplemented with their poster. Schools and school systems have embraced IMBD; in 2001, a consortium of 23 school districts highlighted IMBD as part of their county-wide internet-based project on migratory birds. IMBD has recently partnered with the Council for Environmental Education (Project WILD) to support a new middle-school based program, Flying WILD.

IMBD belongs to all who celebrate it, and IMBD coordinators are eager to develop new partnerships that advance its goals.

Future Directions

By definition, IMBD is a single-day observance. In hindsight, perhaps it might have been easier to have International Migratory Bird Week or Month. Also, its annual date – the second Saturday in May – often conflicts with the timing of bird counts or surveys. However, these issues really aren't limiting. Event planners are encouraged to schedule activities on the date or dates best suited to the presence of migrants in their area and are certainly not discouraged from celebrating IMBD on an alternative date. The date of IMBD has intentionally been left off of IMBD products to avoid drawing attention to necessary or appropriate rescheduling. Moreover, for those skilled birders with commitments on the second Saturday in May, what better way to celebrate IMBD than to involve new enthusiasts in their activities?

More importantly, IMBD is a movement as well as a day of recognition. The materials and messages created for IMBD are useful year-round. And indeed, IMBD posters are distributed at bird walks and talks all summer long. As another example, IMBD-related educational materials, including the new Junior Birder packets have been embraced by the Girl Scouts. Wild Bird Centers and Wild Birds Unlimited shops stock IMBD items. Public festivals will always be a core element of IMBD, but providing year-round resources for migratory bird educators is also an important aspect of the program.

How secure is IMBD's future financially and organizationally? Sales of IMBD products provide income and prices are set to recover the costs of production and some development. However, an objective of IMBD coordinators is to provide celebrants, educators especially, with resources at the lowest price possible. Thus, it is likely that IMBD products development will always require sponsorship. "External" funding is also necessary to continue IMBD coordination, the bulk of which is performed under contract. However, IMBD itself has been embraced and institutionalized by many organizations. For example, the National Wildlife Refuge System holds IMBD as one of its primary observances. Many zoos and aquariums report IMBD as one of their most successful events. Festivals providing positive economic returns are unlikely to be cancelled. IMBD as an observance will persist as long as it is needed.

Has IMBD been effective? Those involved with IMBD at the time of its creation asked three questions of the program, the answers to which can help us decide if IMBD is achieving its goals.

1) Does IMBD educate the public about migratory birds: their habitats, the challenges they face, and status of their populations? Yes. The

materials and messages crafted for IMBD each year always include conservation issues (i.e., they are not limited to natural history or ornithology topics). Given the increasing size of the audience reached, IMBD has certainly been an effective vehicle for education.

2) Does it raise awareness of our biological and economic ties to Latin America? Needs Improvement. While IMBD materials and messages traditionally have focused on neotropical migrants, more could be done to directly connect northern audiences to individuals and organizations in Latin America. For example, some festivals highlight an adopted sister-city in the tropics. Or correspondence programs could be developed enabling students to communicate internationally (similar to the Shorebird Sister Schools Program). Also, it has been a challenge to provide affordable IMBD materials to Latin America to encourage them to celebrate IMBD. Additional sponsorship to support Latin American celebrants would be welcomed.

3) Does it prompt the initiation of conservation projects or supported existing ones? We don't know. A primary purpose of IMBD is to stimulate the audience to engage in activities that provide real benefits to populations of wild birds. To this end, IMBD coordinators have strived to integrate suggestions for how people can support bird conservation through specific actions. Themes of recent years promote ongoing conservation projects (e.g., shade coffee campaigns, the IBA Programs). However, no evaluations have been conducted to determine if audiences have actually changed their behaviors as a result of exposure to IMBD activities. This question is at the heart of all environmental education programs, and researchers are invited to conduct studies as a means of answering it.

Acknowledgments

The authors wish to acknowledge the sponsorship and support of the National Fish and Wildlife Foundation and the U.S. Fish and Wildlife Service. Special thanks to those individuals – M. Deinlein and T. Rich – who provided review of the manuscript.

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People, Wings, and Forests: An International Program for Conservation of Migratory Birds and their Habitats to Benefit People[1]

Jack C. Capp[2]

Introduction

One in eight bird species in the world have a real risk of becoming extinct in the next 100 years (Birdlife International 2000). About three-fourths of these species occur in forests and over half of these species suffer from severe fragmentation of their habitats. Tropical deforestation is the major reason for bird decline in the world (Youth 2003). Almost half the forests that once covered the Earth are gone, and deforestation is expanding and accelerating (Abramovitz 1998).

More than one-third of the bird species in the United States migrate to Latin America and the Caribbean each year (North American Bird Conservation Initiative 2003). For many, they spend more time south of the US than inside U.S. boundaries. Therefore, what happens outside the US will often determine if these species will survive. Yet, for most species, little information is available on what that species needs and the availability plus security of these needs in other nations. By providing the requirements of these birds outside the US we not only help save the species, we also help prevent triggered restrictions on land use in the US, as well as protect the conservation investments we have made at home.

Americans highly value their wild birds. Over 65 million Americans feed, study, watch, or hunt birds. These Americans spend over $25 billion a year in these activities (U.S. Fish and Wildlife Service 2002). Bird watching is the fastest growing activity (Cordell et al. 1999, American Birding Association 2003).

Discussion

Reasons for Concern

Most migratory birds that spend part of the year outside the US are declining. Many of these species, including the Swainson's Hawk (*Buteo swainsoni*), are declining due to disappearing and degraded habitats. Why? Because some of these habitats are in countries that lack the resources or information to adequately protect and sustain the forests, wetlands, coastlines, grasslands and other much-needed habitats. Other factors in these countries include pesticide use, invasive species, and over harvest of timber. The human population in Latin America and the Caribbean is expected to increase between 50 percent and 100 percent in the next 50 years. Worldwide, habitat loss and degradation are the major causes of endangerment of birds. Most important is the loss and fragmentation of forests, especially tropical forests. Over 75 percent of threatened bird species worldwide occur in forests (Birdlife International 2000).

Our Starting Point

In the Forest Service, we began by defining the problems and establishing conservation partnerships with organizations and agencies already committed to international conservation on the ground. First, we established criteria for targeting our work. These include:

- Habitats degraded or at high risk
- Imperiled and declining bird species
- Opportunities and needs for conservation partnerships
- Importance of Forest Service expertise
- Need for conservation of biodiversity
- Importance of birds to humans

We identified the species most declining or most at risk. We used species listed in the United States Endangered Species List, the Canadian List of Species of Conservation Concern, the Partners at Flight Strategic Plan, North American Waterfowl Management Plan, U.S. Shorebird Conservation Plan, and the North American Waterbird Conservation Plan. These lists represented the expert analyses and conclusions of conservation priorities from experts in North America's bird conservation community.

We identified biodiversity and habitat hotspots. We analyzed results of biodiversity conservation planning

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California**.

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and other work that identified habitats of greatest conservation concern and of highest bird species use. We utilized work done by The Nature Conservancy (Brooks et al. 1999). We then compared migration distribution of migratory bird species of highest concern with areas of highest biodiversity conservation concern. The combination of bird species of greatest concern occupancy of areas of highest biodiversity concern indicated where we should be working. Where conservation partners were available to collaborate on the ground we began conservation projects. Forest Service direct involvement in all projects is done to strengthen the partnership and expand Forest Service international experiences. Bird conservation work is direct or indirect. Direct is where we target funding and personnel on the ground in work to directly benefit migratory bird species, for example identifying distribution and specific habitat use of a species in another country. Indirect is where we work with another nation to, for example, establish ecological fire management to protect the forest and benefit birds, other species, and provide forest harvest or other utilization of the forest. Multi-year action plans are completed for each project with co-project managers representing the Forest Service and the coordinating partner.

Protecting U.S. Interests and Investments at Home

This program benefits the United States in several ways. First, Americans want the birds sustained that visit the US each year. Birds provide many economical, recreational, cultural, and environmental benefits. Many businesses involved with birding, bird hunting, and other enterprises depend on birds. Millions are spent each year inside the US on conservation of migratory birds. Second, if species are lost, or populations are too low due to events outside the United States, we lose our investments made at home. With diminished bird populations, especially when these species are listed or petitioned for listing under the U.S. Endangered Species Act, we lose land use opportunities here at home. Third, events and situations outside the US can trigger land use restrictions here in the US. It is in the best interests of the US to work wherever needed to prevent the need to list species under the Endangered Species list and thus prevent need to restrict natural resources management options in the US. Fourth, other nations that protect their natural resources and use them sustainably over time help; sustain their democracies and stable governments. Stable and democratic governments abroad help prevent need for U.S. economic assistance or humanitarian relief and provide economic opportunities for the US in the form of trade and sales by U.S. companies. Lessons learned by other countries can be helpful to the US in addressing our conservation and business concerns and opportunities.

Partnerships are Critical

Where organizations and governments share the same goals we have a foundation for partnerships. Working in other countries normally means we need to approach conservation in new ways from those at home. Governments, social systems, and ways of doing things are all different in different countries. Partners within other countries normally provide the best leadership and practicable knowledge for conducting conservation there. By combining United States expertise and commitment with the same in other countries conservation is more effective, efficient and sustained. Community-basing conservation in the other country is very important. We target partners that can help design, apply and sustain conservation long term on the ground based-locally. Partnerships also mean leveraging of the federal tax dollar. We always seek this leveraging.

Partnership initiatives are important. We established the Copper River Migratory Bird Initiative with Ducks Unlimited Inc, Ducks Unlimited Mexico, Forest Service Pacific Northwest Research Station, and the Alaska, Pacific Northwest, and Pacific Southwest Regions of the Forest Service. The Initiative is linking critical migratory bird stopover sites along the Pacific Coast for birds from Alaska's Copper River Delta. We have expanded the Forest Service Taking Wing Program to expand to all birds and all Forest Service program areas: National Forest System, Research and Development, State and Private Forestry, and International Programs. We have strengthened Forest Service participation and leadership in bird conservation Joint Ventures. Joint Ventures, born under the North American Waterfowl Management plan, are great working models for bird conservation at home and abroad.

Putting Resources on the Ground

It is essential that tangible work be done on the ground. Birds most threatened and habitats most threatened or diminished need help as soon as possible. Often, funding targeted for conservation is never placed in the hands of those that can make a direct difference. We emphasize that our funding be directed to projects that are locally based and spent on the ground targeted at highest field needs. Our partnership projects in year 2003 directly addressing bird conservation needs on the ground are located in over 14 countries with over 20 partners leveraging over $1.3 million of Federal dollars into over $4.0 million of leveraged funding. These countries include Brazil, Bolivia, Paraguay, Dominican Republic, Colombia, Ecuador, Panama, Mexico, Canada, Trinidad and Tobago, Belize, and the Bahamas. Indirect projects, using funding from the United States Agency for International Development and other funding are conducted in many other nations.

Our work centers on priority aspects of bird needs. Field projects in 2003 include:

- Geographic Information Systems (GIS) and landscape habitat partnership data bases,
- Wetland restoration,
- Bird habitat use research,
- Training of Latin American and Caribbean land managers,
- Encouraging shade-grown coffee,
- Teaching fire ecology and establishing fire ecology-based land management plans,
- Change detection in coastal wetlands and estuaries,
- Impact analysis of energy development and forest harvest on wetlands,
- Grassland conservation strategies and management plans,
- Writing shorebird conservation plan for Mexico,
- Bird population monitoring and teaching monitoring.

The Forest Service Can Help

The Forest Service is a conservation leader. The over 30,000 employees of the Forest Service have expertise and comprehensive skills in natural resource management and research. The agency's State and Private Forestry, Research and Development, National Forest System, and International Programs staff areas provide a vast array of skills and experience. The multiple use management experience of the agency in managing the over 190 million acres of national forests and national grasslands is in demand by nations that must use their lands for development while sustaining those lands and resources. The agency multiple-use mandate spans the spectrum from wilderness and protected area management to mining and research. Skills of the Forest Service include social, cultural, ecological, and economic studies. Programs to assist private land owners in natural resource management position the agency to help other nations dealing with private land issues.

The Future Outlook

Bird conservation is changing. Lacking, and needed, is more commitment to targeting conservation work by assessing the entire geographic range of the species. United States conservation efforts have been too focused on the United States. Recent developments like the North American Bird Conservation Initiative (NABCI), the new MOU soon to be signed among Canada, Mexico, and the United States strengthening NABCI, recent developments of the Waterbird Conservation Plan for the Americas, and the Mexico shorebird plan, all point that the needed international and landscape perspectives are gaining ground. Joint Ventures, initiated under the North American Waterfowl Management Plan are strengthening and adopting integrated, all-bird approaches. This leads them to think bigger and broader. The Sonoran Joint Venture now includes partnership collaboration with Mexico. The Atlantic Coast Joint Venture now includes Puerto Rico. Soon, other Joint Ventures will follow these leads and deliver bird conservation based on priorities throughout the ranges of the birds, and not just within the United States. Mexico is considering regionally based, landscape-oriented, biologically-driven partnership approaches, similar to the vision of NABCI and United States Joint Ventures. Our program, which we call "People, Wings, and Forests," will continue to intensively target our work and base our success on changes on the ground in the highest priority areas on the highest priority migratory bird species with action-oriented partners.

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Relative Prevalence of African Americans Among Bird Watchers[1]

John C. Robinson[2]

Abstract

The demographics of bird watchers have recently become a topic of increased interest. Race or nationality is one demographic parameter that has been discussed in some depth. This paper further quantifies the relative prevalence of African Americans among U.S. bird watchers and identifies potential barriers that may prevent African Americans from becoming bird watchers. Two questionnaires (one for bird watchers and one for African Americans) were developed and distributed from August 2000 to June 2001. One-third of the 322 respondents to the bird watching questionnaire had never met an African American bird watcher. Results indicate that the average bird watcher will meet no more than two or three African-American bird watchers over a 20-year period. The two greatest barriers to becoming a bird watcher identified by African Americans were "No interest in birds" and "No friends to teach me how to study birds." Only ten (27 percent) of the 37 African Americans who identified themselves as non-bird watchers had ever met someone who was a bird watcher, and two-thirds of all African Americans responding to the questionnaire had never met a bird watcher. The results of this study were compared with demographic data collected through the National Survey on Recreation and the Environment and with U.S. Census Bureau population growth projections. The proportion of African Americans who participate in bird watching is smaller than the proportion of African Americans in the U.S. population. The importance of these findings in light of our society's increasing cultural diversity is highlighted. Recommendations are provided for future studies on this topic.

Key words: African American, bird watcher, cultural diversity, demographics, recreation barrier.

Introduction

The demographics of bird watchers have become a topic of increased interest in recent years. Race or nationality is one demographic parameter that has been discussed in some depth. For example, in the February 1999 and October 1999 issues of *Birding* magazine, a number of letters to the editor were written on this very topic (Baicich 1999a, 1999b).

The discussions centering around the race or nationality of bird watchers is but a subset of a larger concern currently being expressed about the race or nationality of people who develop an interest in the environment and its natural resources, both within and outside of North America. For example, discussions similar to the ones voiced in the 1999 issues of *Birding* magazine have been documented within the National Audubon Society (Flicker 1999), the National Park Service (Wilkinson 2000), the North American Butterfly Association (Glassberg 2000), and a birding and ornithological organization in Australia called "Birds Australia" (Harrington 2001).

One theme that is consistent across many of these discussions is recognition of the increasing cultural diversity of our society. It has been estimated by some demographers that nine out of every ten people added to the U.S. population by 2050 will be of a nonwhite nationality (Murdock 1995, Wilkinson 2000). It has been found that recreational preferences and environmental opinions held by individuals in our society differ substantively between social strata. Moreover, these society-wide demands and attitudes will fluctuate as proportions of our national population shift among these social strata over time (Cordell et al. 2002). Recognizing the political influence that nonwhites will have in the not-too-distant future is critical to understanding why more attention should be focused now on understanding what nonwhites' views of the environment and our natural resources are.

Except for American Indians, all four nonwhite demographic groups (Black, Hispanic, American Indian, and Asian) are under-represented among bird watchers compared to their respective representation among the 2000-2001 U.S. population that was sampled by the National Survey on Recreation and the Environment (NSRE 2000-2002). The objectives of this paper are to further quantify the relative prevalence of African Americans among U.S. bird watchers and to identify potential barriers that may prevent African Americans from becoming bird watchers. Information gleaned from this study may be applicable to other nonwhite groups (e.g., Hispanics, American Indians, and Asians) and/or other resource or recreational areas besides birds and bird watching.

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[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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Materials and Methods

In the fall of 2000, two questionnaires were developed. Bird watchers comprised the intended audience for the first questionnaire (*fig. 1*), which will henceforth be called the "Bird Watcher Questionnaire". This questionnaire was designed to have the respondent identify how many African American birders she or he had met and in what state(s) or Canadian provinces those encounters took place. From August 2000 through June 2001, this questionnaire was taken to birding festivals and local National Audubon Society chapter meetings, where it was distributed to bird watchers. In addition, the American Birding Association posted the questionnaire on its web site, where it was available from November 2000 through May 2001 for bird watchers to download and fill out. All completed questionnaires were returned to the author. No attempt was made to identify in advance whether each recipient of this questionnaire had ever met an African American bird watcher.

Also, in the fall of 2000, a second questionnaire (*fig. 2*) designed exclusively for African Americans was developed for the purpose of validating the assumption that relatively few African Americans participate in the outdoor recreational activity known as bird watching. This questionnaire (hereafter "African American Questionnaire") was distributed by postal mail and e-mail to a limited number of African Americans between October 2000 and May 2001. Respondents to this second questionnaire did not necessarily have to be bird watchers, and in fact no attempt was made to identify in advance whether each recipient of this questionnaire was a bird watcher. Each African American was asked to identify a) whether she considered herself a bird watcher; b) any barriers that may have precluded her from becoming a bird watcher; and c) the level of interest she had in the outdoors and the environment, biology, and birds. Note that the term "bird watcher," as used in this study, is defined as "someone who spends approximately 3-5 d each mo watching birds with a pair of binoculars and a bird field identification guide."

All data from these two convenience samples were entered into a Microsoft Access database for purposes of analysis. During the analysis, we compared the results from these questionnaires with the larger data sets developed by the National Survey on Recreation and the Environment project (NSRE 2000-2002). For both questionnaires, response rates were not measured and non-respondent checks were not conducted.

Results

Bird Watcher Questionnaire

A total of 322 respondents returned the Bird Watcher Questionnaire. Responses were received from 36 states, the District of Columbia, and Ontario province in Canada.

The average number of years spent bird watching by the 322 respondents was 20.57 and ranged from 1 to 74 years (*table 1*). Of the 322 respondents, 111 (34 percent) of them had never met an African American birder. The average number of African American bird watchers met by the 322 respondents was 2.38, and ranged from 0 to 19, with one outlying record of 120 African American bird watchers met by one individual (*table 1*).

Table 2 displays information about encounters bird watchers had with African Americans who were also bird watchers. Of the 757 encounters, 197 (26 percent) of them took place in California, and 116 (15 percent) of them took place in the District of Columbia. Twenty five (3 percent) of these encounters took place somewhere outside of North America. Eighteen (2 percent) of these encounters took place within North America at locations that could not be remembered by the respondents.

Table 1— *Number of years respondents have spent bird watching and number of African American bird watchers encountered*

	Number of years spent bird watching	Number of African American bird watchers encountered
Average (*N*)	20.57 (322)	2.38 (322)
Standard deviation (variance)	14.63 (214.09)	7.14 (50.99)
Range	1 - 74	0 – 19 (one record of 120)

How many years have you been birdwatching? _____

What is your state (or Province) of residence? _____ (If you live outside of North America, simply list your country of residence)

Have you ever met a black (African American) bird watcher? _____ Yes _____ No

If Yes, approximately how many black birders have you met? _____

If Yes, of the total listed above (and to the best of your memory), please indicate below how many black birders you have met in the following states or Canadian provinces ***(enter your #'s to the left of the state designations!)***:

_____ Alberta _____ AK _____ AL _____ AR _____ AZ _____ British Columbia _____ CA _____ CO _____ CT

_____ DE _____ FL _____ GA _____ HI _____ IA _____ ID _____ IL _____ IN _____ KS _____ KY _____ LA

_____ MA _____ Manitoba _____ MD _____ ME _____ MI _____ MN _____ MO _____ MS _____ MT

_____ New Brunswick _____ NC _____ ND _____ NE _____ Newfoundland _____ NH _____ NJ _____ NM

_____ Nova Scotia _____ NV _____ Northwest Territories _____ NY _____ OH _____ OK _____ Ontario

_____ OR _____ PA _____ Prince Edward Island _____ Quebec _____ RI _____ Saskatchewan _____ SC

_____ SD _____ TN _____ TX _____ UT _____ VA _____ VT _____ WA _____ WI _____ WV _____ WY

_____ Yukon Territory

Have you ever met one or more other minority birders in North America? _____ Yes _____ No

If so, please indicate the race/national origin of other minority birders you have met (you may check more than one):

○ American Indian or Alaska Native ○ Asian or Pacific Islander ○ Hispanic

○ Other. **Please specify:** _____

Your comments are welcome! If you have any comments, you may record them here:

OPTIONAL:
Your Name: _____ Phone Number: _____

Mailing Address: _____

E-mail Address: _____

Figure 1— Bird Watcher Questionnaire

Official Author Research Form

What is your educational background? *Please check one*
_____ 12 Years or Less _____ 13-16 Years _____ 17-20 Years _____ More than 20 Years _____
What is your income range? *Please check one*
_____ Less than $10,000.00 _____ $10,001.00 - $20,000.00 per year
_____ $20,001.00 - $30,000.00 per year _____ $30,001.00 - $40,000.00 per year
_____ $40,001.00 - $50,000.00 per year _____ $50,001.00 - $60,000.00 per year
_____ $60,001.00 - $70,000.00 per year _____ $70,001.00 or more per year
What State or Province do you live in? _____ What is your sex? _____ F _____ M
What is your age?_____
How would you define your occupation?
_____ Professional, Technical, or Managerial Occupation
_____ Clerical and/or Sales Occupations
_____ Service-oriented Operations
_____ Agricultural, Fishery, Forestry, and Related Occupations
_____ Processing and/or Refining Wood, Metal, Food, Ore, or Other Products
_____ Machinist/Machine Operator
_____ Product Fabrication, Assembly, and Repair
_____ Construction, Electrical Assembly & Repair, and Painting
_____ Student
_____ Other. **Please Specify:** _____
Do you have a membership in a local birding club or organization? _____ Yes _____ No
If Yes, please print the name of the club or organization: _____
Do you have a membership in a national conservation society (e.g., the Audubon Society, or the National Wildlife Federation)? _____ Yes _____ No
If Yes, please print the name of the conservation society: _____
How many different birds do you know by name? _____ 1-5 _____ 6-10 _____ 11-20 _____ 21 or more
Do you feed birds with a bird feeder? _____ Yes _____ No
On average, how many visits to state parks, national parks, or wildlife refuges do you make each year? ____
On average, how many days do you spend camping each year? _____
How would you describe your interest in the **outdoors and the environment**?
_____ Low _____ Low-Medium _____ Medium _____ Medium-High _____ High
How would you describe your interest in **biology**?
_____ Low _____ Low-Medium _____ Medium _____ Medium-High _____ High
How would you describe your interest in **birds**?
_____ Low _____ Low-Medium _____ Medium _____ Medium-High _____ High
(Note: a bird watcher is someone who spends approximately 3-5 days each month watching birds with a pair of binoculars and a bird field identification guide)
Do you classify yourself as a bird watcher? _____ Yes _____ No
If not, what do you feel has been the **greatest** barrier to your becoming a bird watcher (check one)?
_____ No interest in birds
_____ No friends to teach me how to study birds
_____ I don't understand why one would want to study birds
_____ Lack of interest in the outdoors and the environment
_____ Other. **Please specify:** _____
Have you ever met a bird watcher? _____ Yes _____ No
If Yes, how many have you met? _____ 1-5 _____ 6-10 _____ 11-20 _____ 21 or more

Figure 2— Questionnaire for African Americans

Table 2— *Number of encounters with African American bird watchers reported by birders who filled out the bird watcher questionnaire.*

Name of state where encounter took place	Number of African American bird watchers met
California	197
District of Columbia	116
Texas	36
Florida	34
Pennsylvania	33
Illinois	29
Outside of North America	25
Arizona, Maryland	23
New Jersey, New York	22
Unknown	18
Virginia, Washington	17
Massachusetts, Indiana	13
North Carolina	12
Wisconsin	11
South Carolina	10
Missouri	9
Colorado	9
Delaware	7
Minnesota, Michigan	6
Oregon, Louisiana, Ontario, Ohio	5
New Mexico, Tennessee, Georgia	4
Arkansas	3
Kansas, British Columbia, West Virginia	2
Connecticut, Utah, Nebraska, Kentucky, Manitoba, Alaska, Oklahoma, New Hampshire, Nevada	1

African American Questionnaire

There were 42 respondents to the African American Questionnaire; 31 were female, 11 were male. Four (9 percent) reported membership in a local birding club or organization; six (14 percent) reported membership in a national conservation society. Two (4.7 percent) respondents stated that they knew no birds by name, while the majority of respondents (71 percent) stated that they could recognize between one and ten birds by name (*table 3*). Of the six who stated that they could recognize 21 or more birds by name, 4 identified themselves as bird watchers.

Table 3— *Number of birds that respondents to the African American Questionnaire could identify by name.*

Number of birds respondents knew by name	Number of respondents
Zero	2
One to Five	19
Six to Ten	11
Eleven to Twenty	4
Twenty-one or More	6

African Americans' views of the outdoors and the environment, biology, and birds, as sampled by this study, are displayed. Nearly half of the African Americans expressed a "medium-high" or "high" level of interest in the outdoors and the environment. However, only 30 percent of African Americans expressed a medium-high or high interest in biology, and even fewer (26 percent) expressed such an interest in birds. Over 50 percent of the respondents reported a low or low-medium level of interest in birds (*table 4*). Of the 42 respondents, 28 (67 percent) African Americans have never met a bird watcher (*table 5*). Only 5 (11.9 percent) respondents had met 21 or more bird watchers. Four of the 5 respondents who had met 21 or more bird watchers also identified themselves as being a bird watcher (the fifth respondent identified "time" as being the greatest barrier to his becoming a bird watcher). Only 2 African Americans claimed to have met between 6 and 20 bird watchers; both of these individuals identified themselves as not being bird watchers.

Periodically, several Federal agencies, professional associations, private organizations, and industries collaborate to conduct a survey of the recreational interests of the American people; this survey has become known as the National Survey on Recreation and the Environment (NSRE). The two most recent NSRE surveys occurred in 1994-1995 and 2000-2001 (NSRE 2000-2002). Seventeen thousand people were involved in the 1994-1995 survey, and up to 50,000 people were surveyed in the 2000-2001 survey. One focus of the NSRE surveys is the growing popularity of birding. Note that a bird watcher in the NSRE study is defined as a person who has participated in out-of-doors birding (regardless of the level of dedication to the activity) at least once during the preceding 12 mo covered by each of the surveys.

The NSRE (NSRE 2000-2002) found that 8.4 percent of bird watchers were African Americans in 1994-1995 and that 8.2 percent of bird watchers were African Americans in 2000-2001. In contrast, the proportion of the U.S. population (based on the 1990 and 2000 census) comprised of African Americans was much higher, ranging from 11.7 percent in 1990 to 12.3 percent in 2000 (U.S. Census Bureau 1990 and U.S. Census Bureau 2000a); moreover, the percentage of bird watchers who were

Table 4— *African Americans' range of interest in the outdoors and the environment, biology, and birds.*

Interest category	Number of respondents				
	Low	Low-medium	Medium	Medium-high	High
Outdoors and the Environment	8	5	11	10	8
Biology	8	9	12	9	4
Birds	14	8	9	7	4

Table 5— *Number of bird watchers met by African Americans*

Number of bird watchers met	Number of respondents (Number of respondents who are bird watchers)
Zero	28 (1)
One to Five	7 (0)
Six to Ten	1 (0)
Eleven to Twenty	1 (0)
Twenty-one or More	5 (4)

African American actually dropped between 1995 and 2001, even while the proportion of African Americans in the general population increased over the 1990-2000 period.

By way of comparison, 86.3 percent of bird watchers were Caucasian in 1994-1995, and 77.4 percent of bird watchers were Caucasian in 2000-2001 (NSRE 2000-2002). In contrast, the proportion of the U.S. population (based on the 1990 and 2000 census) comprised of Caucasians was lower, ranging from 75.6 percent in 1990 to 69.8 percent in 2000 (U.S. Census Bureau 1990 and U.S. Census Bureau 2000a); moreover, the percentage of bird watchers who were Caucasian declined between 1995 and 2001, consistent with a decrease in the proportion of Caucasians in the general population over the 1990-2000 period.

Discussion

Based on the results displayed above, it is pertinent to examine what bird watchers are telling us and what African Americans are telling us. Only then will we be able to see what society as a whole is telling us, and that will show us where we go next.

What Are Bird Watchers Telling Us?

Only two-thirds of the bird-watching respondents in this study had ever met one or more African American bird watchers. The author, himself an African American bird watcher, could only recall meeting three other African American bird watchers between 1979 and 2000, prior to the initiation of this study. Eight respondents reported they had been bird watching for 60 or more years and had a total of 509 years of bird watching experience among them; however, these eight respondents, collectively, could only remember having met 23 African American bird watchers, which is the equivalent of meeting one African American bird watcher every 22.1 years. One respondent estimates that of the 30,000 bird watchers he has met in North America, only about 12 have been African Americans. Another respondent who has led more than 600 birding tours has met only 2 African American bird watchers out of the 2,700 birders who participated on his tours. On average, based on the results of this study, most birders who remain active in bird watching for 20 years or more will meet fewer than three African American bird watchers during that time period (*table 1*).

The majority (over 89 percent) of African Americans in the United States reside in the southeastern or northeastern regions of the country, especially the area extending from eastern Texas to New York city (Cordell et al. 2002). Given this fact, one may ask if there are any locations in the United States where one is more likely to find African American bird watchers. The sampling size and sampling methodology used in this study is admittedly a convenience sample and is not considered robust enough to definitively answer this question; however, what data we do have indicates that California, the eastern section, and the southern section of the United States are where most encounters with African American bird watchers took place. However, the large number of encounters reported from California (*table 2*) is due in part to the correspondingly large sample (99 responses) received from that state and may not indicate that proportionately more African American bird watchers reside in California or travel to California as a birding destination.

Respondents had the opportunity to provide comments on their completed questionnaire. Of the 322 respondents, 159 provided detailed comments. These comments broadly fall into three categories:

What's the Point?

Commenters in this category essentially feel that bird watching is simply something that African Americans do not do, or that there is no significance to the apparent lack of participation by African Americans in bird watching. Many commenters in this category feel it is "futile and insulting ... to fret and scheme about the present."

Barriers are the Explanation

Commenters in this category recognize the lack of participation by African Americans in bird watching and attempt to explain this phenomenon. Barriers that are identified by these individuals include social and economic pressures or the lack of a role model. One respondent writes, "... once a Black ... person admits to being a 'birder,' they have broken with the image they are expected to maintain to belong to the Black [subculture], ... and have instead aligned themselves with the white majority. Being unique in a group you are otherwise expected to belong to is very difficult." Another respondent states the insufficient number of role models is "the most important factor" that would explain the relative absence of African Americans among bird watchers. To visualize the impact of role models, one need only look at the game of golf, where the number of African American fans of that sport increased between 1995 and 2001 by as much as 221.9 percent—more than any other ethnic group. This is likely the result of Tiger Woods' popularity, which has escalated by 177 percent over the 4-year period ending in 2001 (Beckwith 2001).

Call to Action

Commenters in this category not only recognize the lack of participation by African Americans in bird watching, but they also feel there is a compelling reason to initiate outreach programs to encourage more Blacks and other minorities to participate in bird watching. One respondent writes that conservationists "expend so much effort trying to expose the majority of our population to wildlife/wilderness experiences in the hopes they will want to preserve it." Another respondent states that, "It's so much that I would like to encourage more minorities to bird. I think further inclusion and engagement in conservation is key to truly creating sustainable communities."

The comment categories listed above are not unlike the comments made by readers in the February and October 1999 issues of *Birding* (Baicich 1999a and Baicich 1999b). For example, Martin Reid (*Birding* 31[1]:12) identifies a call to action when he writes, "in some parts of our country, to leave minorities from our 'club' is to alienate the local majority who will decide the fate of that which we love." In contrast, Jim Vardaman (*Birding* 31[5]:406) expressed amazement at the idea that birders have a responsibility to assure that others participate in bird watching; Mr. Vardaman believes that, "Persons choose a hobby because something fascinates them. It is impossible to instill this fascination in anyone else." Lamar Gore (*Birding* 31[5]:406), himself an African American birder, offered a list of some barriers he has seen or experienced that explain the relative lack of African Americans among bird watchers. Mr. Gore felt that "The market has to make a conscious decision to seek out and court other groups .... A change in advertising and possible programs scheduled in the right areas, along with support from Blacks who back this effort, can change everything."

What Are African Americans Telling Us?

At its most basic level, bird watching is a social event. By that we mean that one often becomes a bird watcher by virtue of having met others who also watch birds. While it is true that numerous bird watchers prefer to watch and study birds in solitude, many of these individuals most likely got started in birding as a result of having been introduced to it by someone else.

Based on the NSRE studies (NSRE 2000-2002), it has already been documented that the proportion of African Americans who participate in bird watching is smaller than the proportion of African Americans in the U.S. population. As a result, the small sample (N=42) of African Americans included in this study was used primarily to provide an initial barometer of African American's views of the outdoors and the environment, especially birding. It is believed that with a greater understanding of these issues, we can began to identify the barriers that preclude African Americans from participating in bird watching and even begin to effect some solutions.

In general, based on the results of this study, it appears that African Americans are victims of a "Don't Loop" phenomenon with respect to their level of participation in bird watching. The Don't Loop works as follows: if you don't meet others who are engaged in a particular activity, the odds are you will not take interest in that activity yourself. For example, membership in local or national birding clubs or conservation organizations was one question that African Americans responded to on the questionnaire. Less than 15 percent of the respondents reported any ties to a national conservation organization, and less than 10 percent of the respondents had a membership in a local organization. Because people do not usually become active in bird watching unless they are introduced to it by a friend or family member, the low membership rate in local and national birding and conservation organizations reported here by African Americans more than likely merits further investigation.

The Don't Loop is also evident in many of the other questions we asked on the African American Questionnaire. Two-thirds of the respondents, for example, had never met a bird watcher and only one of the respondents in this category identified himself as a bird watcher. In contrast, of the seven respondents who had met six or more bird watchers, four identified themselves as being bird watchers (*table 5*).

The Don't Loop epitomizes the barriers that African Americans face in becoming bird watchers. Over half of the respondents stated they had "No interest in birds" or did not "understand why one would want to study birds"; yet only three of these respondents had ever met a bird watcher themselves—yet another example of the Don't Loop in action (*table 6*). Seven other respondents identified lack of a friend (a.k.a., role model) as the most significant barrier to becoming a bird watcher (*table 6*).

It must be recognized that disproportionate nonparticipation by African Americans in bird watching is not a novel phenomenon. Aside from walking and outdoor team sports, African Americans are significantly underrepresented across a wide array of outdoor recreational activities ranging from swimming and hiking to downhill skiing and big game hunting (Cordell et al. 2002).

Most of the respondents in this study expressed a Medium, Medium-High, or High level of interest in the outdoors and the environment. This is consistent with the finding that most Americans are of the environmental opinion that the balance of nature is delicate and that humans are significantly impacting the natural environment (Cordell et al. 2002). However, African Americans surveyed as part of the NSRE feel more so than other groups ($P < 0.001$) that we are not approaching the limit to the number of people who can inhabit the earth and that we (humans) have a right to modify, control, and rule over nature (Cordell et al. 2002). This is but one example of how environmental opinions differ across social strata.

In the current study, the level of interest in the environment expressed by African Americans declines when we begin to focus on specific aspects of the outdoors, such as biology or birds (*table 4*). Nevertheless, given that over two-thirds of the African Americans in this study expressed a Medium, Medium-High, or High level of interest in the outdoors and the environment, the potential exists for more African Americans to express an interest in birds. Such a change in interest in birds would not be unprecedented: the NSRE (NSRE 2000-2002) documented an 8.9 percentage point increase in the proportion of bird watchers who are of Hispanic origin between 1995 and 2001; during this period, Hispanics accounted for 39.6 percent of the total growth in bird watchers across North America.

What Are Other Researchers Telling Us?

The study of racial and ethnic minority participation in leisure or recreational activities has been a focus of social scientist researchers only since about the 1960s (Floyd 1999). Bird watching is among the list of "viewing- and learning-oriented activities" that are most popular as an outdoor recreational pursuit, as measured by the number of people reporting they had participated in one or more of those types of activities (Cordell et al. 1999). In light of this statistic, is it possible to explain why apparently so few African Americans participate in bird watching as a recreational activity? A number of theories and explanations can be brought to bear on this question, and some of them are described here.

Floyd (1999), in a review of social science literature on racial and ethnic minority use of the National Park System, describes four theoretical paradigms that describe use of national parks and participation in outdoor recreation activities by minority populations.

The Marginality Hypothesis states that limited access to socioeconomic resources (e.g., income or transportation) explains the low participation rate in wildland recreation among ethnic minorities.

The idea that "racial and ethnic differences in recreation behaviors can be attributed to different norms, value systems, and socialization practices adhered to by racial and ethnic groups" is the basis for the Subcultural Hypothesis.

When the cultural characteristics of a majority population have been "acquired" by a minority population, cultural assimilation is said to have occurred. The Assimilation Hypothesis holds that individual members of an ethnic group exhibit varying degrees of cultural assimilation, which is why patterns of recreation participation differ between cultural groups.

Finally, the Discrimination Hypothesis asserts that experiences with (or perceptions of) discrimination help to explain a lower visitation rate to National Parks among racial and ethnic minorities.

Table 6—*Barriers that African Americans Identified as preventing them from becoming bird watchers.*

Name of barrier	Number of respondents (Number of respondents who have met a bird watcher)
No interest in birds	20 (3)
No friends to teach me how to study birds	7 (4)
Other	5 (2)
Lack of interest in the outdoors and the environment	3 (1)
I don't understand why one would want to study birds	2 (0)

It is possible that the theories described by Floyd (1999) to help explain the usage rates of National Parks by minority and ethnic groups may also have some bearing on the relative absence of African Americans among bird watchers. For example, among the comments to the Bird Watching questionnaire in thus study, one can find references to discrimination and "assimilation" as possible explanations of why more African Americans are not involved with bird watching.

Johnson (1999), Hutchison (1993), and other researchers have postulated the idea that an environmental ethic may exist among some cultural and ethnic groups and that this ethic may be different from the land ethic that is the basis for resource conservation in North America; this may even be the case among people of cultural and ethnic groups who have been in the United States for several generations. In his study of a Hmong population in northern Wisconsin, Hutchison (1993) found that the Hmong undoubtedly retained an ethnic subculture that was distinctly different from the dominant culture found in American society.

Differences in cultural patterns can help explain the variance in behavioral and psychological characteristics attributed to different culture groups. Four such patterns have been identified as key descriptors that help explain the differences in leisure and environmental orientation among different cultures (Simcox 1993). These descriptors include a) World View, b) Time Orientation, c) Activity Orientation, and d) Relationship to Self and others. Simcox (1993) provides detailed explanations for each of these descriptors and concludes that Western cultural patterns (which govern the infrastructure of many recreational opportunities in the United States) are notably different from other cultural patterns and may therefore have an impact on how successfully recreational activities available in the United States will meet the needs of a diverse cultural public.

Finally, as we continue our attempts to understand the differences in participation rates for various recreational activities among various ethnic and minority groups, it behooves us not to bias our studies from the outset by assuming the activities of any one culture can be considered the norm (Floyd 1999; Gramann 1996). For example, participation by Caucasians in bird watching activities could just as easily be described as "over-representation" or "over-participation."

Where Do We Go Next?

This study took a two-pronged approach towards investigating the relative prevalence of African Americans among bird watchers. It used one questionnaire (*fig. 1*) to sample active bird watchers across the United States in an attempt to quantify how frequently the average birder encounters an African American bird watcher. A second questionnaire (*fig. 2*) was targeted for African Americans and attempted to ascertain the views and attitudes this social class has towards the outdoors and the environment, biology, and birds; it also focused on identifying barriers that African Americans face in becoming bird watchers.

We recognize that this study is but an initial step toward understanding the social and political contexts of this issue. It is recommended that a more robust sample of African Americans that is statistically significant and scientifically defendable be undertaken, using the same questionnaire created for this study. In addition, this more robust sample of African Americans should be supplemented by detailed interviews of selected African Americans, including those who identify themselves as bird watchers and those who do not. These efforts will result in a more focused delineation of the barriers to becoming bird watchers that African Americans face and will facilitate the identification of one or more solutions.

We also recommend that, if at all possible, a fully randomized sample of bird watchers be completed using the Bird Watcher Questionnaire (*fig. 1*) to repeat this study with increased scientific rigor. By comparing the results of this study with one that is completely randomized, we can more confidently quantify the relative prevalence of African Americans among bird watchers. For example, although the NSRE (NSRE 2000-2002) reported that currently 8.2 percent of bird watchers are African Americans, their definition of a bird watcher included anyone who had spent as few as one d watching birds over a 12 mo period; thus, it was found that an even smaller percentage of African Americans participate in bird watching six or more d each yr. The NSRE referred to this category of bird watcher as either *Active Birders* (who spend 6-50 d a yr engaged in bird watching activities) or *Enthusiast Birders* (who spend more than 50 d birding each yr). Currently, Caucasians make up a large percentage of all *Active* and *Enthusiast* birders. Indeed, the definition of *bird watcher* may influence how many respondents categorize themselves as bird watchers.

We recommend that others who initiate studies in this area must eventually expand the scope of their efforts to include other ethnic groups. For example, prior to the 2000 census, the U.S. Census Bureau (2000b) released projections of the resident U.S. population by age, sex, and race over the next 100 years. Looking at the data for just the next 60 years, the Bureau estimated that the proportion of the population made up of nonwhite races would increase while the proportion of whites in the U.S. population would decline over the same time period (*table 7*).

By 2061, it is expected that the proportion of the U.S. population made up of Asians will more than double in

size; the proportion of the U.S. population made up of Hispanics will also more than double in size; and that the proportion of the U.S. population made up of African Americans will increase by about 1 percent. Interestingly, the 2000 census revealed that this trend has already begun, with the proportion of Asians increasing from 2.8 percent in 1990 to 4.0 percent in 2000 in conjunction with a 5.8 percent decrease among whites. In fact, based on the 2000 census, whites are already below the 71 percent projection forecast for 2001 (*table 7*). If these trends continue, then the question posed by Wilkinson (2000) is an important one: "In the future, if *parks* are not relevant to people, then how relevant will they be to the lawmakers those people elect?" (Emphasis added; simply substitute "birds" for "parks" to make this question relevant to the study of birds and bird watching).

Environmental opinions held by members of our society are not static; rather, they vary over time and across social strata. One key variable affecting the shifts in environmental opinions is the rising proportion of Hispanics, Blacks, Asians, and people who are born in another country; in just 50 years, these peoples will comprise approximately 47 percent of the U.S. population (Cordell et al. 2002). This is why recognizing the political influence that nonwhites will have in the not-too-distant future is critical to understanding why more attention should be focused now on understanding what nonwhites' views of the environment and our natural resources are.

Acknowledgments

I wish to thank P. Baicich, Dr. H. K. Cordell, Dr. C. J. Ralph, the American Birding Association, and various National Audubon Society chapters for their assistance in collecting some of the data presented in this paper.

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Table 7— U.S. population demographics, by race, for the 2000 census and projections[1] up to the year 2061

	White	African American	American Indian and Alaska Native	Asian and Pacific Islander	Hispanic
1990 Census	75.6	11.7	0.7	2.8	9.0
2000 Census	69.8	12.3	1.0	4.0	12.5
Projected 2001	71.0	12.2	0.7	4.0	12.1
Projected 2010	67.3	12.5	0.8	4.8	14.6
Projected 2031	59.7	13.0	0.8	6.8	19.7
Projected 2040	56.3	13.1	0.8	7.8	21.9
Projected 2061	49.3	13.3	0.8	9.9	26.8

Note: All figures represent percentages of the population made up of the identified demographic groups.
[1]Projections shown are based on the 1 April 1990 decennial census and were released prior to the 1 April 2000 decennial census.

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