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Strategies for Bird Conservation: The Partners in Flight Planning Process

Proceedings of the 3rd Partners in Flight Workshop
Cape May, New Jersey
October 1-5, 1995

Abstract

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This volume represents a compilation of papers presented at the 3rd International Partners in Flight Workshop held October 1-5, 1995, at the Grand Hotel in Cape May, NJ. The title of the workshop was "Partners in Flight Conservation Plan: Building Consensus for Action." Manuscripts have been available on-line at the Cornell Laboratory of Ornithology web site (http://birds.cornell.edu/pifcapemay) since the year 1999, and the majority of them have been updated recently to reflect knowledge available by the 2000 publication date. The volume is divided into seven sections that range from general planning considerations to a case study in bird conservation planning. References from all papers are compiled in a single "References" section at the end of the volume.

Keywords: Neotropical migratory birds, conservation, habitat management, ecology, Partners in Flight, cooperation

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Ogden, UT
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Foreword

As an early and active supporter of the Partners in Flight program and publisher for the Second International PIF Conference held in 1992 at Estes Park, Colorado (Finch and Stangel [eds.] 1993, Status and Management of Neotropical Migratory Birds, Rocky Mountain Research Station, Fort Collins, CO), the Rocky Mountain Research Station is pleased to publish this Proceedings. Layout, production, and printing was financed by the Station's Albuquerque Forestry Sciences Laboratory in cooperation with the Station's Ogden Office of Publishing Services. Numerous agencies, organizations, and individuals, however, have contributed to the production of the conference and proceedings, and readers are reminded that Partners in Flight is a program that crosses organizational, political, and other boundaries in its cooperative efforts to conserve birds.

Deborah M. Finch
Rocky Mountain Research Station
Albuquerque, New Mexico

Preface

"Strategies For Bird Conservation: The Partners in Flight Planning Process" is the proceedings of the 1995 Partners in Flight (PIF) International Workshop, "Partners in Flight Conservation Plan: Building Consensus for Action," held October 1-5, 1995, at the Grand Hotel in Cape May, New Jersey.

The workshop, constituting the third International Partners in Flight conference, was organized by the PIF Management Steering Committee to develop a blueprint for building a coherent, large-scale bird conservation Plan. The PIF management committee hoped to build consensus for the plan by involving all states and regions in developing one coordinated effort to maintain bird populations nationwide and beyond. More than 700 people attended the workshop, including biologists, researchers, educators, natural resource managers, and industry representatives.

The workshop had three main objectives:

1. To train wildlife biologists, land managers, education specialists, administrators, and other professionals involved in the long-term protection of landbirds in current knowledge of landbird research, monitoring, management, education, and on-the-ground conservation.

2. To devise a mechanism for developing regional bird conservation plans, and an overall national plan, by coordinating the actions and desires of all geographical and technical working groups.

3. To begin the planning process by setting goals, objectives, and timelines; to assign tasks; and to help four newly hired PIF coordinators get their work under way.

Now, five years later, much of what we dreamed about at Cape May has become reality. Bird Conservation Plans for virtually all of the continental United States are being completed. Implementation of ambitious conservation recommendations is under way, and new partnerships are developing that should result in the resources necessary to greatly speed the rate of implementation.

But even though the process is well along, the invited papers presented at the Cape May workshop stand as important, often unique, tools and references for conservation planning. They are presented here as a permanent reference and record.

None of the papers are printed exactly as they were presented. Many have been completely revised to update information and changes during the past four years. Some represent combinations of two or more papers that were presented separately at the workshop. Two are brand new. All of them have been peer reviewed, accepted for inclusion, and modified through an intensive editorial process to ensure that this publication is a worthy and useful product of the PIF planning process.

We are indebted to many people who made this workshop happen. First and foremost is Sharon Paul, who served as conference coordinator. The planning committee, chaired by Rick Bonney, Larry Niles, and David Pashley, included Amanda Dey, New Jersey Division of Fish, Game, and Wildlife; Naomi Edelson, International Association of Fish and Wildlife Agencies; Martha Fischer, Cornell Lab of Ornithology; Brad Jacobs, Missouri Department of Conservation; Dick Jahowski, National Biological Service; Dan Petit, U.S. Fish and Wildlife Service; Debbie Pressman, USDA Forest Service; C. J. Ralph, USDA Forest Service; Terry Rich, Bureau of Land Management; Roberta Roca, The Nature Conservancy; and Marcia Wilson, National Biological Service. Session moderators were Rick Bates, Rick Bonney, Greg Butcher, Susan Carlson, Bob Cooper, Naomi Edelson, Chuck Hunter, Brad Jacobs, Stephanie Jones, Madge Lindsay, Jim Nichols, Larry Niles, Nadav Nur, Chris Paige, David Pashley, Dan Petit, Bob Petty, Debbie Pressman, Terry Rich, John Sauer, Frank Thompson, and Marcia Wilson. And, the local committee included Steve Atzert, Emile Devito, Pete Dunne, Jay Laubengeyer, and Joan Walsh.

We also thank these individuals who provided editorial expertise: Greg Butcher, Nadav Nur, Mike Powers, Ken Rosenberg, and John Sauer. Finally, we thank Deborah Finch and the Rocky Mountain Research Station for financing the costs of publishing this proceedings and providing design, layout, and editorial expertise.

The Editors

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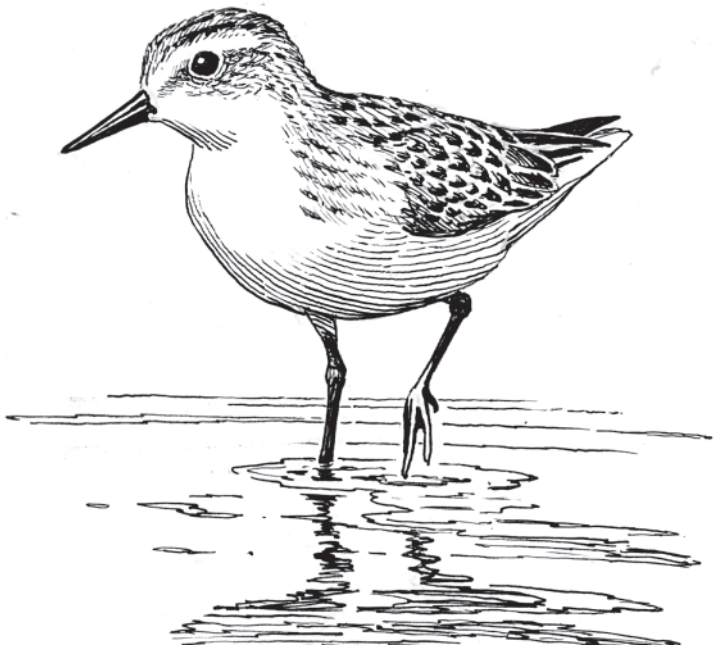

Semipalmated Sandpiper

1. Section Overview—The Mississippi Alluvial Valley: A Case Study in Bird Conservation Planning

David N. Pashley

Many accomplishments of Partners in Flight planning efforts have been based upon work in the Mississippi Alluvial Valley physiographic area (MAV), which has led the country in comprehensive bird conservation planning at the ecoregional level. Because of this leadership, the Cape May Partners in Flight workshop presented the MAV planning process as a case study, to show how bird conservation planning can and should work in other areas.

Of course the ecological foundation and history of the MAV, as well as the conservation challenges and opportunities which the MAV presents, are unique to that area. Some of the planning tools that have been used, the specific objectives that have been developed, and the methods for implementing those objectives may be irrelevant for other ecosystems. However, the conceptual planning process developed for the MAV should be universally applicable. That is, any ecosystem-level Bird Conservation Plan should examine current conditions and the ecological history that created them; identify priority species and habitats; set population and/or habitat objectives; explicitly state assumptions as well as research and monitoring needs; investigate where and how on the landscape the objectives can be met; and begin to explore possibilities for implementation.

The papers presented in this section are based on a series of presentations that summarized this comprehensive planning effort. They cover the ecological foundation upon which the work rests (Brown and others); the means by which habitat objectives were set for (1) waterfowl and shorebirds (Loesch and others) and (2) forest birds (Mueller and others); and the assumptions behind this process and the research and monitoring needs that result from the effort (Twedt and others).

In: Bonney, Rick; Pashley, David N.; Cooper, Robert J.; Niles, Larry, eds. 2000. Strategies for bird conservation: The Partners in Flight planning process; Proceedings of the 3rd Partners in Flight Workshop; 1995 October 1-5; Cape May, NJ. Proceedings RMRS-P-16. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

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The Ecological Basis for the Conservation of Migratory Birds in the Mississippi Alluvial Valley

Cynthia R. Brown
Charles Baxter
David N. Pashley

Abstract—In 1994, leaders in bird conservation in the Mississippi Alluvial Valley (MAV) formed the MAV Migratory Bird Planning Group to devise a conservation plan that integrates habitat objectives for three bird species groups: Wintering waterfowl, migratory shorebirds, and breeding and wintering migratory forest birds. The intent was to better coordinate the activities of three separate conservation efforts—the North American Waterfowl Management Plan, Partners in Flight, and the Western Hemisphere Shorebird Reserve Network—in a geographic area of great importance to birds. The goal of the Planning Group was to develop habitat objectives, based on population goals for each species group, which can be met simultaneously through integrated and complementary landscape management activities.

The MAV once was defined and driven by hydrofluvial processes. At present, land clearing and hydrologic manipulations have dramatically altered the natural structure and processes of this vast wetland ecosystem. Setting management objectives at the site-specific level of wildlife management area, national refuge, or privately owned land, has therefore necessitated an analysis of how regional changes in ecosystem structure and processes have affected the ability of the MAV to function as wintering habitat for mid-continent waterfowl, migratory habitat for shorebirds, and breeding and wintering habitat for forest birds.

In 1994, the Mississippi Alluvial Valley (MAV) Migratory Bird Planning Group began to devise a conservation plan that integrates habitat objectives for three groups of bird species—wintering waterfowl, migratory shorebirds, and breeding and wintering forest birds. The goal of the plan was to develop habitat conservation objectives based on population goals for each species group—objectives that could be met simultaneously through integrated and complementary management activities. The objectives were to be set within a large ecosystem that originally was heavily forested and defined and driven by hydrofluvial processes, but which now is highly altered and functionally impaired. The planning process that resulted required a regional analysis of how changes in ecosystem structure and process have affected the ability of the MAV to function as bird habitat.

This planning process is an explicit effort to better coordinate the activities of the North American Waterfowl Management Plan (NAWMP), Partners in Flight (PIF), and the Western Hemisphere Shorebird Reserve Network. The Lower Mississippi Valley Joint Venture staff in Vicksburg spearheaded this effort with strong support from elsewhere in the U. S. Fish and Wildlife Service, and from wildlife agencies from the seven states of the MAV (fig. 1), academia, private landowners, and nongovernment organizations such as The Nature Conservancy, the American Bird Conservancy, and the Tennessee Conservation League.

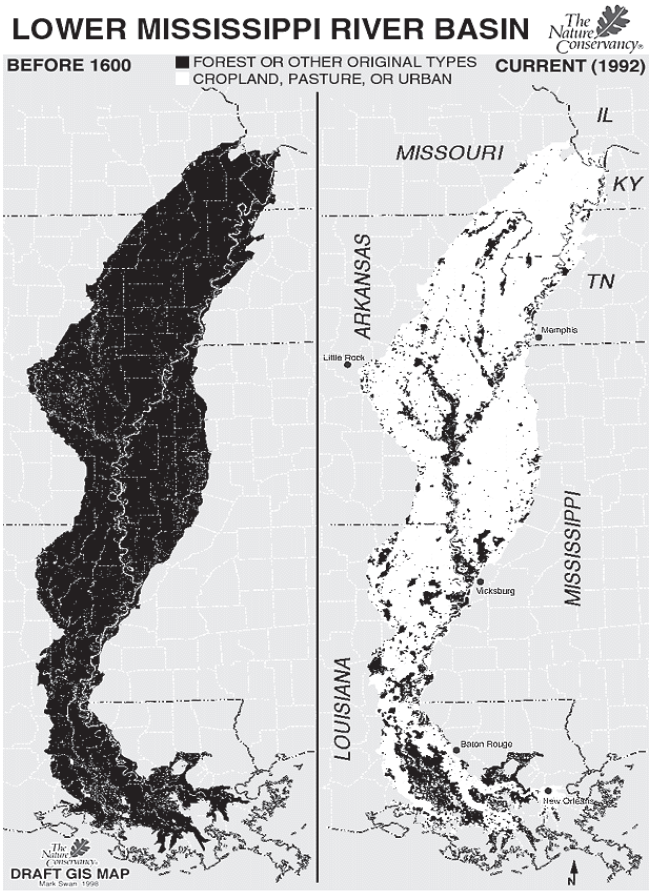

Figure 1—Lower Mississippi River Basin.

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Ecosystem Description

Historic Structure and Processes of the Mississippi Alluvial Valley Landscape

The Mississippi Alluvial Valley (MAV) once was a 10 million ha forested wetland system—the largest in North America—created and maintained by regular backwater and headwater flooding, and by localized ponding on poorly drained soils. The headwater or mainstem flooding resulted from rainstorms and snow melt in the watersheds of Mississippi River tributaries and produced great spring floods that characterize the MAV. Backwater flooding is a phenomenon in which high water stages on the Mississippi create a damming effect, preventing tributary drainage into the mainstem and at times reversing tributary flow upstream. This situation results in long-duration flooding, accompanied by sediment and nutrient deposition, throughout tributary watersheds.

Concomitant with these flooding mechanisms were the hydrofluvial processes associated with meandering river systems. The high energy inherent in the Mississippi River and its tributaries originally sculpted the MAV landscape, producing a surface geomorphology consisting of natural levees, meander scar lakes, point bars, and ridges and swales. These hydrofluvial processes created primary successional substrate for the establishment of pioneer communities that eventually were replaced by later seral communities distributed according to varying flood regimes. Site conditions within the MAV ranged from permanently flooded areas supporting only emergent or floating aquatic vegetation to high elevation sites supporting complex hardwood forests.

The historic dominant natural communities of the MAV were various types of bottomland hardwood forests. The distribution of types and stages of bottomland hardwood communities is in part determined by the timing, frequency, and duration of flooding. Elevational differences of only a few inches result in great differences in soil saturation characteristics and thus plant distribution. As a result, components of a bottomland hardwood ecosystem range from bald cypress/tupelo swamp communities in saturated or inundated situations, to a cherrybark oak/pecan community where inundation is infrequent and temporary. Between these distinct types are transitional overcup oak/water hickory, elm/ash/hackberry, and sweetgum/red oak communities.

With time and sediment deposition, succession in the MAV proceeds from pioneer communities dominated by black willow or cottonwood (depending on soil drainage characteristics), to a red oak- and finally white oak-dominated climax community (Hodges 1994). Disturbances, both nature- and human-induced—including windfall, beaver activity, hydrologic alteration, and silvicultural practices—greatly influence the rate and direction of succession. There is emerging thought that the dynamic nature of this water- and sediment-driven system, coupled with frequent disturbance, generally precludes the development or long-term viability of a closed canopy of senescent trees commonly thought of as old-growth (Meadows 1994). The 24 million acres of presettlement forests in the MAV likely consisted of a shifting mosaic of small, even-aged patches, themselves of differing ages, further defined by minute differences in elevation.

Historic Habitat Function of the Mississippi Alluvial Valley

The diversity of landforms and community types on the historical landscape provided extraordinary habitat for a range of species, including more than 200 species of fish, 50 species of mammals, 45 species of reptiles and amphibians, 37 species of mussels, and approximately 60 percent of all bird species in the conterminous United States (Fremling and others 1989; Sparks 1992; USACE 1988).

Migratory dabbling ducks historically have made significant use of the natural wooded wetland/slough complex in the winter, feeding primarily on acorns, seeds, and invertebrates. The bottomland hardwoods of the MAV provided the primary overwintering habitat for Mallards (*Anas platyrhynchos*) in North America. Diving ducks benefited from food sources characteristic of permanently flooded wetlands. These wintering habitats were critical not only to sustain ducks through the winter, but also to provide for nutritional demands that influence breeding success in the following spring (Yaich 1990).

The bottomland hardwood forests of the MAV also provided diverse habitat for a variety of forest birds. The continuous nature of the historical forest, along with its complex vertical structure and multiple seral stages, provided a haven for forest-interior species and niche specialists. Migratory forest birds used the bottomland hardwood forest in various ways, with many showing habitat preferences based on vertical structure, flooding regimes, and microhabitat features such as vine tangles, canebrakes, Spanish moss, and scour channels.

Use by migratory shorebirds was relatively low in the predominantly forested and shrub-scrub wetland types of the historical MAV. However, late summer evaporation from sloughs and backwater areas created some habitat. Also, sandbars and mudflats of the major river systems—including the Mississippi and Arkansas rivers—probably served an important function for many species of in-transit shorebirds, as have localized prairie habitats of eastern Arkansas and north central Louisiana.

Ecosystem Alteration

The last two centuries have witnessed dramatic changes in the structure and processes of the bottomland hardwood system of the MAV, which have affected its ability to function as habitat for waterfowl, shorebirds, and migratory forest birds. A concerted flood control effort began in 1879 with the establishment of the Mississippi River Commission. Its flood control functions were assumed by the U. S. Army Corps of Engineers after the great flood of 1927 and the passage of the 1928 Flood Control Act (MacDonald and others 1979). Since that time, one of the world's most comprehensive flood control systems has been developed along the Mississippi River and its tributaries, consisting of some 6,880 km of levees (Interagency Floodplain Management Review Committee 1994). As a result, mainstem flooding

has been virtually eliminated, and tributary flooding has been reduced by approximately 90% (Galloway 1980). In addition, channels have been cut and rivers straightened to improve drainage of the hydric soils that are characteristic of the vast majority of the landscape. These activities have reduced localized ponding due to rain by about 90% (Charles Baxter, personal communication). Continued rechannelization of streams that flow through agricultural lands, and general stream dredging and/or straightening still are carried out on most tributaries. This drainage has resulted in a gradual drying of the landscape. Flooding and ponding on poorly drained soils have decreased in both duration and frequency. Even in more flood susceptible areas where drainage has been less achievable, winter flooding is often less extensive and more ephemeral.

By the late 1930s, the elaborate system of levees and drainage projects had created increased opportunities for agricultural production. As a result, the bottomland hardwood forest has been reduced to only 1.8 million ha, or about 20 percent of its former extent. The remaining forest exists as fragmented patches of varying size and habitat quality. Recent satellite data show more than 35,000 discrete forest blocks of 1 ha in size or larger (Mueller and others this proceedings). Much of this remaining habitat is found in the wettest backswamp systems of the Yazoo River in Mississippi, the Tensas River in Louisiana, and the Cache/Bayou DeView/White River in Arkansas. Forests on drier ridges and higher terraces were cleared early in the history of human settlement in the MAV, as these better-drained soils provided optimal conditions for growing commodity crops.

Altered flow regimes along the Mississippi and its tributaries have threatened the structure and function of the remaining forested wetland ecosystem. Most forested wetlands outside the mainstem levees of the Mississippi River no longer are connected to floodplain processes that once shaped community age, composition, and distribution. Timing, duration, depth, and velocity of flood events have been severely altered, with the overall effect of eliminating the natural, annual process of overbank and backwater flooding in much of the historic floodplain, thus preventing the delivery of nutrient-rich sediments and water. Natural hydrofluvial processes, critical for establishment of early successional conditions, have been virtually eliminated from the floodplains. Only in a few places, such as the Lower Arkansas River, are processes such as bank erosion still relatively active.

Effects on Avian Populations

Habitat loss and fragmentation and hydrologic alteration in the MAV have resulted in population declines in both overwintering waterfowl and migratory forest birds.

Populations of dabbling ducks have decreased in the past several decades. Little evidence suggests that factors such as disease, environmental contaminants, or predators are responsible for this decline. Rather, availability of foraging habitat has had the greatest influence on the abundance, distribution, and body condition of waterfowl in the MAV (Loesch and others 1994). The NAWMP suggests that the foraging requirements for wintering waterfowl in the MAV include more than 2.8 million ha of naturally flooded bottomland hardwood forest. With only 1.8 million ha of this forest remaining, and with much of it hydrologically impaired, land managers have augmented habitat by mimicking seasonal ponding through winter water management on agricultural land. Unfortunately, the increased reliance on managed habitats has resulted in a shift in waterfowl diet from natural food sources to waste grain and weed seeds. Although agricultural grains and natural wetland foods are largely interchangeable as sources of energy, grains do not provide the same protein and nutrients. Furthermore, in early winter when the landscape is naturally dry, and in all seasons during years when precipitation is normal to below normal, there is a scarcity of foraging habitat, managed or natural, to meet waterfowl requirements (Loesch and others 1994).

Populations of diving ducks, because of their dependence on permanently flooded wetlands that still are abundant in the MAV, and because of the establishment of catfish and crayfish ponds in the southern reaches of the floodplain, appear to be faring well.

Agricultural expansion has resulted in an increase in cleared habitat that potentially could be used by migratory shorebirds if it were not impaired by hydrologic alteration. Migratory shorebirds use the MAV predominantly in the early fall and spring, when they exploit flooded farm fields and moist soil units as foraging habitat at all latitudes. Spring habitat requirements for shorebirds are largely met in the MAV as a result of natural flooding and ponding. Winter waterfowl management can be a relatively passive process of damming runoff from typically abundant rainfall; this form of management generally is compatible with agricultural practices (Loesch and others 1994). However, active water management is required to provide the summer/early fall shorebird habitat and early winter habitat for waterfowl. Late summer/early fall is the period of lowest rainfall, and water delivery during this time will require greater expense.

The decline in the extent, form, and composition of the bottomland hardwood forest has been mirrored by a decline in many species of migratory forest birds in the MAV. Fewer than 1% of the remaining forest patches are large enough to support source populations of the more area-sensitive species such as Cerulean Warblers (*Dendroica cerulea*), Swainson's Warblers (*Lymnothlypis swainsonii*), and Swallow-tailed Kites (*Elanoides forficatus*) (Mueller and others this volume). Forest fragmentation has resulted in the creation of edge habitat along forest patch margins, which encourages predation and brood parasitism. This and other factors associated with small patch size have had a negative impact on many bird populations in all but the largest remnant blocks of forest. Some species have been affected by changes in habitat quality separate from issues of forest loss and fragmentation. The demise of Bachman's Warbler (*Vermivora bachmanii*), for example, may have been caused by the eradication of the formerly abundant canebrake habitat (Remsen 1986), a community typically found on better drained soils that now support agricultural crops. Cerulean Warblers may be reduced in number because the tall trees that they favor, such as cottonwoods in early successional communities, have been largely eliminated from the landscape.

Summary

Ecosystem management requires "protecting or restoring the function, structure, and species composition of an ecosystem while providing for its sustainable socioeconomic use"(U.S. Fish and Wildlife Service 1994a). Partners in Flight Bird Conservation Plans should follow this general guideline, but must be more specific regarding the status and conservation needs of birds. A first and necessary step toward this end is to develop a clear understanding of the ecosystem: The way it functioned prior to human alteration, the history of change, and structure and function as they currently exist.

Alterations to the ecological processes and structure characterizing the floodplain of the Mississippi River system have been widespread and thorough. Over 80% of the bottomland hardwood forest has been converted to non-forest conditions, and the natural hydrologic and geomorphologic processes that created and maintained this vast wetland system have been virtually eliminated. It is clear that one result of these changes is a reduced capability to support populations of birds. In this paper, we have identified the nature of the problem. The remaining papers in this section trace the thought processes that have been aimed toward ameliorating, if not actually solving, the problems that bird populations face in this degraded ecosystem.

Development of Management Objectives for Waterfowl and Shorebirds in the Mississippi Alluvial Valley

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Kimberly Tripp
William C. Hunter
Mark S. Woodrey

Abstract—The goal of the Lower Mississippi Valley Joint Venture of the North American Waterfowl Management Plan is to provide sufficient habitat to support 4.3 million wintering ducks and 1.0 million wintering geese annually. Under the assumption that the amount of foraging habitat is the primary limitation to supporting waterfowl population goals in the Mississippi Alluvial Valley (MAV), a habitat objective to make available 285,000 ha of waterfowl foraging habitat is divided among seven states. This habitat objective is further divided between public and private ownership and among three habitat types: Bottomland hardwood forest, moist-soil sites, and agricultural fields. Management objectives for shorebirds within the MAV which provide foraging habitat for 0.5 million shorebirds during their southward migration have been tentatively established. Several as yet unverified assumptions were used in establishing these objectives; consequently, we caution that the objectives are subject to revision as the assumptions are tested. We assumed that 0.5 million shorebirds move through the MAV during late summer and fall, each foraging for an average of 10 days. During this migration period, foraging shorebirds are assumed to require sufficient forage to gain 1 g of biomass per day, in addition to their basal metabolic needs. Given an invertebrate food supply that provides 17.6 kj • g^{-1}, we calculated that an average 45 g shorebird requires about 8 g of invertebrate forage per day. Further assuming that each ha of managed shorebird habitat can provide 20 kg of invertebrate food resources available to shorebirds, we extrapolated a need for 2000 ha of shorebird foraging habitat. We suggest that the bulk of this foraging habitat be provided on public lands and that it be distributed throughout the MAV.

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Waterfowl

Long-term declines in waterfowl populations prompted the development of the North American Waterfowl Management Plan (NAWMP) during the early 1980s. The NAWMP identified the Mississippi Alluvial Valley (MAV) as one of several regions in North America containing habitat vital to the recovery of waterfowl populations. The Lower Mississippi Valley Joint Venture (LMVJV) was organized in the late 1980s to develop a strategy for conserving, managing, and restoring wetland habitats that support wintering waterfowl populations in a joint venture area that includes the MAV. Midwinter Waterfowl Inventory data, harvest data from 1970 to 1979, and population goals set in the NAWMP were used to set state-specific waterfowl population goals. The overall goal for the MAV is to provide habitat to support 4.3 million wintering ducks and 1.0 million wintering geese annually.

Assuming that foraging habitat is limiting for waterfowl wintering in the MAV, we calculated the energetic needs of waterfowl, winter mortality rates, length of the wintering period, and the energy available in various foraging habitats. Then we incorporated the population goal to determine that approximately 285,000 ha of foraging habitat are needed to support wintering waterfowl in the MAV. Within each state, habitat goals are divided between public and private ownership and three main foraging habitats: Bottomland hardwood forest, moist-soil sites, and agricultural fields. Availability of waterfowl foraging habitat depends on adequate precipitation and resultant ponding or overbank flooding, and water-control infrastructure (i.e., levees, dikes, water-control structures, pumps) to facilitate flooding. The rationale and methodology used to develop these waterfowl population goals and habitat objectives for waterfowl have been published previously (Lower Mississippi Valley Joint Venture Management Board 1990; Loesch and others 1994). Refer to these documents for details and clarification of waterfowl goals and objectives.

Shorebirds

Although some shorebirds breed (Robbins and others 1986) or winter (Ouchley 1992) in the MAV, many more shorebirds, both total individuals and species, use this floodplain as a migratory corridor between breeding areas to

the north and wintering areas to the south (Helmers 1994; Twedt and others 1998) (table 1). Thus, we feel that the greatest conservation need for shorebirds within the MAV is foraging habitat during migration.

Typically, winter floodwater that recedes during early spring and the agricultural practice of shallow-flooding rice fields during late spring provide abundant shallow-water and mudflat foraging habitat within the MAV during northward migration. During southward migration, however, in late summer and fall, naturally occurring floodwater is rare because of seasonally low precipitation. Also, agricultural fields are purposefully kept dry at this time to facilitate harvest of crops. Therefore, the period from 15 July through 30 September has tentatively been identified as the time interval when foraging habitat for migrating shorebirds is least available. Our primary conservation objective is to ensure that adequate shallow-water habitat is available in the MAV to meet or exceed the foraging requirements of shorebirds during their southward migration.

Establishing Shorebird Population Goals

Neither census data nor any specific estimates of shorebird populations moving through the MAV during southward migration are available. To establish such an estimate and thereby set a tentative population goal, we examined data from International Shorebird Survey sites (Manomet Bird Observatory 1993) and consulted shorebird biologists (e.g., D. L. Helmers and B. A. Harrington) knowledgeable of migration patterns and continental population estimates (Howe and others 1989). Based on these sources, we have assumed that about 0.5 million shorebirds (table 1) move through the MAV during fall migration. Maintenance of this number is our population goal. This is a relatively unambitious effort to maintain the assumed status quo, and should be reexamined within the context of evolving continent-wide goals for shorebird populations.

Table 1—Shorebird species, mass, and hypothesized abundance during southward migration through the Mississippi Alluvial Valley (Manomet Bird Observatory 1993).

Common name	Scientific name	Mass (g)	Abundance
Wilson's Phalarope	*Phalaropus tricolor*	50	171
American Avocet	*Recurvirostra americana*	150	232
Black-necked Stilt	*Himantopus mexicanus*	125	778
Common Snipe	*Gallinago gallinago*	150	2,374
Dowitcher species	*Limnodromus* spp.	125	2,242
Stilt Sandpiper	*Calidris himantopus*	75	3,310
Red Knot	*Calidris canutus*	140	162
Pectoral Sandpiper	*Calidris melanotos*	60	121,077
White-rumped Sandpiper	*Calidris fuscicollis*	40	221
Baird's Sandpiper	*Calidris bairdii*	40	690
Least Sandpiper	*Calidris minutilla*	25	151,119
Dunlin	*Calidris alpina*	35	7,866
Semipalmated Sandpiper	*Calidris pusilla*	30	37,713
Western Sandpiper	*Calidris mauri*	30	3,382
Sanderling	*Calidris alba*	60	5,052
Calidris spp. ('peeps')	*Calidris* spp.	30	32,286
Marbled Godwit	*Limosa fedoa*	200	39
Greater Yellowlegs	*Tringa melanoleuca*	125	3,235
Lesser Yellowlegs	*Tringa flavipes*	75	21,120
Solitary Sandpiper	*Tringa solitaria*	60	2,608
Willet	*Catoptrophorus semipalmatus*	175	92
Upland Sandpiper	*Bartramia longicauda*	125	237
Buff-breasted Sandpiper	*Tryngites subruficollis*	50	964
Spotted Sandpiper	*Actitis macularia*	40	4,112
Black-bellied Plover	*Pluvialis squatarola*	150	769
American Golden-Plover	*Pluvialis dominica*	130	449
Killdeer	*Charadrius vociferus*	50	91,838
Semipalmated Plover	*Charadrius semipalmatus*	35	4,765
Piping Plover	*Charadrius melodus*	40	121
Ruddy Turnstone	*Arenaria interpres*	140	405
Other shorebirds		40	571
	mean weighted mass	= 45	total = 500,000

Estimating Forage Needs of Shorebirds During Migration

Although data on the composition of species moving through the MAV are fragmentary, some information for the MAV during southward migration is available from International Shorebird Survey sites as well as from local study sites (e.g., Reid and others 1983; Ouchley 1992; Twedt and others 1998). These data indicate that although shorebirds as small as 30 g and as large as 200 g migrate through the MAV, the average mass (weighted by abundance) of individual shorebirds in the area is 45 g (table 1). This average mass was used as an assumption of shorebird body mass for calculating estimates of energetic needs and foraging habitat requirements.

The amount of energy (kj) required by a 45 g shorebird to maintain its existence metabolic rate (EMR) was calculated following Kersten and Piersma (1987) as:

$$\text{EMR (kj)} = 912 \bullet (\text{BODY MASS [kg]})^{0.704}$$

$$102.77 \text{ kj} = 912 \bullet (0.045 \text{ kg})^{0.704}$$

Thus, 103 kj are required per day to sustain a 45 g shorebird.

For the purpose of modeling, we have assumed that chironomids are a primary food item consumed by shorebirds. One g (dry weight) of chironomids has a gross energy content of 23.8 kj (Cummins and Wuycheck 1971). Because the assimilation efficiency of birds feeding on invertebrates is approximately 73 percent (Castro and others 1989), the net energy content (NEC) of chironomids is about 17.6 kj per g:

$$\text{NEC} = \text{GROSS ENERGY CONTENT} \bullet \text{ASSIMILATION EFFICIENCY}$$

$$17.6 \text{ kj} \bullet \text{g}^{-1} = 23.8 \text{ kj} \bullet \text{g}^{-1} \bullet 0.73$$

The mass of invertebrates that a 45 g shorebird requires to maintain its existence metabolic rate can then be extrapolated as:

$$\text{MAINTENANCE INVERTEBRATE MASS } (IM_{MAINTENANCE}) = \text{EMR} \bullet \text{NEC}^{-1}$$

$$5.84 \text{ g} = 102.77 \text{ kj} \bullet \text{d}^{-1} \bullet (17.6 \text{ kj} \bullet \text{g}^{-1} \bullet \text{d}^{-1})^{-1}$$

Thus, a 45 g shorebird requires about 6 g of invertebrate forage each day to maintain its body mass.

To provide the fat reserves necessary to complete migration, however, shorebirds must increase their biomass by about 1 g per day. Assuming about 2 g of invertebrate forage must be consumed each day to increase biomass by 1 g (Kersten and Piersma 1987), the mass of invertebrates required for fat deposition ($IM_{DEPOSITION}$) becomes 2 g per day. The daily food requirement during migration ($IM_{MIGRATION}$) of a 45 g shorebird then becomes about 8 g:

$$\text{MIGRATION INVERTEBRATE MASS } (IM_{MIGRATION}) = IM_{MAINTENANCE} \bullet IM_{DEPOSITION}$$

$$8 \text{ g} \bullet \text{d}^{-1} = 6 \text{ g} \bullet \text{d}^{-1} + 2 \text{ g} \bullet \text{d}^{-1}$$

Determining Habitat Requirements for Migrating Shorebirds

For the purpose of proposing the amount of habitat required to support migrating shorebirds, we have assumed that habitat will be provided primarily in the form of shallow water managed to create optimal foraging depths for shorebirds and about 2 g of benthic invertebrates are available per square meter (Helmers, personal communication). Consequently, an average shorebird requires about 4 m^2 of foraging habitat each day. Over the duration of an assumed 10-day migration period, each shorebird migrating through the MAV would therefore require 40 m^2 (0.004 ha) of managed foraging habitat. Assuming an equal habitat need for each of the 0.5 million shorebirds that we assume move through the MAV during southward migration results in an overall shorebird habitat objective of 2,000 ha (ca. 5,000 acres) in the MAV between 15 July and 30 September.

$$\text{FORAGING HABITAT} = IM_{MIGRATION} \bullet \text{DURATION} \bullet \text{FORAGE DENSITY}^{-1} \bullet \text{POPULATION}$$

$$2{,}000 \text{ ha} = 20{,}000{,}000 \text{ m}^2 = 8 \text{ g} \bullet \text{bird}^{-1} \bullet \text{d}^{-1} \bullet 10 \text{ d} \bullet [2 \text{ g} \bullet (\text{m}^2)^{-1}]^{-1} \bullet 500{,}000 \text{ birds}$$

Following is a summarized list of the assumptions that were used in setting these shorebird habitat objectives:

- About 500,000 individual shorebirds migrate through the MAV each year; the average duration of stay of each individual is ten days.
- The time period in which shorebird habitat is critical in the MAV is during southward migration from approximately 15 July to 30 September.
- The average mass of one of these shorebirds is 45 g.
- The daily food requirements (for maintenance plus needed fat gain) of this average-sized bird is about 8 g.
- Chironomids are the primary food source for these birds, and about 2 g of these and other benthic invertebrates are available to foraging shorebirds in each square meter of habitat. One ha of managed habitat will produce about 20 kg of forage.

With the exception of migration timing, all of these assumptions require critical attention.

Establishing Habitat Objectives for Migrating Shorebirds

Shorebird objectives were established for the entire MAV and then allocated among states to ensure an adequate geographic dispersion of shorebird habitat (table 2). The available land base and the perceived ability of each state to achieve shorebird objectives were taken into consideration in these state allocations. The state habitat objectives will subsequently be allocated to individual management units of public land.

Table 2—Proposed distribution of shorebird habitat among states making up the Mississippi Alluvial Valley (MAV).

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

Different shorebird species use water of different depths, but the total range of utilized conditions—from damp mud to several cm—covers only a portion of any water management unit at any time. Over time, this band shifts with gradual flooding, draw down, or evaporation, and these shifts are necessary to expose new foraging opportunities to the birds. Careful attention can maximize the value of managed impoundments to shorebirds over the course of migration, but it is unlikely that more than 10% of a unit will be useful at any single point in time. The total amount of land required to achieve a targeted area of shorebird habitat at the most important times during migration can be determined only on the basis of knowledge of management unit conditions and potential.

Shorebirds primarily use wet open areas that, in late summer and early fall, generally occur exclusively on public lands managed primarily for waterfowl. Thus, shorebird objectives will be implemented within the context of habitat objectives for late fall-early winter waterfowl. It will be important to test for compatibility between these species groups. Early shorebird flooding may benefit some early migrant ducks, for example, Blue-winged Teal (*Anas discors*). On the other hand, fields flooded in July or August may produce less waterfowl forage later in the fall than would be produced if the fields had remained dry throughout the summer.

The perceived opportunities to create managed shorebird foraging habitat within states correspond, in large part, with the distribution of public lands among those states. We have initially restricted shorebird foraging habitat objectives to managed shallow-water habitats of public lands

Figure 1—Proposed balance sheet, for use in tracking progress toward shorebird foraging-habitat objectives, depicts three potential shorebird habitats and three management categories.

	Public managed	Private managed	Unmanaged
Mudflat—Drawdown	?	?	?
Moist Soil—Flooded	?	?	?
Cropland—Flooded	?	?	?
Objective (ha)	5,000	?	?

because of limited opportunities to establish shorebird foraging habitat on private lands during late summer and fall. Unlike foraging habitat for wintering waterfowl, which may be provided in flooded croplands on private lands within the MAV, the presence of unharvested crops and generally dry conditions during late summer restricts the ability of many private landowners to create shorebird habitat. We are not suggesting, however, that shorebird habitat is nonexistent on private lands. There certainly are opportunities, especially at aquaculture facilities, for the creation of additional shorebird foraging habitat on private lands (Sykes and Hunter 1978; Hands and others 1991). Enhancement of these lands should be encouraged wherever possible. Thus, although our habitat objectives focus on establishing managed foraging habitat for shorebirds on public lands, we recognize the contribution of unmanaged habitats, as well as the benefit of habitat on private lands, toward meeting the energetic requirements of shorebirds during southward migration. We suggest that a balance sheet (fig. 1), similar to that developed to monitor progress toward waterfowl habitat objectives (Loesch and others 1994), can be used to monitor the status of shorebird habitat within the MAV and to assess progress toward meeting habitat objectives.

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Development of Management Objectives for Breeding Birds in the Mississippi Alluvial Valley

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Abstract—We used a six-step process to set habitat objectives and population goals for breeding birds in the Mississippi Alluvial Valley. Specifically, we used existing empirical studies and mathematically derived viable population estimates to define habitat objectives and population goals for bottomland hardwood forest, the most important habitat type in this physiographic area. Although habitat objectives must address both quality and quantity, we concentrate here on the size and number of forest patches in this highly fragmented landscape. To support source populations of all forest breeding birds we recommend the protection/restoration of 52 forest patches that are 4,000-8,000 ha in size, 36 patches of 8,000-40,000 ha, and 13 patches greater than 40,000 ha. Although every physiographic area is unique, the methodology applied here should be applicable in other situations.

Bird Conservation Plans (BCPs) for each physiographic area will make critical contributions to the national Partners In Flight (PIF) conservation plan. To be most useful, these regional BCPs should promote on-the-ground conservation actions by developing quantified, site-specific habitat and population objectives. As a model for the PIF planning process, the North American Waterfowl Management Plan has had great success in putting conservation on the ground through the preparation of detailed regional plans with objectives that focus conservation efforts, provide funding justifications, and provide perspective on the "big picture."

Frequently we do not have firm scientific information to quantify conservation issues. However, if we wait for all of the information that we think we require, the time for effective conservation action may pass. We therefore must move forward and make conservation recommendations as soon as possible, based on the best information currently available. As new information becomes known, recommendations can be modified. This iterative method of operation, called adaptive management, is becoming widely accepted in the conservation/scientific community (Franklin 1995; Kirchhoff and others 1995; Meffe and Viederman 1995; Petit and others 1995). This paper presents a general model for setting detailed, regional bird conservation objectives, and describes the application of this model, using the best available information in the Mississippi Alluvial Valley (MAV).

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The Model

Our generalized model for setting regional bird habitat and population objectives consists of a six-step process (table 1). The issues addressed in this model should be covered in all bird conservation planning efforts, although the sequence of steps and the emphasis on each one will vary among local situations.

Step 1: Establish Species Priorities—In an ecosystem or landscape approach to planning we often are confronted with trying to meet the conservation needs of many bird (and other) species with widely varying ecological requirements. The conservation needs of some species, however, will be greater than others. The PIF prioritization process (Hunter and others 1993a; Carter and others, this proceedings) can be modified to fit any situation, and will help focus the jumble of apparently conflicting conservation needs.

Step 2: Establish Habitat Priorities—Species priorities should help to establish habitat priorities. Depending on the location and prioritization scheme, habitat priorities can emphasize breeding, wintering, or migration stopover habitat.

Step 3: Identify Habitat Requirements to Maintain Individual Populations of Priority Species Groups in Priority Habitat(s)—Habitat requirements of priority species must be identified explicitly to effectively direct the

Table 1—A model process for setting bird conservation goals.[a]

Step	Process
1	Establish species priorities
2	Establish habitat priorities
3	Identify habitat requirements to maintain individual populations of priority species groups in priority habitat(s)
4	Determine the extent and location of existing habitat suitable for meeting the habitat requirements of individual populations of priority species groups
5	Set site-specific habitat objectives
6	Set meta-population goals

[a]This model shares the philosophy of and is compatible with the processes described by Petit and others 1995.

implementation of conservation actions. (This is the first point at which we face the inadequacy of our information base.) First, the habitat needs of each high-priority species should be defined and quantified. That is, the habitat area sufficient to support and maintain a "population," however it is defined—viable, source, etc.—of a species must be quantified. Then, the needs of all priority species occurring in a habitat type can be considered collectively. Species requiring similar conditions can be grouped into suites; habitat requirements for each suite should be based on the needs of the single most demanding species in the suite.

Step 4: Determine the Location and Extent of Existing Habitat Suitable for Meeting the Habitat Requirements of Individual Populations of Priority Species Groups—Knowledge of the current distribution, configuration, condition, and extent of key habitat types is required to set realistic habitat objectives. A Geographic Information System (GIS) or some comparable database is essential in this assessment. Although the expense of assembling a GIS specifically dedicated to PIF planning may be prohibitive, GIS is a widely used tool. For example, most states and major universities operate a GIS and probably have land use/cover data for at least part of any given planning area. If GIS is unavailable, other databases that are less site specific, such as river basin studies and forest inventories, can provide much useful information on the habitat composition of a given physiographic area. However, even when sophisticated spatial imagery is used, assessing the many habitat characteristics that determine the quality of an area for priority species usually requires on-the-ground bird inventory work to verify estimates of habitat extent and condition.

Step 5: Set Site-Specific Habitat Objectives—Having defined habitat requirements for priority species, and having identified the location and extent of existing habitat that is suitable for meeting those requirements, the next step is to determine whether the existing habitat is adequate to provide long-term support for secure bird populations. If the current situation is satisfactory, then habitat objectives should be framed in terms of maintaining existing conditions. If the situation is unsatisfactory, then objectives should recommend acquisition or restoration of habitat or changes in management of existing, non-suitable habitat. These recommendations can, at least at first, be opportunistic. That is, they can build on existing efforts that may not specifically be dedicated to birds, or they can build on cooperative arrangements that benefit birds but are not prohibitively expensive to partners. Objectives should be ambitious, but realistic. Site-specific objectives have a much better chance of being implemented than general recommendations for a region. Local knowledge of conservation opportunities should be used to help set site-specific objectives.

Step 6: Set Meta-Population Goals—Ideally we would set overall population goals before we establish habitat objectives. We would know how many individuals (i.e., populations) of a species are needed for a secure population (i.e., meta-population) to assure the long-term stability of the species. Unfortunately, this information does not exist for most species addressed here. In addition, unlike conservation models that start with defined population goals (e.g., waterfowl), this model is being applied to bird species that do not have adequate population estimates. Consequently, meta-population goals should be set based on a pragmatic evaluation of what is possible, tempered by the best available scientific evaluation of what is needed for long-term species stability. Population goals may be established in terms of the total number or overall density of birds, the number or distribution of populations constituting the meta-population, source-sink or meta-population dynamics, population trends, or security of existing habitat.

The Mississippi Alluvial Valley Example

Despite the radical habitat changes that have occurred in the past two centuries in the 9.7 million ha MAV (Brown and others, this proceedings), this physiographic area still retains significant habitat values for wintering waterfowl, breeding forest birds, and other transient and resident wildlife. This example focuses on retaining, restoring, and enhancing those values specifically for forest breeding birds. Our long-term, overall goal is to establish and maintain source populations of all breeding bird species in the MAV.

Step 1: Establish Species Priorities—We used the PIF prioritization process (Hunter and others 1993a; Carter and others, this proceedings) to set breeding bird species priorities in the MAV (table 2). Although we focused on breeding birds, we recognize that the MAV is important winter habitat for vast numbers of temperate migrants as well as in-transit habitat for long distance migrants. We tentatively assume that conditions sufficient for breeding birds also will be sufficient for these other species; this assumption needs to be tested rigorously. Additionally, some areas not suitable to high-priority breeding birds can be very important for wintering and transient birds. Ultimately, these factors need to be incorporated into the overall BCP for the MAV but are beyond the scope of this paper.

Step 2: Establish Habitat Priorities—Six of the seven MAV species that have breeding season prioritization scores of 24 or more nest in bottomland hardwood forest (table 2). Based on this and the historical ecosystem structure of the MAV, we selected bottomland hardwood forest as the highest-priority habitat type for breeding bird conservation in this region.

Step 3: Identify Habitat Requirements to Maintain Individual Populations of Priority Species Groups in Priority Habitat—Habitat requirements conceptually can be separated into issues of quality and quantity. Qualitative factors such as vegetative structure, plant species composition, successional stage, flood regime, and other microhabitat features affect the ability of bottomland hardwood habitat to support a diversity of breeding bird species (Pashley and Barrow 1992). Given time and even a marginally natural flood regime, we assume that most sites of sufficient size will achieve the internal diversity to support the needs of most birds in this system.

Table 2—Breeding bird species priorities in the Mississippi Alluvial Valley.

Species	Score
Bachman's Warbler (*Vermivora bachmanii*)	35 - BLH[a]
Ivory-billed Woodpecker (*Campephilus principalis*)	35 - BLH
Swainson's Warbler (*Limnothlypis swainsonii*)	29 - BLH
Cerulean Warbler (*Dendroica cerulea*)	28 - BLH
Swallow-tailed Kite (*Elanoides forficatus*)	26 - BLH
Prothonotary Warbler (*Protonotaria citrea*)	24 - BLH
Painted Bunting (*Passerina ciris*)	24
Bell's Vireo (*Vireo bellii*)	23
Worm-eating Warbler (*Helmitheros vermivorus*)	23
Northern Parula (*Parula americana*)	23 - BLH
Kentucky Warbler (*Oporornis formosus*)	23 - BLH
Orchard Oriole (*Icterus spurius*)	23 - BLH
White-eyed Vireo (*Vireo griseus*)	23 - BLH
Yellow-billed Cuckoo (*Coccyzus americanus*)	22 - BLH
Wood Thrush (*Hylocichla mustelina*)	22 - BLH
Red-headed Woodpecker (*Melanerpes erythrocephalus*)	21 - BLH
Dickcissel (*Spiza americana*)	21
Prairie Warbler (*Dendroica discolor*)	21
Yellow-breasted Chat (*Icteria virens*)	21 - BLH
Chuck-will's-widow (*Caprimulgus carolinensis*)	21
Hooded Warbler (*Wilsonia citrina*)	21 - BLH
Hooded Merganser (*Lophodytes cucullatus*)	21 - BLH
Louisiana Waterthrush (*Seiurus motacilla*)	21 - BLH
Scissor-tailed Flycatcher (*Tyrannus forficatus*)	21
Mississippi Kite (Ictinia mississippiensis)	21 - BLH
White Ibis (Eudocimus albus)	21 - BLH
Acadian Flycatcher (Empidonax virescens)	20 - BLH
Eastern Wood-Pewee (Contopus virens)	20 - BLH
Northern Bobwhite (Colinus virginianus)	20
Yellow-throated Vireo (Vireo flavifrons)	20 - BLH
Yellow-throated Warbler (Dendroica dominica)	20 - BLH
Baltimore Oriole (Icterus galbula)	20 - BLH
Carolina Chickadee (Poecile carolinensis)	20 - BLH
Loggerhead Shrike (Lanius ludovicianus)	20
Field Sparrow (Spizella pusilla)	20
86 additional species have priority scores of 19 or less	

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

Much of the topography of the lower Mississippi Valley floodplain consists of ridges and swales, with high, dry sites interwoven with low, wet sites. Over recent history, however, agriculture has claimed almost all of the high sites, leaving only the wettest places for forest and wildlife. These wet sites, regardless of the time that has passed since major disturbance, may not provide conditions necessary for some of the highest priority birds in this system, such as Cerulean Warbler and Swainson's Warbler. Therefore, we must ensure that a sufficient number of forest patches are of average wetness or drier. Habitat quantity must be considered with an awareness that the current landscape of the MAV is at least 75 percent deforested (MacDonald and others 1979), and most remaining forested patches are small and isolated (Rudis 1995). Because the vast majority of this system is unlikely to be reforested, planners must determine the necessary size, configuration, number, distribution, and interconnectivity of remaining forest patches.

To maintain bird populations, a forest patch should be of sufficient size to support source populations of all priority bird species, with little likelihood of extirpation or genetic degradation. Smaller patches will provide adequate habitat for only a subset of priority species. To determine necessary patch sizes, we used two sources of information: (1) empirical studies and (2) mathematically derived theoretical genetically viable populations.

Empirical studies were used primarily for Swallow-tailed Kite (Cely and Sorrow 1990, Meyer and Collopy 1990) and Cerulean Warbler (Hamel 1992a).

To determine forest patch-size requirements for theoretical genetically viable populations of other species we used the formula:

$$A = (N \bullet D) + B, \text{ where}$$

A = area of forest patch required to support a source population, N = number of reproductive units (usually breeding pairs) required for a source population, D = breeding density (usually expressed as ha/breeding pair), and B = the area of a 1 km forested buffer around the forest core (forest core = N • D).

To determine N, we first considered the work of Soule (1987), who guessed that a population size "in the low thousands" should represent an adequate minimum viable population for vertebrates, although he strongly cautioned that the size should be independently calculated for each species. Thomas (1990) generally concurred with this estimate. We assumed that individuals of a species in one block of habitat in the MAV are not genetically isolated from individuals in other patches. Furthermore, with the exception of the Ivory-billed Woodpecker (which undoubtedly is extinct in the United States), virtually all of the high-priority birds in this system are Neotropical migrants, which show very low natal site fidelity (Sherry and Holmes 1992; Roth and Johnson 1993). This suggests a high likelihood of gene flow among patches. Therefore, retaining populations above the "low thousands" in the entire physiographic area should ensure viability from a genetic perspective. But even though genetic deterioration within blocks does not seem to be a threat if populations in the physiographic area (or whatever planning area is under consideration) are high enough, a target number of birds for each patch is required to ensure a source population. A proposed minimum effective population of 500 breeding adults (Franklin 1980) was adopted by the U.S. Fish and Wildlife Service (1985) as the minimum size for each of several populations in the recovery plan for the Red-cockaded Woodpecker (*Picoides borealis*). For monogamous species this N constitutes 250 breeding pairs. However, establishing conservation goals at the minimum threshold, based upon a series of unverified assumptions, seems fraught with peril. Therefore, to provide adequate population levels in the face of these uncertainties, we set N at 500 breeding pairs per forest patch.

For the value of D, we used average breeding densities from Breeding Bird Censuses, as summarized for the southeastern United States by Hamel (1992b). We realize, however, that because of differences in habitat quality, birds might not occur in the MAV at densities as high as those reported in the literature. Even under optimal conditions, bird density in bottomland hardwoods is determined by the frequency of occurrence of necessary patchily distributed microhabitat features, e.g., thickets for Swainson's Warblers, cypress brakes for Yellow-throated Warblers (*Dendroica dominica*), etc. This is another reason for adopting

a target of 500 breeding pairs per forest patch; this number both increases the number above a theoretically determined minimum and reflects our assumption that birds may occur at only one-half the densities reported in ideal conditions.

Finally, because the agricultural matrix that dominates the MAV generally is considered hostile to birds breeding within forest patches, we used an adjustment factor (B) to account for this degradation in suitability. Robinson and others (1995b) found that nest predation and parasitism were high even in large forest patches (2,200 ha) in landscapes with a low percentage of forest cover. Working in Illinois and Missouri, Thompson (1994) found that female Brown-headed Cowbirds (*Molothrus ater*) traveled an average of 1.2 km between feeding and breeding sites. Undesirable edge effects also can extend to mating patterns. Van Horn and others (1995) found that male Ovenbirds (*Seiurus aurocapillus*) singing on territories less than 300 meters from the edge of the forest were much more likely to be unpaired than males from the interior of the forest. For planning purposes, we assumed that a 1.0 km forest buffer surrounding an interior forest core will reduce these negative impacts. Only those pairs within the forest core (N • D) are assumed to reproduce at a rate sufficient to serve as a source population.

Large forest patches also are required to maintain the density of breeding individuals that facilitates extra-pair mating systems found in many Neotropical migrants (Morton 1989; Wagner 1993; Stutchbury and Morton 1995). We assumed that patches designed to include a core large enough to support a source population within a 1 km buffer also will mitigate for these other issues of area sensitivity. Clearly, all of the assumptions in this process need to be tested. Because the area of a 1 km buffer will vary with the geometric configuration of each forest patch, the area requirements of each forest patch will differ. For planning purposes, until the actual areas of interior forest within each forest patch are determined, doubling the core forest area [(N • D) • 2] generally will result in forest patch requirements that approximate or exceed a 1 km buffer around the desired interior forest area.

As an example of the completed calculation for one species, breeding Swainson's Warblers occur at a density of one pair per 4.7 ha (Hamel 1992b). If Swainson's Warblers occur over a large area at this density, then 500 pairs would require 2,350 ha. Applying the doubling factor as a surrogate for the 1 km buffer produces a desired forest patch size of 4,700 ha for one source population of this species.

To determine the minimum forest patch size required to support 500 breeding pairs for all MAV forest breeding species, we performed the above calculations for each species (table 3). Next, we grouped the species into species suites based on their minimum area requirements. We used three forest patch sizes designed to meet the area requirements of three area-sensitive species groups: 4,000 to <8,000 ha, 8,000 to 40,000 ha, and >40,000 ha. A similar technique was used to determine the areal habitat needs of raptors in French Guiana (Thiollay 1989), Golden-cheeked Warblers (*Dendroica chrysoparia*) in Texas (Pease and Gingerich, no date), and grizzly bears (*Ursus arctos*) in the Yellowstone ecosystem (Shaffer and Samson 1985). Wenny and others (1993) discussed this process as one technique for determining areal habitat needs. A good deal of uncertainty is inherent in these assumptions and extrapolations. However, Robinson (this proceedings), working in the hardwood forests of Illinois, recommended greater than 8,000 ha "macrosites" to maintain regional metapopulations, and Hamel (1992a) recommended 8,000 ha mature forest patches to secure Cerulean Warbler populations. The agreement of these independently derived figures adds confidence to our forest patch objectives.

Table 3—Forest patch size requirements to support 500 breeding pairs within the Mississippi Alluvial Valley.

Species	Score	Forest patch size
		(*ha*)
4,000 to <8,000 ha species group		
Swainson's Warbler	29	4,700
Prothonotary Warbler	24	2,700
Northern Parula	23	3,000
Wood Thrush	22	2,800
Hooded Warbler	21	2,500
Acadian Flycatcher	20	2,800
Blue-gray Gnatcatcher	19	4,000
Red-eyed Vireo	16	1,800
American Redstart	16	4,600
8,000 to 40,000 ha species group		
Cerulean Warbler	28	8,000
Kentucky Warbler	23	8,300
Yellow-billed Cuckoo	22	6,600
Louisiana Waterthrush	21	7,200
Yellow-throated Vireo	20	7,800
Yellow-throated Warbler	20	7,800
Eastern Wood-Pewee	20	5,400
Summer Tanager	18	6,600
Great Crested Flycatcher	17	7,200
Scarlet Tanager	17	4,900
White-breasted Nuthatch	14	8,500
>40,000 ha species group		
Swallow-tailed Kite[a]	26	40,000
Red-shouldered Hawk	17	57,000
Broad-winged Hawk	15	100,000
Pileated Woodpecker	15	19,000
Cooper's Hawk	15	44,000

[a]Based on Cely and Sorrow's (1990) work, a 40,000 hectare patch of bottomland hardwood forest would support only about 80 pairs of Swallow-tailed Kites. A secure (source) population would realistically have to be based on a regional (Southeast U.S.) population.

Step 4: Determine the Extent and Location of Existing Habitat Suitable for Meeting the Requirements of Individual Populations of Priority Species Groups—A GIS allowed an analysis of the current status of forested habitat in the MAV. Using 1992 Landsat thematic mapper images, we located and measured more than 35,000 forest patches 1 ha or larger (fig. 1). The average patch size is less than 40 ha. Fewer than one percent of the forest patches are larger than 4,000 ha, but they account for more than 52% of the total forest area. The GIS helped to identify opportunities in which relatively minor improvements of size or configuration through reforestation could create patches at or above threshold sizes. Maps produced through this process have been invaluable tools in all subsequent phases of bird conservation planning in the MAV.

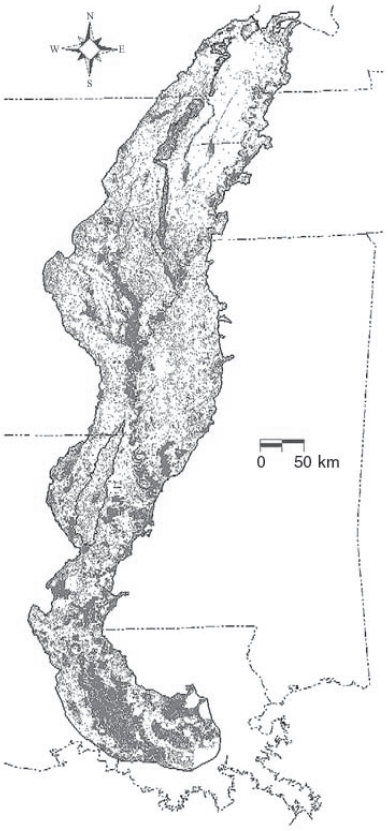

Figure 1—Existing forest patches in the Mississippi Alluvial Valley circa 1992.

Step 5: Set Site-Specific Habitat Objectives—Having determined the areal habitat requirements for source populations of the high-priority species and having measured the amount of existing habitat that can support these populations, we had enough information to identify the specific locations desired for habitat protection/restoration. In addition to habitat requirements and existing forest locations, several other factors, such as flooding frequency and current land use, were used to identify proposed habitat protection/restoration sites. Where possible, restoration sites were centered on existing public land. Where linkages could logically be created, existing forest patches were combined to reach target sizes. For this reason, several existing 4,000 or 8,000 ha patches sometimes were combined into a proposed 40,000 ha patch.

Land use adjacent to existing or proposed forest patches was an important consideration in identifying and locating conservation areas. Adjacent land use can be beneficial, neutral, or hostile to bird survival and reproduction in forest patches. The Mississippi River and other large bodies of water are considered neutral, and the forested uplands on the periphery of the MAV are considered neutral or beneficial. Land uses that support large numbers of Brown-headed Cowbirds and predators are clearly hostile. Grazed levees, which support large populations of cowbirds, are one of the most hostile land uses. Crop lands are generally hostile, but this likely varies with the type of crop.

We identified 101 target forest patches (table 4, fig. 2), but the number of these sites and their location is not final, and probably never will be. A massive reforestation effort will be necessary to create these patches, and developing them will be opportunity driven. As new opportunities arise and old patch objectives become unattainable, locations of target patches will change.

The current distribution of target patches within the MAV is not even, largely reflecting existing opportunities. For example, more and larger patches exist in southern Louisiana than in northern Mississippi. As a result, the planning team tended to include marginal patches in northern Mississippi more frequently than in areas with adequate numbers of apparently higher quality sites. The most disturbing bias in patch distribution is that a majority of patches are in wetter parts of the MAV, either within the mainline levee systems, or in other areas where permanent or frequent flooding precludes consistent agricultural productivity. A concerted effort is needed to ensure that the range of conditions within the forest patches adequately represents the range of naturally occurring soil and community conditions in the MAV. This ultimately may require more or different forest restoration efforts than currently are contemplated.

Step 6: Set Meta-Population Goals—Assuming that each target patch truly will support a source population of the target species, does the number of patches in the three size classes represent an acceptable meta-population goal for the high-priority species? We feel cautiously optimistic that it does, with the possible exception of the Swallow-tailed Kite. Eventually a population and habitat viability analysis on the range of this species throughout the Southeast may be necessary to generate more reliable conservation goals. For all other species, we feel that the patch goals we have recommended in the MAV, if achieved, should preclude any local extinctions, and should allow population trends to stabilize (inasmuch as breeding ground conditions affect the survival and success of long distance migrants).

In some ways, however, the issue of sufficiency of population goals at the physiographic area level is not biological in nature, but instead depends upon the future demands of society for populations of birds and other elements of biological diversity. From this perspective, evaluating the sufficiency of these ambitious but realistic goals is difficult. The next phase of planning will involve establishing

Table 4—Distribution of 101 target forest patches in the Mississippi Alluvial Valley.

State	4,000-8,000	8,000-40,000	>40,000
		(*ha*)	
Arkansas	9	11	3
Illinois	0	1	0
Kentucky	3	1	0
Louisiana	19	15	7
Mississippi	14	6	2
Missouri	6	1	0
Tennessee	1	1	1
MAV Total	52	36	13

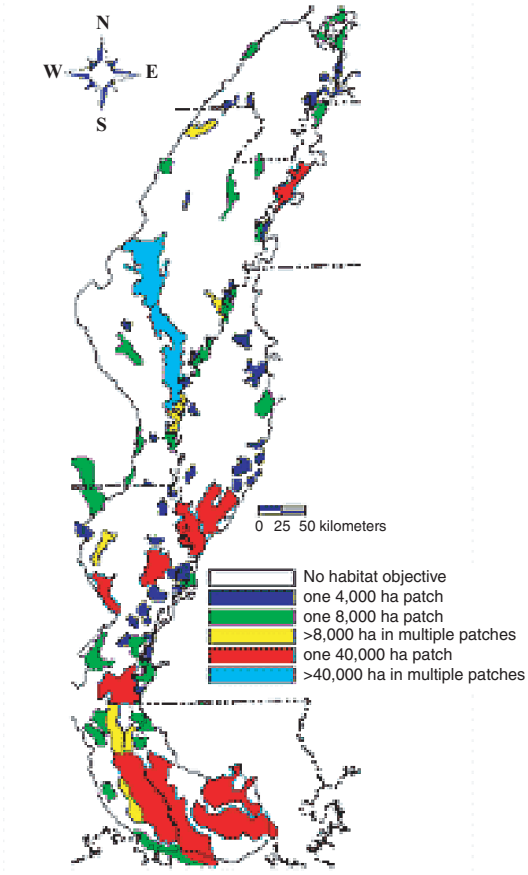

Figure 2—Proposed bird conservation areas in the Mississippi Alluvial Valley (some areas contain >1 targeted forest patch).

specific objectives for each of these target forest patches. These objectives will be based upon current size and configuration of forested habitat, ownership, intent of the landowners, flood regimes, and the avifauna. In general, forest habitat on public land, private industrial forests, and in limited partnership hunting clubs is considered secure. However, private landowner involvement also will be essential to achieve conservation objectives, because land acquisition by public and private conservation agencies never will be adequate. Indeed, this planning process is not intended to result in a land acquisition plan, but to serve as a guide to focus reforestation efforts of all kinds.

Conclusion

The model planning process for the MAV provides site-specific habitat objectives within the context of landscape level conservation needs. The process also gives land managers a perspective on how their management decisions blend with the overall conservation needs of the MAV, at least with regard to forest breeding birds. The process should aid local planning and help to direct, justify, and fund conservation projects. Many assumptions were made in setting these objectives, often based on little existing information. Research to test these assumptions is critical. Monitoring and evaluating the implementation of these recommendations also is essential (Twedt and others, this proceedings). Through adaptive management, objectives will change as research refines our assumptions, or if monitoring indicates that the intended results are not being achieved.

Acknowledgments

This process was a cooperative planning effort from the very beginning. Gary Myers, Executive Director of the Tennessee Wildlife Resources Agency, was the catalyst that started this effort, and he made many calls to free staff time to work on this project. The outline and structure of the plan was produced by a core team consisting of (in addition to the authors) Charles K. Baxter, U.S. Fish and Wildlife Service (USFWS); Cindy Brown, The Nature Conservancy (TNC), Louisiana; Robert J. Cooper, University of Georgia; Robert P. Ford, Tennessee Conservation League; Paul B. Hamel, USDA Forest Service; Robert Hatcher, Tennessee Wildlife Resources Agency; W. C. (Chuck) Hunter, USFWS; Seth E. Mott, USFWS; David N. Pashley, American Bird Conservancy; Lance Peacock, TNC, Arkansas; Karen Rowe, Arkansas Game and Fish Commission (AGFC); Cathy Shropshire, Mississippi Department of Wildlife, Fisheries and Parks; Mike Staten, Anderson-Tully Company; Mark Swan, TNC, Louisiana; Mark S. Woodrey, Mississippi Department of Wildlife, Fisheries and Parks; and Scott C. Yaich, AGFC. A large group of wildlife professionals contributed to the selection of restoration/protection sites at a meeting in Memphis, Tennessee, and in subsequent reviews. Their input was critical to making the habitat objectives as realistic as possible. As this plan evolves in response to better information and conservation opportunities, involvement by a wide range of biologists, business people, farmers, politicians, and the public will be essential for its successful implementation.

An Evaluation Strategy for Conservation Goals in the Mississippi Alluvial Valley

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Abstract—The population goals and habitat objectives established by the Mississippi Alluvial Valley Migratory Bird Initiative are based on several unverified assumptions. We have developed an evaluation strategy that identifies research needed to verify these assumptions. We also have outlined a monitoring strategy designed to track progress toward achieving habitat objectives and population goals.

Several assumptions, based on the best available scientific data, were made to establish population goals and habitat objectives for the conservation of wintering waterfowl, migrating shorebirds, and breeding Neotropical migratory birds (NTMBs) in the Mississippi Alluvial Valley (MAV). Conservation goals were established for each of these three species groups based on perceived habitat requirements and limitations on the availability of habitat during critical periods in the life history of these species. Unique research and monitoring strategies have been developed to evaluate progress toward goals for each species group. In each case, research will focus on testing the validity of assumptions used in establishing conservation goals, whereas monitoring is used to assess progress toward achieving population goals and habitat objectives that have been established.

Waterfowl

The goal of the Lower Mississippi Valley Joint Venture of the North American Waterfowl Management Plan is to provide sufficient foraging habitat within the MAV to support wintering populations of 4.3 million ducks and 1.0 million geese (Lower Mississippi Valley Joint Venture Management Board 1990). Foraging habitat for wintering waterfowl is assumed to be the primary determinant of carrying capacity within the MAV. It is further assumed that foraging habitats consist of a combination of flooded cropland, forested wetlands, and moist-soil areas, and that these habitats are located on both public and private lands. The Lower Mississippi Valley Joint Venture Evaluation Plan (Loesch and others 1994) provides detailed information regarding research needs for testing assumptions used in developing population goals and foraging habitat objectives for wintering waterfowl. Major evaluation issues include: (1) establishment of a geographic information system to assess progress toward habitat objectives; (2) testing the assumption that foraging habitat limits carrying capacity; (3) assessing relationships among waterfowl habitat, farming practices, and water quality; and (4) determining waterfowl population responses to habitat changes. Current studies address key assumptions such as: (1) the size and distribution of wintering waterfowl populations (Reinecke and others 1992); (2) winter survivorship (Reinecke and others 1987); (3) the distribution of flooded habitat during winter (Uihlein and others 1994); (4) the availability of forage; and (5) avian use of managed habitats (McAbee 1994).

Shorebirds

The MAV Migratory Bird Initiative has established a goal of providing foraging habitat for one-half million shorebirds during southward migration. Most of this habitat will be provided on managed public lands through development and management of shorebird foraging habitat. Because of generally dry conditions in the MAV during late summer, water must be actively managed on these shorebird management units (Helmers 1992). Critical assumptions for establishing shorebird conservation goals include: (1) foraging habitat limits the carrying capacity of the MAV and is most limited during late summer and fall; (2) about one-half million shorebirds pass through the MAV during southward migration; (3) the average duration of southward migration, during which time shorebirds forage in the MAV, is ten days; (4) migrating shorebirds require about 8 g of invertebrate forage per day; (5) one ha of managed shorebird foraging habitat provides about 20 kg of invertebrate forage; and (6) managed habitats will attract and support migrating shorebirds. Research is needed to address each of these assumptions. Below we have listed research questions associated with shorebird conservation in the MAV and suggested possible mechanisms to address these questions.

Objective I: Assess the Availability and Distribution of Foraging Habitat—Research is needed to determine the extent and distribution of shallow water foraging

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habitat during southward migration (15 July-30 September) of shorebirds. The distribution of habitat between public and private lands must be assessed to provide estimates of the area flooded by managed and unmanaged water.

Flooded habitat can be determined from classified Multispectral Scanner (MSS) images obtained during the period of southward migration. Using these data, the area and distribution of suitable foraging habitat can be estimated and an effort made to detect all major shorebird stopover areas within the MAV. A database of stopover habitats for shorebird foraging needs to be assembled from reports of knowledgeable observers, areas reported by wildlife managers as being managed for shorebirds, areas identified on remotely sensed imagery, and from aerial reconnaissance. As shorebird management units are created on national wildlife refuges and state wildlife management areas, their location and area will be added to an MAV-wide database. This database of shorebird management units will be used to monitor progress toward shorebird foraging habitat objectives. Aerial transect surveys may be required to assess the proportion of the total suitable shallow water foraging habitat that is included in the shorebird habitat database.

Objective II: Estimate the Number of Shorebirds Using the MAV During Southward Migration—Statistically based, MAV-wide surveys of shorebird populations should be conducted to estimate the shorebird population during southward migration. The georeferenced database of shorebird stopover habitats should be used to ensure that major shorebird concentrations are accounted for in surveys of shorebirds. International Shorebird Survey (Manomet Bird Observatory 1993) sites within the MAV should continue to be monitored and additional sites established. If possible, International Shorebird Survey data should be related to population estimates from MAV-wide surveys using ratio or regression estimators (Cochran 1977).

Objective III: Determine Foraging and Energetic Requirements of Shorebirds—Literature reviews are needed to assess the extent to which foraging requirements of shorebird species are known. Where a paucity of data exists for shorebird species with large populations within the MAV, laboratory studies and field experiments are needed to assess species- and time-specific forage requirements of these species. An assessment of the metabolic use of foods obtained from lands managed for shorebirds should be conducted.

Objective IV: Assess Food Availability on Managed Habitats—To ascertain the quantity and types of food available to migrating shorebirds, we suggest sampling shorebird management units on public lands and suitable unmanaged habitats on private lands. Mud core samples should be used to assess the abundance and types of invertebrates over time and under different management strategies (e.g., flood-up versus draw-down).

Objective V: Determine the Phenology of Southward Migration Through the MAV—Research is needed to determine the duration of southward migration, the average number of stopover sites used, and the average length of stay at each stopover within the MAV.

Observations of color-marked or tagged individuals, concurrent with intensive monitoring of foraging habitats, may provide information on individuals and allow estimates of duration of stay at stopover sites and rate of passage through the MAV. To accomplish this, shorebirds must be uniquely color marked in the northern part of the MAV such that they can be recognized by field personnel using binoculars or spotting scopes. After releasing color-marked birds, observers located strategically throughout the MAV would record all color-marked individuals encountered. Time and distance between repeated observations would provide insight into the temporal dynamics of shorebird migration. If shorebirds were indelibly color marked, subsequent observations during monitoring of International Shorebird Survey sites or other shorebird foraging sites may provide information on movements and survival of shorebirds using the MAV.

Alternatively, or in addition, radio-instrumented shorebirds could be used to estimate the duration of passage through the MAV. To accomplish this, individuals of at least two species of shorebirds should be radio-tagged in the northern part of the MAV. These birds would subsequently be monitored from the ground and from aircraft. One or more radio-locations should be obtained daily for each radio-tagged shorebird until they leave the MAV. Repeated radio-locations provide estimates of daily movements among stopover sites, provide information on the location of stopover sites, and provide an estimate of the time required to pass through the MAV.

Objective VI: Assess the Effectiveness of Management at Providing Suitable Foraging Habitat—The effectiveness with which foraging habitat can be provided on public lands will, in large part, be dictated by the management strategies employed by land managers. Research and monitoring is needed to assess the extent to which lands managed for shorebirds are used by migrant shorebirds, and to determine the most efficacious management strategies. Also of interest is the impact of shorebird management on the use of these areas by waterfowl and other waterbirds. To accomplish this, we recommend that local personnel monitor avian use of shorebird management units. Where possible, these data would become part of the International Shorebird Survey database. Temporal changes in species and abundance of shorebirds would be related to geographic location, local conditions, and management strategies. Specific shorebird management units or management strategies that support little shorebird use should be replaced with alternate locations or modified management techniques.

Neotropical Migratory Birds

Unlike the energetically based foraging habitat assumptions used to establish population goals for wintering waterfowl and migrating shorebirds, population goals for NTMBs assume the need for spatial requirements of territorial individuals. To ensure that source populations exist within forested habitat, several assumptions have been made. These assumptions fall into five broad categories: (1) habitat availability; (2) species distribution; (3) breeding bird densities; (4) source populations; and (5) genetic viability.

We assumed that habitat availability is the primary limiting factor for populations of birds breeding in bottomland hardwood forests in the MAV and that maintaining or restoring "suitable" forest patches (i.e., patches of adequate size, shape, and management) will provide adequate habitat for these species. We also assumed that the breeding bird densities recorded in Hamel (1992b) based on data from the southeastern U.S. reflect the average densities of birds in the MAV. Further, territory distribution within forest patches is assumed to be such that the target number of 500 breeding pairs of the appropriate species (with some exceptions; e.g., Swallow-tailed Kite, [*Elanoides forficatus*]) will occur within suitable forest patches. Each suitable forest patch is assumed to support a source population of each of its representative breeding species; that is, populations that on average produce more offspring than the number required to replace mortality of adults within the forest patch. Finally, we assumed that gene flow within and among populations in forest patches is sufficient to maintain and/or increase the current genetic diversity of the species within the MAV. Evaluation of the MAV Migratory Bird Conservation Initiative for forest-breeding NTMBs will focus on testing these assumptions through a series of objectives.

Objective I: Quantify Bottomland Hardwood Forests in the MAV—A key assumption in the MAV Migratory Bird Initiative is that bottomland hardwood forest habitat is critical to meeting population goals for a majority of breeding migratory birds. To assess the current availability, fragmentation, and isolation of forested habitat within the MAV, an inventory of forest distribution is required. Information is needed not only on the area and distribution of forested habitat but also on the number, area, and "interior area" of contiguous forest patches, and a qualitative assessment of these forest patches (e.g., land ownership, habitat type, hydrological regime).

Using 1992 (spring and fall) thematic mapper (TM) imagery and geographic information system technology, USGS Biological Resource Division and U.S. Fish and Wildlife Service personnel classified the area and distribution of bottomland hardwood forests within the MAV. Forests have been tentatively classified into five primary habitat types: Three hydrologically defined bottomland hardwood forest classes, forest edge habitat, and other forest habitats. Discrete forest patches have been delineated and, in cooperation with The Nature Conservancy, public land boundaries have been defined. From these data, we have obtained: (1) an estimate of the total area of bottomland hardwood forest, by state; (2) estimates of the number of discrete forest patches, their size distribution, and their geographic distribution; (3) estimates of the area of forest in public and in private ownership; and (4) estimates of the forest habitat type within these forest patches.

Within each state, GAP analysis projects (Scott and others 1993) will provide an independent estimate of the area of forested habitat and patch distribution for verification of the above estimates. Databases of public lands, private lands under forest easements (e.g., lands enrolled in the Wetland Reserve Program), and corporate lands managed for forest products have been initiated; these databases should be maintained and periodically updated. Finally, to assess progress toward habitat objectives, periodic updates of land cover derived from remotely sensed data are recommended at 10 to 15 year intervals.

Objective II: Assess the Relationship Between Forest Patches and Breeding Birds—The remaining forests within the MAV are fragmented, and their ability to support NTMBs may be further reduced by intrusion of agriculture, transportation networks, flood control structures, or timber management. Isolation, resulting from forest fragmentation and other anthropogenic impacts, may adversely affect avian diversity and abundance (Robinson 1992).

Although recent studies provide information on the relationship between forest area and species richness (Robbins and others 1989a), and other studies provide information on specific forests within the MAV (Dickson 1978; Christman 1984), these studies have not elucidated the relationship between forest area or forest type and avian richness and abundance in the MAV. Additional information is needed on the diversity and abundance of breeding birds using forest patches of different sizes and different forest types in the MAV.

Specifically, we need research to: (1) evaluate the efficacy of breeding bird point count methods for assessing the relationship between birds and habitats; (2) determine the relationship between avian species richness and forest area-habitat type within the MAV; (3) determine the relationship between relative bird abundance and forest area-habitat type within the MAV; and (4) develop models to predict the distribution and relative abundance of breeding birds based on landscape and vegetative characteristics of forest patches.

An assessment of point count techniques applied to bottomland hardwood forests, based upon standards of the Partners in Flight Monitoring Group (Ralph and others 1993), was conducted and resulted in specific point count recommendations for forests in the MAV (Smith and others 1993; Hamel and others 1996). Following these recommendations, point count surveys and vegetation sampling were conducted within randomly selected forest patches as well as on selected public lands within the MAV. These data will be combined with landscape characteristic data to assess the relationship between forest patch characteristics and species richness and abundance. Species specific surveys have been used to systematically inventory forest patches for the presence of Cerulean Warbler (*Dendroica cerulea*) and Swainson's Warbler (*Limnothlypis swainsonii*). Using these data, as well as other count and Breeding Bird Survey data, models that depict bird distribution within and among forest patches of the MAV are being developed.

Land managers are encouraged to develop lists of breeding and wintering birds for each managed area. Established Breeding Bird Surveys within the MAV should be conducted annually. Breeding Bird Atlases could be used to corroborate predictions of species distributions within the MAV.

Breeding Bird Point Counts should be established and conducted annually in each of 50 or more disjunct stands of the following habitats: (1) semipermanent flooded forests such as those dominated by cypress or tupelo [SAF types 101, 102, 103, 104]; (2) frequently flooded forests such as those dominated by overcup oak, water hickory, willow, or red maple [SAF types 95, 96]; (3) infrequently flooded bottomland hardwood forests such as those dominated by red oaks, sweetgum, sugarberry, or ash [SAF types 61, 62, 63,

64, 65, 88, 89, 91, 92, 93, 94]; (4) upland forests located within the MAV (Macon's and Crowley' Ridges) or within the adjacent "bluff" forests [including pine, hardwood, and mixed pine-hardwood forests]; (5) early successional forests resulting from timber harvest or forest plantings; (6) grasslands; and (7) agricultural habitats. Until a regional or national repository for point count data is established, these data should be submitted in standard ASCII format (Hamel and others 1996) to the Breeding Bird Point Count Repository, c/o Mark S. Woodrey, Mississippi Museum of Natural Science, 111 North Jefferson Street, Jackson, MS 39201.

Objective III: Determine Breeding Bird Densities in Bottomland Hardwood Forests in the MAV With Respect to Intrinsic and Extrinsic Patch Characteristics—The assumption that the breeding densities reported in Hamel (1992b) are reflective of densities in the MAV requires validation. To assess the adequacy of forest patches of known area for harboring a minimum number of breeding pairs, the density of breeding birds within forest patches must be ascertained. A potential problem arises from the assumption that the habitat within and among forest patches is uniformly suitable for breeding by a particular species, and that breeding bird densities are constant over time and space. This obviously is a faulty assumption, because variation within and among patches is the essence of habitat selection. Thus, stochastic breeding bird densities are required that reflect the prevailing habitat conditions (i.e., breeding bird density estimates with associated confidence intervals). Research is needed to estimate breeding bird densities within bottomland hardwood forest patches in the MAV and to refine those estimates based on (a) patch characteristics and (b) habitat types.

To accurately assess actual breeding bird density, counts of breeding pairs must be made over sufficient areas to measure population sizes at a landscape scale. Accurately assessing actual density of breeding birds over such large areas (i.e., thousands of ha) is not economically feasible. Therefore, we intend to assess the densities of the birds indirectly, primarily by using the results of point count surveys. These provide information on the relative abundance of breeding birds and can be used as an index to their actual density. Although a number of assumptions are required to go from relative abundance, as determined through point count protocols, to actual breeding bird densities, the most practical option is an indexing approach, such as using point count surveys. By assessing actual densities on small plots, such as 10 to 50 ha spot-mapping plots used in demographic assessments, and indexing those densities to relative abundance estimates derived from point count surveys on those same sites, we intend to extrapolate densities from point count surveys applied over larger areas and among forest patches with different characteristics using ratio or regression estimators (Cochran 1977).

To account for variation in breeding bird density due to structural habitat variation within patches, we have assumed that habitat variability provides suitable breeding habitat at some particular rate. This rate is reflected in the observed density of the species in forest patches having similar characteristics. By providing areas large enough to accommodate the target number of breeding pairs at their observed density, we believe that we have accounted for this source of variation. To test the validity of this approach, we will assess the habitat used by breeding individuals of the species and compare the occurrence of habitat used to its availability within forest patches. Where existence of apparently suitable habitat differs from the rate of use, factors other than habitat limitation may be implicated in the distribution of the species (Rappole and McDonald 1994).

Established point count data will be used to assess annual variation in the relative abundance of breeding birds and as an index to actual breeding bird densities. In addition, a minimum of 10 Breeding Bird Censuses (Hall 1964), with associated concurrent point counts, should be established within bottomland hardwood forests within the MAV. Both Breeding Bird Censuses and point counts should be conducted annually.

Objective IV: Quantify Species-Specific Demography of Bottomland Hardwood Forest Breeding Bird Populations in the MAV (Productivity, Survival, Dispersal, and Modeling)—The assumption that the proposed forest patches of 4,000, 8,000, and 40,000 ha (10,000, 20,000, and 100,000 acres) will support source populations of forest breeding bird species within their respective size classes is difficult to evaluate. Only species-specific demographic analyses, over broad geographic areas and over extended time periods, can accurately assess this assumption. To evaluate populations within forest patches, we need information regarding avian productivity, specifically nest survivorship, nest parasitism rates, nest predation rates, and renesting effort. Additionally, data are needed on age-specific survival of individuals, dispersal, and philopatry. Obtaining all these data is time consuming, difficult, and expensive, but they are essential to understanding the ability of forest patches of different sizes to support populations of breeding birds.

Our assumptions about habitat utilization, patch characteristics, and survivorship are currently based upon the habitats of breeding adults as we understand them. Few or no data exist on differences in habitat utilization between breeding adults and non-breeding adults during the breeding season, or between adults and their offspring subsequent to the breeding season. Research designs that identify habitat use and dispersal of post-breeding adults and of young-of-the-year will be extremely useful to evaluating the landscape conditions that promote source populations.

Logistic and fiscal constraints mandate collection of demographic data at only a few locations. We assume, however, that demographic parameters can be related to forest patch characteristics, and thereby extrapolated to other, similar forest patches within the MAV. To accomplish this goal, we must be able to relate demographic parameters to forest patch metrics and within-patch vegetation characteristics.

Species-specific data on productivity, survival, and dispersal are needed within forest patches of different sizes (<4,000 ha, 4,000 to <8,000 ha, 8,000 to <40,000 ha, and >40,000 ha) and in different habitats or under different management regimes. Productivity data are needed on (1) nest survival, (2) rate of nest parasitism, (3) rate of nest predation, and (4) rate of renesting. By extension, data are needed on annual and lifetime productivity of individuals.

Data on age- and sex-specific survival of individuals are needed. Specific survival estimates are needed (a) within the breeding season, and (b) among breeding seasons.

Age- and sex-specific rates of philopatry, and/or rates of dispersal, are needed to bolster estimates of individual survival, both as a measure of population stability and to provide information on gene flow among forest patches. Specifically, information is needed on: (1) dispersal and habitat use by post-fledging and post-breeding birds within the same season; (2) rate and distance of dispersal of birds between natal and subsequent breeding sites; and (3) rate and distance of dispersal of adult breeding birds among breeding seasons. The impact of forest management on rates and distances of dispersal also needs to be examined. Finally, predictive models need to be created that estimate species-specific demographic parameters within a forest patch based on the characteristics of the patch.

Demographic studies currently are under way in bottomland hardwood forests in the MAV from southern Illinois to southern Louisiana. Current studies are being conducted on different target species and species groups, by different personnel, and with different overall objectives. However, these studies follow similar, mutually agreed upon methodologies of data collection. Most of the studies will obtain estimates of productivity, nest survival, nest parasitism rates, and nest predation rates.

Although obtaining adequate demographic data on certain high-priority species is difficult, some demographic data on species such as Cerulean Warbler are becoming available. Additionally, demographic data from studies of more common species, such as Acadian Flycatchers (*Empidonax virescens*) and Prothonotary Warblers (*Protonotaria citrea*), on a wider array of sites, are being obtained. Results of current demographic studies will be extrapolated to other sites and to other species within these sites. Additional research, however, will be needed to confirm the appropriateness of extrapolation.

Survival of individuals, including age-specific estimates within and among seasons, is difficult to assess, because we have little data on the dispersal of individuals. Data on site fidelity and dispersal are similarly difficult to obtain, and require extensive investigations across both area and time to estimate. Minimal estimates of survival of individuals and site fidelity, however, are being obtained through color marking of individuals in mark-recapture studies or through constant-effort mist netting. Application of open population models (e.g., Pollock and others 1990; Lebreton and others 1992) to these data should result in estimates of survival with defined confidence limits that can be used for stochastic population modeling.

We intend to derive species-specific predictive models of demographic parameters from data obtained on studies in forest tracts of different sizes and under different forest management regimes. By examining demographic parameters of selected species under different landscape conditions, we will be able to evaluate the assumption that demographic parameters can be predicted from forest patch characteristics. Subsequent demographic studies will be required in forest patches not used to develop models to examine the validity of these predictive models.

Estimates of demographic parameters should be monitored using techniques such as MAPS constant-effort mist netting (DeSante and others 1993b; DeSante and Burton 1994a) and bird nest searching protocols (Martin and Guepel 1993a; Martin and others 1997). Future work should be treated as experimental tests of predictions derived from the results of initial studies.

Objective V: Determine Optimal Number of Populations and Population Sizes Required to Maintain Genetic Viability—We assumed that the number of source populations proposed within the MAV constitutes an adequate number of breeding individuals within an overall meta-population to ensure long-term maintenance of genetic diversity and population viability. We are not now in position to test whether the proposed minimum of 500 breeding pairs is sufficient to ensure viability within a forest patch, nor do we have sufficient data to support meta-population dispersal within the MAV. The proposed number of 500 pairs, however, establishes a target for planning and for eventual genetic assessment of these populations as more data on demographics and dispersal become available.

Data needed to begin a meta-population analysis within the MAV include species-specific estimates of: (1) survival rates of hatching-year birds, (2) rates and distances of dispersal of young to breeding sites, (3) among year dispersal of breeding adults, and (4) rates of gene flow among breeding populations.

Summary

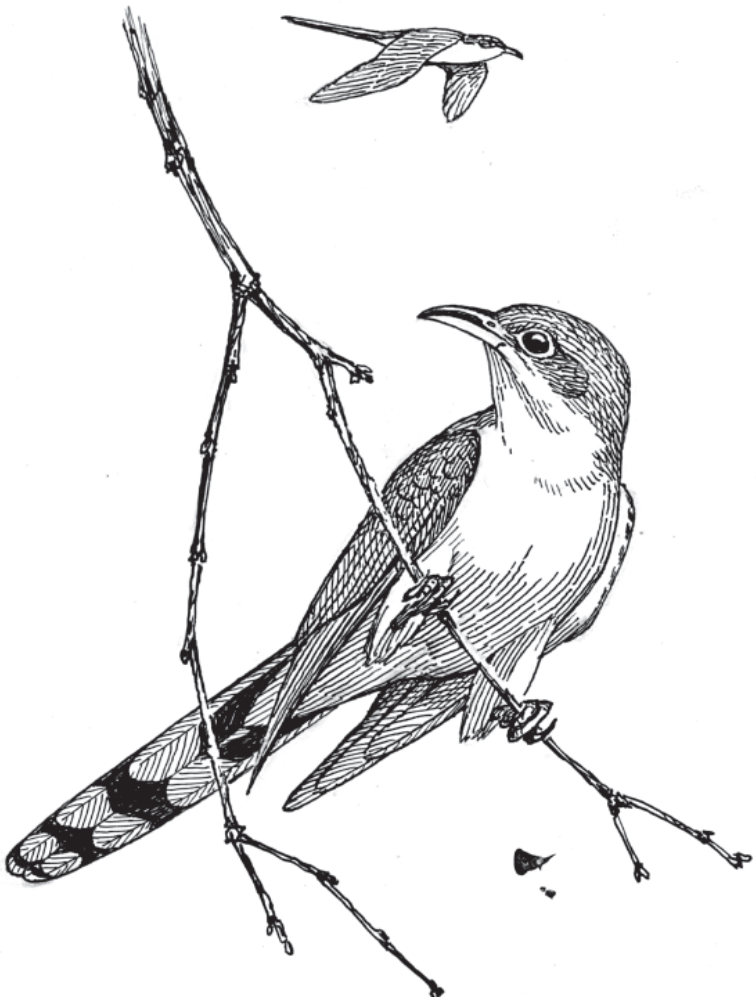
The evaluation strategy outlined above builds upon an evaluation plan developed for wintering waterfowl by the Lower Mississippi Valley Joint Venture. This enhanced evaluation strategy identifies research needs that are targeted at providing verification of the assumptions used to establish conservation goals for wintering waterfowl, migrating shorebirds, and forest-breeding landbirds. Monitoring strategies have been proposed that will gauge progress toward habitat objectives and, ultimately, population goals.

Although proposed research and monitoring are primarily directed at the objectives identified in the MAV Migratory Bird Conservation Initiative, other research needs that are related to migratory landbirds in the MAV have been identified, including: (1) habitat use during migration; (2) use of nonforested habitats; (3) use of food resources; and (4) winter habitat use.

More specific research objectives, including investigators, study plans, cooperators, and time tables, have been identified for wintering waterfowl (Loesch and others 1994). Similarly detailed research objectives currently are being developed for shorebirds and forest-breeding birds. In all cases, however, completion of proposed research and implementation of monitoring plans will require increased levels of personnel and funding. Given sufficient support, we are optimistic that many of these objectives can be achieved within the next 10 years. A notable exception, however, is quantifying demographic parameters of forest breeding birds. With four forest patch classes, different habitats, and different management strategies to assess, obtaining necessary demographic data for even a few species could take considerably longer.

Investigation of these issues, however, will require a considerable expenditure of effort and time to obtain even minimally adequate information on some of these relationships. All monitoring and research undertaken in the MAV will require a tremendous amount of cooperation.

2. Setting Conservation Objectives: Principles



Yellow-billed Cuckoo

2. Section Overview—Setting Population Objectives: Principles

David N. Pashley

A clear statement of objectives increases the likelihood that any endeavor will be successful. For conceptually simple conservation projects, such as those targeted to a single species or a single plot of ground, objectives are reasonably easy to phrase. However, objectives for complex conservation projects, such as those intended to protect the health of a continental avifauna, are difficult to phrase explicitly. Partners in Flight began such a grand endeavor with simpleminded objectives, such as "keep common birds common," and to "reverse declines of migratory birds." Recently, one of PIF's greatest accomplishments has been the insertion of rigorous standards into the means by which bird conservation objectives are set.

The first two papers in this section address this thought process. First, Mike Carter and coauthors lay out the PIF Species Prioritization Process that is at the core of the objective-setting process. Then, Ken Rosenberg and Jeff Wells build on this structure, adding important insights based on more detailed investigations of bird distribution and population status.

Establishing priority species is but the first step in setting objectives, however. Both logistical and conceptual obstacles still remain. The third paper, by E. J. Williams and myself, addresses the logistical issue of conflicting means of carving up the geography of the continent into conservation planning units.

The four remaining papers in this section deal with conceptual issues. The first two, by Frank Thompson and coauthors and by Terri Donovan and coauthors, wrestle with many of the "big picture" concepts to which these groups of authors have made enormous contributions over the years. Then, Carol Beardmore and Jeff Hatfield deal specifically with Population Viability Assessment, a potentially powerful tool in setting objectives for less common species. Finally, Mike Conroy reminds us that objectives, once set, should never be cast in stone, but rather should be subjected to continual reanalysis and revision as knowledge is gained and the results of conservation actions are evaluated.

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Setting Conservation Priorities for Landbirds in the United States: The Partners in Flight Approach

Michael F. Carter
William C. Hunter
David N. Pashley
Kenneth V. Rosenberg

Abstract—Partners in Flight (PIF) was created in 1990 in response to concern for declining populations of Neotropical migratory songbirds (Robbins and others 1986; Askins and others 1990) and in the realization that conservation of these species required efforts beyond the ability of any single organization or agency (Finch and Stangel 1993b). In subsequent years, PIF expanded its mandate to include all nongame landbirds and succeeded in raising awareness regarding the status of bird populations, but it had difficulty recommending which specific conservation actions were most warranted.

In 1995, PIF began a comprehensive planning effort to conserve nongame landbirds and their habitats throughout the United States. A critical first step in the planning process was to establish clear and consistent priorities among the several hundred landbird species based on their vulnerability and need for conservation action. To this end, PIF developed a species prioritization process for the southeastern United States (Carter and Barker 1993; Hunter and others 1993a) by modifying earlier efforts (Millsap and others 1990; Master 1991) and later expanded the effort to include all of North America north of Mexico. This prioritization process has been reviewed extensively by local and regional bird experts and most recently by the AOU Conservation Committee (Beissinger and others 2000). Here, we describe the species prioritization process and provide the context for its application in conservation.

One objective of the PIF process was to develop a system that could be applied consistently to any group of species, in any geographic area, and in any season. Initial development focused on the breeding avifauna of North America north of Mexico, although efforts will be expanded to include breeding birds south of the border and wintering and transient birds. A series of scores is assigned to each species, ranging from 1 (low priority) to 5 (high priority), for seven parameters that reflect different degrees of need for conservation attention. These scores are assigned within physiographic areas, which were modified from Breeding Bird Survey (BBS) physiographic strata (Robbins and others 1986). The entire matrix of priority scores and accompanying documentation are maintained at the Colorado Bird Observatory <http://www.cbobirds.org>.

Partners in Flight Species Prioritization Process

The seven parameters in the prioritization process are based on global and local information. Three of the parameters are strictly global in that a single value is assigned for the entire range of a bird. These are Breeding Distribution (BD), Nonbreeding Distribution (ND), and Relative Abundance (RA). Global values are assigned to three other parameters, Threats to Breeding (TB), Threats to Nonbreeding (TN), and Population Trend (PT), but these may be superseded by values assigned specifically to a physiographic area when appropriate and possible. The last parameter, Area Importance (AI), is always assigned locally for a specific physiographic area. Scores for each of these seven variables are determined independently.

Wherever possible, scores are based on quantitative and objective data. For most species, the BBS (Robbins and others 1986) provides relative abundance and trend data used to assign scores for RA, PT, and AI. Where BBS data are not available, scores may be based on other quantitative data, expert opinions, or may reflect lack of current knowledge. Scores for range size (BD, ND) are based on published maps, and scores for threats are based on expert opinion. In addition, Population Trend Data Quality (PTDQ) assesses BBS sample size and variance to gauge the confidence in data used to assign PT.

Breeding Distribution (BD)

Generally, species with the widest breeding distributions are the least vulnerable to deleterious environmental changes and catastrophic events. BD is based on the proportion of North America that is covered by a species' breeding range. We have defined North America to include the main body of the continent (excluding Greenland) through Panama and the islands of the Caribbean, comprising an area of 22,059,680 km^2 (National Geographic Society 1993). A species inhabiting a breeding area that represents 2.5% or less of North America

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is assigned a BD score of 5 because species with such small ranges could be significantly and negatively affected by a catastrophic event, such as a hurricane (table 1). At the other extreme, species inhabiting breeding ranges covering 20% or more of North America should be at relatively low risk from stochastic and other negative environmental events and are assigned a score of 1. Species with ranges between 2.5% and 20% were ranked on a graded scale (table 1). The primary sources of information for bird distribution for BD and ND (see below) were maps from two well-known field guides (National Geographic Society 1987; Howell and Webb 1995).

Nonbreeding Distribution (ND)

Nonbreeding Distribution reflects the proportion of North America or equivalent area that is covered by a species' nonbreeding range. It is scored in the same manner and using the same scale as BD (table 1). This parameter is based on the smallest nonbreeding range that a species occupies. Therefore, species that move through severe migratory bottlenecks, such as Red Knots (*Calidris canutus*) staging at Delaware Bay, receive high scores to reflect the risks associated with such concentration.

Relative Abundance (RA)

Relative Abundance measures the abundance of a species in appropriate habitat within its range relative to other bird species. Species that are uncommon are assumed to be at greater risk and receive higher RA scores. Scores for RA are determined using one of two methods. Where BBS data are available, RA values are assigned on the basis of the mean number of birds on the 10 BBS routes on which a species is most abundant (table 2) using an analysis derived from Price and others (1995). A less-quantitative approach is necessary for species for which BBS data are unavailable or unreliable, including many arctic, boreal, and tropical species whose breeding ranges largely fall outside of the area sampled by the BBS. In these cases, RA scores are assigned on a qualitative scale of abundance (table 2) on the basis of published notes and expert opinions, as described in earlier versions of the PIF prioritization process (Carter and Barker 1993; Hunter and others 1993a). All departures from BBS-derived criteria and justifications for departures are documented in the database.

Table 1—Criteria used to score Breeding Distribution (BD) and Nonbreeding Distribution (ND) parameters in the Partners in Flight species prioritization process.

BD/ND score	Percent of North America or equivalent area
1	20% or more (>4,411,940 km^2)
2	10 to 20%
3	5 to 9.9%
4	2.5 to 4.9%
5	Less than 2.5% (<551,493 km^2)

Table 2—Criteria used to score the Relative Abundance (RA) parameter in the Partners in Flight species prioritization process.

RA score	RA criterion no. 1[a]	RA criterion no. 2[b]
1	100 or more	Abundant
2	30 to 99.9	Common (or locally abundant)
3	10 to 29.9	Uncommon to fairly common
4	1 to 9.9	Rare to uncommon
5	Less than 1	Very rare to rare

[a]Mean number of birds per BBS route.
[b]Expert opinion.

Threats to Breeding (TB) and Threats to Nonbreeding (TN)

These parameters reflect recent and predicted threats that may put a species at risk of decline or extirpation from an area. TB and TN are scored using a standardized scale for evaluating conditions, including what has happened in the past and what is likely to happen in the future, that affect an area's ability to support healthy populations of a bird (table 3). These conditions include the amount of suitable habitat, other factors that affect the species' survival or reproductive success, including cowbird parasitism, pesticides, and predation, and the capacity of the species to withstand or recover from negative conditions. Present conditions are based on the percent of conditions that existed around 1945 that still exist today. Future conditions are the percent of current conditions anticipated to exist in subsequent decades.

We illustrate this process for two species that inhabit the Central Shortgrass physiographic area. Much of the shortgrass prairie, the preferred habitat of McCown's Longspur (*Calcarius mccownii*), has been lost or degraded over the last two centuries (Knopf 1994). Perhaps 51 to 75% of the habitat that existed in 1945 has been lost (with 25 to 49% remaining). Using the 25 to 49% remaining column, McCown's Longspur could only score a 3, 4, or 5 (table 3). Using similar reasoning, we estimate that loss rates of shortgrass habitat will not exceed 50% in the next few decades, but that not all shortgrass prairie that exists today will exist in the future. Therefore, McCown's Longspur in this physiographic area scores a TB of 4. The Horned Lark (*Eremophila alpestris*) also occurs in the same shortgrass prairie habitat but would be scored differently. The conversion of shortgrass to agricultural lands has not been as detrimental to Horned Larks as to many other species, so perhaps 100% of past conditions remain for this species, leaving possible scores of 1 to 5. Because future conditions are likely to favor Horned Larks (i.e. no future loss), the species scores a 1 for TB. Although the scoring process for TB is heavily based on amount of habitat, it also may incorporate factors related to the ability of an area to support a species. For example, if we concluded for Horned Larks that new threats (e.g., pesticides, plowing of nests) existed that could limit breeding success to less than 25% of what would occur under current conditions, then Horned Larks would receive a TB score of 5.

TN is scored using the same criteria as TB (table 3). As with Nonbreeding Distribution discussed earlier, TN is named and scored to reflect not only wintering conditions

Table 3—Scoring of Threats Breeding (TB) and Threats Nonbreeding (TN) in the Partners in Flight species prioritization process, based on an evaluation of past, present, and future conditions available to support healthy populations of a given species (see text).

Percent of present conditions in future	Percent of past condition remaining today				
	100+	75 to 99	50 to 74	25 to 49	<25
100+	1	1	2	3	4
75 to 99	2	2	3	4	5
50 to 74	3	3	4	4	5
25 to 49	4	4	4	5	5
<25	5	5	5	5	5

but also threats faced during migration. Species that pass through severe ecological bottlenecks during migration may score higher than they would based on winter conditions alone. Species that reside within an area throughout the year are often assigned the same TB and TN scores, but those that change habitats within that area, or are otherwise more or less vulnerable in winter, could receive different scores for the two parameters.

Population Trend (PT) and Population Trend Data Quality (PTDQ)

Population trend scores, reflecting the magnitude and direction of population change, are assigned globally as well as locally for each physiographic area. When possible, population trend scores are assigned on the basis of BBS data (table 4) as analyzed by the BBS laboratory of the United States Geological Survey's Biological Resources Division (J. Sauer, personal communication). Each PT score is linked with a PTDQ score that assesses the quality of BBS data based on sample size and statistical significance.

A population trend must meet the thresholds of magnitude and reliability associated with PTDQ scores of A or B to warrant either a very high (4 or 5, declining) or a very low (1, increasing) score (table 4). Species not meeting these minimum requirements are assigned a PT of 3 (trend unknown) and receive PTDQ scores of D, E, or F. A PTDQ score of D is assigned to species for which a large sample size indicates positive or negative nonsignificant trends of at least 1%. This often applies to birds whose local populations fluctuate greatly from year to year, possibly reflecting fluctuating habitat conditions and/or possibly obscuring long-term trends. Species assigned a PTDQ score of E1 or E2 have insufficient sample sizes. Species not detected on the BBS in the area are given a PTDQ of F and usually are locally rare or difficult to detect.

A PT score of 2 reflects two possibilities that are differentiated from each other by the PTDQ score and the magnitude of the trend. A PT of 2 with a PTDQ of A2 or B2 and a trend between ±1% indicates a well-sampled species whose population is essentially stable. A PT of 2 with a PTDQ of C1 or C2 and an increasing trend (at least 1% per year) reflects a species that is probably increasing, but without statistical certainty.

Table 4—Criteria for scoring population trend (PT) and population trend data quality (PTDQ). PTDQ depends on number of BBS routes (*n*) within a physiographic area and the statistical significance of the population trend being different from 0 (*P*). In addition, a PTDQ symbol of X should be applied whenever PT is based on data other than the BBS (expert opinion, Christmas Bird Count, etc.); the source should be specified in the database.

PT score	BBS trend (% year^{-1})	PTDQ	*n*	*P*
1 = Significant increase	$1.0	A1	$34	#0.10
		B1	14 to 33	#0.10
2 = Possible increase	$1.0	C2	$14	0.11 to 0.35
		C1	6 to 13	#0.10
2 = Stable	!1.0 to 1.0	A2	$34	Any *P*
		B2	14 to 33	Any *P*
3 = Trend uncertain	<!1 or >1.0	D	$14	>0.35
	Any trend	E1	6 to 13	>0.10
		E2	<6	Any *P*
	No data	F	—	—
4 = Possible decrease	#!1.0	C2	$14	0.11 to 0.35
		C1	6 to 13	#0.10
5 = Significant decrease	#!1.0	A1	$34	#0.10
		B1	14 to 33	#0.10

In cases where BBS data are unsatisfactory, other population trend data or the opinions of local experts may be substituted with the scoring mimicking the criteria in table 4. PT scores not derived from the BBS are assigned a PTDQ score of X, and the origin of the information is noted in the database.

Area Importance (AI)

This variable is intended to evaluate how important a particular physiographic area is to the conservation of a given species. AI scores compare the abundance of a species within a physiographic area relative to other areas throughout its range (table 5). Because these scores are based on an index of relative abundance, they are not influenced by the size of the geographic unit in question. Data for this criterion are derived from the BBS, when they are adequate. The first step is to identify the physiographic area within the bird's range with the maximum mean number of individuals per BBS route. Mean numbers of birds per route for other physiographic areas are compared with the physiographic area maximum. For cases in which BBS data are not available or seem to be misleading, AI can be assigned on the basis of local review by experts knowledgeable about the distribution and abundance of the species, following as closely as possible the rationale behind the quantitative method.

Other Data Quality and Supplemental Scores

Although PTDQ is the only supplemental value currently assigned, it may be beneficial to document the quality of information used in developing scores for other variables. In the past, PIF has assigned some data quality scores for TB and TN, but these have been rarely used or have caused confusion. Hunter and others (1993a), following Millsap and others (1990), described a potentially useful supplemental score termed "Management Needs" that documents the amount of management attention that a species is receiving. This could assist in differentiating among species that are receiving an adequate amount of attention from those with similar prioritization scores that may require additional management effort.

Table 5—Criteria for scoring Area Importance (AI) in the Partners in Flight species prioritization process.

AI score	AI criterion no. 1[a]	AI criterion no. 2[b]
1	0 to 1.9	Accidental or extremely uncommon
2	2.0 to 5.9	Occurs regularly, but is peripheral
3	6.0 to 24.9	Present in low relative abundance
4	25.0 to 49.9	Present in moderate to high relative abundance
5	50 or more	Present in highest relative abundance

[a]Percent of maximum BBS abundance.
[b]Expert opinion.

Interpretation and Application of Priority Scores

As accurate as individual scores in a prioritization database may be, their usefulness depends on how they are interpreted and applied to conservation actions. In the following section we suggest various uses of the species prioritization database, address issues regarding interpretation of scores, and give examples of their current application. A simple application is a summation of the seven parameter scores to indicate overall conservation priority. This total, which can range from 7 to 35, is a potentially useful number, but only when considered in the context of its component parts. Relying solely on total scores to set conservation goals can be misleading and is perhaps the most common misuse of the prioritization process and the numbers it generates. Beissinger and others (2000) suggest a categorical approach that determines an overall level of priority based on combinations of scores, emphasizing declining population trend and high threats to populations. PIF bird conservation plans, described below, use a combination of approaches, including the sum of all scores, as a flexible tool to indicate priority status.

Weighting and Sorting

At present, the seven variables in the prioritization process are equally weighted in the database. When the database was initially developed, suggestions were made to weight certain parameters in situations where one factor might be considered more important than another. A particular score may be emphasized or de-emphasized by being multiplied by a factor greater than or less than 1 and used to generate a new total score. We caution against such weighting, however, because the relative contribution of the seven parameters to the overall vulnerability of a species usually is unclear. Rather, we suggest that using parameters as sorting factors may result in conservation priorities that are easier to interpret.

As a first step in sorting priority scores, an AI threshold can be chosen that eliminates a species from the peripheral parts of its range, where conservation efforts would be ineffective. Efforts in a physiographic area generally should be limited to species with an AI score of 2 or higher. A three-tiered sorting of species with an AI score of 4 or 5 in the top rank, 3 or 2 in the second rank, and 1 in the third rank would increase emphasis on species for which an area has the greatest conservation responsibility. When reliable BBS data exist, PT scores provide a useful second sorting, after AI, in that PT ultimately is the parameter that is the object and measure of conservation action. Birds with high scores for PT may be more in need of conservation action than are birds with low scores. An additional sorting on the basis of TB in breeding habitat and TN in wintering or migration habitat will also focus conservation actions where they potentially can do the most good, particularly where local PT is uncertain. In addition, sorting by PTDQ may be useful because species that receive both a high total score and a PTDQ that indicates poor data generally are those that are most in need of attention in developing monitoring programs.

Total Scores and Independence Among Parameters

Beissinger and others (2000) caution against summing the seven rank scores to derive a single value because of the potential for lack of independence among the parameters. Although scores for some parameters can be shown to be correlated, this does not necessarily result from lack of biological independence. For example, a species may have a small breeding distribution (high BD score) but occur in high relative abundance (low RA score), and its populations may or may not be threatened (high or low TB). The seven parameters in the species prioritization process were selected partly because of our ability to score them independently. That in practice some species exhibit correlations among scores suggests to us patterns of conservation need, rather than lack of independence. Species that score high on multiple parameters, and therefore have high total scores, exhibit compounding evidence of vulnerability. These species may have a small total distribution, occur in low relative abundance, show threats to breeding and wintering populations, *and* exhibit a significantly declining population trend. Other species that show vulnerability only in one or two of these categories would have moderate total scores, the meaning of which is unclear without inspection of the component scores. Very low and very high total scores, however, have easily interpretable meanings in terms of whether some sort of conservation attention is warranted.

Beissinger and others (2000) suggested a categorical approach that sorts species primarily according to thresholds of scores for Population Trend, Relative Abundance, and threats. In their analysis of the breeding bird species of New York State, categorical rank (e.g., high versus moderate concern) was highly correlated ($r_s = 0.76$) with the sum of the seven parameter scores. More important, the same species of greatest conservation concern were clearly identified by both approaches. A rigid categorical approach has a drawback, however, in that the greatest emphasis (weighting) may inadvertently be placed on parameters for which scientific data are unreliable. The combination of approaches used by PIF in its planning process (see below) places species into priority categories based on their total scores as well as on combinations of scores for the component parameters, especially AI and PT. This is essentially a categorical approach in which a species can enter the priority pool by exceeding any one of several thresholds.

Responsibility Versus Concern

Not all species identified through the prioritization process as high priority are of immediate conservation concern or require immediate management actions in all areas. Rosenberg and Wells (1995, 1999) introduced the concept of "area responsibility" to highlight an area's share in the responsibility for long-term conservation of species, including those that are not currently declining or threatened in that area. Such species may have relatively high total scores, including high AI, BD, or RA, but low to moderate locally derived PT and TB (or TN for wintering birds) scores. These may be species for which the physiographic area should assume conservation responsibility and for which close monitoring is warranted. Area responsibility also is a prominent component of species prioritization efforts in Canada (Dunn and others 1999). In contrast, species that are most in need of on-the-ground conservation actions in a region receive high scores for local concern (PT and TB) and global priority (very high total scores) but may score high or low for area responsibility (AI). Focusing on high-responsibility species or global-priority species that are of immediate concern is an improvement over many state threatened and endangered species lists, which often contain peripheral populations that are locally rare and declining and that may have little consequence for long-term conservation of the listed species.

Partners in Flight Bird Conservation Plans

We believe that the most important application of priority scores to date is their use in the drafting of Bird Conservation Plans for all of the physiographic areas and/or states of the continental United States. From among the breeding avifauna of each physiographic area, a priority species pool is derived using a combination of criteria from the prioritization database. A species may be included in this pool if it is in immediate need of conservation action, has a global high-priority status, or has a large population for which there is high local responsibility. All species in this priority pool are then grouped into habitat-species suites, each consisting of one or more co-occurring species. Within habitat-species suites, specific conservation needs or actions may be suggested by patterns of priority scores. If, for example, there are consistently poor PTDQs for species in a suite, increased monitoring effort may be required in that habitat. Habitats used by one or more species with very high total scores, high PT and TB, and high AI scores may be in need of rapid remedial management or other conservation actions. Conditions in habitats for suites that consist of many birds with high total scores and high AI scores but low PT and TB scores may be adequate at present but in need of long-term maintenance.

The plans will also include quantitative population and habitat objectives for habitat-species suites, suggestions for implementation actions to achieve conservation objectives, and an adequate program to evaluate the success or failure of those actions. The overall intent of the PIF planning process is to guide the efficient expenditure of conservation resources to ensure the long-term health of populations of landbirds throughout the United States, with an understanding that comparable efforts may be required in other countries to provide sufficient wintering and migration habitat for many migratory species.

Watch Lists

Partners in Flight prioritization scores have been used to generate a national Watch List for the United States (Carter and others 1996; Pashley 1996) that is based on the sum of global scores for six parameters (AI is omitted because it never receives a global score). The value of a national Watch List is to highlight species that may be in need of conservation attention throughout their range and to attract interest in bird conservation. Such a national list based on summed

global scores is less useful for conservation planning at regional or local scales than are physiographic area scores in which AI, PT, and TB are scored locally. Therefore, we urge caution in the use of the national Watch List, or any other compilation of species at an inappropriate geographic scale, as a guide for conservation priorities.

Discussion

Because species prioritization is a critical component of the conservation planning process, prioritization scores must reflect the best scientific information available. The current database has been reviewed extensively by state and regional experts, as well as by specialists on various taxonomic groups. The AOU Conservation Committee supported the overall structure of the database, as well as the relevance of the seven categories used for evaluating vulnerability (Beissinger and others 2000). Nevertheless, improvements regarding several issues are needed.

Because of reliance on the BBS for population data, many species (i.e., some raptors, nocturnal birds, marsh birds, colonial waterbirds, and other patchily distributed or low-density breeders) receive an unknown score for population trend (PT = 3). Where alternative or additional survey data exist, incorporation of more reliable trend estimates will greatly strengthen the database. In addition, for many species that are peripheral in the United States or Canada, assigning priority scores is hampered by poor knowledge of distributions, abundance, population trends, and sometimes taxonomy beyond those borders.

At present, only full species are assigned scores in the database. Several of the highest-scoring species throughout North America only recently have been recognized as full species (AOU 1998), such as Oak Titmouse (*Baeolophus inornatus*), Bicknell's Thrush (*Catharus bicknelli*), and Saltmarsh Sharp-tailed Sparrow (*Ammodramus caudacutus*). Some taxa are legally recognized at the subspecies level for their high conservation importance (e.g., Least Bell's Vireo [*Vireo bellii pusillus*], Southwestern Willow Flycatcher [*Empidonax traillii extimus*]). Many others are worthy of conservation attention, and some, such as the Appalachian Bewick's Wren (*Thryomanes bewickii altus*), may be slipping toward extinction, partly as a result of inattention given to subspecies. Our ongoing efforts to remedy this gap in conservation efforts will require input from taxonomic specialists, as well as additional studies of geographic variation and population structure.

As a tool for conservation planning, the species prioritization process is helping to identify conservation priorities for the hundreds of breeding landbird species in North America. The database will also assist in the integration of conservation objectives for priority landbirds with objectives for taxa, such as waterfowl and other game birds, that traditionally are included in wildlife conservation efforts. Prioritization has been useful in illuminating gaps in our understanding of bird distribution and population status. For example, many species with uncertain population trends and poor PTDQ scores are in need of better or new monitoring efforts. As new information becomes available, the importance of maintaining an active and adaptive prioritization process cannot be overemphasized. To ensure that conservation is based on the best science available, we invite the academic and ornithological communities to participate in continued review and refinement of this database.

Acknowledgments

The Partners in Flight species prioritization process benefited from comments from numerous individuals over the last decade, including many reviewers who provided lists and commented on scores for physiographic areas throughout the country. We particularly thank Chuck Aid, Keith Barker, Jim Bradley, Greg Butcher, Jeff Price, and John Sauer for conceptual contributions; Rick Bonney and Steve Beissinger for editorial assistance; Carol Beardmore, Jane Fitzgerald, and Bob Ford for experience in practical application; and Frank Gill, Dan Petit, and Steve Beissinger for stimulating the accompanying review process. Funding for the first phase of the prioritization project (Nearctic-Neotropical migrants) was provided by the U.S. Fish and Wildlife Service, U.S. Forest Service, Bureau of Land Management, and National Park Service. Funding for the second phase (all species and winter scores) was received from the U.S. Fish and Wildlife Service (in part with assistance from the Conservation Fund), Environmental Protection Agency, U.S. Forest Service, National Audubon Society, and Department of Defense through the National Fish and Wildlife Foundation. We sincerely thank all who have been involved in the process.

Global Perspectives on Neotropical Migratory Bird Conservation in the Northeast: Long-Term Responsibility Versus Immediate Concern

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Abstract—We assessed the conservation priorities of Neotropical migratory bird species in the Northeast Region (USFWS Region 5) using the most up-to-date information available on distribution, abundance, and population trends. Priority rankings were developed using the percent of the total population in the Northeast as a measure of the importance of the region to each species' long-term persistence. We identified 34 species with at least 15% of their total population in Region 5. Species for which the Northeast Region is particularly important include Bicknell's Thrush, Scarlet Tanager, Worm-eating Warbler, Louisiana Waterthrush, and Wood Thrush. The importance of adjoining USFWS Regions, states and Canadian provinces, and physiographic areas to each species was established using the same measure. Eastern Canada and the Southeast Region are particularly important to consider as partners in any regional planning for high-priority species. Important Geographic Areas were identified by developing a weighted ranking based on the Atlas-block concentration of the 34 priority species in each state/physiographic area unit. Important Geographic Areas identified included (1) much of New England, especially northern Vermont and New Hampshire; (2) West Virginia and western Maryland; and (3) the Allegheny Plateau of New York. A separate list of species, because of a combination of high proportion of total population and declining Breeding Bird Survey population trend, may be considered of immediate conservation concern. These included Henslow's Sparrow, Golden-winged Warbler, Worm-eating Warbler, Cerulean Warbler, and Louisiana Waterthrush.

We then identified "hot spots"—regions of immediate conservation concern, based on the Atlas-block concentrations of these high-concern species. The highest-priority "hot-spot" is the Ohio Hills and Cumberland Plateau portion of West Virginia and southwestern Pennsylvania; next in priority were the Allegheny Plateau, Great Lakes Plain, and Ridge and Valley areas of New York, Pennsylvania, and western Virginia. Our prioritization procedure highlights a dichotomy in bird conservation from a global or regional perspective. On the one hand, species with high proportions of their total population in the Northeast are important because the region has a large share of the *responsibility* for conserving the entire species. On the other hand, species whose populations are declining are important because we are *concerned* about their immediate welfare. Responsibility for important populations leads to long-term conservation planning, especially in the most important geographic areas, whereas concern for declining populations leads to immediate conservation action, especially in "hot-spot" areas.

Setting regional conservation priorities is an important step in the Partners in Flight (PIF) planning process. At the regional level, prioritization may represent a conflict between global needs of the entire population of a species and local concerns or pressures. The PIF species prioritization scheme (Carter and others, this proceedings) provides an objective means for assessing the relative conservation concern for bird species throughout the United States. Applying these priority rankings to local or regional conservation planning efforts requires detailed knowledge of species' distributions and relative abundances, so that the geographic areas most important to high-priority species in each region can be identified.

The Northeast Region is relatively small and homogeneous, compared with other PIF planning regions. Largely covered with deciduous and mixed conifer forests, this region comprises all or part of 16 physiographic areas, and supports substantial populations of many Neotropical migratory landbirds (NTMB) typical of eastern forests. The earliest studies suggesting that certain species of NTMBs were declining originated in the northeastern United States near Washington, DC (Johnston and Winings 1987; Robbins 1980; Briggs and Criswell 1978; Lynch and Whitcomb 1978). Since that time, a host of studies throughout the region have examined the question of whether population declines have occurred and why (Askins and others 1990; Hagan and Johnston 1992; Askins 1993). Except for reviews by Askins and others (1990) and Smith and others (1993), no studies have attempted to establish conservation priorities for NTMBs from the perspective of the entire Northeast Region. None have considered populations in the Northeast in relation to their entire ranges or total population. None have incorporated up-to-date, region-wide databases (Breeding Bird Survey [BBS]; Breeding Bird Atlas [BBA]) to develop region-wide priorities or conservation recommendations. Consequently, land managers remain confused about which species are of greatest concern or conservation priority, and in which areas our efforts should be concentrated.

Building upon the work of Carter and others, we present a scheme for prioritizing NTMBs and determining which geographic areas in the northeastern U.S. are most important for their conservation. The need for a document

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summarizing the status of NTMBs in the Northeast and outlining regional priorities grew out of: (1) formalization of the Northeast regional planning process of PIF; and (2) the common need, expressed by many states in the Northeast, for assistance in implementing regional priorities at the state level. This paper summarizes our prioritization process; the complete results of these efforts may be found in Rosenberg and Wells (1995).

Our scheme differs from PIF's national prioritization database in that it explicitly considers the importance of *the entire region* to the total population of each species as the primary criterion for establishing conservation priority. We then consider each species' population trend and local distribution *within* the region to assess degree of regional concern and to identify areas of greatest importance for high-priority species. This information will serve as the framework behind a Northeast regional conservation plan.

Methods

The Northeast Region of PIF, defined as U.S. Fish and Wildlife Service (USFWS) Region 5, includes the states of Maine, New Hampshire, Vermont, Massachusetts, Connecticut, Rhode Island, New York, New Jersey, Pennsylvania, Delaware, Maryland, Virginia, and West Virginia. This region also includes portions of 16 physiographic areas (fig. 1), derived from BBS Physiographic Strata and used in PIF conservation planning.

Our basic approach is to draw together and integrate several existing databases on NTMBs in the region, roughly following the procedure outlined by Smith and others (1993) in their preliminary assessment of NTMB status in the Northeast. This "regional-filter" approach integrates abundance and trend data from the BBS with state-level BBA data to identify species of regional importance and concern, based on the proportion of total species populations that are supported in the region and their population trends. For those species with relatively high proportions of their populations in the Northeast, we then determine areas of most concentrated occurrence, based on distribution of occupied atlas blocks. Important geographic areas are defined as those with the highest concentrations of the highest-ranking species. We next identify which of these species also are declining, and identify areas with the highest concentrations of declining species.

This information ultimately will be combined with land-classification programs, such as GAP Analysis, to simultaneously assess the status of bird populations and their habitats. We believe that synthesizing available data on NTMBs using the resources at hand is important now, in anticipation of GAP analysis completion. Our analysis is intended to be a working document that will provide the raw materials for conservation planning in the Northeast.

Prioritizing Species: Importance of Area

Percent of Range—We began the process of determining importance of area by considering the percentage of each species' range lying within Region 5. Because of PIF's early emphasis, we consider only Neotropical migratory species; future revisions will include all landbird species. After reviewing many existing published range maps, we determined that the most up-to-date, detailed, and readable maps available for all species are those in the Peterson (1980, 1990) field guides. From these range maps, we estimated the percent of each state or province occupied by each bird species. We then multiplied these percentages by the area (sq. mi) of each state. By summing these areas we derived an estimate of total range size for each species. We then summed the areas for the states within Region 5 and divided by the total range area to determine the percent of range in the Northeast (see Rosenberg and Wells 1995, appendix 1). Because this method does not compare portions of the entire range to one another, it protects against biases caused by map projection distortions.

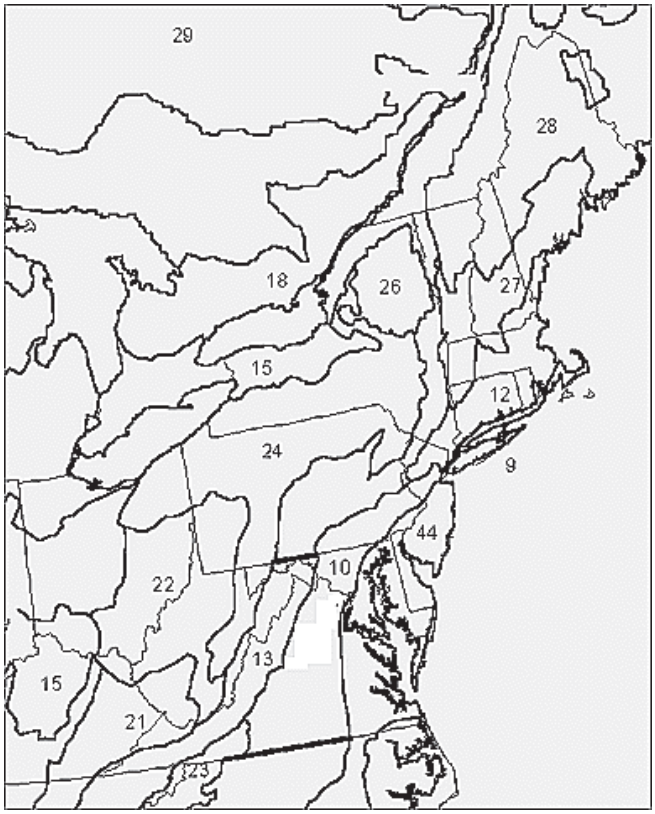

Figure 1—Map of physiographic areas of eastern North America, showing the 16 areas represented in the Northeast Region. Note: Some physiographic area boundaries and numbers have changed after 1996.

Percent of Population—A more accurate measure of the importance of an area to a species' long-term probability of persistence is the percent of the total *species population* (Wells and Richmond 1995) that occurs within that region. Although in practice this measure is difficult to obtain, an index that reflects percent of population can be formulated by weighting range areas derived from the above procedure with relative abundances from BBS data. We multiplied the range area occupied in each state and province by the relative abundance for that area. We then summed the values for states within the Northeast Region and divided by

the sum for all areas occupied to determine the percent of total population in the region. Note that this procedure also yielded an index of total population size for each species.

We obtained BBS relative abundances for all states, provinces, and physiographic areas directly from the BBS database (Sauer and others 1996b). These values represent average numbers of birds counted on all BBS routes in each geographic area from 1966 through 1994. Note that we make several assumptions when using BBS relative abundances that could bias our estimates of population sizes (B. Peterjohn, personal communication). First is that detectability of a species does not vary across all the geographic areas in our analysis. Also, large changes in relative abundance over the 29 year period could result in overestimates or underestimates of percent of population, and therefore importance, in a given area. For example, if a species has declined greatly in a physiographic area, using the long-term average abundance may greatly underestimate the true importance of that area to the species' total population. Our estimates of total populations are probably most accurate for those species that occur primarily in the continental U.S. and southern Canada, and are least accurate for those species with extensive portions of their range in Canada above the region covered adequately by the BBS.

Regional Importance of Geographic Areas

BBAs provide the most detailed and up-to-date information on the distributions of species within individual states or provinces. To incorporate this finer scale resolution into our importance of area rankings, we estimated the percent of BBA blocks occupied in portions of physiographic areas within each state. Atlas data for this analysis were available in published form or were made available from Connecticut (Bevier 1994), Delaware, Maine (Adamus, no date), Maryland, Massachusetts, New Hampshire (Foss 1994), New York (Andrle and Carroll 1988), Pennsylvania (Brauning 1992), Rhode Island (Enser 1992), Vermont (Laughlin and Kibbe 1985), Virginia, and West Virginia (Buckelew and Hall 1994). We also used published Atlases or atlas data from adjacent regions (Kentucky, Ohio [Peterjohn and Rice 1991], Michigan [Brewer and others 1991], Ontario [Cadman and others 1987], and the Canadian Maritimes [Erskine 1992]) to complete our analysis of physiographic areas that extend beyond the borders of Region 5.

We computed an "area importance score" to identify areas within the Northeast Region with highest concentrations of the highest-priority bird species. First, for each bird species, we "normalized" the percent Atlas-block occupancy across the 44 state/physiographic area units (see Rosenberg and Wells 1995, appendix 4); the area with the highest percent occupancy was set to 100, and each other area unit was expressed relative to the maximum occupied unit. Then, for each of the 44 areas, we summed the importance rankings of each bird species, divided by its relative percent occupancy of Atlas blocks, to compute an overall importance score:

$$\text{area importance score} = \sum \frac{\text{species rank}}{\left(\frac{\%\ \text{occupancy}}{\text{max. }\%\ \text{occupancy}}\right)}$$

These scores also were normalized (i.e., the highest score set to 100) to reflect relative importance of each of the 44 areas in the Northeast.

Incorporating Population Trends

We used population trend estimates to identify those species that have high proportions of their total populations in the Northeast and that are declining (or increasing) significantly in geographic areas of interest. We obtained estimates of population trends for NTMBs in Region 5, and for each state and physiographic region, directly from the BBS Lab (Sauer and others 1996b). These trend estimates were updated in spring 1995 and are based on BBS data from 1966 through 1994. They therefore represent the most up-to-date estimates available, and supersede any previously published BBS results (e.g., Robbins and others 1986; Peterjohn and Sauer 1993, 1994). Trends were calculated (by BBS Lab) using the Linear Route-Regression method, modified with estimating equations (Link and Sauer 1994), and are expressed as a percent change per year. We combined estimates of regional trends with our previously determined percent of total population to compute a "species concern score" for each declining species. This score was calculated as:

$$\text{species concern score} = \sum \frac{(\%\ \text{of population})\ (\text{trend})}{\text{total population size}}$$

where the total population size was estimated by summing relative abundances times the area occupied for each state and province.

Finally, to identify geographic areas with the highest concentrations of high-concern species, we calculated an "area concern score" based on the percent Atlas-block occupancy of each declining species in each state/physiographic area unit:

$$\text{area concern score} = \sum (\text{species concern score})\ (\%\ \text{Atlas-blocks})$$

These area concern scores were then normalized (i.e., highest score set to 100) to represent relative concern among the 44 areas in the Northeast.

Results

Percent of Population and Range in the Northeast

We estimate that 34 species have 15% of their population in the Northeast Region (table 1). This analysis identified three species (Bicknell's Thrush, Scarlet Tanager, Worm-eating Warbler), for which the Northeast supports >50% of the population; ten other species have >25% of their population in the region. Our cut-off of 15% is somewhat arbitrary; an additional 15 species have between 10 and 15% of their populations, in the Northeast. These include mostly widespread species such as Song Sparrow, Common Yellowthroat, and Chimney Swift, which happen to be abundant in the Northeast. These species may be considered of moderate priority in regional planning.

Table 1—Priority rankings of Neotropical migrant bird species, based on percent of total population in the Northeast Region. Range sizes in millions of sq. mi; relative abundance and trend (1966-1994) in Region 5 based on Breeding Bird Survey (Sauer and others 1996).

Rank species (code)	% of pop.	% of range	Range size	RE- 5 abund.	RE- 5 trend
1. Bicknell's Thrush (BITH)	>75?	34.0	0.17	?	?
2. Scarlet Tanager (SCTA)	60.1	21.1	1.09	4.6	–0.3
3. Worm-eating Warbler (WEWA)	52.6	22.6	0.57	0.3	–1.4
4. Louisiana Waterthrush (LOWA)	44.3	18.3	0.75	0.4	–0.9
5. Wood Thrush (WOTH)	44.2	17.7	1.26	14.8	–1.8[a]
6. Black-thr. Blue Warbler (BTBW)	44.2	24.3	0.65	1.0	0.6
7. Blue-winged Warbler (BWWA)	39.5	17.0	0.46	0.7	1.0
8. Gray Catbird (GRCA)	38.7	9.9	2.41	11.1	–0.2
9. Golden-winged Warbler (GWWA)	30.8	30.8	0.30	0.2	–7.5[a]
10. Eastern Phoebe (EAPH)	30.6	10.5	2.24	4.7	0.2
11. Acadian Flycatcher (ACFL)	30.2	15.4	0.90	3.1	0.8
12. Cerulean Warbler (CEWA)	30.0	11.7	0.58	0.6	–2.9[a]
13. Blackburnian Warbler (BBNW)	29.4	21.5	0.65	1.4	1.0
14. Solitary Vireo (SOVI)	23.1	10.5	1.42	1.6	6.2[a]
15. Yellow-throated Vireo (YTVI)	22.8	17.4	1.22	0.9	–0.1
16. Veery (VEER)	22.4	12.1	1.48	7.8	–0.7[a]
17. Northern Parula (NOPA)	22.4	17.1	1.27	1.8	0.7
18. Eastern Wood Pewee (EWPE)	22.4	14.8	1.61	4.8	–2.2[a]
19. Henslow's Sparrow (HESP)	21.4	24.4	0.52	0.1	–12.2[a]
20. Whip-poor-will (WHIP)	21.2	17.5	1.32	0.3	–2.0[a]
21. Chestnut-sided Warbler (CSWA)	19.2	23.5	0.76	5.0	–0.6
22. Rose-breasted Grosbeak (RBGR)	18.4	11.9	1.53	3.0	0.0
23. Red-eyed Vireo (REVI)	18.0	7.5	3.15	23.4	1.3[a]
24. Black &White Warbler (BAWW)	17.5	8.6	2.79	2.4	–1.8[a]
25. Field Sparrow (FISP)	17.3	15.0	1.42	6.9	–4.1[a]
26. Hooded Warbler (HOWA)	17.2	16.8	0.77	1.1	1.4[b]
27. Yellow-bellied Sapsucker (YBSA)	17.0	9.6	1.50	2.0	2.2[b]
28. Cedar Waxwing (CWAX)	17.0	8.7	2.62	7.0	1.4[a]
29. American Goldfinch (AMGO)	17.0	8.5	2.76	11.1	–2.6[a]
30. Indigo Bunting (INBU)	16.8	14.0	1.59	14.7	–0.2
31. Northern Oriole (NOOR)	16.3	6.9	3.17	4.5	–1.1[a]
32. Canada Warbler (CAWA)	16.1	16.8	0.94	0.9	–5.5[a]
33. Ovenbird (OVEN)	16.1	10.4	2.29	9.4	1.7[a]
34. American Redstart (AMRE)	15.6	8.0	2.99	4.8	–0.6

Significance of trend estimates:
[a] = $p < 0.01$.
[b] = $p < 0.10$.
[c] = $p < 0.05$.

Initially we had identified 44 species with >10% of their range in the Northeast (see Rosenberg and Wells 1995, table 1). When population size was considered, the importance of the Northeast to several of these species was enhanced (relative to percent of range alone). For example, even though Scarlet Tanager is a widespread species, its high relative abundance in several northeastern states suggests a much higher percent of population in the region than predicted from geographic range alone (60% versus 21%). Other species that gained considerably in importance compared with their percent of range included Gray Catbird (39% versus 10%), Eastern Phoebe (31% versus 11%), Cerulean Warbler (30% versus 12%), Solitary Vireo (23% versus 11%), and Northern Oriole (16% versus 7%). Species with higher relative abundances outside the Northeast dropped in importance rank, however; these included Henslow's Sparrow, Chestnut-sided Warbler, Canada Warbler, and Whip-poor-will. Still others (e.g., Nashville Warbler, Grasshopper Sparrow) dropped off our importance list because the bulk of their populations are outside our region.

The resulting list of 34 top-ranked species (table 1) is diverse, both taxonomically and ecologically, and includes species of both northern and southern affinities. The largest group represented are the wood warblers (14 species); other "typical" NTMBs include 3 flycatchers, 3 thrushes, and 3 vireos. Although most of the list can be considered forest species, several important species of grasslands and successional habitats are represented. Even among the top 10 species are birds of coniferous mountaintops, deciduous bottomland forests, shrubby clearings, and pastures. Clearly, no obvious suite of species associated with a particular habitat type stands out as being of highest conservation priority.

Shared Importance With Adjacent Regions

To determine which regions to consider in collaborative conservation planning for NTMBs, we compared percentages of total populations in the Northeast with those in adjacent USFWS Regions and Canada (appendix). The

clearest result of this analysis is the overriding importance of Canada to NTMBs. Among all NTMBs that breed in the Northeast, 42 species have >50% of their population within Canada, and 29 species have >75% of their population there. For 16 species, Canada supports >90% of the total population. Among the top 34 ranked species in the Northeast, almost half have the largest proportion of their population in Canada. For Black-throated Blue, Blackburnian, and Canada warblers, Ontario and Quebec alone hold 40-70% of the total population (Rosenberg and Wells 1995, table 5). For Bicknell's Thrush, at least ½ of the total range is in Quebec and the Maritime provinces. Clearly, any conservation plan for northern forest birds in the Northeast must seek cooperation with Canadian provinces, although populations may be larger in the U.S.

Among other Regions in the U.S., Region 4 (Southeast) is next in terms of shared importance with the Northeast. Twenty shared species have >50% of their population in Region 4 (recall that only 3 species had >50% in Region 5). Of the 34 top-ranked species, 9 have the highest proportion of their population in Region 4; the most important examples are Hooded Warbler (82%), Yellow-throated Vireo (55%), Northern Parula (52%), Louisiana Waterthrush (51%), Cerulean Warbler (51%), and Wood Thrush (46%).

Region 3 (Midwest) is important for several highly ranked species. Henslow's Sparrow, Golden-winged Warbler, and Whip-poor-will have >50% of their population in this region, which also ranks highest in importance for Blue-winged Warbler, Field Sparrow, and Northern Oriole. For Golden-winged Warbler, Wisconsin and Michigan hold 59% of the total population, and Michigan, Ohio, and Wisconsin support nearly 80% of the total population of Henslow's Sparrow.

This analysis clearly shows that collaboration with Canada, the Southeast, and Midwest regions will be important for the conservation of NTMBs in the Northeast.

Important Geographic Areas

Having identified species for which the Northeast is particularly important, our next step was to highlight the most important geographic areas for bird conservation in the Northeast. Based on relatively high atlas-block concentrations of high-priority species among state/physiographic area units (table 2), the most important areas occur in several disjunct blocks (fig. 2). The first includes the *Northern New England* and *Northern Spruce-Hardwood Forest* portions of Vermont and New Hampshire. This area is important because of high concentrations of Bicknell's Thrush, Scarlet Tanager, Wood Thrush, and Black-throated Blue Warbler. Adjacent portions of Maine, Massachusetts, Connecticut, and New York are classified as of secondary importance.

The second major area of high importance includes all of West Virginia, and adjacent highland and *Ridge and Valley* portions of Maryland. Note that the contiguous Ohio portion of *Ohio Hills* also is classified as of highest importance. This area supports among the highest relative concentrations of Scarlet Tanager, Worm-eating Warbler, Louisiana Waterthrush, and Wood Thrush, our 2nd through 5th-ranked species. In addition, the New York portion of the *Allegheny Plateau* was classified of relatively high importance because of moderate concentrations of many priority species.

Note that in this analysis, very small areas may tend to receive greater importance ranks because Atlas coverage may have been more complete there, resulting in greater percentage occupancy for many species than is shown in larger, more diverse areas. Combining small areas with adjacent portions of the same physiographic area probably would give a more accurate assessment of their importance.

Table 2—Relative importance of 44 state/physiographic area units in the Northeast. Regional importance is based on atlas-block concentrations of high-priority species (see table 1). Conservation concern is based on atlas-block concentrations of priority species that show declining population trend (see Methods section).

State / physiographic area	Area importance score	Area concern score
28 - New Hampshire	100	5
27 - Connecticut	87	38
21 - West Virginia	86	100
24 - Maryland	85	76
27 - Vermont	83	24
12 - New York	82	52
13 - Maryland	81	66
27 - New Hampshire	80	12
22 - West Virginia	80	61
28 - Vermont	76	7
12 - Connecticut	75	24
28 - Maine	73	5
24 - West Virginia	73	39
27 - Massachusetts	73	15
13 - West Virginia	71	43
12 - Maine	71	7
23 - Virginia	71	23
27 - New York	70	24
10 - Maryland	70	22
24 - New York	70	42
27 - Maine	70	7
22 - Pennsylvania	68	68
18 - Vermont	67	19
24 - Pennsylvania	66	37
13 - Pennsylvania	66	36
26 - New York	65	4
13 - Virginia	64	31
13 - New York	64	29
21 - Virginia	64	34
10 - Virginia	63	16
4 - Maryland	62	17
4 - Delaware	62	14
12 - Pennsylvania	58	13
16 - New York	57	37
11 - Virginia	55	11
10 - Pennsylvania	53	10
18 - New York	53	15
12 - Rhode Island	51	8
12 - Massachusetts	51	9
9 - New York	44	4
4 - Virginia	40	6
3 - Virginia	33	4
4 - Pennsylvania	32	5
9 - Massachusetts	32	2

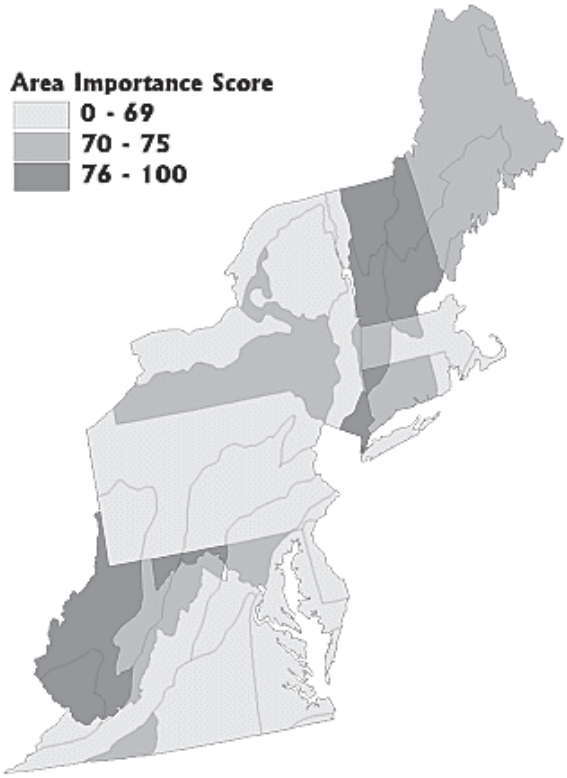

Figure 2—Map of important state/physiographic area units in the Northeast, based on high atlas-block concentrations of high-priority NTMB species. Red areas are those with area importance scores >75 (table 3); pink areas scored 70-75. These areas represent those where long-term planning for regionally important populations is most needed.

Incorporating Population Trends

Overall, it appears that the high-priority species identified in the Northeast are not the same species for which population declines have generated so much concern within PIF. Of the top 12 high-ranked species (other than Bicknell's Thrush) that have at least 30% of their total population in the Northeast, only three show significant long-term declines since 1966 (fig. 3). Of the 6 most important species, only the Wood Thrush has declined. Overall, two-thirds of the 34 priority species are stable or increasing.

Species showing the steepest declines (>5% per year) region-wide are Henslow's Sparrow, Golden-winged Warbler, and Canada Warbler. Of the 11 declining species, about half are species of successional habitats or forest edge. Declining forest birds include Wood Thrush, Cerulean Warbler, Canada Warbler, Eastern Wood Pewee, and Black-and-white Warbler. Solitary Vireo has shown the largest significant increase in the region, and Yellow-bellied Sapsucker and Ovenbird also have increased significantly since 1966.

Among the total list of NTMBs that breed in the Northeast, 35 species (31%) show significant long-term declines of at least 1% per year, whereas 15 species (13%) have increased significantly (table 3). Among this list of declining species, 67% are birds of primarily open (nonforest or successional) habitats. Of the top 10 species with the steepest declining trends, only 2 (Olive-sided Flycatcher, Canada Warbler) can be considered forest species. In contrast, of the top ten increasing species in the region, all but two are forest species. This pattern of greater declines in nonforest species in the Northeast has been noted

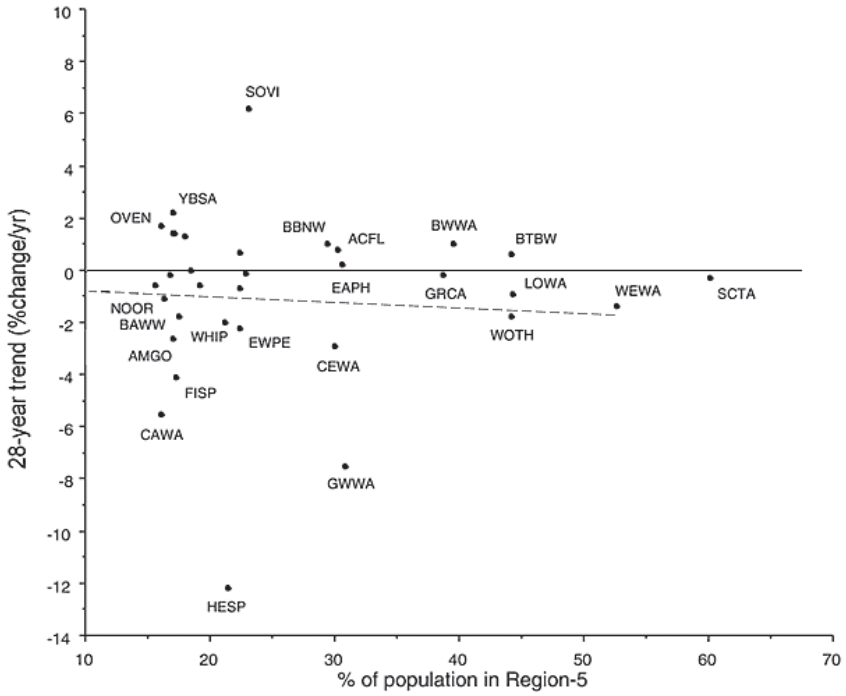

Figure 3—Relationship between percent of total population in the Northeast and long-term population trend for 34 NTMB species. Species below the dotted line are declining significantly, according to BBS data.

Table 3—Increasing and decreasing species of NTMBs ranked by long-term (1966-1994) trend estimate from Breeding Bird Survey data for USFWS Region 5 (Sauer and others 1996). Habitat defined for simplicity as Forest (including open woodland, mid-successional, and edge habitats) and Open (including early second-growth, grassland, shrub-scrub, and other nonforest habitats).

Most declining species			Most increasing species		
Species	**Trend**	**Habitat**	**Species**	**Trend**	**Habitat**
Common Nighthawk	–13.7[a]	Open	Philadelphia Vireo	+8.2	Forest
Henslow's Sparrow	–12.2[a]	Open	Solitary Vireo	+6.2[a]	Forest
Loggerhead Shrike	–8.1	Open	Yellow-thr.Warbler	+5.9[a]	Forest
Golden-winged Warbler	–7.5[a]	Open	Tennessee Warbler	+5.8	Forest
Olive-sided Flycatcher	–7.3[a]	Forest/Edge	Cape May Warbler	+4.0	Forest
Marsh Wren	–5.9[a]	Open	Yellow-rumped Warbler	+3.8[a]	Forest
Vesper Sparrow	–5.8[a]	Open	Pine Warbler	+3.3[a]	Forest
Canada Warbler	–5.5[a]	Forest	Ruby-thr. Hummingbird	+3.3[a]	Open
Eastern Meadowlark	–5.1[a]	Open	Purple Martin	+3.0[c]	Open
Yellow-shafted Flicker	–5.0[a]	Forest/Edge	Chuck-will's Widow	+2.9	Forest
Ruby-crowned Kinglet	–4.8[c]	Forest	Blue-gray Gnatcatcher	+2.9	Forest
Horned Lark	–4.7[a]	Open	Pine Siskin	+2.8	Forest/Edge
Rufous-sided Towhee	–4.7[a]	Open	Orchard Oriole	+2.7[a]	Open
Brown Thrasher	–4.4[a]	Open	Hermit Thrush	+2.7[a]	Forest
Field Sparrow	–4.1[a]	Open	Eastern Bluebird	+2.5[a]	Open
Nashville Warbler	–4.0	Forest	Blue Grosbeak	+2.0[a]	Open
Brown-headed Cowbird	–3.0[a]	Open	Yellow-bel. Flycatcher	+2.0	Forest
Cerulean Warbler	–2.9[a]	Forest	Ovenbird	+1.7[a]	Forest
Red-winged Blackbird	–2.9[a]	Open	Magnolia Warbler	+1.5	Forest
White-thr. Sparrow	–2.9[a]	Forest/Edge	Warbling Vireo	+1.5[a]	Forest/Edge
Savannah Sparrow	–2.7[a]	Open	Cedar Waxwing	+1.4[a]	Open
Grasshopper Sparrow	–2.7[a]	Open	Hooded Warbler	+1.4[c]	Forest
American Goldfinch	–2.6[a]	Open	Red-eyed Vireo	+1.3[a]	Forest
Swainson's Thrush	–2.4[b]	Forest	Wilson's Warbler	+1.2	Open
Yellow-breasted Chat	–2.4[a]	Open	Tree Swallow	+1.2[c]	Open
Eastern Wood-Pewee	–2.2[a]	Forest			
Belted Kingfisher	–2.0[a]	Open			
Whip-poor-will	–2.0[a]	Forest/Edge			
Black-billed Cuckoo	–1.9[a]	Forest			
Bank Swallow	–1.9	Open			
Black-&-white Warbler	–1.8[a]	Forest			
Wood Thrush	–1.8[a]	Forest			
Eastern Kingbird	–1.6[a]	Open			
Chimney Swift	–1.4[a]	Open			
Least Flycatcher	–1.4[a]	Forest			
Bay-breasted Warbler	–1.4	Forest			
Worm-eating Warbler	–1.4	Forest			
Song Sparrow	–1.3[a]	Open			
Kentucky Warbler	–1.2	Forest			
Northern Oriole	–1.1[a]	Forest/Edge			
Northern Waterthrush	–1.1	Forest			
Prothonotary Warbler	–1.0	Forest			
Prairie Warbler	–1.0	Open			

Significance of trend estimates:
[a] = $p < 0.01$.
[b] = $p < 0.05$.
[c] = $p < 0.10$.

previously (Askins and others 1990; Witham and Hunter 1992; Askins 1993; Franzreb and Rosenberg 1997).

These trends highlight the dichotomy between importance of regional populations (and therefore responsibility of the Northeast Region to conserve them) and population declines (which may dictate concern and conservation action). In general, the most important species are not declining, and the most steeply declining species do not have large proportions of their populations in the Northeast. The implications of this dichotomy will be discussed further below.

Species of Conservation Concern

Some species do have important populations in the region and also are declining. Combining information on importance of regional populations and their trends, our concern scores identified four species that stand out as being in need of immediate conservation action (table 4). The Henslow's Sparrow score was much higher than that of any other species because of the small total population of the species, relatively large proportion in the Northeast, and precipitous

Table 4—Conservation concern scores for priority-ranked Neotropical migratory bird species that show declining population trends in Region 5. Concern scores are based on long-term trend, percent of total population in Region 5, and total estimated population size (see Methods section). Trends and significance levels from Breeding Bird Survey (Sauer and others 1996) (see table 1).

Species	Concern score	Significant declining trend?
Henslow's Sparrow	767.89	yes
Golden-winged Warbler	248.39	yes
Worm-eating Warbler	96.77	no
Cerulean Warbler	88.76	yes
Louisiana Waterthrush	25.39	no
Whip-poor-will	14.42	yes
Canada Warbler	9.24	yes
Scarlet Tanager	1.01	no
Wood Thrush	1.01	yes
Black-and-white Warbler	1.00	yes
Eastern Wood Pewee	0.91	yes
Field Sparrow	0.69	yes
American Goldfinch	0.28	yes
Northern Oriole	0.27	yes
Yellow-throated Vireo	0.24	no
Chestnut-sided Warbler	0.23	no
Veery	0.13	yes
American Redstart	0.13	no
Gray Catbird	0.11	no
Indigo Bunting	0.02	no

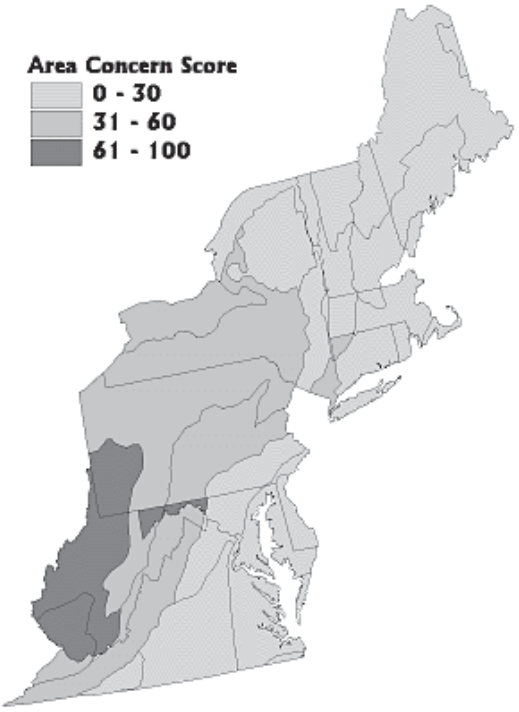

Figure 4—Map of conservation "hot-spots," based on high atlas-block concentrations of Neotropical migratory bird species with high species-concern scores. Black areas represent state/physiographic areas with area concern scores >60 (table 2); gray areas scored >30. These areas are those where immediate conservation action for regionally declining bird populations can best be implemented.

declining trend. Immediate planning and active management for this sparrow should be a high regional priority. Golden-winged Warbler was second in terms of regional concern, followed by Worm-eating and Cerulean warblers. Although the declining trend for Worm-eating Warbler was not statistically significant, any potential declines are of concern because of the small population of this species and its high importance in the region. Louisiana Waterthrush, Whip-poor-will, and Canada Warbler were ranked as species of moderate concern. Other species such as Wood Thrush, which receive attention because of their declining trend, scored much lower—indicating less of an immediate concern from a global perspective.

Conservation "Hot-Spots"

Our final procedure was to identify geographic areas that support high concentrations of species designated as high concern. This process identified only one highest-priority "conservation hot-spot" within the region (table 2; fig. 4). This area encompassed the *Ohio Hills* portions of West Virginia and Pennsylvania (and also Ohio), and the adjacent *Cumberland Plateau* portion of West Virginia. All four of the highest concern species occur in relatively high concentrations in this area. Surrounding areas formed a "second-priority hot-spot" (fig. 4). Areas to the north on the *Allegheny Plateau* and *Great Lakes Plain* ranked highly because of high concentrations of Henslow's Sparrow and Golden-winged Warbler, whereas areas to the east (*Ridge and Valley*) have high concentrations of Worm-eating and Cerulean Warblers.

Note that the highest priority area also is one of the two areas identified as regionally important in terms of concentrations of highly ranked species (regardless of trend). The other high importance area in northern New England was not identified as an area of high immediate conservation concern (table 2). Realize, however, that we lack population trend estimates for Bicknell's Thrush; a declining trend for that species would elevate northern New England to highest-concern status. Most coastal areas from Virginia to southern New England did not rank highly in terms of either regional importance or concern for declining species. These coastal areas, however, may be extremely important as migration stopover sites for birds breeding to the north, and they support important communities of widespread grassland species that independently have been recognized as a conservation priority (Askins 1995; Wells and Rosenberg 1999).

Discussion

Any scheme to assign conservation priorities to species or sites necessarily is based on a number of assumptions and must be interpreted with caution. The numbers, scores, and ranks that we have generated are not absolute; rather they are intended to illustrate relative importance from a regional or global conservation perspective. Because our results may appear to differ from the widely accepted scheme of Carter and others (this proceedings), and because the

critical reader may question certain aspects of our analysis, we will address several issues and concerns related to prioritization. In the end, we want to stress that there is no one "best list" of priority species; each approach will generate a list that should elicit particular conservation actions. In this regard, our analysis has highlighted a dichotomy between species of long-term regional responsibility and those of immediate conservation concern, which we discuss below.

Importance of Area: The "Regional Filter" Approach

By considering importance in the entire Northeast Region as a means of selecting species for further consideration in conservation planning, we have employed a "regional filter" approach to species prioritization. Species with high proportions of their total population in the region initially rank highly in our analysis, regardless of their population trend or threats to their habitats. Highly ranked species that also show declining population trends are of greatest immediate conservation concern. We believe that conservation actions and dollars can be directed most efficiently at those species for which the region can significantly influence global population status or trends.

The PIF prioritization scheme (Hunter and others 1993a; Carter and others, this proceedings) is intended to inform managers at state and local levels about the global significance of their lands and to give federal and international policy makers the information needed to preserve *entire* species. In its most recent form, the prioritization scheme ranks species according to a variety of factors, some of which are considered global factors (e.g., threats on nonbreeding grounds) and some of which are area specific. Among the latter, the *Area Importance* score reflects the abundance of a species within an area relative to its rangewide abundance. For example, if a species was relatively abundant on BBS routes in a given state, then the state would receive a high *Area Importance* ranking for that species. Although this scheme will provide an overall priority ranking based on equal consideration of all factors, it may be preferable to give greater initial weight to particular factors that reflect local status. For example, by first listing species with high *Area Importance* scores in a particular state or physiographic area, managers can focus on those species that they can effectively conserve.

Small states in the Northeast face a particularly difficult dilemma in trying to prioritize conservation strategies for NTMBs. We understand that state fish and wildlife agencies have a mandate to preserve the species found within their state borders. Therefore, each state must consider the importance of its own lands for the persistence of the species within their state. A state such as Rhode Island could opt to put efforts either into preserving species at high risk of extirpation within the state, without consideration of their global status, or into managing species that are widespread and abundant within the state (i.e., with high *Area Importance* scores), but that are exhibiting regional or global population declines. Ideally, Rhode Island could enter into partnerships with other New England states to help conserve bird populations on a larger scale. Prioritization of species and habitats at the regional level will facilitate this process by providing a larger perspective for local decisions.

One of our goals in this analysis was to provide a quantitative evaluation of *Area Importance* at regional, state, and physiographic-area scales that incorporates both the percentage of the total range and various measures of relative abundance (see Rosenberg and Wells 1995 for discussion of species' status in individual states and physiographic areas). Basing conservation strategies on the total species population usually is not considered feasible for small, migratory landbirds. The analogy of waterfowl management in North America, however, illustrates the importance of a global perspective. The successful North American Waterfowl Management Plan (USDI 1986) explicitly considers the total population of each species, including breeding potential, limiting factors, and seasonal and geographic variation in habitat use. Strategies for management (providing habitat, setting harvest limits) are then apportioned among the migratory flyways, USFWS regions, states, and individual wildlife refuges. Provisions for state and local needs exist, and conflicts between local and national goals may arise, but the ultimate goal of conserving waterfowl populations is accomplished at an international scale.

Similarly, conservation of migratory songbirds cannot be accomplished in a piecemeal manner, with each local entity solely responsible for setting priorities and carrying out actions. Although the knowledge necessary to craft an analogous conservation plan for NTMBs is fragmentary and difficult to attain, this remains the ultimate goal of PIF. By drawing together extensive, existing data on the distribution, status, and relative abundance of each species, we have made the first attempt to provide such a global perspective for NTMBs in the Northeast.

Assessing Population Trends: Controversy and Consensus

Although importance of area rankings may identify bird species most appropriate for long-term, regional conservation planning, setting priorities for short-term management requires knowledge of species' status or population trends at regional or continental scales. At present, the only dataset available for evaluating changes in abundance of landbird populations at these scales, over a relatively long time period, is the BBS (Robbins and others 1986; Droege 1990; Butcher and others 1993; Sauer 1993).

Like all datasets, the BBS has certain limitations that can complicate trend analysis. The various limitations of the BBS dataset have been discussed by a number of authors (e.g., Droege 1990; Geissler and Sauer 1990; James and others 1990; O'Connor 1992; Butcher and others 1993). Despite these limitations, with proper analytical techniques the BBS dataset can yield important trend information. Recently, much controversy has centered over which analytical techniques are appropriate for studying trends in BBS data. The BBS Lab's statisticians developed a technique called the Linear Route-Regression method (Geissler and Noon 1981; Geissler and Sauer 1990), which was modified with estimating equations estimates (Link

and Sauer 1994). Others have criticized this technique and have applied other methods of analyzing BBS trend data (e.g., James and others 1990; O'Connor 1992; Lauber and O'Connor 1993; Wiedenfeld and others 1992; James and others 1996).

Although much has been made of the controversy between these schools of thought (James and others 1996; Thomas 1996), no comprehensive, quantitative comparison of the results of the different methods has yet been published. A full review of the controversies regarding BBS data and its analysis is beyond the scope of this paper. We believe, however, that problems with data and discrepancies among results of different analytical techniques have been overstated and exaggerated by some authors.

From what we have seen of the various critiques mentioned above, the overall result of determining which species are exhibiting long-term, region-wide trends seems little affected by choice of analytical method. For example, all studies of BBS trends have concluded that Wood Thrushes and Cerulean Warblers have experienced long-term, steady population declines. Although caution must be used when interpreting BBS trends for smaller geographic areas or shorter time periods, a conservative approach to conservation planning suggests that erring on the side of concern for potentially declining species is best. Important, long-term, regional declines, such as those evident in Cerulean Warbler, Golden-winged Warbler, and Henslow's Sparrow, are usually unambiguous, and are verifiable from data other than the BBS.

Responsibility Versus Concern: A Dichotomy in Landbird Conservation

In this paper we have identified bird species and geographic areas that are "important" or "high-priority" for two very different reasons. The reasons behind these priority rankings lead to two very different kinds of conservation action. Some species are important because a high proportion of their total population resides in the Northeast Region. Some areas within the Northeast are important because, from a global perspective, they support high relative concentrations of these same important species. Importance or priority for these species or areas can be interpreted as the *responsibility* of managers in a given state or physiographic area to conserve the populations of those species, or similarly, their *ability* to affect the entire populations of these species through conservation planning or action. As an example, Scarlet Tanager is a widespread species with (mostly) stable populations, but also is a species for which the Northeast Region has a high responsibility for conserving. Conservation planning in areas with high local abundances or concentrations of Scarlet Tanagers (e.g., West Virginia, Pennsylvania, Allegheny Plateau) can have a large effect on the total population of this species.

Another set of bird species can be considered important because their populations are experiencing long-term declines in the region. From a global perspective, declining species are of greatest concern if they also have a large proportion of their population in the region of decline. Geographic areas with high concentrations of these important *and* declining species become conservation "hot-spots." As an example, Henslow's Sparrow has only a moderate proportion of its population in the Northeast (ranked 19 out of 34 species), but its populations are declining precipitously. Concern for this species, therefore, is higher than for any other in our analysis, and areas with relatively high concentrations of Henslow's Sparrows (western Pennsylvania and New York, Great Lakes Plain) become extremely important from a regional or global perspective.

The dichotomy, then, is between concern for declining species, which leads to immediate conservation action, and responsibility for species with high proportions of their population in the region, which leads to long-term conservation planning. The PIF regional landbird conservation plan being developed for the Northeast is considering both types of priority and action.

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Appendix: Percent of total population in Region 5 and adjacent USFWS Regions (plus Canada) for A- and B-list NTMB species that occur in the Northeast.

Species	Region 5	Canada	Region 4	Region 3	Region 6	Region 2
Yellow-billed Cuckoo	4.6	0.1	42.4	14.1	6.6	32.1
Black-billed Cuckoo	9.3	44.6	0.0	27.6	18.3	0.0
Chuck-will's-widow	0.2	0.0	86.4	5.0	0.0	8.3
Whip-poor-will	21.1	3.5	25.1	50.1	0.0	0.0
Common Nighthawk	0.2	9.1	11.7	1.3	13.8	51.6
Chimney Swift	12.4	1.8	45.9	28.7	4.35	6.6
Ruby-thr. Hummingbird	15.7	9.3	46.9	21.6	0.0	6.4
Belted Kingfisher	8.3	51.1	12.9	11.3	5.3	3.2
Northern Flicker	10.6	45.8	12.2	19.6	10.9	0.8
Yellow-bellied Sapsucker	17.0	76.8	0.0	6.1	0.0	0.0
Eastern Kingbird	4.9	27.0	16.0	14.7	32.0	4.4
Great-crested Flycatcher	10.4	10.0	42.0	25.4	3.0	9.0
Eastern Phoebe	30.6	30.6	13.8	19.8	2.0	3.2
Yellow-bellied Flycatcher	0.3	99.6	0.0	0.1	0.0	0.0
Acadian Flycatcher	30.2	0.0	55.6	13.5	0.0	0.6
Willow Flycatcher	8.1	20.3	0.0	11.3	15.2	0.0
Alder Flycatcher	5.2	93.5	0.0	1.3	0.0	0.0
Least Flycatcher	6.7	84.2	0.0	8.1	1.0	0.0
Eastern Wood-Pewee	22.4	6.2	38.8	29.9	0.3	2.4
Olive-sided Flycatcher	0.8	68.2	0.0	0.5	2.9	0.0
Horned Lark	0.1	19.4	0.1	6.0	47.5	13.7
Tree Swallow	6.6	78.1	0.0	7.2	4.0	0.0
Bank Swallow	4.7	74.8	0.0	7.5	7.7	0.0
N. Rough-winged Swallow	3.4	6.4	14.1	14.9	24.8	12.7
Barn Swallow	8.0	33.6	8.0	17.8	17.6	8.5
Cliff Swallow	na	na	na	na	na	na
Purple Martin	4.1	5.2	57.0	17.7	0.9	15.0
Brown Creeper	11.3	47.5	0.0	2.1	0.0	0.0
House Wren	10.4	39.2	0.4	23.9	20.1	0.01
Marsh Wren	0.9	35.7	0.0	16.0	39.5	0.0
Sedge Wren	0.0	32.0	0.0	60.5	7.5	0.0
Gray Catbird	38.6	10.3	14.4	30.7	5.2	0.2
Northern Mockingbird	4.2	0.01	36.6	3.3	2.5	52.5
American Robin	9.0	53.0	3.8	15.2	9.8	1.1
Wood Thrush	44.2	0.6	45.7	9.5	0.0	0.0
Hermit Thrush	4.9	80.4	0.0	2.9	6.8	0.0
Swainson's Thrush	0.4	94.6	0.0	0.1	0.01	0.0
Bicknell's Thrush	75?	25?	0.0	0.0	0.0	0.0
Veery	22.4	56.9	0.0	16.8	2.9	0.0
Eastern Bluebird	10.2	0.6	47.3	22.4	3.2	16.2
Ruby-crowned Kinglet	0.3	94.1	0.0	0.2	3.3	0.0
Blue-gray Gnatcatcher	11.5	0.0	60.0	13.7	0.7	13.7
Cedar Waxwing	17.0	58.8	0.4	16.1	1.3	0.0
Loggerhead Shrike	0.2	1.3	24.4	4.4	22.1	34.9
White-eyed Vireo	5.5	0.0	81.6	4.9	0.0	7.8
Yellow-throated Vireo	22.8	0.1	54.6	20.9	0.0	1.4
Solitary Vireo	23.1	74.1	0.41	2.3	0.0	0.0
Red-eyed Vireo	18.0	61.3	9.0	10.4	0.4	0.5
Philadelphia Vireo	0.4	99.6	0.0	0.0	0.0	0.0
Warbling Vireo	2.3	57.4	0.5	9.1	20.3	0.3
Black-and-white Warbler	17.5	46.1	6.4	29.2	0.0	0.6
Prothonotary Warbler	2.5	0.0	96.4	1.1	0.0	0.0
Swainson's Warbler	1.0	0.0	99.0	0.0	0.0	0.0
Worm-eating Warbler	52.6	0.0	47.3	0.0	0.0	0.0
Golden-winged Warbler	30.7	3.5	0.0	65.6	0.0	0.0
Blue-winged Warbler	39.5	0.0	18.3	42.1	0.0	0.0
Tennessee Warbler	0.3	99.7	0.0	0.0	0.0	0.0
Nashville Warbler	5.3	85.0	0.0	5.9	0.0	0.0
Northern Parula	22.3	20.0	52.1	5.5	0.0	0.0

(con.)

Appendix (Con.)

Species	Region 5	Canada	Region 4	Region 3	Region 6	Region 2
Yellow Warbler	8.6	64.3	0.9	5.7	12.5	0.0
Magnolia Warbler	5.1	93.6	0.0	1.2	0.0	0.0
Cape May Warbler	3.5	96.0	0.0	0.5	0.0	0.0
Black-thr. Blue Warbler	44.2	51.5	0.0	4.3	0.0	0.0
Yellow-rumped Warbler	3.6	95.9	0.0	0.8	0.0	0.0
Black-thr. Green Warbler	12.7	84.8	0.0	2.3	0.0	0.0
Cerulean Warbler	30.0	0.0	51.1	18.8	0.0	0.0
Blackburnian Warbler	29.3	62.5	0.0	8.0	0.0	0.0
Yellow-throated Warbler	2.5	0.0	95.6	1.9	0.0	0.0
Chestnut-sided Warbler	19.1	67.6	0.0	13.1	0.0	0.0
Bay-breasted Warbler	3.1	96.8	0.0	0.0	0.0	0.0
Blackpoll Warbler	1.0	99.0	0.0	0.0	0.0	0.0
Pine Warbler	8.4	0.3	89.8	1.4	0.0	0.0
Prairie Warbler	2.5	0.0	96.4	1.1	0.0	0.0
Palm Warbler	na	na	na	na	na	na
Ovenbird	16.0	64.9	2.4	16.5	0.0	0.0
Northern Waterthrush	1.1	98.4	0.0	0.5	0.0	0.0
Louisiana Waterthrush	44.2	0.0	51.4	4.3	0.0	0.0
Kentucky Warbler	13.3	0.0	73.0	13.5	0.0	0.0
Mourning Warbler	1.3	93.5	0.0	5.2	0.0	0.0
Common Yellowthroat	12.2	38.8	15.8	23.0	8.0	0.7
Yellow-breasted Chat	9.70	0.0	70.5	10.4	1.5	5.6
Hooded Warbler	17.2	0.0	81.6	1.2	0.0	0.0
Wilson's Warbler	0.1	83.7	0.0	0.0	0.0	0.0
Canada Warbler	16.0	79.4	0.0	4.52	0.0	0.0
American Redstart	15.6	77.2	0.4	5.4	1.3	0.0
Red-winged Blackbird	5.1	24.1	10.0	24.5	18.8	8.2
Brown-headed Cowbird	3.3	25.8	6.9	14.0	32.0	12.7
Bobolink	13.7	36.5	0.0	32.6	17.0	0.0
Eastern Meadowlark	5.4	0.6	31.9	23.3	3.6	35.1
Orchard Oriole	3.2	0.0	58.5	7.0	17.5	13.7
Northern Oriole	16.2	26.3	2.8	27.7	23.2	3.8
Scarlet Tanager	60.0	3.5	11.0	25.3	0.0	0.0
Summer Tanager	4.3	0.0	78.2	8.4	0.0	9.2
Rose-breasted Grosbeak	18.4	41.5	0.0	39.3	0.8	0.0
Blue Grosbeak	5.7	0.0	55.8	6.0	6.3	26.0
Rufous-sided Towhee	14.0	1.8	51.4	6.7	7.1	5.2
Indigo Bunting	16.8	1.3	47.9	31.2	0.9	1.8
Savannah Sparrow	1.6	81.7	0.0	9.1	5.1	0.0
Grasshopper Sparrow	3.6	0.2	2.2	19.8	70.0	4.1
Henslow's Sparrow	21.3	0.0	0.0	78.6	0.0	0.0
Chipping Sparrow	13.8	49.5	6.9	13.7	6.7	1.2
Field Sparrow	17.3	0.4	32.5	34.5	4.8	10.3
Lincoln's Sparrow	0.1	98.7	0.0	0.0	0.7	0.0
Vesper Sparrow	0.6	46.6	0.0	15.1	31.7	0.0
Swamp Sparrow	5.1	84.2	0.0	10.8	0.0	0.0
Song Sparrow	13.6	49.8	2.3	24.2	3.7	0.0
Fox Sparrow	0.0	96.4	0.0	0.0	0.0	0.0
White-throated Sparrow	2.7	96.2	0.0	1.1	0.0	0.0
Pine Siskin	0.2	81.4	0.0	0.1	11.8	0.0
American Goldfinch	17.0	31.1	4.6	29.3	10.6	0.3
Purple Finch	11.3	78.6	0.0	2.6	0.0	0.0

na = data not available.

Designation of Conservation Planning Units

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Abstract—Developing a comprehensive set of Bird Conservation Plans for North America requires the designation of conservation planning units. Many systems are available, including designations by political boundaries, watersheds, and vegetation types. Partners in Flight has chosen to use physiographic areas as its conservation planning units. These areas are based on the Breeding Bird Survey system, which was the first planning effort to reflect actual bird distributions. Partners in Flight has designated 58 physiographic areas for the contiguous United States (map included). physiographic areas are effective and sensible conservation planning units because vegetative communities, bird populations, and species assemblages, as well as land use and conservation issues, tend to be more uniform within than across these areas. Issues involving the needs of birds and their habitats, and the objectives required to meet those needs, are therefore evaluated within physiographic areas. However, because actions required to achieve the objectives are implemented within states, the Partners in Flight conservation process also relies on political boundaries. Programs and activities that focus specifically on conservation of land birds are still relatively new to most organizations and agencies. A logical organization of effort, relying where possible on existing alliances and relationships, is needed to establish such programs as permanent conservation elements. Examples from the Southeastern United States illustrate that the combination of physiographic area planning with state implementation promises to provide such acceptable organization.

The task of developing a comprehensive set of Bird Conservation Plans for North America is enormous in complexity and importance. A basic issue is the designation of conservation planning units. The lack of one clearly superior system for defining planning units is reflected in the multitude of conflicting systems now in use, including designations by political boundaries, watersheds, and vegetation types. All systems have advantages; none is clearly better than the others. In this paper, we examine a model that takes into account both ecological and political boundaries, drawing examples from the Southeast in general and the state of Georgia more specifically.

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Types of Planning Units

States and provinces often are used as planning units. In some cases, planning within such political boundaries is the simplest and most expedient method available. However, bird habitats normally cut across political boundaries. Also, the federal agencies that deal with land management, including the USDA Forest Service, the U.S. Fish and Wildlife Service (USFWS), and the Environmental Protection Agency, as well as the International Association of Fish and Wildlife Agencies all have differing schemes for grouping states into larger planning units, which can cause confusion.

Recognizing the limitations of wildlife management by political boundary, some agencies have recently begun ecoregional planning. Watersheds, for example, are planning units for both the USFWS and the U.S. Army Corps of Engineers. Unfortunately, watershed boundaries are useful for managing aquatic resources but have only marginal applicability to birds, which frequently cross watershed boundaries within their breeding and wintering ranges.

To deal with this problem, several other ecoregional planning systems divide the continent on the basis of potential vegetation types. All of these systems share many similarities, and all are relevant to, but not precisely descriptive of, the distribution of birds.

The first system to reflect actual bird distributions was developed by planners for the Breeding Bird Survey (BBS). These biologists considered the strengths and limitations of existing systems, then developed a new set of monitoring units called "physiographic strata," which blend together several of the previously designated vegetation types (D. Bystrak, personal communication). BBS data have been analyzed and reported on the basis of physiographic strata for the past three decades.

To begin defining bird conservation planning units, Partners in Flight (PIF) chose the BBS physiographic strata as a starting point, because data on bird abundance and population trends already were available on that basis. However, some physiographic strata, even though biologically relevant, do not lend themselves to practical conservation work. For example, the Atlantic Coastal Plain physiographic strata stretches from New Jersey all the way around the coast to Texas. So PIF planners broke that strata into four units that reflect avian issues but also facilitate internal communication, travel to meetings, and shared conservation issues.

In other cases, small physiographic strata were combined, or borders of strata that barely cross into a state were truncated and merged with the state boundaries, so that planners would have fewer planning units (and thus meetings) with which to contend. All of these delineations and

modifications eventually resulted in a map of the United States that is based upon, but significantly different from, the original BBS physiographic strata map. To stress the difference and reduce confusion between the two, the PIF conservation planning units were named physiographic areas (fig. 1: Note that physiographic area boundaries are agreed upon only for the contiguous 48 states).

Utility of Physiographic Areas

As an example of how physiographic areas are used, consider the Southeastern Region of PIF. This region encompasses 16 states and all or part of 24 physiographic areas. Some areas are entirely contained within a single state, such as the Edwards Plateau in Texas, whereas other areas cover parts of several states, such as the Mississippi Alluvial Valley. For planning purposes, the evolving Southeastern model takes advantage of both state borders and physiographic area boundaries: The distribution, priority, and needs of birds and habitats—and the objectives required to meet those needs—are evaluated within the physiographic areas, whereas actions required to achieve the objectives are implemented within states.

The physiographic area is a sensible conservation planning unit because vegetative communities, bird populations, and species assemblages, as well as land use and conservation issues, tend to be more uniform within than across physiographic areas. As an example, Georgia is a large and diverse state in which the avifaunal and biological issues in an area such as the mountainous Blue Ridge are distinct from, independent of, and difficult to compare with, the avifaunal and biological issues in the South Atlantic Coastal Plain. At the same time, biological issues in Georgia's South Atlantic Coastal Plain are similar to issues in the South Atlantic Coastal Plain of South Carolina.

Therefore, physiographic area boundaries should be used to consider population trends, habitat preferences, and species suites; evaluation of the impacts of management and land-use practices; and the setting of habitat and population objectives. If continental or range-wide objectives exist for a species or a habitat type, then physiographic area objectives should be set within the context of that larger scale. In the absence of larger-scale objectives, the sum of physiographic area conservation objectives for each high-priority bird species should eventually be considered for consistency and sufficiency.

In some cases, a species' potential densities and population sizes are too low within a single physiographic area to provide long-term security for the species. In such cases, conservation objectives must initially be set at the regional level. An example in the Southeast and Georgia is the Swallow-tailed Kite (*Elanoides forficatus*). The proposed Southeastern goal for this species is the maintenance of at least 80 pairs of kites in each of 13 floodplain forests. Each of these forests should provide about 100,000 acres of habitat suitable for nesting and foraging. Neither Georgia nor the South Atlantic Coastal Plain physiographic area alone can satisfy this goal, but a river system, such as the Altamaha and Savannah, can contribute to the regional objective.

Often physiographic area boundaries are similar to the boundaries of other ecologically defined conservation planning units. For example, the PIF Mississippi Alluvial Valley physiographic area roughly coincides with the boundaries of the North American Waterfowl Management Plan Lower Mississippi Valley Joint Venture. The South Atlantic Migratory Bird Initiative is a combined effort within the PIF South Atlantic Coastal Plain physiographic area and the Atlantic Coast Joint Venture. In these and other cases, the United States Shorebird Conservation Plan has developed shorebird objectives within the same geographic boundaries. These schemes provide valuable opportunities for broader partnerships.

Planning Relationship Between Physiographic Areas and States

Once objectives are set forth in physiographic area conservation plans, the best means of carrying out the objectives is probably on the basis of state or provincial boundaries. The actions of state wildlife agencies will be critical for achievement of many of these conservation objectives: These state agencies tend to have good relationships with many private landowners and corporations whose active and willing participation in PIF is imperative. Also, most federal agencies and private conservation groups are organized on a state basis. In addition, many of the corporations and nongovernmental organizations that own significant amounts of land, or have resources to support conservation action, are organized at least partially by states.

At present, each state working group in the Southeast Region is focusing on implementation of the biological objectives defined in the conservation plans for those physiographic areas that extend into the state. These objectives must be combined, balanced, and prioritized within each state. All of the responsibilities for accomplishing conservation actions should be adopted by one or a combination of the partners in the state working group.

Examples for which physiographic area objectives are translated into state-level organization abound in Georgia. Portions of five physiographic areas, the South Atlantic Coastal Plain, Southern Piedmont, Southern Blue Ridge, Southern Ridge and Valley, and Cumberland Plateau, extend into this state. Long-term monitoring is a priority conservation action that is being successfully implemented by Georgia's state PIF working group. The Georgia Wildlife Resources Division (WRD) took the lead in establishing a statewide monitoring system, building upon the extensive U.S. Forest Service system of point counts on the Chattahoochee-Oconee National Forest. Many Georgia WRD biologists and technicians have been trained in bird identification and point-count methodology, along with staff from numerous other organizations including industrial timber corporations, St. Catherines Island Foundation, Little St. Simons Island, USGS Biological Resources Division, Department of Defense (Fort Stewart), and the USFWS. The combined efforts of these many partners have resulted in a statewide monitoring system that covers most of the priority habitats in each of Georgia's physiographic areas. Monitoring in Georgia has become contagious, and continuing expansions and addition of new partners will ensure that birds in all habitat types in the state will be adequately monitored.

Figure 1—Map of Partners in Flight physiographic areas.

Key for PIF Physiographic Area Codes

01 Subtropical Florida
02 Peninsular Florida
03 South Atlantic Coastal Plain
04 East Gulf Coastal Plain
05 Mississippi Alluvial Valley
06 Coastal Prairies
07 South Texas Brushlands
08 Oaks and Prairies
09 Southern New England
10 Mid Atlantic Piedmont
11 Southern Piedmont
12 Mid Atlantic Ridge and Valley
13 Southern Ridge and Valley
14 Interior Low Plateaus
15 Lower Great Lakes Plain
16 Upper Great Lakes Plain
17 Northern Ridge and Valley
18 St. Lawrence Plain
19 Ozark-Ouachita Plateau
20 Boreal Hardwood Transition
21 Northern Cumberland Plateau
22 Ohio Hills
23 Southern Blue Ridge
24 Allegheny Plateau
25 Open Boreal Forest
26 Adirondack Mountains
27 Northern New England
28 Spruce-Hardwood Forest
29 Closed Boreal Forest
30 Aspen Parklands
31 Prairie Peninsula
32 Dissected Till Plains
33 Osage Plains
34 Central Mixed Grass Prairie
36 Central Shortgrass Prairie
37 Northern Mixed Grass Prairie
38 West River
39 Northern Shortgrass Prairie
40 Northern Tallgrass Prairie
42 West Gulf Coastal Plain
44 Mid Atlantic Coastal Plain
53 Edwards Plateau
54 Rolling Red Plains
55 Pecos and Staked Plains
56 Chihuahuan Desert
62 Southern Rocky Mountains
63 Fraser Plateau
64 Central Rocky Mountains
66 Sierra Nevada
68 Northern Rocky Mountains
69 Utah Mountains
80 Basin and Range
81 Mexican Highlands
82 Sonoran Desert
83 Mohave Desert
84 Mogollon Rim
85 Mesa and Plains
86 Wyoming Basin
87 Colorado Plateau
89 Columbia Plateau
90 Central and Southern California Coast and Valleys
93 Southern Pacific Rainforests

It also is advantageous to develop education and outreach materials at a state level. Specific accomplishments in Georgia include a Neotropical migratory bird poster, a teachers' workshop on Neotropical migrants, and a landowners' guide to landbird management. Not only is a delivery mechanism for these types of projects lacking on a physiographic area basis, but the materials resonate best to the intended audience within a state context.

States that share a physiographic area must communicate in order to assure that their combined efforts meet the needs outlined in the physiographic area plan. Although adding some additional costs such as interstate travel to meetings, multistate efforts foster beneficial communication. The savings in time, effort, and direct expenses realized by this sharing of information and workload more than make up for any additional expenses. In addition, the contribution of each state's efforts toward broader scale objectives and achievements serves as both impetus and justification for involvement.

Programs and activities that focus specifically on conservation of land birds and Neotropical migrants are still relatively new to most organizations and agencies. A logical organization of effort, relying on existing alliances and relationships where possible, is needed to establish such programs as permanent conservation elements. In the Southeast, the combination of physiographic area planning and state implementation promises to provide such acceptable organization.

Multi-Resource and Multi-Scale Approaches for Meeting the Challenge of Managing Multiple Species

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Abstract—The large number of Neotropical migratory bird (NTMB) species and their diverse habitat requirements create conflicts and difficulties for land managers and conservationists. We provide examples of assessments or conservation efforts that attempt to address the problem of managing for multiple NTMB species. We advocate approaches at a variety of spatial and geographic scales, and believe that successful NTMB conservation will require a broad "top-down" perspective combined with management actions taken from the "bottom up." A top-down approach is needed to establish priorities or objectives at regional and sub-regional scales for species, ecosystems, and ecological processes (e.g., the role of fire in grasslands and woodlands). Multi-species or multi-resource concerns require broad spatial perspectives (regional, continental, global), because many ecological processes and economic concerns are regional, continental, and global in scope. We believe that multi-resource, multi-species conflicts can be reduced if managers at a local level try to contribute to regional priorities.

More than 200 species of Neotropical migratory landbirds (NTMBs) breed in North America (Gauthreaux 1992). They inhabit nearly all terrestrial ecosystems, comprising a wide range of habitats and structures. In grasslands, for example, species may prefer tall versus short grass, or dense versus sparse vegetation (Herkert and others 1993; Dobkin 1994). In woodlands, species may prefer old versus young forest, open savanna versus closed-canopy forest, or even-aged versus all-aged forests (Dobkin 1994; Thompson 1996). Given the large number of species and their diverse habitat requirements, the potential conflicts and difficulties of single-species management for NTMBs are obvious. These difficulties are even more apparent when acknowledging that NTMBs are only one of the components of biological diversity that we are trying to conserve, and only one of the resources being managed for multiple values, products, or services.

In addition to addressing the complexities of diverse habitat requirements, successful NTMB management must address structure and process at large spatial scales. Many species have broad distributions that span states, regions, and countries. Some processes affecting NTMBs require a biogeographic or continental perspective (Robinson and others 1995b; Thompson and others, in press). One such process that potentially affects NTMBs is source-sink population dynamics. Populations of some NTMBs may be structured as population sources or sinks (Robinson and others 1995b; Donovan and others 1995b); subpopulations with low reproductive success ("sinks") are dependent on immigrants from more productive "source" habitats (Pulliam 1988). One potential problem with local or bottom-up planning is that a species may not be considered a priority in an area where it is abundant, yet that area could be a critical source habitat or contain a significant proportion of the species' global population.

Given the realities of multi-species/multi-resource management, many conservationists and scientists have acknowledged the need for a combination of top-down multi-scale approaches and species-specific management to conserve biological diversity. We review approaches to species management that are applicable to NTMBs and present these from the perspective of the geographic or ecological scale at which they are applied. We conclude that a number of different approaches are needed, spanning the scale from species-level "bottom-up" approaches to "top-down" biogeographic and regional approaches. We define "top-down" planning efforts as those based on assessments or patterns at larger spatial and ecological scales than the scale of interest, and "bottom-up" efforts as those based on patterns or data at scales smaller than the scale of interest. For consistency in terminology regarding ecological and spatial scales we refer to the National Hierarchical Framework of Ecological Units (Bailey and others 1994; McNab and Avers 1994) (table 1) when appropriate.

Species Level Approaches

Managing multiple habitat types, structures, and stages for a wide array of wildlife species, each having different life history requirements, is a complex problem that natural

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Table 1—The Forest Service National Hierarchical Framework of Ecological Units (McNab and Avers 1994).

Planning and analysis scale	Ecological Units	Purpose, objectives, and general use	General size range
Ecoregion Global Continental Regional	Domain — — — — — Division — — — — — Province	Broad applicability for modeling and sampling,strategic planning and assessment, and international planning	Millions to tens of thousands of square miles
Subregion	Section — — — — — Subsection	Strategic, multi-forest, statewide, and multi-agency analysis and assessment	Thousands to tens of square miles
Landscape	Landtype association	Forest, area-wide planning and watershed analysis	Thousands to hundreds of acres
Land unit	Landtype — — — — — Landtype phase	Projects and management area planning and analysis	Hundreds to less than ten acres

resource agencies have struggled with for several decades. Traditionally, managers have manipulated habitats to improve the likelihood that populations of single species such as game species, large charismatic species, and featured species would flourish. With the advent of the Endangered Species Act of 1973, federally listed threatened and endangered species were added to the growing list of single species for which state and federal agencies were responsible. Managing habitats for single species such as game, featured, or endangered species had potential to benefit populations of NTMB species that had requirements similar to those of the management species, but this narrow approach was just as likely to have negative effects on NTMB species with different habitat needs (Block and others 1995). Alternative species-level approaches that attempt to manage a wider array of species include the management indicator approach for species and guilds and species prioritization schemes.

Management Indicator Species and Guilds

The concept of the management indicator species was developed for use in land-management planning, and was based on the idea that a single species could indicate environmental changes or population responses of other ecologically similar species. Management indicator species are categorized by the U.S. Forest Service as threatened and endangered species, featured species, species with specialized habitat needs, and ecological indicators (Salwasser and others 1982). Used to index population health of other species with similar environmental requirements, the ecological indicator idea and its spin-off—the guild-indicator—have been widely discussed, tested, and criticized (see overview by Block and others 1995). Criticisms include (1) species are unique, and therefore cannot reliably reflect the needs or responses of other species, (2) because migratory bird species are highly mobile compared to other taxa, their responses to environmental change may be adaptable and thus less predictive, (3) reducing numbers of managed bird species by counting only indicators does not reduce monitoring costs, even though saving money was a rationale behind the indicator concept, (4) *a priori* classification of species into appropriate groups or guilds typically fails, and (5) life history requirements of bird species are too complex and interspecifically variable to manage using a single indicator species. In many situations, however, extreme or long-term population changes in single bird species have called attention to important environmental problems. These include pesticide contamination (common indicators: raptors, waterbirds), forest fragmentation (example indicators: Spotted Owl, *Strix occidentalis*; forest-interior NTMBs), wetland loss (indicators: ducks and geese), and riparian habitat degradation (example NTMB indicators: Least Bell's Vireo, *Vireo bellii pusillus*; Southwestern Willow Flycatcher, *Empidonax traillii extimus*). Our general conclusion is that the use of NTMB indicator species as ecological indicators has limited predictive power and scope. The selection of species as management indicators because of concern or interest in their populations due to their status (threatened, endangered, sensitive, high management concern, or high public interest or demand) may have more merit, but also may suffer from the same limitations of traditional featured species approaches.

Species Prioritization

Prioritization schemes have been used in conservation for a wide range of taxa (Master 1991; Millsap and others 1990; Rabinowitz 1981; Reed 1992). Partners in Flight acknowledged the challenge of managing for multiple NTMB species from its beginning and developed a species prioritization process (Hunter and others 1993a; Carter and Barker 1993; Carter and others, this proceedings) that ranks all nongame landbirds. Prioritization schemes may be superior to indicator-species strategies because all species are evaluated and ranked in relation to each other and their habitats. Additionally, priority species can be used to identify priority ecosystems or habitats. This bottom-up process of

identifying priority species and associated habitats has enabled PIF to begin conservation planning for this large group of species. While basically a species-level approach, this process has multiple-scale components because it acknowledges the importance of a regional population to the global population. Furthermore, species priorities can be developed at several spatial scales, including physiographic or eco-regions as well as broad geographic regions (Probst and Thompson 1996).

Dobkin (1994) is an example of a similar species-level approach. He evaluated the status of NTMB species in the Northern Rockies and Great Plains including their regional distribution and impacts of management practices.

Limitations of species-level prioritization approaches are that (1) individual bird species rather than species assemblages, geographical areas, or ecosystems are still the ultimate focus of the prioritization and could result in many of the same failings described for the indicator-species concept, (2) other priorities such as ecosystem degradation, economic return, recreational and social values, or endangerment of species belonging to other taxonomic groups are not assessed, (3) bureaucratic inertia and costs create obstacles for adaptively responding to shifts in species priorities resulting from changes in habitats, populations, and management, and (4) management priorities of natural resource agencies are much broader and more complex than priorities for NTMBs.

Mapping and Gap Methods

Mapping methods using area-specific data at any spatial scale of interest can be used to define geographical areas where diverse, multiple priorities are concentrated (i.e., "hot spots"). These data are often species-level data, such as range maps or occurrence records of species. For example, Flather and others (1994) identified countrywide priorities for plants, invertebrates, amphibians, reptiles, mammals, and amphibians of the continental United States by mapping numbers of endangered species in each taxonomic group and as a whole. State GAP analyses using Geographic Information Systems are excellent mapping models for sorting out statewide conservation priorities for plants and animals, including birds (Scott and others 1993). Using these kinds of mapping and ranking approaches, priorities for NTMB species can be mapped and analyzed over a defined area at any scale; concentrations of multiple NTMB priority species can be isolated; and the priorities of the NTMB layer of data can be ranked relative to layers developed for other priorities such as ecosystem rarity, plant species richness, numbers of endangered species, extent of habitat loss, imminence of threat, vegetation management (manipulation) plans, or anything else of special interest.

Landscape or Ecosystem Scale

Ecosystems and landscapes (collections of ecosystems) are a particularly important scale for NTMB conservation (Freemark and others 1993). Many factors at this scale affect population size as well as processes, such as reproductive success. This is an important scale for integrating NTMB conservation with other land uses, and Ecosystem Management is the approach used by the U.S. Forest Service to manage multiple uses of national forests and grasslands. This scale is the landscape or land unit scale of the National Hierarchical Framework (table 1).

Several landscape- or ecosystem-based approaches to NTMB conservation have been recommended for the Midwest (Thompson 1996). These approaches review status of NTMBs in broad ecosystem types (grasslands, agriculture, northern hardwood-conifer forest, central hardwood forest, bottomland forest), review land management trends and impacts, and recommend conservation approaches that acknowledge the need for multi-resource management.

Many federal and state agencies have shifted their management practices to larger scales that accommodate whole ecosystems. Managing for ecosystems requires flexibility in strategic planning, because ecosystems and their components, such as populations of NTMBs, change over time and space in response to climate change, succession, fire, and human use. Ecosystem management blends the needs of people and environmental values to maintain productive and sustainable ecosystems.

Priorities for ecosystem and NTMB management can be arrived at from both top-down and bottom-up processes; we suggest that both are needed for the conservation of biological diversity. An example of top-down conservation prioritization of ecosystems is presented by Noss and others (1995). They identified priority ecosystems based on assessment of their current and historic distribution of those systems. An example of a bottom-up approach is the PIF species prioritization. Priority habitats or ecosystems are identified by assessing the habitat associations of priority species within the area of interest.

The conservation and restoration of oak savannas in the midwestern United States is a good example of the need for both top-down and bottom-up conservation efforts. Oak savannas are an acknowledged priority for conservation because of their rarity, particularly when compared to their historic abundance (Noss and others 1995). Oak savannas are used by an interesting mix of NTMBs including priority species such as the Yellow-billed Cuckoo *(Coccyzus americanus)* and Prairie Warbler *(Dendroica discolor)*. None of the species, however, are limited to savannas, and an assessment of conservation priorities based on habitat affinities of priority NTMBs might not include savannas.

Western riparian ecosystems are another example of the need for both top-down and bottom-up conservation approaches. Riparian habitats are critical centers of biodiversity and are crucial to landscape processes (Brussard and others 1998), and they support many species of NTMBs (Dobkin and Wilcox 1986; Dobkin 1994; Saab and others 1995). Nearly all riparian habitats have been degraded (United States General Accounting Office 1988; Chaney and others 1990), and this ecosystem is considered a conservation priority. Very few of the riparian-associated NTMBs are endangered or threatened, however, due to a general pattern of large ranges and use of other habitats. Nevertheless, a bottom-up focus on selected NTMBs could provide a meaningful gauge of the success of top-down approaches to riparian ecosystem restoration. By contrast, native-grassland ecosystems are an acknowledged priority

based on both top-down assessments (Noss and others 1995) and bottom-up assessments based on habitat associations of high priority NTMBs (Thompson and others 1993a).

Active management for NTMBs can be part of an ecosystem plan if priorities for their conservation are defined. Finch and others (1993) offered the following approach to sustain multiple NTMBs as part of ecosystem management:

1. Identify species that need most attention, i.e., threatened, endangered, and declining species, or those sensitive to current management.
2. Identify species favored by current land management and habitat patterns.
3. Identify those on the second list that will decline if management is changed to favor those on the first list.
4. Determine the conditions needed to sustain the most vulnerable species on lists 1 and 3.
5. Integrate management for these desired conditions with other resource values.

An important part of ecosystem management is the monitoring of ecosystem diversity, integrity, and productivity (Finch and others 1993). Adaptive management is the ability to adjust management practices in response to new information such as findings from monitoring data. To adaptively manage for NTMBs in an ecosystem context, we recommend a step-by-step process that involves: (1) setting priorities for multiple species management which include information about current status of species and their habitat quantities, seral stages, and conditions; (2) identifying consequences to other species if high priority species are managed for; (3) monitoring populations of multiple species over time and space to determine success of management; (4) adjusting management strategies based on monitoring information; and (5) creating partnerships between landowners, experts, and managers to manage effectively across boundaries of land, discipline, and knowledge.

Ecoregion and Subregion Scale

This scale represents ecological units such as Domain, Division, Province, Section, and Subsection (table 1), or an area equivalent to geographically defined regions such as those used by Partners In Flight (i.e., Northeast, Southeast, Midwest, and West). Several recent efforts have assessed the status of NTMBs at this scale. Hunter and others (1993a), Smith and others (1993), and Thompson and others (1993a) assessed the status of NTMBs in the Southeast, Northeast, and Midwest, respectively, and identified high-priority species for conservation in each region. More recently, Probst and Thompson (1996) presented a similar approach as part of a multi-scale assessment. They pooled species prioritization information from the PIF database (which is organized by physiographic areas) to identify priority species for the Midwest. They examined the distribution of all NTMBs, NTMBs with declining populations, and regional high-priority NTMBs across ecological provinces, habitats, and habitats within provinces (table 2). This approach highlights the distribution of species among ecological units such as provinces and habitats, and can help managers identify conservation opportunities for locally common but regionally important species.

The Partners in Flight Conservation Plan is an effort to implement bird conservation at this scale. Within planning units (typically physiographic areas analogous to provinces or sections [table 1]), species are prioritized and species "suites" or habitat conditions are identified as priorities. Objectives are then set for the distribution of these habitats or species within the region.

The Southern Appalachian Subregional Assessment: An Example of a Multi-Resource Multi-Scale Assessment

The Southern Appalachian Subregional Assessment (SAA) used a coarse and fine filter approach to assess terrestrial plant and animal resources for the region (SAMAB, 1996). Through "coarse filtration," 16 broad landcover classes were identified. Nine of these forest classes were further defined by 4 successional classes, including early successional grass/shrub, sapling/pole, mid-successional, and late successional. Ages for these successional stages varied by forest type. These broad cover classes were used to determine current and past landscape patterns for these general habitats. The information also was used to model habitat suitability for

Table 2—Numbers of Midwestern Neotropical migratory birds and priority species (in parentheses) that breed in habitats and ecological provinces. Species can be associated with more than one habitat, so rows and columns do not sum to species totals. Adapted from Probst and Thompson (1996).

	Ecological Province[a]							
Habitat	**212**	**222**	**251**	**331**	**332**	**M222**	**M334**	**Total**
Agric/developed	38(5)	38(5)	40(6)	39(6)	39(6)	31(4)	29(4)	47(6)
Aquatic	8(1)	6(1)	6(1)	6(1)	6(1)	4(1)	0(0)	8(0)
Forest	71(19)	34(10)	35(6)	31(3)	27(4)	20(5)	20(2)	94(24)
Grassland	26(6)	25(6)	39(15)	35(9)	33(8)	20 (5)	21(4)	45(16)
Savanna	27(6)	30(6)	33(6)	31(3)	34(5)	27(5)	20(2)	39(7)
Shrub	65(14)	54(16)	54(11)	51(8)	48(8)	35(8)	29(3)	95(22)
Total	129(30)	124(30)	136(33)	126(23)	125(27)	93(21)	81(10)	187(47)

[a]Based on Bailey and others (1994): 212 = Laurentian Mixed Forest Province; 222 = Eastern Broadleaf forest (continental); 251 = Prairie Parkland (Temperate); 331 = Great Plains Palouse Dry Steppe; 332 = Great Plains Steppe; M222 = Ozark Broadleaf Forest-Meadow; M334 = Black Hill Coniferous.

specific groups of species. In addition, 31 rare communities were identified through this coarse filter.

As part of the fine filter approach, a total of 472 individual plant and animal species were identified for emphasis in the SAA. Of these, 47 bird species met selection criteria for further detailed consideration. Species and their relationships to habitats were documented using a species/habitat matrix. Information from the matrix was used to develop landscape habitat suitability models and to organize the 47 species into 11 groupings based on habitat associations. These groups then became the focus of the assessment. This same process is applicable to forest and project-level planning.

Analysis of Landscape Habitat Suitability

To identify broad scale habitat patterns within the SAA, spatial analysis was conducted to determine the current habitat conditions for the groups of species. Information used in the analysis included Forest Inventory and Analysis (FIA), LANDSAT Thematic Mapper Imagery, and national forest CISC data. Models were developed using information in the species/habitat matrix to conduct landscape-level analysis for habitat suitability. As an example, we summarize results for area sensitive species.

Area Sensitive Species in SAA Area—Sixteen species are included within this habitat association. These species have minimum forest tract size requirements ranging from 2 acres (Wood Thrush, *Hylocichla mustelina*) up to around 4,500 acres (Cerulean Warbler, *Dendroica cerulea*). Analysis for the total SAA area revealed approximately 15.8 million acres of mid- to late-successional deciduous forest habitats in tracts greater than 2 acres in size. Of these acres, 8.2 million are in tracts greater than 5,000 acres in size. These 8.2 million acres have the highest potential for supporting all 16 area sensitive bird species. Analysis of forest interior habitat found that around 66 percent of the 15.8 million acres was suitable forest interior habitat.

Habitat Availability by Ecological Unit—Around 7.1 million acres (4.8 million acres in tracts greater than 5,000 acres) occur within ecological sections that are greater than 75 percent forested (Blue Ridge Mountains, Northern Cumberland Plateau, and Southern Cumberland Mountains). The remaining acres of suitable habitat in large tracts were in ecological sections with significant amounts of agricultural and developed land.

Habitat by Ownership—Around 39 percent of the suitable acres in large tracts are on national forests. National forests and national parks together contain 46 percent of this habitat in the Southern Appalachians. On national forests it is estimated that around 90 percent of this habitat is suitable forest interior habitat. Federal ownerships are a key component in maintaining habitats for bird species associated with this habitat in the Southern Appalachians.

Conclusions

Biologists have been developing more holistic, multi-species approaches to conservation as an alternative to single-species approaches. Such approaches should include not only most vertebrate species, but also should be integrated with disturbance regimes and forest harvesting (e.g., Probst and Crow 1991; Thompson and others 1993a). Multi-scale assessments are necessary because of the interaction between local and regional populations as well as other resources and processes. Coarse-grain assessments at large scales are a necessary first step in understanding finer-scale patterns and setting local priorities. Multi-scale assessments can be broad, comprehensive, and cost effective if done by step-wise successive approximation (Probst and Thompson 1996).

We have provided just a few examples of assessments or conservation efforts that attempt to address the problem of managing for multiple NTMB species. We selected these examples because they represented a variety of spatial and geographic scales. We believe that successful NTMB conservation will require a broad top-down perspective combined with management actions taken from the bottom up. A top-down approach is needed to establish priorities or objectives at regional and sub-regional scales for species, ecosystems, and ecological processes (e.g., the role of fire in grasslands and woodlands). Multi-species or multi-resource concerns require broad spatial perspectives (regional, continental, global), because many ecological processes and economic concerns are regional, continental, and global in scope. A strictly local or bottom-up perspective for comprehensive resource planning can lead to high local diversity but low ecosystem integrity and conflicting prescriptions for multiple resources or species (Probst and Thompson 1996). Most management decisions and actions, however, occur at a local level. We believe that multi-resource, multi-species conflicts can be reduced if local level managers try to contribute to regional priorities. By placing local decisions in a regional, multi-resource context, land managers and planners can direct local planning to meet different but complementary objectives.

Setting Local and Regional Objectives for the Persistence of Bird Populations

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Abstract—Managing lands to promote persistence of a wide diversity of native species, often with opposing habitat needs, requires a complex set of decisions to be made at multiple spatial scales. Management goals and objectives for species are established under a variety of constraints, and each land manager faces unique challenges particular to his/her location. However, the ultimate success of a bird conservation plan depends upon coordinated efforts by managers at regional and local scales, emphasizing the need to standardize the decision-making process at all scales. In this paper we outline a suggested process by which decisions about management of North American birds can be made to establish specific objectives and implement actions at regional and local scales. We also provide some suggestions regarding biological criteria that can be used as tools in making management decisions and evaluating management results at regional and local levels.

Managing lands to promote persistence of a wide diversity of native species, often with opposing habitat needs, requires a complex set of decisions to be made at multiple spatial scales (Noss 1983; Probst and Crow 1991; Maurer 1993; Freemark and others 1995; Petit and others 1995). Developing effective plans for highly mobile species such as birds is particularly challenging because bird populations may be regulated during any phase of their life cycle. North American plans that focus on maintaining viable breeding populations may be ineffective if heaviest mortality occurs during migration or winter. Conversely, South, Central, and Latin American plans that focus on maintaining habitats associated with high overwinter survival may be ineffective if an insufficient number of birds are produced during the breeding season. Furthermore, even within North American breeding habitat, it is thought that most species occur as spatially distinct breeding populations that interact by dispersal; the effectiveness of local-scale management actions may be difficult to track if birds disperse to and from the local area.

For these reasons, we discuss the development of effective, regional plans in North America, where a region is defined as the geographic scale that is thought to encompass the majority of natal and breeding dispersal movements of a population (sensu Greenwood and Harvey 1982). We discuss regional planning with the realization that plans can be expanded or altered as more is learned about population regulation and limitation in birds, and about the spatial scale that best defines population interactions.

Flowchart Overview

The overall goal in developing regional bird conservation plans is to maintain viable populations of native species at some predetermined level of regional abundance and distribution. To achieve the stated goal, we propose a decision-making process that follows the form of a flowchart, where each step in the process must be addressed before proceeding to the next step. The decisions are carried out by both "regional" and "local" managers, although the distinction between the two may be obscure. Simplistically speaking, a local manager usually focuses management decisions on achieving local objectives, and implements specific management actions, whereas a regional manager coordinates the management actions of local managers to achieve regionally defined objectives. Refuge or park managers are examples of local managers, while state wildlife biologists or Partners in Flight (PIF) Regional Coordinators are examples of regional managers.

The flowchart can be viewed as a top-down approach where local scale management is influenced by, but not limited to, regional scale objectives. The entire chart is followed first by the coordinated efforts of regional and local managers to address regional priorities, and then subsequently by local managers to address more localized priorities. The process emphasizes the need to develop plans at much larger spatial scales than traditionally have been developed. The process also includes an adaptive management approach, whereby each step in the process can be evaluated and revised to improve the development and implementation of specific

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management objectives (at all relevant spatial scales) to maximize results in an uncertain future.

Step I is to determine the geographic context in which all management objectives will be integrated. This context, which includes the spatial and temporal distribution of habitats and species within an area of concern, will determine the management objectives that are possible, feasible, and optimal for the region in which the plan will be implemented. Once this context is determined, a prioritization scheme can be used to prioritize species for management action (e.g., Hunter and others 1993a; Carter and others, this proceedings; Dunn 1997). The outline presented here assumes that priorities already have been established.

The remainder of the decisions in the process, Steps II through VIII, are outlined by a large box to indicate that all remaining decisions are made in light of this geographic context and the sociopolitical constraints operating within it. In this paper, we focus our discussion primarily on Steps I through VI; more in-depth discussions about the steps that describe monitoring and evaluation (Steps VII and VIII) are described in Twedt and Loesch (this proceedings).

The chart flows as follows (fig. 1): Once the geographic context and species priorities are known (I), managers must decide (II) what is the "object of management" at the regional scale. That is, they must define exactly what will be targeted for management—habitats or species, or both—and then set management objectives at a regional scale. Given the object(s) of management and regional objectives, managers must then (III) assess what constitutes high-quality habitat within the region for each object of management. Once the basis for habitat quality is known for each object of management, regional and local managers together (IV) model the spatial or temporal arrangements of habitats at a regional scale to determine a plan that optimizes management when all objects of management are considered simultaneously. Based on the model simulations, recommendations can be made, and (V and VI) specific management objectives can be implemented at the local scale. Adaptive management requires (VII) short- and long-term monitoring and assessment of progress of management efforts toward local and regional goals. Depending on results from monitoring/assessment efforts, (VIII) any or all of the steps (including Step I) can be revised to improve management effectiveness. The flowchart can be followed to assess regional priorities, but also can be used by local managers to set local scale priorities and objectives.

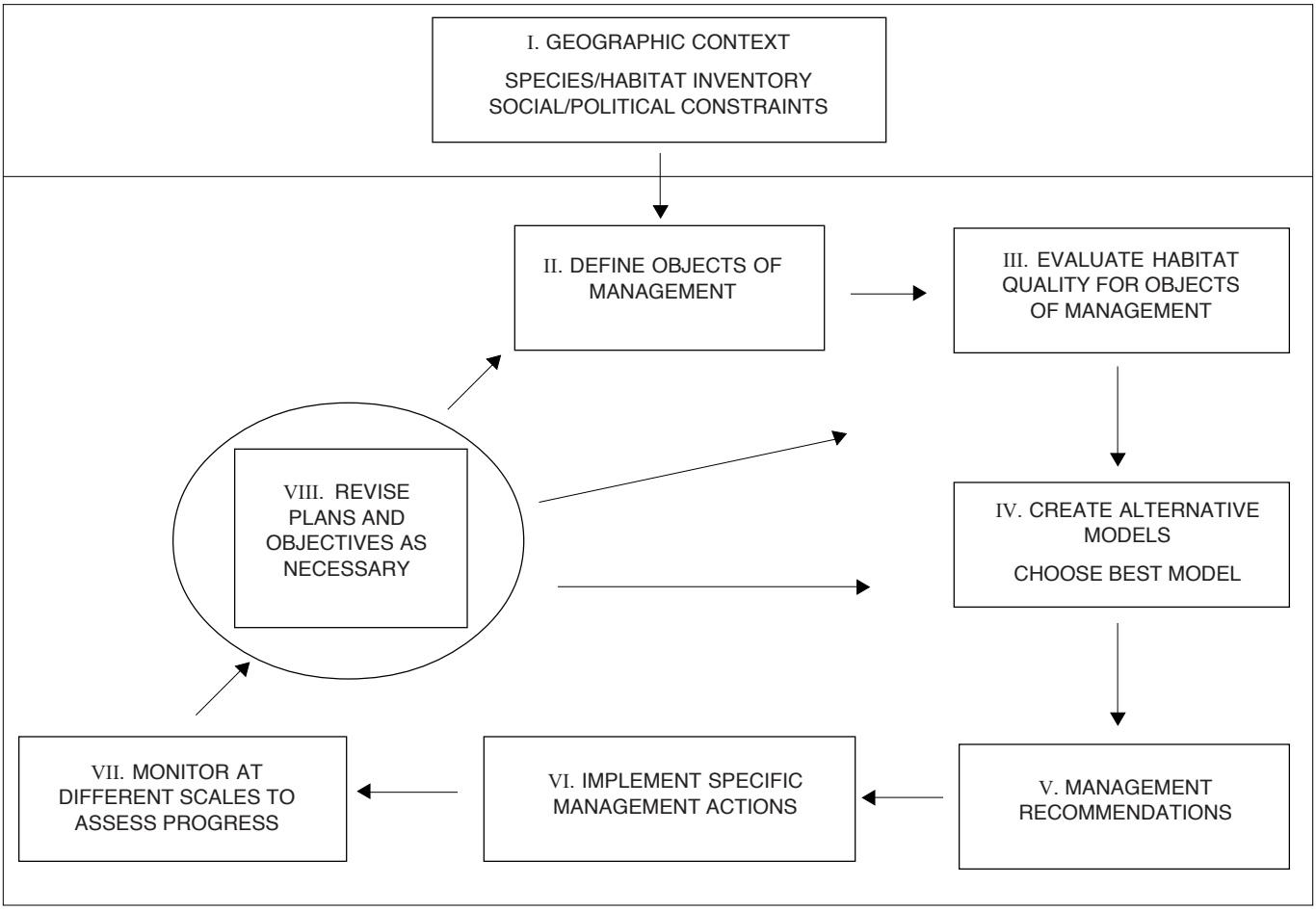

Figure 1—Flowchart.

Step I: Identify the Geographic Context of a Management Plan

The first step is to define the spatial and temporal context for management actions.

Spatial Context—This step defines the regional scale for management, and identifies species and habitats that occur within the defined area. We suggest that biological considerations should underscore the actual number and sizes of each regional unit within North America. For example, if the regional units are too small relative to the distance that birds disperse from one breeding season to the next, then regional plans may be confounded by dispersal of individuals into and out of the region of concern, and may complicate the evaluation of management actions. In contrast, if regional units are too large relative to the size of average populations, then development of regional plans may be unwieldy and ineffective. Thus, the size and number of regional units must be carefully considered from a biological perspective before any plans are drawn. Given the biological context, additional attention should be given to social, economic, and political constraints.

The scale selected by PIF for conservation planning is that of the physiographic area (Williams and Pashley, this proceedings). physiographic areas vary in size from 20,000 km^2 (Subtropical Florida) to 2,000,000 km^2 (Boreal Forest). The selection of this scale undoubtedly influences which species become management priorities. Because physiographic area boundaries often cut across political boundaries, implementation of management objectives may take place at various scales, such as within states. Additionally, at this time there is little evidence that any physiographic area encompasses the majority of dispersal movements of a population. Theory suggests that dispersal (natal and breeding) should be limited in geographic extent (Shields 1982), yet banding recovery data suggest that dispersal may be wide-ranging. The selection of the physiographic area, however, is thought to have more biological meaning than political boundaries, because physiographic areas contain a collection of relatively homogeneous habitats (Williams and Pashley, this proceedings). Boundaries can be adjusted as more practical solutions become apparent, and as we learn more about bird distributions and their relevance to boundary designations.

Temporal Context—Step I also identifies the temporal context in which management actions will be evaluated. The lack of a defined temporal context has been problematic with previous attempts of adaptive management (D. Bonter, personal communication), indicating the need to identify a specific time period for initiation of reviews. The evaluation (see Step VII) includes an assessment of whether objectives have been met, and also re-evaluations of species priorities, which are scheduled at approximately 5-year intervals (D. Pashley, personal communication). Five years may be an appropriate interval for evaluating priority species. However, considering the time required to go through the planning process (up to two years), and to manipulate habitats, five years is likely to be too short for assessing the entire management plan. Ten to twenty years may be more suitable because populations are then given sufficient time to respond to specific management actions. However, in rapidly changing environments, 20 years might be too long if species decline without being noticed. In these cases, or where an immediate response to a management action is expected, more frequent evaluation may be warranted. Although evaluation of the entire management plan may take place infrequently (every 10-20 years), monitoring of populations to assess response to management should occur throughout the process, preferably on an annual basis.

All future steps must be considered within the context established by this geographic and temporal context.

Step II: Define the Object(s) of Management and Set Objectives

Step II, a critical point, is where the "object of management"—the unit upon which management objectives will be based—is determined. For example, in the Northern Tallgrass Prairie, 27 of 185 species have been identified as management priorities (Fitzgerald and others 1998). Potential objects of management include, but are not limited to: These 27 individual priority species; umbrella species whose habitat requirements encompass the requirements of other species (e.g., Murphy and Wilcox 1986); focal species that include priority and non-priority species which are most sensitive to a process that threatens their persistence or to the management practices being used in a given habitat type (Lambeck 1997); or all species that share a general macrohabitat type (species-habitat suites).

Which of these "objects of management" will best achieve the overall goal? First and foremost, the object must be selected so that effects of a management scheme are measurable and can be evaluated. For example, if the object of management is a priority species, then measurable features such as abundance, distribution, and reproductive success must be related to specific management actions, and then evaluated in terms of success or failure. Objects of management for which outcome measures are vague should be avoided (e.g., "viable populations of forest birds").

The current PIF planning process uses "species-habitat suites" as objects of management. This approach is designed to achieve the goal of maintaining viable regional populations and to "keeping common birds common." The PIF prioritization scheme is based not only on identifying species in need of immediate conservation action, such as those that are sharply declining, but also on identifying species that are unique to a region. It also focuses on identifying those species within a region where regional persistence is critical not only for the region, but also for the species' persistence across its range. The result is a list of priority species from various habitats which are grouped into species-habitat suites. Birds within the suites represent focal species, and management for those species is thought to ensure persistence of other, non-priority species. Whether managing for "species-habitat suites" will achieve long-term goals more effectively than other "objects of management" is likely to be a focus of conservation interest in the coming decade.

Setting Objectives—Once objects of management have been selected, region-level population and habitat objectives

are determined. An objective is a clearly defined statement of what is intended to be accomplished in a given amount of time. A clearly defined objective establishes a set of criteria that can be evaluated in terms of success or failure; ambiguous objectives will cause confusion among various land managers and cannot be evaluated. For example, if an objective is to provide sufficient habitat to maintain Bobolink populations, mixed impressions among managers will result. Some might think "Bobolink populations" is a few singing males in the region; others might think "Bobolink populations" is a single viable source population. Some might think Bobolink habitat is native prairie; others might think Bobolink habitat is Conservation Reserve Program lands. Clearly stated objectives specify what is to be done and when (W. Porter, personal communication), for example: "Maintain habitat in the Northern Tallgrass Prairie Physiographic Region to support 5,000 breeding territories of Bobolinks with average nesting success of >40% by the year 2020." As PIF conservation plans are developed, considerable thought will be needed to establish objectives that are well defined. This will be a long and complicated process.

Our flowchart incorporates an adaptive management phase in every step, emphasizing the need to explicitly state each objective and the means by which management actions can be evaluated. As such, if the object of management is a priority species and a regional goal is to maintain viable populations of at least 5,000 individuals, then measures of both population viability and abundance should be used to assess the success of management actions. In contrast, if an object of management is a particular habitat that accommodates a suite of species, (e.g., maintain 5,000 ha of old-growth forest), then assessment of management strategies should be habitat-based.

Considerations for Setting Objectives—In our opinion, objectives for objects of management should be population based (numbers of individuals), rather than habitat based (amount of habitat). First, numerical objectives appear to be easier to "sell" from a policy standpoint (e.g., the huge success of the North American Waterfowl Plan is based, in part, on the establishment of numerical objectives). Second, if numerical objectives are achieved, sufficient habitat likely has been managed. In contrast, setting habitat objectives may be achievable (e.g., maintain 3,000 ha of riparian forest), but population numbers may not be maintained on those habitats. Habitats, for example, can change in quality and go from "prime" to "poor" even when habitat size, configuration, or structure are not changed. This can happen when factors extrinsic to the patch itself affect the quality of the patch, or when factors intrinsic to the patch vary over time.

Consider the Everglades National Park, where decreased water levels—owing to urban, suburban, and agricultural development outside of park boundaries—has impacted the hydrology and habitat quality of the park itself, although the area has remained constant. If densities decrease as habitat quality decreases, the same area will support fewer individuals. Thus, use of numerical population objectives may provide an important cushion for unforeseen impacts, both intrinsic and extrinsic, on habitat quality in a changing environment.

Step III: Evaluate Habitat Quality for the Object(s) of Management

Step III involves identifying the full range of habitats that can be used by each object of management in the region, assuming that objects of management are species or species combinations. The emphasis here is on identifying high-quality habitats that allow populations to persist at the regional level (habitats where productivity and/or survival is high). The end result is a list of habitats, sizes, and configurations that could be targeted for management to achieve regional objectives. Objects of management require region-specific evaluation of high-quality habitat and its spatial arrangement for two reasons. First, populations may differ regionally in demography, density, and dispersal ability (e.g., edge versus center of the geographic range). Second, the constitution of high-quality habitat for the same object of management may vary regionally. For example, birds nesting along forest-edges that are situated in heavily forested landscapes may experience high nesting success, but birds nesting along forest edges in highly fragmented landscapes are likely to experience low nesting success (Donovan and others 1997). In this situation, edges are "low quality" for breeding in one landscape type and "high quality" in another.

Considerations for Assessing High-Quality Habitat—Conservation biologists and wildlife managers have used several criteria for determining high-quality habitat for an object of management. These include, but are not limited to:

- Minimum number of pairs supported (e.g., habitat conditions needed to support 10 breeding pairs).
- Nesting success adequate to support local breeding populations (e.g., habitat conditions needed to achieve a "high" nesting success over time).
- Presence of an area-sensitive priority species (e.g., forest area needed for area-sensitive species to occur with some degree of regularity).
- High density of a priority species.
- Habitat that promotes high survival levels.
- Habitat that facilitates dispersal among local areas.

When assessing high-quality habitat for each object of management, a few key issues must be considered. First, the ability of a population to sustain itself locally may be unrelated to the density of individuals or the size of a local habitat; sinks can support many individuals, and sources can be numerically quite small. Thus numbers can be misleading, and management plans should aim to protect a diversity of habitats and landscapes used by the species, not just areas where the species is most common. Second, source and sink populations can be characterized by their relative importance depending on their intrinsic rate of growth and the number of individuals present. "Strong" sources are better than weak sources in maintaining regional populations. Third, owing to temporal variation, a habitat patch may oscillate between supporting a source population and a sink population. Fourth, although demographically viable, sources can become extinct via non-demographic processes (e.g., stochastic events), and if regional sources collapse, the

regional population will go extinct. Maintaining multiple sources that are geographically spaced appears to be a good strategy for maintaining regional viability.

Finally, although sinks depend on sources to persist, they may benefit the regional population by "housing" a large proportion of the population at any given time. Additionally, a substantial number of young may be produced in sink habitat even though reproduction occurs at a level below replacement. However, if sinks act as ecological traps that draw birds away from higher quality source habitats, or act as a conduit to spread parasites or disease, then maintenance of sink habitats at a regional level may not be desirable. Planning should be flexible to accommodate new management principles as more is learned about the benefits or detriments of sink habitats in maintaining regional populations.

To evaluate source-sink status, the fecundity (season long reproductive success per individual) and death rates of adults in the population must be measured. Therefore, population trends, presence-absence data, and population density may not be capable of establishing source-sink status (Brawn and Robinson 1996) and may be misleading indicators of habitat quality (e.g., Van Horne 1983; Pulliam 1988). Unfortunately, direct measures of fecundity and survival are perhaps the most data-intensive measurements for assessing high-quality habitats. Surrogate methods are needed. Several indirect measures of productivity have been used to estimate habitat quality, including nesting success, pairing success (e.g., Villard and others 1993), juvenile: adult ratios (e.g., Robinson 1992), and others. While these measures do not directly estimate number of offspring produced per individual per year, they are thought to be correlated with productivity. Variation in numbers over time is another indirect assessment of habitat quality. Because sink populations theoretically fluctuate over time more than sources (Howe and others 1991; Curnutt and others 1996; Boulinier and others 1998), simple measures of change in abundance over time may be an indicator of habitat quality. Of course, criteria used in determining high-quality habitat for an object of management should be carefully considered and tested for their effectiveness.

Targeting Threats—In the absence of direct measures of fecundity and survivorship for an object of management, identification of threats to persistence or other indirect measures of viability may be used to evaluate high-quality habitat. For example, parasitism by the Brown-headed Cowbird (*Molothrus ater*) reduces fecundity for many species in fragmented Midwestern landscapes, but is not a major threat in heavily forested landscapes, whether in the Midwest or in other regions such as the Northeast. In regions where parasitism is identified as a major threat for a priority species, managers can assess habitat and landscape conditions that limit cowbird abundance, and thus manage indirectly for the priority species.

Step IV: Create Alternative Models of Landscape Configuration Based on Geographic Context

How is a region going to maintain 5,000 Bobolink pairs with an average nesting success of 40% by the year 2020? Once high-quality habitat has been established for each object of management, Step IV involves the collaborative efforts of both regional and local managers to create alternative management plans that will meet regional management objectives when all objects of management are considered simultaneously. This step addresses a regional-scale question: How should we manage the regional landscape (habitats and their configuration) to achieve the regional population (numerical) objectives? The possible habitat/management arrangements (blueprints) that will meet regional objectives may be few or many.

The goal could be achieved by modeling an array of potential management actions at the regional level (landscape configurations), and by coordinating efforts of all public land managers and cooperating private landowners to reach regional population objectives (e.g., Hansen and others 1993). This step uses an adaptive approach that identifies the effect of each management scenario on each object of management. For example, dynamic population models for each object of management can be developed, where each model predicts the response of the object of management to landscape management prescriptions as a function of the initial population or habitat status, environmental conditions, and management actions. The functions provide a measure of the effect of different management policies at the regional scale, and thereby permit identification of optimal policies for the region.

How can this be accomplished? One approach is to link simulation models with GIS to create locally accurate models of populations in landscapes. To achieve this step, information is required on (1) bird-habitat relationships, which depend on a consistent means of counting birds and describing habitat, (2) habitat distribution throughout the region, which depends on a consistent vegetation classification, and (3) satellite imagery, which relies on an accuracy-checked vegetation classification scheme. A simpler approach is to examine current maps of classified vegetation and land ownership, to determine where large tracts of manageable habitat exists, and to develop various management blueprints around such "cursory" information.

The result of any of these exercises will be one or many blueprints thought to be suitable for achieving regional objectives. In reality, physiographic areas can be tens of millions of hectares in size, and developing blueprints of that size entails numerous inherent difficulties.

As a simplified example, one blueprint might suggest the amount and location of the following habitats: At least 4,000 ha of mature hardwood forest (with at least 75% as contiguous habitat), 2,000 ha of wetland forest (with some high level of connectivity), and 1,000 ha of native grassland (with at least 50% as contiguous habitat). A second blueprint for the same physiographic area might prescribe the location of 3,000 ha of mature hardwood forest (with at least 90% contiguous habitat), 2,000 ha of wetland forest (with the same level of connectivity in Blueprint 1), and 2,000 ha of native grassland habitat (with at least 25% as contiguous habitat). The different blueprints will identify the total amount of habitat needed, where it is located, and how it is configured to achieve the regional population objectives.

Blueprints likely will target large tracts of habitat under public jurisdiction, but also may target habitats under private ownership to build cooperative agreements for bird

conservation. Undoubtedly, tactics for successfully achieving regional objectives will vary depending on the social, political, and economic values of the region.

Step V: Make Management Recommendations—Choose the Best Blueprint

Both regional and local plans are developed at this step, which involves the coordinated efforts of all participants within the region. Local managers identify how they can contribute to the regional objectives, and select the blueprint that best achieves consensus. They are presented with a list of priorities (habitat and species) for the region and make management decisions about one, many, or all of the species on the list, working in concert with the regional manager to ensure that regional objectives will be addressed. Coordination of local-scale decisions is needed to ensure that all of the regional objectives are met (e.g., that no regional objectives slip through the management plan because none of the local scale managers elect to manage for a regional object of management).

As a simplified example of Steps IV and V, suppose that two priority species have been identified as objects of management for the St. Lawrence Plain physiographic area, the Bobolink (BOBO) and the Golden-winged Warbler (GWWA). For nesting, one species requires grasslands of a certain structure, while the other requires shrubby habitats of a certain structure. Both species require that forest succession be prevented. Multiple regional blueprints are developed that consider different management scenarios, and the plan(s) that achieve both species' population objectives are selected for discussion. Local level managers, aware of the regional goals because they assisted in the regional planning process, identify how they can contribute toward meeting regional goals on their properties. Because BOBOs and GWWAs demand conflicting management actions, some managers may contribute toward BOBO habitat and others may contribute to GWWA habitat. Given the regional priorities, each local manager can then decide how to manage for their target species (following flowchart Steps II-VIII). Both regional and local managers must work together to decide how the regional landscape will be managed to meet regionally defined objectives.

Step VI: Implement Specific Habitat Management Strategies and Actions

Given the regional objectives, management actions are implemented by local managers. Within a local context, managers may have options for implementing actions for the species defined at the regional level. For example, if the GWWA is identified as a priority for the area, then local managers can consider how to restore and enhance GWWA habitat, how to increase the size and number of GWWA source populations, and how to make weak GWWA sources into stronger ones. Local managers can follow Steps II –VIII to make local management decisions to meet local objectives that involve local as well as regional priorities. Implementation of conservation objectives is a huge and critical step in the overall process; however, a more complete discussion of implementation is beyond the scope of this paper.

Step VII: Monitor Bird Populations and Habitats at Local and Regional Levels

Both short- and long-term monitoring are needed to assess how well management efforts are achieving goals for long-term persistence of regional bird populations. In general, the more sophisticated and precise the monitoring, the easier it is to resolve uncertainties about biological mechanisms and thus to improve the management plan (Lancia and others 1996).

Monitoring strategies should be integrated at both regional and local scales. The types and timing of monitoring may be targeted for different locales to ensure regional representation of different types of data (e.g., nest monitoring, constant effort mist netting, surveys, migration monitoring). For example, more extensive and general survey work on distribution and habitat use could be combined with less extensive, but more intensive and detailed field work on productivity and survivorship of priority species. Such an approach facilitates implementation of coarse-filter conservation and management strategies while progressively finer filters are being developed.

The entire process outlined here depends on collecting information that can be used to assess the success of a particular management scheme. To that end, partnerships between the management and scientific communities are critical in developing effective plans for the long-term persistence of regional populations. However, most research studies are conducted at a local scale, and because results may vary dramatically between locations, generalizations regarding population regulation or limitation may be difficult, and management actions based solely on locally conducted studies may be ineffective. As such, national databases can provide necessary information to obtain regional perspectives on bird populations. Existing monitoring programs such as the Breeding Bird Survey and productivity programs such as BBIRD and EMAP should be supported by both scientific and management communities, and new programs targeted at regional scale population dynamics should be implemented.

Step VIII: Revise Management Plan and Objectives as Necessary

Depending on results from monitoring efforts, management plans and/or specific management objectives may need to be revised by changing any one or all of the decisions made previously in the overall flow chart.

Conclusion

Management of lands to promote persistence of all native bird species is not an easy task. Here, we have suggested a plan that emphasizes the importance of considering regional-scale "metapopulation" dynamics in the development of management plans. Our understanding of population dynamics at a regional scale is at an early stage, and our plan

represents only one hypothesis of how lands should be managed at both local and regional scales to promote species persistence. Like all hypotheses, we hope that this approach is tested and then modified as more is learned about the populations that are being managed.

The PIF planning process is currently under way, and is attempting to define priorities and management objectives for all physiographic areas and states. These plans are incorporating some of the guidelines outlined in this paper, and they undoubtedly will evolve as more precise information becomes available about demography, habitat requirements, and management alternatives.

Acknowledgments

This paper is the result of input from many individuals who participated in a workshop held at Patuxent Environmental Science Center in Laurel, MD, prior to the Cape May workshop, and prior to development of actual PIF physiographic area management plans. The PIF plans are currently emerging, and some examples from the new plans have been incorporated here. In addition to all of the co-authors, the following individuals contributed to the ideas presented in this paper: Dan Petit, Bob Adamcik, Roxanne Bogart, David Smith, John Sauer, Jim Nichols, Marcia Wilson, Janet Ruth, Chan Robbins, Deanna Dawson, Barbara Dowell, Ben Wigley, David Pashley, Ken Rosenberg, and Jim Herkert.

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Population and Habitat Viability Assessments for Golden-Cheeked Warblers and Black-Capped Vireos: Usefulness to Partners in Flight Conservation Planning

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Abstract—Golden-cheeked Warblers and Black-capped Vireos are Neotropical migratory birds that are federally listed as endangered. Recovery plans for both species advise the use of viability modeling as a tool for setting specific recovery and management targets. Population and Habitat Viability Assessment workshops were conducted to develop population targets and conservation recommendations for these species. Results of the workshops were based on modeling demographic and environmental factors, as well as discussions of management issues, management options, and public outreach strategies. The approach is intended to be iterative, and to be tracked by research and monitoring efforts. This paper discusses the consensus-building workshop process and how the approach could be useful to Partners in Flight.

Population and Habitat Viability Assessments (PHVA) were used to develop population targets and conservation recommendations for Golden-cheeked Warblers (*Dendroica chrysoparia*) and Black-capped Vireos (*Vireo atricapillus*). This paper explains what PHVAs are, discusses how they are conducted, describes the general results that are produced, and suggests how Partners in Flight (PIF) might use a similar process for bird conservation planning. Detailed results of the assessments are not discussed here; however they can be found elsewhere (Beardmore and others 1996a,b).

Population and Habitat Viability Assessments were considered for Golden-cheeked Warblers and Black-capped Vireos because they are controversial, endangered species, and the species' recovery plans list PHVAs as tools to develop recovery recommendations. The U.S. Fish and Wildlife Service (USFWS) realized that the data needed to perform PHVAs for these species is limited, but that various conservation efforts, such as the Balcones Canyonlands Conservation Plan and other endeavors, were proceeding without benefit of the biological summarization and guidance that a PHVA could provide.

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Function and Structure of PHVAs

A PHVA is a tool to compile, evaluate, and synthesize data and build a framework for conservation actions. It provides an in-depth examination and synthesis of what is known of a species' life history, ecology, management, and other factors to determine courses of action to manage for viable populations. Assessments include consideration of model analysis, habitat management, captive breeding (if appropriate), genetic factors (if appropriate), life history, status, threats, geographic distribution, education and information, other conservation efforts, human demography, research, and any other component deemed necessary. In contrast, Population Viability Analysis (PVA) refers to computer simulation modeling of biological processes that produce probabilities of extinction or survival under different scenarios. That is, a PVA is often only one step of a PHVA.

Why Were PHVAs Conducted?

Recovery plans for both Golden-cheeked Warblers and Black-capped Vireos list viability model development as a task in the Narrative Outline for Recovery Actions (U.S. Fish and Wildlife Service 1991; U.S. Fish and Wildlife Service 1992). The intent of USFWS was to initiate a process that would result in information that could be used in determining the population sizes, and the habitat patch size and distribution needed, to ensure viable populations (i.e., one of the recovery criteria). Other results that were anticipated included recommendations for habitat management, research needs, and public outreach strategies.

How Were the PHVAs Conducted?

A PHVA workshop, hosted by the USFWS, was held for each species. The format of the workshop was similar to PHVA workshops conducted by the IUCN's Conservation Breeding Specialist Group (CBSG 1993). The consensus-building, group discussion format was assisted by a trained facilitator. A group of biologists representing federal, state, county, and local governments; universities; consulting companies; and nongovernmental organizations was invited to participate. These biologists had either direct research experience with the warbler or vireo in the field, direct association with managing the species' habitat, or responsibility for

education programs that would benefit recovery. The group was kept small to facilitate group discussion, but included a representative from all groups that had conducted research or management on these species. CBSG often includes many stakeholders in their workshops, including private landowners involved in implementation. However, because of the complexity of developing biological objectives for these species, our workshops focused only on the species' biological needs and not on implementation. Future workshops are planned that will involve landowners and land managers, and that will encourage their participation in developing and implementing recovery solutions using the biological information developed in the first workshops.

The workshops had several steps. Introductory material was presented on the general intent of the workshop, an overview of small population biology, new biological data, the importance of informing the public of what is needed to recover endangered species, and a demonstration of the simulation model. Then, the group developed a set of workshop goals. The Black-capped Vireo group agreed to the following set of goals, which were similar to those developed in the Golden-cheeked Warbler workshop (Beardmore and others 1996b):

- Update and describe range-wide distribution and status (breeding, wintering).
- Update information on habitat characteristics.
- Identify and rank threats.
- Describe population dynamics, conduct simulation models, and estimate extinction probabilities (range-wide, special cases); define and estimate viable population sizes.
- Evaluate data on critical biological parameters, review methods and recommend standardization.
- Identify stakeholders and partners (agencies, organizations, private sector) and resources for implementing recovery.
- Develop a cooperative urban and rural outreach strategy.
- Describe short-term and long-term consequences of action or inaction by stakeholders.
- Specify research needs.
- Determine management needs for cowbirds, habitat (public and private ownership); discuss cost-benefit analyses and incentives and disincentives (Beardmore and others 1996a).

These goals were divided among four subgroups to address: (1) population biology and modeling, (2) habitat management strategies, (3) outreach and partnerships, and (4) distribution, status, and threats. All subgroups identified future research needs for their topics. Each subgroup drafted a report that summarized information, discussions, and recommendations. After the workshop, draft reports were compiled into chapters of a draft document and sent out for participant review. Each species group asked to have a subsequent one-day meeting during which comments on the draft document were discussed and chapters modified. The revised chapters from the one-day meetings were incorporated into final reports (Beardmore and others 1996a,b).

The reports from the PHVA workshops are intended as a framework from which managers can develop habitat in such a way that it will help meet the report recommendations. We were cognizant of possible misinterpretations, and were careful to include our assumptions and caveats. The results represent the best direction we have with the current state of knowledge, recognizing that we used minimal data for some values. Further data collection and analysis and the results of recommended conservation efforts will change the scope of recovery needs. That is, we intend the PHVAs to be part of an iterative process. The workshops' participants will meet again, both to target strategies for specific situations and to refine recommendations with new data. To implement recommendations found in the final reports, local workshops will be needed to involve landowners and land managers in developing specific strategies for action at the site level. Also, when research provides new information about processes, threats, and/or species biology, a reassessment of the targets and recommendations may be needed.

What Resources Were Needed to Conduct a PHVA Workshop?

The Golden-cheeked Warbler and Black-capped Vireo PHVAs were supported by a National Biological Service (NBS) grant and the participants' agencies and organizations. Total expenses for one workshop were about $7,000, including a computer simulation model, biostatistician support, and partial costs for travel and meeting facilities. This figure does not include the field work necessary for data gathering, but does include data synthesis.

What Data Were Needed for the PHVA?

By working through the available data in the population biology and modeling subgroups, the participants realized that the complexity of the simulation model that could be used for the analysis relates directly to the adequacy of the data available. If a substantial amount of the necessary data is available, a customized model can be developed that simulates important aspects of a species' life history; if data are limited or not appropriate for the model, a less sophisticated model can be used. For the Black-capped Vireo and Golden-cheeked Warbler, we did not have sufficient data to develop a customized simulation model. Instead we used a generalized, commercial model, RAMAS/metapop (Akáakaya 1994). RAMAS/metapop, like all PVA models, required an estimate of survivorship (from mark-recapture banding) at the same location for more than three consecutive years (to provide temporal variance), fecundity (number of fledglings per adult), and dispersal rates and distances (anecdotal information was used for the warbler and vireo from banded individuals).

PHVA Workshop Results

Each workshop had valuable tangible and intangible results. The final reports have population targets and habitat recommendations that can be used by agencies, organizations, and individuals to plan, justify, and guide conservation actions. Intangible values were produced by the interactions among participants. Each workshop capitalized on the dynamics of a group that was brought together for a specific purpose. The participants built consensus on

actions needed to achieve viable populations. Information, including personal knowledge and experience which is not found in the literature, was assembled by the participants. Through the shared workshop experience, participants gained appreciation for each others' perspectives, each others' work, and for the workshop product. Workshop participants realized that new and ongoing research should focus on certain aspects of warbler and vireo biology that previously had been addressed insufficiently. Researchers understood how a better organized, cooperative approach to research was needed that would generate the specific data that could be applied to improve the simulation models and meet other needs. Participants realized how their work contributes, or could be modified to contribute, to the bigger picture. In general, the workshops motivated participants to take action when they returned to their own work stations.

How Can PHVAs Be Useful to Partners In Flight?

The PHVA process includes the basic steps of data collection and synthesis, and building consensus about recommendations to conserve a species. The PIF process for developing population objectives, habitat strategies, and research and outreach recommendations should be essentially the same as the process for developing a PHVA. Often, PHVAs are not seen as applicable to the PIF planning process, primarily because of the perception that PHVAs are only computer modeling exercises, not the consensus-building group process described above.

Regarding data collection and synthesis, several important recommendations are obtained from the PHVA process. The exercise of compiling information, both for modeling and making habitat management recommendations, is useful. During this step, two realizations usually emerge. One is that more information exists than is originally suspected. Often, an important source of information is the experience of local experts, which surfaces during group interactions and is incorporated into recommendations. This information is especially important because local variations can dictate different needs and approaches even for the same species. The other realization is identifying what data are missing or insufficient; this is important for directing future research priorities. In the warbler example, we learned that we had only two banding projects that could be used to estimate survivorship. We recommended that future banding projects should commit to more than three years, because multiple years of banding are needed to provide the survivorship estimate. For the vireo, many workers were observing nesting success, but the methodology varied among projects. In this case, we recommended a standardized methodology to produce the necessary fecundity estimate.

Although simulation model analysis was used in the warbler and vireo PHVAs, it is not a requirement of PHVAs. A PIF group may decide whether a computer simulation is needed. Because of the expense and length of time required to collect survivorship, fecundity, and dispersal data, population viability analyses should be undertaken in special cases. Factors such as vulnerability of the species to risks and documented population declines can be considered to determine if a computer simulation would be useful. However, the exercise of gathering the available data for high priority PIF species—even if limited—and determining if they could be applied to an existing model can be useful, and quickly focuses research needs. If MAPS or BBIRD stations are in the area, survivorship estimates (DeSante 1992a) and fecundity estimates (Martin and others 1997) from these programs can be considered. If data do not exist for simulation modeling, or the PIF group does not want to include modeling in their plans, then the process of "closeting" experts, examining what is known, and making recommendations based on the other components of PHVAs is valuable.

In the Golden-cheeked Warbler example, even with limited data we learned that relatively large, viable populations (1,000-3,000 breeding pairs per population, depending on rates of habitat loss) were needed to prevent an unacceptable probability of extinction (Beardmore and others 1996b). The Black-capped Vireo modeling indicated that smaller populations (200-1,000 breeding females) would be viable, but only with cowbird removal (Beardmore and others 1996a). Because multiple, viable populations are recovery criteria for both species, the species' ranges were subdivided based on ecology and geography, thus giving the number of populations needed for recovery. PIF biological objectives could also be derived from such an approach, such as:

- A viable population should have x acres of optimal habitat that is managed to produce y pairs (e.g., for the Golden-cheeked Warbler y = 1,000-3,000 pairs, and x acres of optimal habitat is figured by taking a local density, x = y pairs, X number of acres needed per pair).
- Z conservation areas should be distributed across the range of the target species, each area consisting of a viable population with its optimal habitat (z = number of areas ecologically determined to be needed).

In conclusion, PHVAs should be considered as a planning tool in bird conservation. In this process data and knowledge can be examined and organized, deficiencies can be found, and recommendations can be made. Computer simulations may or may not be a part of the assessment.

An Adaptive Approach to Habitat Management for Migratory Birds in the Southeastern United States

Michael J. Conroy

Abstract—Modern tools for habitat management of migratory birds include models describing habitat-population relationships, coupled with remote sensing and geographic information systems (GIS). These approaches implicitly assume some degree of underlying understanding about the functioning of bird populations and communities in response to habitat modifications. First I discuss some general principles in modeling, with emphasis on the use of models as tools for generating testable predictions from our provisional understanding. I then describe some approaches for modeling bird-forest habitat relationships, with emphasis on recent mechanistic models based on individual bird behavior. I discuss a specific application of modeling in the management of habitats for Wood Thrush (*Hylocichla mustelina*) populations in Georgia, and how a conceptual model of habitat-population dynamics led to a management experiment designed to test underlying hypotheses of the model. I then discuss some difficulties in parameterization of spatially explicitly models, and some recent work on statistical models for providing habitat-specific estimates of survival and movement rates. Finally, I argue that scientific management only happens when management is treated as "experimentation" and models and other predictions about management impacts as testable hypotheses. Research and monitoring must be integrated with management to assure that the data gathered are relevant to decision making and used to inform decision makers. An adaptive management (Walters 1986) paradigm provides a unifying framework for accomplishing these goals.

Biologists and managers responsible for conservation of migratory birds are faced with a complex array of often confusing information about the potential impacts of forest management on these species. Here "management" includes both manipulation of habitats and populations, such as forest cutting, and the "preservation" of habitats through reserves or other means. A plethora of GIS and other analytical tools, including models, that provide forecasts of bird abundance and species composition under various alternative scenarios of management is now available. Some forest planning tools, traditionally limited to predictions about timber and other commodity production, have or will be modified to include the conservation of biodiversity, often birds, as a component of the objective function (e.g., Smith and others 1981). Other tools such as Gap Analysis (Scott and others 1993) are intended to provide managers with a comprehensive landscape-level approach, with biodiversity conservation as the principal goal. Like other planning tools, these rely on the use of models to make projections about the status of populations, communities, and ecosystems under alternative future conditions, including management.

These uses of models have several common features and potential difficulties. First, unlike many applications of models in the physical sciences, the true nature of the processes that ecologists seek to model is typically both highly variable and incompletely understood. Therefore, models cannot reasonably be expected either to exactly describe a particular system (e.g., a community of forest birds) at a given point in time, or to predict very well its state or condition into the future. Further, because of inherent stochasticity (e.g., because of randomly changing weather conditions), difficulties in quantifying the system (e.g., estimating abundance, demographic parameters, movement rates), and uncertainty about the nature of functional relationships (e.g., is the population resource limited? Is it limited by dispersal or the availability of habitats?), it is even less likely that forecasts about the future will be accurate. In some instances, the state of knowledge of the organisms and their habitats may be so poor that any model constitutes at best a crude guess. For the above reasons, and many more, conservation biologists frequently view models and modeling with distrust and disdain, and question the value of modeling as a part of management.

Much of this skepticism is warranted. In my view, models in ecology, perhaps especially in wildlife management, frequently have been used in an inappropriate and uncritical manner. However, the problem lies not with models or modeling per se, but with the failure to use models as a component in a scientific process leading both to more rationale (i.e., better informed) decisions, and to improved understanding. The moment that a modeler/biologist behaves as if his or her model is the truth, and then uses the model to dictate what a management policy should be, he or she has exited the realm of scientific natural resource management and embarked on a pilgrimage of faith.

On the other hand, judicious use of models as part of a scientific process may prove fruitful, as long as models are recognized simply as the mathematical expressions of our provisional understanding of how a system might work. Models should be treated as hypotheses, and their output as predictions of how the world might look under some management scenario, instead of prescriptions determining how it will look (Conroy 1993b). And in fact, most managers have

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their own conceptual "models" of how forests, populations, and ecosystems function, and therefore how to manage them, although few will have formally described or written down a model (let alone attached equations to one), and most would not see themselves as "modelers."

In this paper I show how such a process might work, first by describing modeling in a bit more detail, then by describing some types of models which have potential use for managing migratory birds. I then will describe a conceptual model that colleagues and I have used to orient field research directed at the impacts of forest management practices on a breeding population of a Neotropical migratory bird (NTMB), and show how our experiments should provide a refined model that may improve decisionmaking. Next, I will discuss the critical issue of the relationship of habitat to demographic processes, and describe some work on methods for empirically estimating these relationships. Finally, I will describe some very recent work, in which model and other sources of uncertainty are explicitly accounted for in conservation decisionmaking. Dynamic animal and forest growth models are imbedded in an adaptive optimization procedure to provide for optimal decisionmaking to achieve long-term goals, and to orient research and monitoring programs to meet these objectives.

Approaches to Modeling Bird-Forest Habitat Relationships

Critical Components to Model Development

In considering the development of a model relating forest habitat to bird populations, clearly stating the objectives of the model is important. I assume that conservation biologists will principally be interested in models that relate in some manner to management, either directed toward conservation of bird populations, or perhaps more commonly, toward some other primary goal, with conservation of birds either a secondary objective or a constraint.

The value of modeling to the manager will be determined by whether it helps the manager better understand or predict the consequences of management. However, because models are abstractions of reality, these predictions will be imperfect; in some instances the model will provide little more than an educated guess about what might happen to populations under various management scenarios. Thus, it is critical that modeling not be viewed as a recipe for what will happen (and thus, what should be done), but rather as a mathematical means of expressing what might happen, if the model is true (Conroy 1993b). Because a single model is unlikely to be completely true, it is crucial for managers to consider alternative models, including some that may be diametrically opposed to the model the biologist believes most likely. The consideration of alternative models is both prudent in terms of hedging management options, and consistent with the scientific method. Closely related, for a model to have scientific credibility, both it and its competitors must produce testable predictions, i.e., must be capable of generating statements that can be supported or refuted with observations. When models become ensconced as articles of faith (or matters of governmental policy) and are not subject to testing, they no longer are a part of science.

Also crucial is the issue of observability. For the most part, useful models must produce predictions about observable phenomena, and must be constituted of parameters that have biological and physical meaning. If predictions cannot be compared to observations, then there is little prospect for verification or falsification of the model, or of discrimination between competing models. For example, habitat suitability models sometimes are claimed to predict the "potential occurrence" of animals, a phenomenon that does not appear to be observable (Conroy 1993b).

The realism of a model is the degree to which it contains the essential elements of the system of interest. For birds in forest systems, realism suggests that the model include key components of environmental and biotic factors (e.g., habitat) and relate in a meaningful way to bird abundance and distribution through time, ideally in terms of demographic parameters (survival and reproduction rates) and behavior (e.g., movements and dispersal). If model parameters have no relation to biology, then the model has little realism (Levins 1966) and is unlikely to provide predictions beyond a narrow range of current conditions, even if empirically validated (Conroy 1993b; Conroy and others 1995). Realism may but does not necessarily require individually based and/or spatially explicit models (e.g., Dunning and others 1992, 1995), recognizing that these approaches carry a heavy burden in terms of model parameterization, validation, and updating (Conroy and others 1995). The point to remember is that the "realism" of a model depends on the purpose for which it is being constructed: i.e., the research questions that are being asked and the management decisions that will be made using the model. A model that is sufficiently detailed ("realistic") for one purpose may be totally inadequate for a second, and unnecessarily complicated for a third (see also Levins 1966).

As alluded to earlier, an additional, desirable feature of a model is its generality, i.e., its ability to describe or predict over a broad range of conditions. Usually (but not always), models based on biological mechanisms, which have been validated under broad conditions, will have greater generality than models that are strictly empirical or validated under narrow conditions. However, as with realism, the generality needed depends on the application; if the application is narrow, the model need not be general, so long as future applications remain narrow, and conditions remain similar to those under which the model was constructed and validated.

Examples

I will illustrate some of the above principles by means of two types of models used in wildlife management, including management of NTMBs. In the first of these, animal abundance or (more typically) presence or absence, is predicted on the basis of vegetation type, structure, configuration, or other attributes (see Van Horne and Wiens 1991 for a critical review of these models for birds). This type of model includes

Habitat Suitability Index (HSI) and Wildlife Habitat Relational (WHR) models developed by biologists in, respectively, the U.S. Fish and Wildlife Service (USFWS) and U.S. Forest Service (USFS). These models are typically based on literature surveys or "expert opinion"; they often have limited field validation; and they usually do not have parameters with biological interpretation. A further difficulty, alluded to earlier, is that these models usually predict habitat "potential" rather than occupancy or other observable phenomenon, making validation problematic (Conroy 1993b). Despite these limitations, HSI and WHR models may provide some qualitative statements about habitat suitability, and may be all that are available for many species.

A second type of model is based on mechanisms operating at the individual or local population level, and includes single population, patch dynamic (Levins 1969) including source-sink (Pulliam 1988), and spatially explicit (SEPMs; Dunning and others 1992, 1995; McKelvey and others 1993) models. For example, the BACHMAP model (Dunning and others 1992) used a spatially explicit approach in which the movement and fate (survival, reproductive status) of individual Bachman's sparrow (*Aimophila aestivalis*) in a dynamic (i.e., undergoing succession and management) landscape is simulated. By summarizing birds' fates across the population, it is possible to assess the effects of various landscape configurations and compositions on population viability. Similarly, McKelvey and others (1993) used a spatially explicit, individual-based model (OWL) to simulate impacts of forest management on Northern Spotted Owl (*Strix occidentalis)* populations.

Models such as BACHMAP and OWL tend to have a strong theoretical base and parameters that have biological interpretation. Further, they generally predict observable phenomena such as animal abundance and spatial distribution, and thus are apparently more subject to empirical validation (or refutation). However, this complexity can make these models difficult to parameterize, for example, values for survival, reproduction, movement, and other parameters. Also, the resolution of observations is frequently insufficient to truly validate such models; for example, predictions from spatially explicit models that are aggregated to correspond to broader scale field observations may not be useful in validating the underlying model (Conroy and others 1995). Nonetheless, in my opinion, the mechanistic nature of these models makes them more likely to perform over a range of conditions, and more amenable to validation and testing against alternatives, than purely empirical or ad hoc models.

Parameterizing, Validating, and Applying Models for the Management of Neotropical Migratory Birds

In my research group, we currently are taking several simultaneous approaches to the problem of model development and application in the management of NTMBs. I will describe these briefly, and try to show how they fit together into a comprehensive and adaptive framework.

Effects of Forest Management on Wood Thrush Populations

Populations of Wood Thrush have declined in recent decades, as have a number of other forest nesting NTMBs (Sauer and Droege 1992). Forest fragmentation on the breeding grounds may be a causal factor, but in significant portions of the range, the population is declining during concurrent periods of increase in the total acreage and average stand size of forests (Turner and Ruscher 1988; Odum and Turner 1990), suggesting that if an impact occurs through forest management on the breeding grounds, it is more complex than simple area or compositional effects. One possibility is that increased patchiness (internal fragmentation) of managed stands may have resulted in decreased reproductive success and survival and changes in dispersal rates, potentially resulting in landscape-level population impacts (Powell and others 1995). However, we view these potential impacts as predictions emanating from our underlying view of what makes Wood Thrush populations work, and freely acknowledge that we may be wrong. We have used our hypotheses about functional relationships between habitat features and Wood Thrush populations, together with general notions of population dynamics, to construct a conceptual model that is spatially explicit and contains alternative hypotheses as specific submodels within an overarching model structure.

The basic components of our model (fig. 1) involve (1) compartment level representation of breeding season survival (adult and juvenile) and reproduction rates; (2) movement rates between-compartment (intra- and inter-year); (3) proportional (temporary) effects of treatments on demographic and movement parameters; and (4) between-year survival and fidelity rates (possible impacts on the latter by treatments).

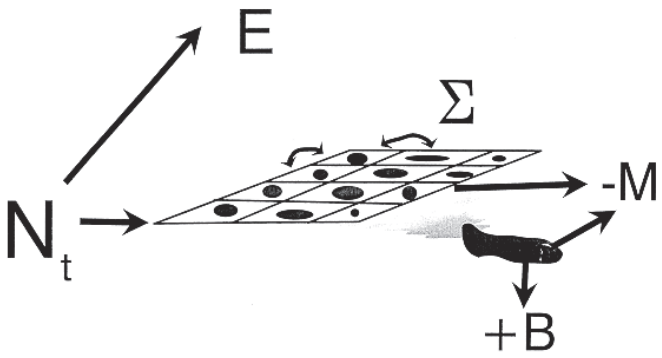


Figure 1—Conceptual model for Wood Thrush breeding population, Piedmont National Wildlife Refuge, GA. A population of size N_t arrives (comprised of individuals breeding or produced on this landscape last year plus "immigrants" from other local breeding populations). Of N_t, E individuals select other landscapes, leaving a local breeding population of N_t - E. Shaded ellipses represent local habitat conditions (stand size, structure, composition) influencing mortality losses (M) and reproductive gains (B). Landscape-level events (e.g., movement among stands to search for food or new nest sites, represented by double-headed arrows) also influence M. Summation symbol represents integration of landscape and local effects on net number of individuals entering fall migratory population. See table 1 for hypothesized local and landscape-level effects of management.

We recently have completed a field experiment that will help us to parameterize our conceptual model, and give us at least a preliminary understanding of the potential effects of landscape changes through management on Wood Thrush population dynamics (Powell and others 1995, 1997; Conroy and Krementz 1997). Our study site is located on the Piedmont National Wildlife Refuge and adjoining Oconee National Forest in Georgia (fig. 2). Management on these federal lands is directed toward a variety of purposes, including production of timber and sustainable harvest of wildlife populations. An important additional component of management is the maintenance of viable populations of Red-cockaded Woodpeckers (RCW, *Picoides borealis*). RCW management includes the thinning of loblolly pine (*Pinus taeda*) stands to encourage the growth of large, older trees as potential nest sites, and the removal of understory and midstory vegetation mechanically and through prescribed fire. Because such management removes potential nesting and foraging structure for Wood Thrushes, we were interested in evaluating its impact on Wood Thrush population parameters, and using our conceptual model of Wood Thrush populations, we developed specific predictions regarding these possible impacts (table 1). These hypotheses and predictions operate at two levels of spatio-temporal resolution. Local effects are those that are thought to directly affect survival and reproduction at the stand or finer scale through alteration of the habitats. For example, the number and success rates of nests would presumably be lowered by the removal of trees structurally suited to contain nests; survival might be lowered by the removal of fruiting trees and shrubs. Landscape effects are those that affect the population at a broader population scale, for example, nest site fidelity of returning birds, immigration of birds from other local breeding populations, dispersal of juveniles, or intra-season movement among desirable habitat patches (stands). Again, alteration of the landscape through management is hypothesized to play a role here, but detecting these effects requires a broader scale analysis and the explicit consideration of the spatial configuration of treatments. The bottom line for the population, though, is the integration of the local and landscape effects in the production of a fall migratory population, of which a fraction will survive and return the following breeding season, thus completing the annual cycle.

Table 1—Hypothesized effect of treatments for Red-cockaded Woodpeckers on Wood Thrush populations.

	Control	Treatment
Local effects		
Nest Success	Higher	Lower
Survival	Higher	Lower
Density	Higher	Lower
Landscape effects		
Survival	Higher	Lower
Fidelity	Higher	Lower
Density	??	
Juvenile Dispersal	Lower	Higher

Our experimental design (Powell and others 1995; Conroy and Krementz 1997) (fig. 3 and 4) allowed us to test the compartment-level effects directly, by the comparison of density, survival rates, reproduction rates, and other parameters on treatment (subjected to RCW management) and control (not recently treated) compartments, two years prior to and following the treatment application. In addition, monitoring conducted within compartments will allow evaluation (albeit nonexperimentally) of gradients in fragmentation, for example, due to uneven application of the treatments. The results of the experimental study are being used in conjunction with the SEPM and GIS to make provisional projections and recommendations regarding the impact of RCW management on Wood Thrush (Powell and others 1997).

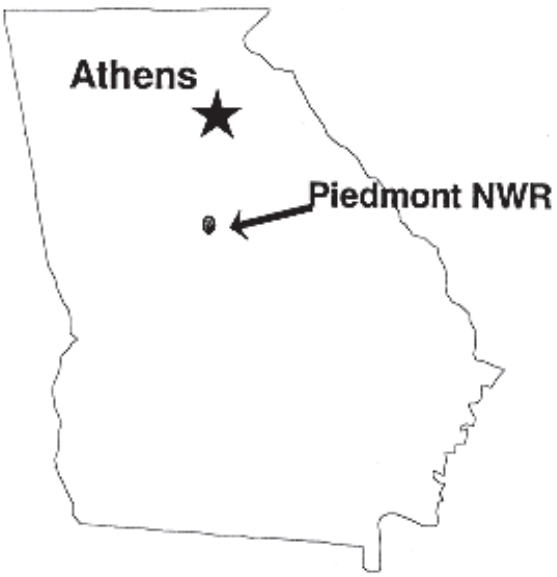


Figure 2—Location of Wood Thrush study area in the Piedmont of Georgia.

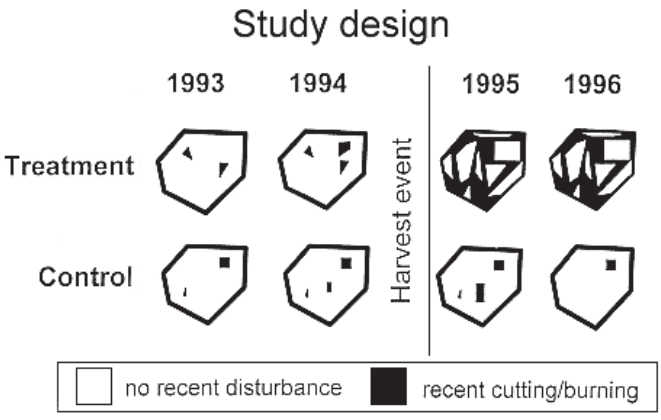


Figure 3—Schematic of experimental design for study of impacts of forest management on Wood Thrush breeding population, Piedmont National Wildlife Refuge, GA. Treatments are comprised of thinning and prescribed burning for Red-cockaded Woodpecker management (see text).

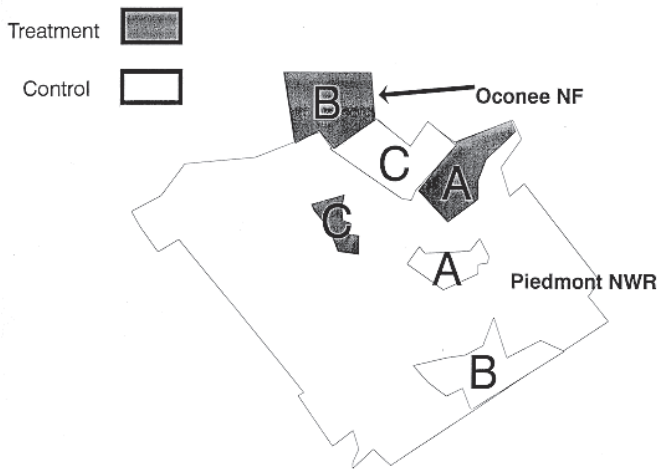


Figure 4—Location of treatment and control compartments for study of impacts of forest management on Wood Thrush breeding population, Piedmont National Wildlife Refuge and Oconee National Forest, GA. Letters represent treatment-control pairs.

Estimation of Habitat-Specific Survival and Movement Rates From Radio Telemetry

As noted earlier, mechanistic models such as patch dynamic and SEPMs require the estimation of (or assumptions about) demographic parameters such as survival rates and reproduction rates, and additional parameters such as movement rates or probability of movement among habitat patches. Empirical estimation and hypothesis testing is needed for these models, for example to evaluate whether a complex model such as a SEPM really is needed (Conroy and others 1995). A number of studies have quantified reproduction rates of NTMBs, through nest searching and monitoring and other methods. Survival and movement rates tend to be more problematic, usually requiring the use of banding, color marking, or radio telemetry. Design and analysis for survival estimation is straightforward when individual birds occupy single habitat patches over study periods of interest. For example, mark-recapture experiments (Pollock and others 1990) may be used to provide estimates of survival for samples of birds stratified by habitat type. However, if movements of birds among habitat patches and/or types occurs during the study, extensions of mark-recapture models may be needed to allow separate estimation of patch-specific survival and movement probabilities (Hestbeck and others 1991; Brownie and others 1993). If movements are very frequent, methods based on radio telemetry may prove more useful. Conroy (1993b) and Conroy and others (1996) evaluated methods for analysis of radio marking data, in which birds freely move (e.g., on a daily basis) among habitats, for testing hypotheses about habitat-specific survival and movement rates. Unfortunately, it appears that large marked samples (100 or more) are needed to detect all but the largest habitat specific differences in survival. Because most study designs would fall short of such sample sizes, the issue of parameter estimation and model comparison for complex models, especially SEPMs, remains problematic (Conroy and others 1995).

Development of an Adaptive Management Framework for Research and Monitoring

As indicated above, models are frequently used to predict the effects of human impacts on habitats—such as loss through agriculture or urban development or alterations through management practices—on bird populations. Models relating bird and other animal populations to habitats are now included as part of planning tools such as Gap Analysis (Scott and others 1993) and forest growth models (e.g., Smith and others 1981), and have been used in conjunction with optimization procedures (e.g., linear programming) to derive strategies for maximization of an objective function incorporating constraints or tradeoffs, for instance, balancing timber revenue with species diversity. Approaches such as these typically have failed to consider one or more difficulties inherent in wildlife models. Commonly the system (e.g., bird population) is treated as a deterministic response to habitat or other effects, and usually only a single model describing habitat-population relationships is used. Models are frequently invoked that have not been properly validated, and for which there are no built in "reality checks."

Given that bird populations, forest landscapes, and other natural resource systems are inherently unpredictable—or predictable only with great uncertainty—and that our understanding of these systems is far from complete, many biologists are tempted to treat modeling efforts with disdain. Another reaction is simply to pretend that these sources of uncertainty do not exist, and to proceed with making management decisions based on models or other information as "the best we can do." An alternative to either approach is to explicitly deal with uncertainty: Not just as a modeling exercise, but as part of the process of making decisions (Lindley 1985). Further, it should be possible to reduce some types of uncertainty through monitoring and research, providing better understanding of how the system under management functions, and how to manage it (Walters 1986).

Johnson and others (1993) applied stochastic dynamic optimization procedures (Williams 1989; Lubow 1993; Puterman 1994) to the management for the optimal long-term harvest of waterfowl in the face of uncertainty. Crocker and Conroy (1995a,b) extended this approach to the problem of managing for multiple species in a dynamic landscape, with species conservation as a component of the objective function. This approach is explicitly stochastic and allows for model uncertainty and competing models as hypotheses. Previous approaches have included some applications of optimization methods (e.g., Bedward and others 1992; Pressey and Nicholls 1989) and decision theory (Lindley 1985) (e.g., Maguire 1986; Haight 1995; Conroy and Noon, in press) but so far none has integrated the achievement of a long-term optimum in an uncertain system, with the iterative incorporation of knowledge, in a truly adaptive sense (Walters 1986).

Consider a simple representation of the species persistence problem, where the "system state" is the number of species persisting (S = 0,1,2) (fig. 5). Given the present state

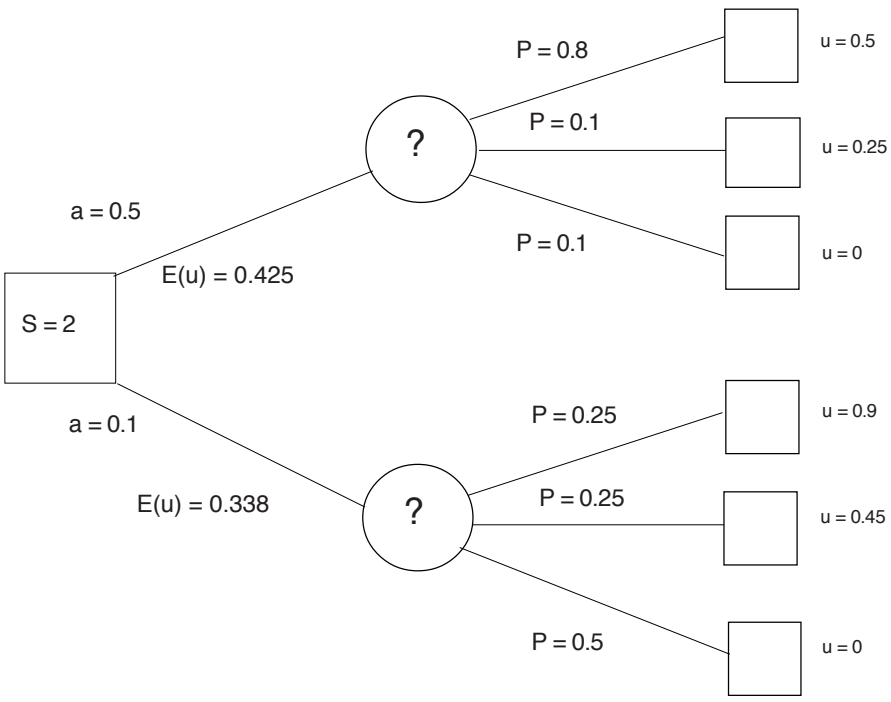


Figure 5—Diagram of a hypothetical decision tree for a species conservation problem. Boxes represent decision nodes, circles represent uncertain events. In illustrated scenario, the decisionmaker observes that there are 2 species present ($S = 2$) of a hypothetical 2 total, and is faced with making 1 of 2 decisions: conserve 50% ($a = 0.5$) or 10% ($a = 0.1$) of the landscape. For each decision, there are 3 possible outcomes: $S = 0, 1,$ or 2, with probabilities of occurrence denoted by P, dependent on the decision. Each of the 6 decision-outcome combinations has a value or utility (u) to the decisionmaker, in this case taken as $S/2(1 - a)$, reflecting (1) the desirability of conserving as many of the 2 species as possible, but (2) imposing a penalty for the proportion of the landscape "removed" from other uses.

(e.g., $S = 2$) we would like to make a decision so as to maximize the average (over uncertain future events) of some objective or "utility," which expresses in this case the tradeoff between species preservation ($S = 2$ having highest utility) and the use of resources for other purposes. In this example the possible decisions are to conserve either 50% or 10% of the total landscape. The utility of the decision-outcome combination represents a value (1 highest, 0 lowest) received by that outcome. For instance, the best outcome would be to conserve both species by reserving 10%, and has utility 0.9; two decision-outcome combinations have utility 0, (no species persist regardless of the decision to conserve). For each decision, we need to make a prediction about the future state of the system. For example, species-habitat relationship models might predict that each of the outcomes $S = 0,1,2$ have different probabilities of occurring depending on the amount of habitat conserved. Finally, the expected utility of each decision is obtained by averaging over all the uncertain outcomes, and the optimal decision is the one that maximizes this average or expectation. In this example, the optimal decision clearly is $a = 0.5$.

The schematic illustrates a simple, one-iteration process: A decision is made one time. In reality, at each decision-outcome (6 combinations here) the decision maker would again be faced with making a decision, and the optimal policy is a vector of decisions through time. For instance, the optimal decision may be to conserve 75% habitat at $t = 1$, and the rest at $t = 2$, or to conserve none now, but 90% of the remaining habitat at equally spaced intervals, noting that these are not necessarily one year apart. The optimal decision will depend on, among other things, system dynamics (e.g., loss of nonconserved habitats) and economic considerations (e.g., commodity and amenity values, discount rates).

We have applied such an approach to a simple system containing four species and two habitat types, with an inherent loss of habitats not conserved, to evaluate the effects of model uncertainty (three simple model structures) and observability (coefficients of variation on the observed system states of 0-100%). The results of preliminary analyses suggest that both model uncertainty and observability have great potential for influencing what the optimal policy is (e.g., how much habitat to conserve, of what type, and when), and in turn have ramifications for the optimal design of survey and research programs for meeting resource management objectives (Crocker and

Conroy 1995a,b). Our next steps are to expand this approach to allow more realism, including spatial explicitness and more complex landscapes and species assemblages. We also will work toward a formally adaptive procedure, in which the relative belief in alternative models is updated through monitoring and research (Johnson and others 1993; Crocker and Conroy 1995a,b).

Summary

Models of bird population dynamics and movements can be a useful component of management, research, and monitoring programs. However, model users (and modelers) must recognize that models are vast simplifications of the real world. Further, at best, models represent mathematically our present knowledge about how populations function: No model ever has produced a single additional scientific fact about a species or a system. Nonetheless, models can be useful in summarizing extant knowledge, providing testable predictions based on underlying assumptions, and directing future research efforts, for example, toward understanding key parameters or functional relationships.

On the other hand, models need not be extremely complex or completely realistic to prove useful to management. By simplifying a system to a few key components and predictions, models sometimes can crystallize a problem in a way not possible by other methods. Further, models offer the possibility of examining multiple combinations of possible management scenarios by the mathematical combination of inputs and parameter values. However, users must recognize that these so called "experiments" are simply manipulations of underlying assumptions, are not better than the model and the assumptions on which they are based, and are no substitute for the real thing.

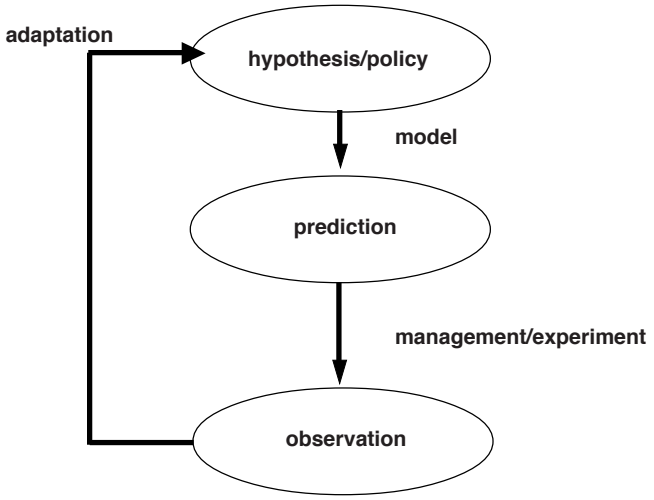
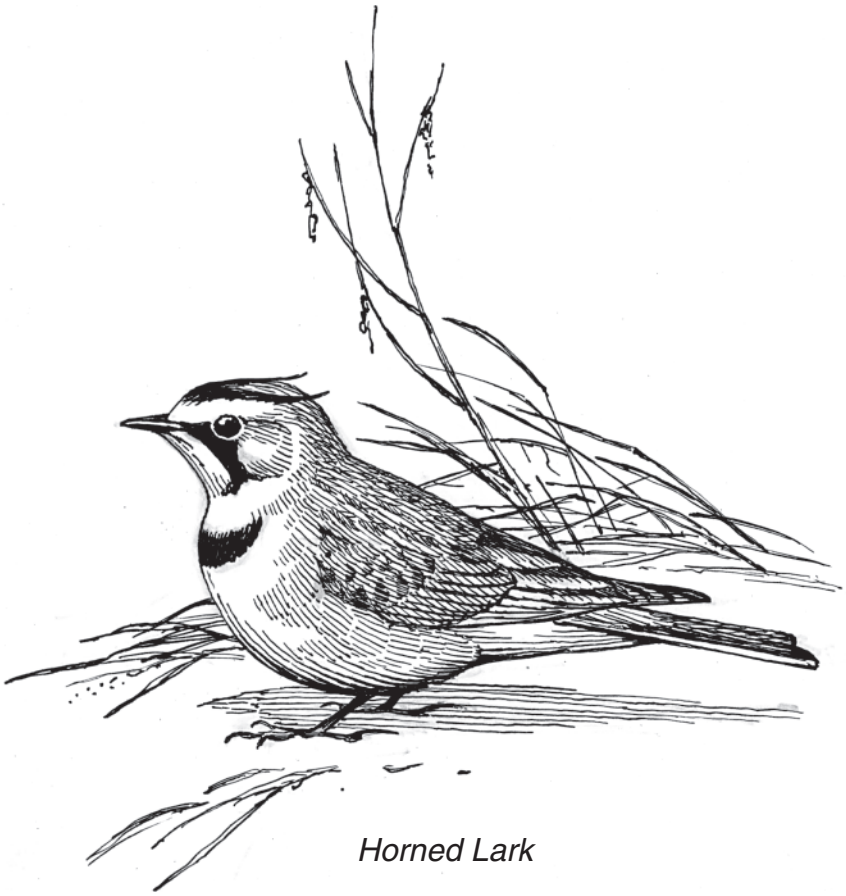


Figure 6—Diagram of adaptive learning process showing the roles of modeling, research and monitoring, and management.

By integrating research and monitoring with management, we can assure that the information gathered is relevant to decision making, and can discriminate between information that is essential for reaching our resource management goal, versus that which would simply be nice to have. Likewise, conservation decisions should continually be reevaluated in the light of new information, and modified as old assumptions change in the light of new data (fig. 6). Further, the actions of managers will themselves frequently provide new information, particularly if management is done in an experimental manner, e.g., with suitable controls and replication. Viewed in this manner, models are simply one component in a continual process of scientific management.

3. Setting Conservation Objectives: Applications



Horned Lark

3. Section Overview—Setting Conservation Objectives: Applications

David N. Pashley

Whereas the preceding section on the principles of setting conservation objectives dealt with difficult concepts in setting priorities, this section establishes the reality that general models for conservation planning must be sufficiently flexible to meet real-world conditions and needs. The North American continent and its avifauna are hugely complicated, and the seven papers in this section represent conservation thinking regarding just a few of dozens of important habitats and hundreds of important issues that Partners in Flight must address.

Three papers consider general issues of bird conservation in broadly defined common habitat types—grasslands, wetlands, and forest. The other four papers describe, in somewhat greater detail, conservation issues in more geographically specific situations.

First, Peter Vickery and his coauthors cover general issues in the many different grassland types and situations across the continent. Then Rick Warhurst and I deal specifically with the grasslands of the Prairie Pothole region of the northern Midwest. Our paper also presages developments subsequent to the Cape May Workshop in growing cooperation between Partners in Flight and the waterfowl and wetland conservation communities.

Mike Erwin and his coauthors cover many of the general issues regarding bird conservation in wetlands, followed by Dave Krueper's analysis of a particular and peculiar water-related community, the riparian habitat of the arid West.

Next, Kay Franzreb and her coauthors summarize thoughts regarding bird conservation issues in forest habitat, with an implicit observation that forests across America vary tremendously in terms of plant composition, avifaunas, and conservation issues. The final two papers take somewhat narrower slices of the enormous issue of birds in forests, as Sallie Hejl treats birds in western coniferous forests, and Bob Ford and Mike Roedel address the varied hardwoods of the Interior Low Plateaus.

Together, these papers represent an insight into what Partners in Flight is up against. Bird Conservation Plans are being written for every physiographic area in the United States, and each of those areas is as unique as any situation described in any one of these papers.

In sum, however, the papers present a picture of how to address bird conservation: Understand the system in which you are working, establish priorities, think hard about objectives, and work with the many partners whose participation will be necessary to make any conservation efforts work. Throughout the process, always rely on solid research, monitoring, and adaptive responses to improve the chances for success.

In: Bonney, Rick; Pashley, David N.; Cooper, Robert J.; Niles, Larry, eds. 2000. Strategies for bird conservation: The Partners in Flight planning process; Proceedings of the 3rd Partners in Flight Workshop; 1995 October 1-5; Cape May, NJ. Proceedings RMRS-P-16. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

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Grassland Birds: An Overview of Threats and Recommended Management Strategies

Peter D. Vickery
James R. Herkert
Fritz L. Knopf
Janet Ruth
Cherry E. Keller

Abstract—Grassland ecosystems are dependent on periodic disturbance for habitat maintenance. Historically, grazing by native herbivores and prairie fires were the agents principally responsible for maintaining grassland areas. However, elimination of native herbivores, widespread fire suppression, and conversion for agriculture have greatly altered grasslands in the United States and Canada. Because of these landscape changes, many grassland birds are increasingly dependent on land managers for habitat creation, maintenance, and health. Grazing, prescribed burning, and mowing/haying are the most frequently used, and versatile, grassland management techniques. Grassland birds prefer a wide range of grass heights and densities, with some species preferring short sparse vegetation, and others preferring taller, more dense vegetation. Due to differences in species habitat preferences and regional differences in soils and floristics, the responses of individual grassland species to specific grassland management practices can be variable and often are regionally dependent. As a result, management of grassland areas is best directed toward the creation of a mosaic of grassland habitat types. This habitat mosaic is probably best maintained through some type of rotational management system in which sections of large grassland areas receive management on a regular schedule. Such a rotational system would provide a variety of habitat types in every year, would ensure the availability of suitable habitat for birds at either end of the grassland management spectrum, and also would provide habitat for birds whose preferences lie between these extremes.

Grasslands are ecosystems that have evolved with frequent disturbances. Historically, the agents principally responsible for maintaining grassland habitats were drought, grazing by native herbivores, and fire. Generally, a west-to-east disturbance continuum exists in North America; grazing has been and continues to be the primary ecological force on western shortgrass areas, whereas fire was the prominent disturbance factor to the east.

Grassland habitats are occupied by a small number of uniquely adapted bird species. Most species select a particular suite of habitat features. Mountain Plovers (*Charadrius montanus*) and Horned Larks (*Eremophila alpestris*), for example, require short, sparse vegetation, whereas Henslow's Sparrows (*Ammodramus henslowii*) and Sedge Wrens (*Cistothorus platensis*) require taller, more dense vegetation. Some grassland species are more abundant on recently burned or grazed grasslands, whereas others are more abundant on undisturbed or idle grasslands. Also, habitat preferences can vary throughout the range of a species. Because of these differences in habitat preferences, and because of regional differences in soils and floristics, the response of a particular species to a specific grassland management prescription may be variable.

During the past quarter century, grassland birds have experienced steeper, more consistent, and more widespread population declines than any other avian guild in North America. While some grassland species are Neotropical migrants, most are short-distance migrants that winter primarily in the southern U.S. and northern Mexico. Thus, opportunities for conservation exist on both breeding and wintering grounds. The winter ecology of most grassland birds is poorly known; winter survivorship could be a critically important factor in the long-term declines that some species have experienced. Therefore, grassland bird conservation programs within North America need to address both breeding and wintering ecology.

This discussion is focused on threats to grasslands east of the Rocky Mountains; grasslands farther west (e.g., California grasslands, palouse prairie) are beyond the scope of this presentation.

Historical Perspectives

Because most grassland ecosystems have been altered profoundly within the past two centuries, many are now among North America's most endangered ecosystems. Effective grassland bird conservation and management must recognize the historical dynamics under which these habitats have evolved and, where feasible, incorporate the ecological processes that have generated and maintained these distinctive grassland biotas.

In: Bonney, Rick; Pashley, David N.; Cooper, Robert J.; Niles, Larry, eds. 2000. Strategies for bird conservation: The Partners in Flight planning process; Proceedings of the 3rd Partners in Flight Workshop; 1995 October 1-5; Cape May, NJ. Proceedings RMRS-P-16. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

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Western Shortgrass Prairie

Western prairies are characterized by short (<10 cm), warm-season grasses on shallow, poor soils, and occur from the Rocky Mountains eastward to the central Great Plains. Predominant ecological forces on these prairies have been seasonal drought and intensive grazing by native herbivores including prairie dogs, bison, and pronghorn. Dominant grasses include buffalo grass (*Buchloe dactyloides*), blue gramma (*Bouteloua gracilis*), and some wheatgrasses; these grasses require—and benefit—from intensive grazing, which prevents this habitat from growing into a shrub- or forb-dominated landscape.

Midwestern Tallgrass Prairie

Historically, the tallgrass prairie extended from the central Great Plains to the Midwest, and was characterized by taller grasses, deeper soils, and more precipitation than shortgrass areas. These ecosystems were maintained primarily by prairie fires, set both by lightning and by Native Americans. Characteristic species include big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), Indian grass (*Sorghastrum nutans*), and cord grass (*Spartina pectinata*).

During the past 150 years, agricultural grasslands (hayfields and pastures) have replaced the native prairies and are currently the dominant grassland habitat throughout much of the tallgrass region. In fact, the decline of tallgrass prairie, estimated to be 88 to 99%, exceeds that reported for any other major ecosystem in North America. However, the acute population declines that could have resulted from such extensive loss of native tallgrass habitat have been buffered somewhat by expansion of agricultural grasslands into previously forested areas in the eastern U.S., which has allowed many species of grassland birds to expand their historic ranges.

Eastern Grasslands

Native grasslands in the East include sites from Maine to Florida and west to coastal Texas. These grasslands range from poor, xeric soils in New England, to mountain balds in parts of the Appalachian range, to wet prairie in Florida, to transitional grasslands emerging from tallgrass prairie and longleaf pine ecosystems into coastal marshes in Texas. Historically, eastern grasslands resulted primarily from natural and Native American-induced fires, usually in xeric habitats and poor soils. Some of these sites were extensive, for example the Hempstead Plains on Long Island, New York, covered more than 24,000 ha. In Florida, lightning ignitions and hydrology were primarily responsible for maintaining prairie habitat. These prairies provide important breeding habitat for grassland birds, e.g., Florida Grasshopper Sparrow (*Ammodramus savannarum*) and Bachman's Sparrow (*Aimophila aestivalis*); they also provide critical wintering habitat for many species. Primary grass species include little bluestem, poverty grass (*Danthonia spicata*), and in Florida, wiregrass (*Aristida beyrichiana*).

Major Threats to Grassland Ecosystems and Recommendations for Grassland Habitat Conservation

Three issues are critical to preservation of grassland habitats throughout North America.

First, all native temperate grasslands have experienced major, sometimes profound, losses of habitat from agriculture, range management, and urban development. In addition, habitat fragmentation and degradation have been severe. Habitat loss is most frequently viewed when grassland is converted to cropland or other uses, but loss of habitat also includes more subtle degradation such as unnatural grazing regimes, planting of exotic grasses, and the succession of grassland to shrubland. These less-obvious changes have resulted in the extirpations of many local bird populations. The highest priority should therefore be preservation and appropriate management of the largest tracts of existing native grasslands to avoid habitat fragmentation and degradation.

Second, conservation planning at the regional level is important for all grassland systems; only by cooperatively managing all grassland habitats on a landscape or regional level can the complete range of grassland bird habitats be addressed. Conservation goals should not include management for the greatest number of grassland bird species at each grassland site; such management is neither necessary nor practical, and is likely to be counterproductive to overall conservation goals. Individual sites are usually best suited for management for a particular subset of grassland birds, e.g., Le Conte's Sparrows (*Ammodramus leconteii*) and Sedge Wrens in sedge meadow habitats, within the context of larger regional goals.

Third, effective management of grassland landscapes will require involvement of a diverse group of natural resource professionals such as range managers, game and nongame biologists, soil conservationists, agronomists, farmers, and ranchers. In many areas, grassland management historically has emphasized soil conservation, and it will be important to combine the goals of avian habitat conservation with soil conservation and agricultural goals.

Threats to Shortgrass Prairie and Management Recommendations

Shortgrass prairies evolved under intense grazing by prairie dogs and bison. Consequently the shortgrass prairie bird fauna evolved to select a variety of different site characteristics, created within landscapes receiving grazing pressure ranging from light to severe. Unfortunately, current range management practices strive to graze rangelands uniformly. These practices remove or inhibit heterogeneous grazing impacts across landscapes, and do not favor the specific habitat requirements of many species. For example, Mountain Plovers require heavily grazed sites for breeding, but Lark Buntings (*Calamospiza melanocorys*) prefer denser vegetation. Thus, moderate grazing everywhere is unlikely

to result in suitable habitat for either species. In many locales, insufficient grazing has led to the invasion of grasslands by shrubs and forbs. Rather than opposing grazing as a management tool in all grasslands, conservation groups should encourage grazing that imitates natural conditions as closely as possible.

Also, native grazers, e.g., bison and prairie dogs, should be encouraged; by cropping vegetation more closely than domestic livestock, native grazers create patchier, more heterogeneous landscapes. Prairie dog populations are still aggressively poisoned, and presently occupy only 2% of their native range.

In addition, planting of non-native grass species and invasion by exotic species also results in grassland degradation.

Recommendations

- Implement practices that restore the inherent heterogeneity of native grazing communities, such as encouraging larger grazing allotments, and grazing more intensively in certain areas.
- Discontinue prairie dog control on public lands.
- Encourage conversion of livestock operations to bison grazing to create more varied habitat mosaics preferred by some grassland specialists, e.g., Mountain Plover.
- Encourage use of seedings native to the shortgrass region. Such grasses require intensive grazing to maintain vigor.

Threats to Tallgrass Prairie and Eastern Grasslands and Management Recommendations

Habitat loss from human development and forest succession, a consequence of fire suppression as well as human development, has led to severely fragmented and isolated grasslands in the East and Midwest. Fire suppression and the resultant encroachment of woody vegetation are major management problems for tallgrass and eastern grasslands, influencing grassland bird distribution patterns and nesting success. In addition, early- and mid-season cutting of agricultural grasslands has catastrophic impacts on nesting success of birds using these habitats. In tallgrass prairie, agricultural conversion of pastures and hayfields into rowcrops also is a major threat to grassland birds. In Florida, loss of native prairie has resulted from agricultural conversion to tame pastures and citrus groves.

Recommendations

- Identify and protect large grassland sites (>100 ha). Avoid further loss and fragmentation of existing grassland habitats. The protection and proper management of these habitats, especially those used by area-sensitive, rare, or declining species, is the most effective means of conserving grassland bird populations.
- Actively manage grasslands to control woody encroachment through the use of fire, grazing, and mowing.
- Within a regional context, protect and manage enough sites to provide sufficient diversity of grassland habitats ranging from wet sedge meadows to dry, xeric grasslands.
- At the local level, large grassland sites should usually be managed to include a mosaic of management prescriptions, including both recently disturbed (i.e. burned, grazed, mowed) and undisturbed grassland areas. This mosaic is probably best maintained through a rotational management system, e.g., on a site with a five year rotation, approximately 20% should be burned each year.
- Mowing and haying on public grassland areas should not be conducted during the height of the breeding season (May 1 - July 15). On private lands, efforts should be made to provide incentives for deferred mowing.

Important Research Needs

As a result of extensive research during the past 20 years, habitat requirements for many species of grassland birds during the breeding season are generally well known. These recommendations highlight important research needs where information is nonexistent or inadequate.

- Improve knowledge of the winter distribution, winter ecology, and winter habitat requirements of many grassland birds. In general, information is poor or completely lacking. This is the primary research need for grassland bird conservation.
- Monitor and document the efficacy of grassland management practices, including measuring the long-term responses of birds to management.
- Develop cost-effective methods of monitoring reproductive success.
- Develop techniques for grassland creation, restoration, and enhancement which benefit grassland birds. In the past, development of restoration techniques has focused on plant ecology, failing to recognize the needs and contributions of birds and other wildlife to the restoration of a functioning ecosystem.

Suggested Reading

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Conservation Planning in the Prairie Pothole Region of the United States: Integration Between an Existing Waterfowl Plan and an Emerging Nongame Bird Model

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Rick Warhurst

Abstract—The Prairie Pothole Joint Venture has assumed a leadership role in bridging the gap between the North American Waterfowl Management Plan (NAWMP) and Partners in Flight (PIF). It has done so by creating internal objectives and a structure to deal with the conservation of nongame birds which parallels the outstanding, ongoing work concentrating on waterfowl. Complementarity between waterfowl and nongame bird conservation is high, both in terms of methodology and habitat management. Spreading the spirit of cooperation from such key areas as the Northern Prairies across the country will be a rewarding challenge for PIF and the NAWMP.

Comprehensive conservation plans designed to meet the ecoregional needs of an entire avifauna can be more efficient mechanisms for the achievement of conservation goals than the sums of plans for single species or species groups. Growing convergence between the North American Waterfowl Management Plan (NAWMP) and Partners in Flight (PIF) has created a fertile opportunity for conservation planning for all migratory birds. This paper describes progress in an example of this growing cooperative endeavor.

In the 1980s, biologists realized that populations of North American waterfowl had declined sharply in recent decades, primarily resulting from habitat loss and degradation. The 1986 NAWMP was designed to reverse these population declines through a partnership approach to restoring vital wetland and upland waterfowl habitat. The NAWMP established the goals of a continental breeding population of 62 million ducks and an average fall flight of 100 million ducks. To reach these goals, the NAWMP delineated 34 Waterfowl Habitat Areas of Major Concern in the United States and Canada. The seven most important of these, six in the United States and one in Canada, were identified as "Joint Ventures," each developing a unique set of conservation initiatives and partnerships. Joint Ventures are therefore the vehicles for implementation of the NAWMP.

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The Prairie Pothole Joint Venture (PPJV) of the U.S. and the Prairie Habitat Joint Venture (PHJV) of Canada were identified as the top duck production areas of the continent. The PPJV includes more than 100,000 square miles in portions of Iowa, Minnesota, South Dakota, North Dakota, and Montana. The area was formerly dominated by tallgrass prairie in the east, mixed grass prairie in the west, and some shortgrass habitat, all interspersed with abundant wetlands. During the past century, conditions for wildlife in this area have deteriorated as wetlands have been drained and filled and grasslands plowed and planted for agricultural crop production. This drainage and conversion led not only to waterfowl population declines and to the creation of the Joint Venture, but also have reduced populations of nongame birds. In fact, grassland species may be exhibiting more rapid and widespread population declines than any other group of North American birds.

The PPJV Implementation Plan was developed to describe how the Joint Venture would achieve its first objective, to "increase waterfowl populations through habitat conservation projects that improve natural diversity across the U.S. Prairie Pothole landscape." A second objective, 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," was added to the PPJV mandate in 1994.

Waterfowl

The PPJV specified that its first objective would be accomplished through the conservation of habitat to support 6.8 million breeding ducks that achieve a recruitment rate of 0.6 by the year 2001 (recruitment rate is defined as young females fledged per adult female in the spring breeding population) under average environmental conditions. Numerous planning sessions were conducted to develop the strategies and plans required to accomplish this objective. In July 1991, many waterfowl biologists (researchers, population biologists, and habitat managers) met to develop guidelines for application of various habitat management treatments and strategies for the enhancement of duck production. These guidelines are necessary tools in developing the PPJV landscape management plans required for meeting the waterfowl population objectives.

Landscape management plans were formulated through a planning- and information-based management process called MAAPE (Multi-Agency Approach to Planning and

Evaluation), using input from more than 250 resource managers, for 14 Waterfowl Management Districts (WMD) in North Dakota, South Dakota, and Montana. To summarize the MAAPE process, resource managers first determine the current population status of the species of concern (where are we?), and then set desired population goals (where do we want to be?). If the current population is lower than the population goal, then a cause for the deficiency is identified. Next, treatments or strategies are suggested for attaining the population goal (how do we get there?). Results of implementing the treatments are predicted through simulation models. The landscape is surveyed to locate treatment sites and, over the course of time, treatments are implemented. Finally, population monitoring and evaluation of treatments determine the effectiveness of the process for reaching the population goal (did we get there?).

Each MAAPE planning session began with a review of current information about the landscape, waterfowl breeding population, and recruitment rate. The Mallard (*Anas platyrhynchos*) was chosen as an indicator of conditions for other breeding ducks in the PPJV since it is the species for which the greatest amount of scientific information exists. Planners assumed that landscape management treatments that improve Mallard recruitment rates at least partially improve recruitment of the other ducks, particularly those that also nest in upland habitats.

Mean recruitment rate for Mallards across the 14 WMDs prior to 1985 was estimated to be 0.41, below the 0.49 recruitment rate necessary for population maintenance, and well below the PPJV objective of 0.6. Only two WMDs were producing Mallards above the level necessary to maintain populations. Therefore, much of the PPJV area, of key importance for Mallard production on the continent, was functioning as a Mallard population sink.

To raise recruitment rates, waterfowl habitat managers, population biologists, agriculture specialists, and other natural resource managers decided upon the array and magnitude of potentially beneficial management treatments and strategies that should be implemented in each WMD. Random, representative 4-square mile samples (335 sample plots in the 14 WMDs in Montana, North Dakota, and South Dakota) provided baseline landscape information. A population simulation model, the Mallard Productivity Model, was used to predict the effects of these management treatments on duck recruitment.

In the PPJV portions of North Dakota, South Dakota, and Montana, including approximately 4 million acres of Conservation Reserve Program (CRP) cover, Mallard recruitment rates have increased over the past decade to 0.54. Nine of the WMDs currently produce this species above maintenance population levels. The results of eventual full implementation of the landscape treatments prescribed in the 14 WMD management plans can be predicted through the Mallard Productivity Model. With CRP remaining in place and all habitat treatments implemented, the recruitment rate is expected to be 0.58, with all but one WMD exceeding maintenance level production. This is near the PPJV objective. Again, planners assume that if the Mallard recruitment rate is at this level, then other duck breeding populations will benefit as well. If, in addition, 91,000 culvert nest structures are installed in the region, the Mallard recruitment rate will increase to 0.63. Achieving this level of full implementation remains an expensive and daunting challenge.

Other Birds

The growth of PIF has brought increased awareness and concern for bird populations other than waterfowl in the PPJV. Managers and planners have assumed that landscape management treatments designed to improve waterfowl production also provide benefits to many grassland and wetland nongame species. The extent of this overlap should be rigorously tested, and additional nongame bird conservation measures implemented, where waterfowl-directed efforts are insufficient.

As part of the PIF planning process, priorities, population objectives, and means of accomplishing objectives must be set for PPJV nongame birds. This process must be undertaken with considerably less data and understanding of natural history and demographics than were available for waterfowl. To address this issue, the PPJV Management Board established a Technical Committee with a nongame working group. The first task of this working group, development of a list of species of conservation concern, was accomplished in a workshop in early 1995 attended by many biologists and managers with knowledge of the status of these birds. The PIF prioritization process was a major source of information. Prioritization was supplemented by detailed analyses of population trends and by participants' general understanding of conservation issues. Although the original language of the second objective of the Joint Venture stressed concern for declining species, participants felt that some species, although in decline, are still demonstrably secure, while others that have stable, increasing, or unknown population trends warrant close conservation concern owing to small populations and/or the importance of the prairies to the species as a whole. Those species included as conservation priorities, the reason for their inclusion, and the ecosystem within the Prairie Potholes most important to each, are listed in table 1.

For each of the three ecoregions (tallgrass, mixed grass, and shortgrass prairie), all priority species were divided into species suites that co-occur under certain habitat conditions and presumably respond to management practices in a similar manner. The habitat for each of these species suites thus becomes a target for conservation action (table 2).

One of the next steps in the planning process for nongame birds is to evaluate the impact of prevailing and potential management and land-use practices on these species suites. The PPJV Technical Committee under the leadership of the Northern Prairie Science Center has undertaken this process, which is yielding an array of conservation practices that can be used to benefit the priority birds.

Once species and habitat priorities are established through PIF planning and the impact of management practices are evaluated, some aspects of the MAAPE used for waterfowl planning may serve as useful models for the formulation of population and/or habitat objectives for nongame birds. Success of the MAAPE planning process is dependent upon accurate information. Much of the habitat information thus far compiled is applicable to all grassland birds. However,

Table 1—Birds of the Prairie Pothole Region that warrant conservation attention.

Species	Population trend	Area importance	Small population size	Tallgrass	Mixed grass	Shortgrass
Pied-billed Grebe	x	x		2	3	1
American Bittern	x	x		2	3	1
Northern Harrier	x	x		1	3	2
Ferruginous Hawk	x	x		0	3	2
Yellow Rail	x?	x	x	2	3	0
Virginia Rail	x?	x	x	3	2	0
Sora	x	x		3	3	1
Piping Plover	x	x		0	3	2
Willet	x	x		1	3	2
Long-billed Curlew	x	x		0	2	3
Marbled Godwit	x?	x	x	1	3	1
Wilson's Phalarope	x?	x	x	1	3	2
Franklin's Gull	x	x		1	3	1
Least Tern	x	x		0	3	0
Black Tern	x	x		2	3	1
Burrowing Owl	x	x		0	1	3
Short-eared Owl	x	x		1	3	2
Sedge Wren	x?	x	x	3	2	0
Sprague's Pipit	x	x		1	3	2
Loggerhead Shrike	x		x	1	2	3
Clay-colored Sparrow	x	x		2	3	1
Lark Bunting	x	x		0	3	1
Baird's Sparrow	x	x		1	3	2
Grasshopper Sparrow	x	x		2	3	1
LeConte's Sparrow	x?	x	x	1	3	0
Nelson's Sharp-tailed Sparrow	x?	x	x	1	3	0
McCown's Longspur	x	x		0	1	3
Bobolink	x	x		3	2	1

x = declining; x? = uncertain; 3 = highest priority area; 2 = moderate priority; 1 = low priority; 0 = no priority).

Table 2—Species Suites.

Tallgrass

1. Wetland suite 1 (Pied-billed Grebe, American Bittern, Virginia Rail, Sora, Wilson's Phalarope, Black Tern)
2. Wetland suite 2 (Yellow Rail, Sedge Wren)
3. Terrestrial suite 1 (Sedge Wren, Grasshopper Sparrow, Bobolink)
4. Terrestrial suite 2 (Loggerhead Shrike, Clay-colored Sparrow)

Mixed grass

1. Nonvegetated wetland edges (Piping Plover, Least Tern)
2. Wet meadow (large tracts) (Yellow Rail, Nelson's Sharp-tailed Sparrow)
3. Semi-permanent large wetland with dense bulrush interspersion (Franklin's Gull)
4. Seasonal wetland zone (relatively large and deep) (Sora, Black Tern)
5. Seasonal wetland zone with upland grassy cover (Willet, Marbled Godwit, Wilson's Phalarope)
6. Seasonal/semi-permanent wetland with emergent cover (Pied-billed Grebe, Virginia Rail)
7. Semi-permanent/permanent wetland with emergent cover or seasonal wetland with dense upland cover (American Bittern)
8. Grasslands with a limited shrub component (Northern Harrier, Ferruginous Hawk, Short-eared Owl, Sprague's Pipit, Loggerhead Shrike, Baird's Sparrow, Grasshopper Sparrow)
9. Grasslands with a more extensive shrub component (Northern Harrier, Short-eared Owl, Loggerhead Shrike, Clay-colored Sparrow, Lark Bunting, Grasshopper Sparrow)
10. Grasslands near wetlands (eastern midgrass) (Northern Harrier, Short-eared Owl, Sedge Wren, LeConte's Sparrow, Bobolink)
11. Western, shorter, mixed grass grasslands (Ferruginous Hawk, Long-billed Curlew, Burrowing Owl, McCown's Longspur)

Shortgrass

1. Relatively short grasslands (Ferruginous Hawk, Long-billed Curlew, Burrowing Owl, Lark Bunting, McCown's Longspur)
2. More mesic grasslands (Northern Harrier, Short-eared Owl, Sprague's Pipit, Loggerhead Shrike, Baird's Sparrow, and, if wetlands are present, Willet, Wilson's Phalarope)

the level of knowledge regarding Mallard population size and recruitment is unlikely to ever be duplicated for high-priority nongame species. Nevertheless, the same expectations exist: (1) Risk of extirpation of sub-populations should be very small; (2) Recruitment rates should be sufficient to allow populations to persist or grow; and (3) Overall population size should exceed some designated threshold.

Population objectives and means of achieving them depend upon features of the landscape and how they are managed. These features are variable across the Northern Prairies. In the south and east, where row-crop agriculture predominates, objectives may be set in terms of protection of stationary blocks of habitat sufficient for high-priority species. Farther west, where entire districts retain relatively large percentage coverage by native or non-native grasslands, blocks may be less of an issue than maintenance of landscapes generally dominated by grasslands and wetlands. Much work remains in working through this step.

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Managing Wetlands for Waterbirds: How Managers Can Make a Difference in Improving Habitat to Support a North American Bird Conservation Plan

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Abstract—Wetlands are the most productive ecosystems in the world, yet they have suffered more loss and degradation than any other ecosystem. Not surprisingly, 50% (29 of 58) of all the bird species in the United States (excluding Hawaii and territories) that are listed either as federally threatened or endangered, or are on the U.S. Fish and Wildlife Service 1995 List of Migratory Nongame Birds of Management Concern, occupy wetland or aquatic habitats even though many remaining wetlands across the North American landscape already are managed primarily for waterbirds. Some of these wetlands are administered by federal and state entities (e.g., national wildlife refuges, national and state parks, state wetland management areas) or are maintained on private lands through federally supported restoration and enhancement programs (e.g., Conservation Reserve Program, Wetland Reserve Program, Waterfowl Production Areas, and Partners for Wildlife). Private organizations, such as the National Audubon Society, The Nature Conservancy, and private hunting clubs also own wetland areas that are managed specifically to benefit wildlife. If management philosophies are altered to consider the entire complex of wetlands, many wetlands can provide benefits to a broad array of waterbirds, as opposed to just one or a few species. However, challenges for natural resource managers are in forming partnerships with owners-managers of wetlands where the objectives are not primarily wildlife oriented. These owners or managers need to be included in wetland training workshops in an attempt to educate them about wetland values and secondary wildlife benefits that may be derived in flooded agricultural lands, aquaculture ponds, altered coastal marshes (mosquito control), and salt evaporation ponds. In some cases, compensation for crop damages by wildlife may be a necessary part of any cooperative agreements. In the development of a North American Bird Conservation Plan, we propose a four-step approach and recommend that emphasis be placed on working with Joint Ventures of the North American Waterfowl Management Plan to ensure that a diverse array of waterbird species will benefit. Efforts also should be devoted to developing similar partnerships in areas where important wetland resources exist but no Joint Ventures are planned.

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Although wetlands are widely recognized as among the most productive ecosystems globally, wetland loss continues both in North America and throughout the world, owing largely to a burgeoning human population and the concomitant conversion of natural wetlands for human uses. For example, the Bay of Fundy is a critical habitat for shorebirds during migration (Morrison and others 1994) but is threatened with both hydroelectric development and harvesting of polychaete worms (major shorebird prey) for sport fishing (P. Hicklin, Canadian Wildlife Service, personal communication). Similarly, James and western Hudson Bays are the subjects of major water development planning, despite their roles as major nesting and migration areas for geese and a number of species of shorebirds. The prairie pothole region of Saskatchewan and Manitoba are part of a Canadian prairie habitat joint venture (JV) under the North American Waterfowl Management Plan (NAWMP[USFWS 1986]). The region has been recognized internationally as one of the premier nesting grounds for many diving and dabbling ducks, and it also provides habitat for endangered Piping Plovers (*Charadrius melodus*). This area historically has faced numerous conversions of potholes to croplands. The western Canadian regions of most concern are the Fraser River corridor and delta and the adjacent Vancouver Island region. Development and growth is rapid in that region, and intense logging occurs along the Fraser. The region is well known for its wintering waterfowl and marine bird concentrations (Vermeer and Butler 1989). Similar examples are numerous throughout most of North America. However, during the past two decades, many federal, provincial, and state programs have been initiated to provide economic incentives for wetland conservation in an attempt to achieve a "no net loss" of wetlands (The Conservation Foundation 1988). These earlier losses of wetlands, and recent changes in the status of wetlands, have broad implications to wildlife.

In this paper we review the status of wetlands as habitats for waterbirds (defined as waterfowl, colonial waterbirds, shorebirds, and rails and allies). We focus on species whose

status is of concern either regionally or nationally, and on current wetland management practices that are detrimental to wetland birds. We identify gaps in our knowledge of ecological principles for managing habitats for waterbirds, and conclude with recommendations for improving wetland management to enhance waterbird populations.

Status of Species and Associated Wetlands

We consulted two recent publications to identify the major waterbird species of concern in North America: The 1994 list of endangered and threatened wildlife and plants (USFWS 1994b) and the 1995 List of Migratory Nongame Birds of Management Concern (Office of Migratory Bird Management [OMBM] 1995). These lists indicate that more than 50% of birds of concern in the U.S. are associated with either wetlands or aquatic habitats (table 1) (Canada and Mexico do not have formal endangered species listings). The federal endangered and threatened list includes 16 of 35 species (not including Hawaii or trust territories) that are wetland or aquatic-dependent, while the comparable figures from the OMBM list are 14 of 23 species.

The habitats used by these species suggest that the majority are associated with freshwater (interior) marshes or coastal beaches and/or islands. These are habitats that have been among the most affected by humans, either by direct disturbance (beaches) or indirectly by agricultural conversions (freshwater marshes). In addition, interior marshes and coastal areas often are intensively managed, suggesting that current habitat management practices should be evaluated relative to providing benefits to a diversity of species. For example, many of the major wetland complexes listed for the U.S. already are included under JVs in the NAWMP (table 2). However, the Atlantic Coast Habitat Joint Venture focuses on American Black Ducks (*Anas rubripes)*. Separate (but unequal) programs are directed at restoration of the endangered Piping Plover, and at monitoring certain declining colonial waterbird species in the mid-Atlantic barrier region.

During the past decade, however, the scope of habitats and avian species being considered has been increasing. For example, discussions are under way (C. Hunter, USFWS, personal communication) to form a JV for part of the extensive

Table 1—List of wetland/aquatic bird species of concern in the United States.

Common name	Scientific name	Habitat	
		Wetland	Aquatic[a]
Federal threatened/endangered [b]			
California Brown Pelican	*Pelecanus occidentalis*		X
Wood Stork	*Mycteria americana*	X	
Spectacled Eider	*Somateria fischeri*		X
Everglade Snail Kite	*Rostrhamus sociabilis plumbeus*		X
Bald Eagle	*Haliaeetus leucocephalus*	X	
Light-footed Clapper Rail	*Rallus longirostris levipes*	X	
Yuma Clapper Rail	*Rallus longirostris yumanensis*	X	
Whooping Crane	*Grus americana*	X	
Mississippi Sandhill Crane	*Grus canadensis pulla*	X	
Western Snowy Plover	*Charadrius alexandrinus nivosus*	X	
Piping Plover	*Charadrius melodus*	X	
(Interior) Least Tern	*Sterna antillarum athalassos*		X
California Least Tern	*Sterna antillarum browni*		X
Roseate Tern	*Sterna dougallii dougallii*		X
Marbled Murrelet	*Brachyramphus marmoratus marmoratus*		X
Cape Sable Seaside Sparrow	*Ammodramus maritimus mirabilis*	X	
USFWS List[c]			
Common Loon	*Gavia immer*		X
American Bittern	*Botaurus lentiginosus*	X	
Least Bittern	*Ixobrychus exilis*	X	
Reddish Egret	*Egretta rufescens*	X	
White-faced Ibis	*Plegadis chihi*	X	
Trumpeter Swan	*Cygnus buccinator*		X
Northern Harrier	*Circus cyaneus*	X	
Red-shouldered Hawk	*Buteo lineatus*		X
Black Rail	*Laterallus jamaicensis*	X	
Snowy Plover	*Charadrius alexandrinus*	X	
Bristle-thighed Curlew	*Numenius tahitiensis*	X	
Black Tern	*Chlidonias niger*	X	
Cerulean Warbler	*Dendroica cerulea*	X	
Seaside Sparrow	*Ammodramus maritimus*	X	

[a]"Aquatic" refers to primary use of lake, river, and/or marine habitats.
[b]United States Fish and Wildlife Service (1994).
[c]Office of Migratory Bird Management (1995).

Table 2—Primary wetland regions for waterbird conservation in North America.

Country	Complex
Canada	Bay of Fundy
	James Bay-W. Hudson Bay
	Prairie potholes (S. Saskatchewan, Manitoba)
	Fraser River corridor-delta
	Vancouver Island region
United States	Atlantic coastal barriers
	Forested wetland of the southeast-lower Mississippi River
	Prairie potholes/Rainwater Basins
	Riparian corridors-Intermountain west
	Copper River delta, Alaska
	Yukon River delta, Alaska
	Playa Lakes Region (Texas, Oklahoma, S. Colorado)
	West coast estuaries
	Agricultural valleys-West
Mexico	Ensenada del Pabellon and Boca de la Barra
	Marismas Nacionales
	Usumacinta-Grijalva delta
	Laguna de Terminos
	Rio Lagartos[a]
	Rio de Celestun[a]
	Sian Ka'an[a]
	Laguna Babicora[a]

[a]Designated as a Faunal Reserve or international Man and Biosphere Reserve (UNESCO).

forested wetlands in the southeastern U.S. from Virginia to Florida where forested wetland loss has resulted in marked declines of wintering waterfowl and certain songbirds such as the Swainson's Warbler (*Lymnothlypis swainsonii*). The lower Mississippi River supports a very active JV that includes waterfowl, shorebirds, and Neotropical migrants. In the interior, agriculture has been modified to be more "friendly" to wetland birds in several JV areas: The Playa Lake region of Texas and southern Colorado, the Prairie Potholes of the Dakotas and Montana, and the Rainwater Basins in Nebraska. The Playas are important waterfowl wintering habitat, while the latter two areas are critical for breeding and migrating waterfowl and shorebirds.

Farther west, the riparian corridors of the arid intermountain west and the large agricultural valleys (e.g., Central, Sacramento, and San Luis in California, and Willamette in Oregon) represent important wintering and migration habitat for waterfowl and shorebirds, respectively. Metal contamination (selenium and boron) of irrigation drainwater in the agricultural basins of the West has stirred major controversies concerning whether wetlands in wildlife refuges should become sumps. Along the west coast, the few estuaries with remaining wetlands (San Francisco Bay, San Diego Bay, Puget Sound, Fraser River delta and corridor) require constant vigilance to protect against further loss and degradation. Recently, the USFWS named Puget Sound as a national estuary program.

In Alaska, numerous wetlands abound both on the coast and on interior wildlife refuges and parks; most of these are under no immediate threats. The major exception is the Arctic National Wildlife Refuge, which some U.S. congressmen refer to as the Alaska Oil Reserve. Special mention also should be made of the Copper River delta, which is critical to enormous numbers of migrating shorebirds in spring and fall (Gill and others 1995). It also is important to many species of geese and ducks.

In Mexico, a number of important wetland areas for waterbirds, especially waterfowl, have been identified under the NAWMP. To date, however, none has been designated as a JV area (USFWS 1995). Several, however, have been designated by UNESCO as Man and Biosphere Reserves or as Faunal Reserves by Mexico (Baldassarre and others 1989) (table 2). Of hemispheric importance is the Usumacinta-Grijalva delta region, which exceeds the size and significance of the present-day Everglades region in Florida (Ogden and others 1988). It is threatened by conversion to agricultural uses and dam construction. The northern coastal lagoons of Rio Lagartos and Rio Celestun are important to the rare Greater Flamingo (*Phoenicopterus ruber*) and are major wintering areas for several species of waterfowl migrants from the U.S.

Wetland Practices Unfavorable to Waterbird Conservation

In this section, we highlight some current practices occurring in wetlands that adversely affect either the quality or quantity of wetland habitat available to waterbirds (table 3). The principal areas affected also are indentified. Where possible, we make recommendations for improvement.

Table 3—Wetland practices unfavorable to waterbirds and wetland conservation in North America.

Issue	All wetlands	Barrier beaches	Coastal marshes	Palustrine forests	Riparian wetlands	Playas-potholes
1. Federal-state wetland policy	x					
2. Contaminants		x	x			x
3. Human disturbance		x	x			
4. Timber harvest				x	x □	
5. Grazing			x (geese)		x (cattle)	
6. Drainage-agriculture	x					
7. Exotic species	x					
8. Single-species (or group) management	x					

Current Practices

Navigation and Flood Control—The hydrology of many rivers has been severely modified. In many cases, peak discharges have been reduced and low flows have been increased, resulting in more stable hydroperiods among seasons and years. Although moderation of flows improves efficiency of hydroelectric power generation, provides more reliable navigation, and reduces the threat of floods, many habitats important for avian species have been destroyed or their value severely decreased. However, recent attempts to coordinate water discharges to facilitate reestablishment of riparian wetland types and regeneration of woody riparian species have met with some success. Additional effort should be directed toward cooperation among responsible agencies and individuals with respect to alternative methods of river management.

Human Disturbances Along Beaches and Islands in the Coastal Barrier Regions—Increases in population and recreational demands by boaters continue, especially in the Atlantic and Gulf coasts of the U.S. In the Yucatan region of Mexico, resort development and ecotourism continue to grow. Increasing access to formerly remote mangrove islands by personal watercraft (e.g., Jet Skis) represents an increasing threat to nesting herons, spoonbills, storks, pelicans, and cormorants in Florida, Texas, Mexico, and other tropical coastal resort areas (Erwin and others 1995; Rodgers and Smith 1995). These threats call for additional regulatory actions regarding land access as well as environmental education, especially for boaters who may be oblivious to bird conservation needs.

Mosquito Control in Coastal Marshes—Historically, coastal marshes were diked to stabilize water levels, thereby reducing the magnitude of mosquito problems. Current mosquito control in most coastal areas combines use of organophosphate pesticides as adulticides with some form of marsh management. The latter often involves use of heavy equipment to create high-marsh ponds and canals that allow fish to access mosquito breeding areas (Meredith and Stachecki 1985). Although this practice may be ecologically superior to using dikes and chemical pesticides, in many areas the net benefit to waterbirds and other wildlife may be marginal at best (Erwin and others 1994). Because few natural coastal marshes remain along the east and Gulf coasts of the U.S., marsh manipulations should be restricted to those areas that already have been severely altered by humans, and where mosquitoes are a major nuisance.

Timber Harvesting on Private Lands—Especially in Canada and the southeastern U.S., timber harvesting in palustrine forested regions has resulted in large losses of wetlands for wildlife (Erwin 1996). In addition, many remaining forested wetlands have been fragmented—or natural hydrologic regimes have been disrupted—by road construction for timber harvesting. Conservation organizations need to develop partnerships with private organizations and corporations to determine market-compatible methods of extraction that are more "friendly" to wildlife. This effort also will require more education of "corporate America" (as well as corporate Mexico and Canada) about the values of biodiversity.

Single-Species Management in Forested Wetlands—Wildlife management in forested wetlands of the Mississippi River corridor and throughout much of the south and northeastern U.S. has concentrated on "greentree reservoirs" where the primary focus has been to produce Wood Ducks (*Aix sponsa*) (Fredrickson and others 1990). The Wood Duck has been a major "target species" for both state and federal refuge lands. Although "woodies" have become increasingly important to waterfowl hunters as other species have declined over the past decade, managing for one species is usually accomplished at the expense of many others in the ecosystem. Within a complex of impoundments, managers should seek to diversify water management schedules to maintain current forest composition and structure as well as to promote natural regeneration.

Grazing in Riparian Zones Along Western Rivers—Exclosures or other methods of preventing livestock access to free-flowing rivers of the arid west are essential to ensuring stream water quality and to resisting further invasions of exotic plants. This problem is critical in the western U.S. (Naiman and others 1995) and especially western Mexico.

Water Rights of Wildlife—In the western U.S. and prairie regions of Canada, water rights among state, provincial, and local interests are politically charged. Wetland managers need to argue that wetland wildlife also has a "share" in this essential commodity, and that refuges should not simply become shunts for receiving irrigation drainwater that will adversely affect water quality. Concentrations of metals (e.g., selenium) in drainwater in vast regions of the arid western U.S., from California across Nevada to Wyoming, have compromised the wildlife quality of many refuge wetlands and other non-federal impounded wetlands (Ohlendorf and others 1986).

Protecting Small Pothole Complexes in the Prairie Regions—In Canada and the U.S., valuable gains have been made to set aside marginal agricultural lands for wildlife. Further efforts are needed to insure that large complexes of these small wetlands are maintained to conserve the diversity of habitat needed by nesting waterfowl, shorebirds, rails, and grebes. Farmers must have continued financial incentives (e.g., the Conservation Reserve Program under the Food Act of 1985) to maintain the successes achieved to date. The lessons learned in Canada and the U.S. need to be applied in Mexico, where farmers presently have few economic incentives to save wetlands.

Runoff and Sedimentation—In the Playa Lakes region in Oklahoma, west Texas, and southeastern Colorado, water quality suffers in many areas due to feedlot manure runoff and sedimentation into the lakes from livestock areas. More effective buffering is needed. Cotton crops are ecologically dangerous because of the intensive pesticides they require, and because of soil erosion resulting from lands left barren much of the year. Alternative land uses are advised.

Pesticides—Modern organophosphate pesticide applications, although not as toxic as organochlorines (Grue and others 1983), are still problematic throughout most agricultural areas in North America. In the Rainwater Basins of Nebraska, in addition to heavy pesticide applications, a number of exotic plants also have invaded. More biological control of pest species is strongly encouraged. Water quality in these small basins has suffered.

Major Gaps in Our Knowledge to Effectively Manage Wetlands for Wildlife

We identify below some major gaps in our understanding of wetland wildlife and its habitat needs, how wetlands function as quality wildlife habitat, and how to more effectively integrate and communicate our knowledge to managers and the public.

Major Gaps in Knowledge

Integration of Wetlands Within the Landscape Matrix—Often, studies of habitats have focused only on the individual habitat type: Wetlands, grasslands, forest type, and so forth. Further, information regarding differential use of wetland types by wetland-dependent species is lacking. Little attempt has been made to determine how the juxtaposition of various wetland or habitat types affects their respective uses by wildlife. Research is required to determine how local (e.g., wetland complex) and regional (e.g., flyway) landscape processes affect patterns of use.

Regional and National Monitoring of Populations—Wintering locations of most waterfowl have been identified as part of the regular inventory of states and USFWS flyway councils. The major shorebird concentration areas have been identified by the Western Hemisphere Shorebird Reserve Network (WHSRN, Myers and others 1987), now part of the larger Wetlands for the Americas Program. Although songbirds are well monitored by the annual roadside Breeding Bird Survey, wetland species are much less covered because of lack of road access to most wetland areas. The International Shorebird Survey is undergoing a review (B. Harrington, personal communication) and a colonial waterbird national database is under development within the Biological Resources Division of the U.S. Geological Survey (BRD) since the National Audubon Society database was terminated in the late 1980s. A marsh bird (rails, bitterns, grebes) survey has been under discussion within BRD (S. Droege, USGS, personal communication) because of the dearth of information on this group of birds, some of which are hunted annually. Currently much less information is available on either migration concentration areas or on important wintering sites of colonial waterbirds, rails, and bitterns. All of these major groups are lacking in comprehensive survey coverage to allow for national assessments of trends in populations.

Fragmentation Effects—Although the effects of forest fragmentation have been well studied for upland bird species (see Askins and others 1990 for a review), much less information is available on the effects of wetland fragmentation. Research is required to investigate how changing sizes and patterns of distinct wetlands (e.g., potholes) affect their use by a variety of wetland birds. In addition, the fragmentation of expansive areas of marshes (e.g., by mosquito control excavation) may adversely affect their use as breeding habitat for some species (Burger and others 1979; Erwin and others 1994).

Large-Scale Experimentation in Wetland Management—Seldom are well-controlled experiments performed in wetlands. Impoundment water management, pesticide applications, *Phragmites* control, mosquito ditching, and marsh burning all are examples of activities for which controlled and replicated experimentation is needed to critically evaluate different management practices in wetlands. These approaches should follow an adaptive resource management strategy (Walters 1986; Conroy, this proceedings).

Training of Professionals—Many private, state, provincial, and federal biologists and managers involved in either the conservation or regulation of wetlands possess only a basic understanding of wetland ecology. More advanced training is required to understand the ecological processes in wetlands and to understand the significance of wetland complexes over a larger landscape. Geographic information systems are becoming vital tools for managers to learn the basics of ecosystem and landscape management.

Public Relations Concerning Wetlands—For the public to appreciate attempts to conserve wetlands, much more emphasis must be placed on teaching the values of wetlands to the citizenry of Canada, the U.S., and Mexico (Conservation Foundation 1988). Especially considering the anticipated demands for fresh water (water consumption in the U.S. has doubled since the 1940s and may double again in the next 20 years [Naiman and others 1995]), the public must develop an appreciation of wetlands for the many ecological, recreation, aesthetic, and public service values that they hold. Teaching of wetland ecology should be included in public school curricula, and should be part of the outreach effort of every scientist and landscape manager.

Recommendations

Our general recommendations to improve wetland management for a wide array of waterbird species are:

- The current JVs in the U.S. under NAWMP should be expanded to include more non-waterfowl avian species. The Canadian prairie habitat JV and the Lower Mississippi Valley JV have significant shorebird components. They also could be expanded to include colonial waterbirds, rails, and bitterns. A single-species or focal-group approach will achieve only limited success.
- New JVs and other partnerships should be established in regions with no current JVs; this includes all of Mexico, parts of eastern Canada, and the southeastern U.S., although the forested wetlands of the southeastern coastal plain are receiving attention (C. Hunter, USFWS, personal communication).
- Criteria should be developed for reaching resource goals for JVs. Are population goals feasible to set? Are habitat area goals sufficient? How are quality criteria set?
- Inventories should be supported to determine waterbird status in critical wetlands, especially for little-studied species. Concentration hotspots for colonial waterbirds or rails could result in designations similar to those used by WHSRN (i.e., sites of international, hemispheric importance).
- Training workshops for wetland biologists and managers should be expanded and should include the private sector. Aquaculturists, rice farmers, hunting preserve managers, large ranch owners, and leaders of ecotourism enterprises should be included in the educational process.
- Assistance in ecological planning for wetland construction or alteration needs to be institutionalized. As part of a permitting process, regulatory personnel in state, provincial, and federal governments should require that a private permit holder consult with professional wetland scientists (certified by the Society of Wetland Managers) before embarking on large-scale wetland projects such as construction of reservoirs, aquaculture facilities, or irrigation systems. For example, if catfish ponds in the south had been constructed as small (half-acre) ponds, then bird exclosures would have been easier to construct to preclude cormorant and heron damage. This information could have been provided by a professional who is knowledgeable about waterbird biology.

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Conservation Priorities in Naturally Fragmented and Human-Altered Riparian Habitats of the Arid West

David J. Krueper

Abstract—Riparian ecosystems are critically valuable to wildlife in arid regions of the western United States. They are particularly valuable in the lowlands, primarily below 5,000 feet, where they provide direct sustenance for a variety of animal species. They also provide a connection between all other habitats, including mountains, forests, prairies, and deserts. Although western riparian ecosystems historically have been structurally fragmented, discontinuous, and highly variable in size and shape, nearly all species of western nongame migratory birds identified as conservation priorities by Partners In Flight have been recorded within them. Unfortunately, owing to habitat alteration and degradation, this critical habitat is now among the rarest of forest types in western North America, where it makes up less than 5% of the total land mass. To retain or restore the values of this sensitive and extremely limited habitat under continued anthropogenic pressure, I recommend: that Riparian habitat issues be viewed in terms of modern conservation principles; that a conservation strategy and mechanism to implement the strategy be developed; and that the traditional paradigms that have guided riparian management in past years be critically evaluated and amended.

Riparian habitats are vegetative communities or ecosystems associated with perennial, intermittent, or ephemeral surface or subsurface water (Krueper 1993). They are among the rarest habitat types in North America, constituting less than 5% of the continental land mass. Traditionally, lowland riparian ecosystems have been the western habitat type that is most heavily affected by human overuse, abuse, and neglect (Fleischner 1994; Ohmart 1994; Krueper 1996). Within the past 100 years, an estimated 95% of this habitat has been altered, degraded, or destroyed by a wide range of human activities including river channelization, unmanaged livestock grazing, clearing for agriculture, water impoundments, urbanization, timber harvest, exotic plant invasion, recreational impacts, groundwater pumping, and fire. Together, these activities have dramatically altered the structural and functional integrity of western riparian habitats (Johnson and others 1977; Dobyns 1981; Bock and others 1993; Krueper 1993; Fleischner 1994; Horning 1994; Ohmart 1994, 1995; Cooperrider and Wilcove 1995; Krueper 1996). At present, natural riparian communities persist only as isolated remnants of vast, interconnected webs of rivers, streams, marshes, and vegetated washes.

Nonetheless, up to 80% of vertebrate species in the arid West use western riparian habitats at some stage of their lives. The high density and diversity of wildlife within these habitats results from the availability of water and prey items, and from high vegetative density, diversity, and structure. More than 50% of the bird species in the American Southwest breed in riparian habitats (Johnson and others 1977; Krueper 1996). More than 60% of the nongame migratory bird species identified as conservation priorities by Partners in Flight (PIF), including tens of millions of individuals, regularly use western riparian areas for breeding, migration, or wintering habitat (Krueper 1993).

Major obstacles to management of riparian areas for wildlife include mixed ownership patterns, high economic value in arid landscapes, and polarization between consumptive and nonconsumptive users. Land management agencies such as the USDA Forest Service, the Bureau of Land Management, and various state agencies are mandated to administer public lands in a multiple-use manner, provided that the impacts do not jeopardize their continued sustainable use. The challenge of responsible riparian habitat management is thus to strike a balance between consumptive and nonconsumptive public needs. This balance can be accomplished only through a consensus, problem-solving process, in which management techniques and implementation methodologies are agreed upon by all affected parties.

Ecosystem management has been the supposed "guiding principle" behind land management during the past decade. Whereas biologists may have an understanding of the concept, most land management agencies and public officials do not have a clear working definition or understanding of ecosystem management and the principles involved. In many instances, agencies do have the understanding, but conflicting mandates and political pressures have prevented adherence to the concept. In an attempt to clearly define the parameters of ecosystem management, Grumbine (1994) critically evaluated peer-reviewed journals and public policy documents from several federal and state management agencies. He identified ten themes common among all sources referenced, which he synthesized into this definition:

> Ecosystem management integrates scientific knowledge of ecological relationships within a complex sociopolitical and values framework toward the general goal of protecting native ecosystem integrity over the long term.

Using this definition, I present the following recommendations for conservation and preservation of western riparian ecosystems and their dependent avian assemblages.

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Recommendations

Ecosystem Management

Adopt basic tenets of ecosystem management and conservation biology to help understand the principles behind riparian habitat conservation and restoration.

1. Improve and expand current riparian habitat to the maximum extent possible, and ensure that a proper spectrum of ecological assemblages exists. Large blocks of habitat, which can sustain several or many pairs of species of concern, are preferable to smaller blocks. Large blocks of continuous habitat are more valuable than blocks that are fragmented or discontinuous. Historic destruction or alteration of western riparian habitats has resulted in highly fragmented and discontinuous habitat patches of adequate breeding habitat for a great number of nongame bird species. Southwestern Willow Flycatcher (*Empidonax traillii extimus*) and Western Yellow-billed Cuckoo (*Coccyzus americanus occidentalis*) have undergone precipitous population and range declines within the last century. These species and many others have reached the critical stage where suitable breeding habitat has become so fragmented and isolated that genetic bottlenecks may have been created. Single individuals cannot locate mates within the remaining suitable fragments of riparian habitat.

2. Tie patches of riparian habitat together to allow avian species to recolonize areas where they have previously been extirpated. Patches of habitats that are close together are more valuable than patches that are isolated. Riparian corridors are beneficial to migrating or dispersing animals.

3. Manage common species to keep them common, but concentrate special management actions on habitats and species of concern. Avian species are less likely to become extinct if they are common across large ranges. Conversely, species with extremely limited ranges are more likely to become extinct through habitat loss or other catastrophic events.

4. Involve all interested or affected parties in riparian management implementation. Stanley (1995) determined that the true concept of ecosystem management, under its current definition, is superseded by human needs and desires. He feels that to maintain or improve ecosystem integrity, humanity must shift its anthropocentric thinking from believing that we are above natural processes to believing that we are a part of nature. While this belief is noble, in reality, it may never be adopted by humanity. Therefore, successful riparian habitat management must accommodate "selfish" human needs and values. Humans are an integral part of the landscape, and to ignore their continued use of riparian habitats is to ignore not only potential impacts, but also the possibility of successful habitat management.

Conservation

Develop a conservation strategy for which the status of riparian habitats is assessed, and management practices and other conservation actions are identified.

1. Evaluate habitat fragments on the basis of size and configuration, connectivity to adjacent habitats, and importance to priority bird species. Determine the location, quality, and extent of remaining riparian habitat. This process is currently under way through the efforts of several western states involved in the PIF conservation planning process (Carter and others, this proceedings).

2. Determine the habitat requirements of priority avian species, including issues of habitat quality and quantity. Develop management strategies for the enhancement of all threatened habitats and resources. Initiate (or complete) inventories to determine the status of sensitive avian species within western riparian habitats, identified in part through the PIF species prioritization process. Identify the bird species and locations of riparian habitats that are rarest and/or most vulnerable.

3. Address the concept of "biotic impoverishment" of riparian ecosystems (Cooperrider and Wilcove 1995). Because western riparian habitats have experienced intensive use for many generations, any management scenario must consider the cumulative impacts of:

- range management (overgrazing, erosion, loss of native vegetation)
- energy and mineral development
- recreation pressures
- displacement of native plant and animal species (exotic plant invasion)
- habitat fragmentation
- suppression/interruption of natural fire regime
- urbanization
- vegetative and mechanical manipulation of riparian habitats
- vegetative restoration efforts/needs
- forestry practices
- agricultural diversions
- traditional wildlife management practices
- information/education needs

4. Ensure that all parts and processes of riparian ecosystems function together. Consider energy flow, hydrologic cycles, nutrient cycles, biotic interactions, and rare species, as well as the connectivity, location, and configuration of habitat and successional stages.

Implementation

Form a conservation delivery mechanism for those actions that need to be implemented.

1. Develop a Western Riparian Ecosystem Management Team, consisting of representatives of each state, to work within the management subgroup of PIF.

2. Protect existing riparian habitat on state and federally administered lands and, where necessary and feasible, add to the amount of riparian habitat owned or managed by conservation agencies or organizations.

3. On private lands, encourage land management practices that enhance the ecosystem values of riparian habitat. This can be accomplished through outreach as well as measures such as cooperative management agreements, protective zoning, and taxes and other types of private landowner incentives.

4. Restore vegetative structure, composition, and hydrologic dynamics, and thus productivity and biodiversity, of degraded riparian habitat on public and private lands where necessary and feasible.

5. Assure that the network of high-quality riparian habitats that are maintained or restored are sufficient to support a satisfactory distribution of healthy avian populations.

6. Monitor the results of implementation efforts and make changes where appropriate. Monitoring should be an ongoing process so that progress can be successfully tracked.

Evaluation

Critically evaluate traditional paradigms.

1. Recognize that a problem exists. Address riparian condition and restoration/recovery as the main objective in land management practices.

2. Develop and encourage a concept of environmentally responsible land management that puts the highest emphasis on properly functioning riparian ecosystems and their dependent plant and wildlife resources.

3. Educate the public and agency resource managers regarding the fragility and value of riparian habitats. Encourage public input through meetings and participation in the decision-making process.

4. Stress interagency and public-private cooperation within the context of ecosystem management. Where necessary, cooperate across state and international jurisdictional boundaries.

5. Endorse the legal mandates and spirit of legislation such as the Endangered Species Act, Federal Land Policy Management Act, National Environmental Policy Act, Public Rangelands Improvement Act, and the Clean Water Act. These acts focus on the recovery of species and habitats and supersede mandates of multiple-use management.

6. Stress that the primary goal of public land management should be the preservation of functioning riparian ecosystems and their native flora and fauna.

7. Recognize that the interrelationships among hydrological processes, vegetative communities, sensitive wildlife populations, and the fragility of riparian ecosystems are integral to the management of all. Riparian ecosystems are uniquely sensitive habitats and should be managed as such, not as part of upland or other adjacent habitats.

8. View riparian habitats as endangered ecosystems (Hunter and others 1987). Shift away from the view that they are "sacrificial areas" which can heal quickly if disturbance is minimized.

9. Change management emphasis from "single use" to a more balanced concept, taking into account all species and processes within a functioning ecosystem. Merge traditional game and nongame programs to achieve a holistic and ecological management approach for the benefit of riparian habitats and all riparian-dependent species.

10. Do not assume that multiple-use mandates mean "all uses in all habitats at all times." Shift to a concept of "appropriate uses in appropriate habitats at appropriate times." Employ objective, sound, and defensible science in making management decisions.

11. Change the concept of "burden of proof." Force consumptive users to show that proposed activities will not damage a resource, including consideration of cumulative impacts, rather than ask land managers to show proof of potential damage or resource conflicts.

12. Hold land managers accountable for riparian ecosystem health, viability, and restoration. Hold permittees and other public land users responsible as well. Reward the public land user who achieves desired goals of riparian ecosystem management, but penalize the public land user who is not achieving desired results, using fee increases or fines.

While many of these recommendations seem obvious to biologists, if we are to ensure that lowland western riparian ecosystems continue to exist and adequately function into the 21st century, then we must do a better job of delivering the management message to land managers, elected officials, and the American public. Riparian habitats are an integral component of western biological ecosystems, and their losses will permanently harm the integrity of the land as well as everything that depends on it, including plant, animal, and human populations. This fact alone should place management and restoration of western riparian habitats as the primary goal of appropriate land management agencies, all of which should strive to reverse the decline of western riparian habitats, stabilize them, and finally increase their quality and quantity throughout the West.

Management Strategies for the Conservation of Forest Birds

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David E. Capen

Abstract—We recommend that managers of forest-associated bird species follow a five-step hierarchy in establishing and implementing management programs. In essence, a manager must evaluate the composition and physiognomy of the landscape mosaic in the context of the regional and subregional goals and objectives. Then he/she can explore alternatives that allow manipulation of the configuration of the land uses within the management area to integrate elements of the surrounding landscape matrix. Wherever possible, spatial relationships within the region should be considered to help maintain connectivity among these and other suitable habitats in various ownerships. Partnerships and cooperation across ownerships are important to incorporate different rotation schedules and spatial arrangements of harvested sites, so that larger blocks of mature forest, rather than scattered small tracts, are emphasized in the management of forest-associated species.

Until recently, most research on the use of forested habitats by birds has focused at the local or stand level, and the majority of management decisions affecting birds also were made at that level. Past studies have provided invaluable information on habitat requirements, foraging behavior, avian community dynamics, and the responses of birds to habitat perturbations (Conner and Adkisson 1975; Webb and others 1977; Conner and others 1979; Crawford and others 1981; Franzreb and Ohmart 1978; Thompson and Fritzell 1990). Increasingly, however, natural resource managers must make decisions that encompass more than just stand level considerations.

With respect to bird conservation, such decisions may involve collaborating with adjacent private or public landowners to conserve habitats for endangered or umbrella species, or managing a national forest for a full range of seral stages required by a mix of high-priority species. To manage for multiple bird species with different habitat needs while continuing to meet other resource objectives, managers and researchers must plan at the landscape and even regional scales.

Managers need a wealth of information to make informed decisions about implementing projects, including information that will help to predict how specific projects aimed at other resources will improve or alter available habitats for birds. Understanding the habitat relationships, distributions, and abundances of each bird species or species assemblage is necessary to plan an appropriate management program. Information on the spatial distributions, quantities, and successional stages of habitats over a large area is essential in a well-devised plan. Temporal considerations such as changes in habitats, species compositions, and bird populations over time must be accounted for, and a monitoring schedule may need to be established to evaluate the temporal success or impacts of a plan. The responses of the targeted as well as non-targeted species or groups must be monitored to fully evaluate management effects. By applying the "adaptive management" concept, monitoring results can be used to modify management plans as necessary. Cooperation among different landowners to manage larger landscapes than those under individual ownership may be called for, especially when habitats or species are shared across ownerships, and are high priority, endangered, or declining in size or population.

Strategies

An effective approach for managing forest-associated species is to use a decision hierarchy consisting of regional, subregional, landscape, ownership, and stand levels (fig. 1). Although definitions for these levels may vary, we define the regional level in the decision tree to be equivalent to the divisions of the United States used by Partners in Flight (PIF). For instance, the Southeast would be considered a region. Physiographic areas or major watersheds would determine the subregional levels whose boundaries usually would incorporate multiple states. The landscape level includes 10 km around the area for which the local management plan or decisions are being made. (In practice, however, there will be greater variability in definition of landscapes than of the other scales.) Land under one ownership or jurisdiction would constitute the ownership level. The stand level is regarded as a forest patch with consistent habitat features. Management decisions should begin with a review of the regional situation and proceed downward through the decision hierarchy to the stand level. In this

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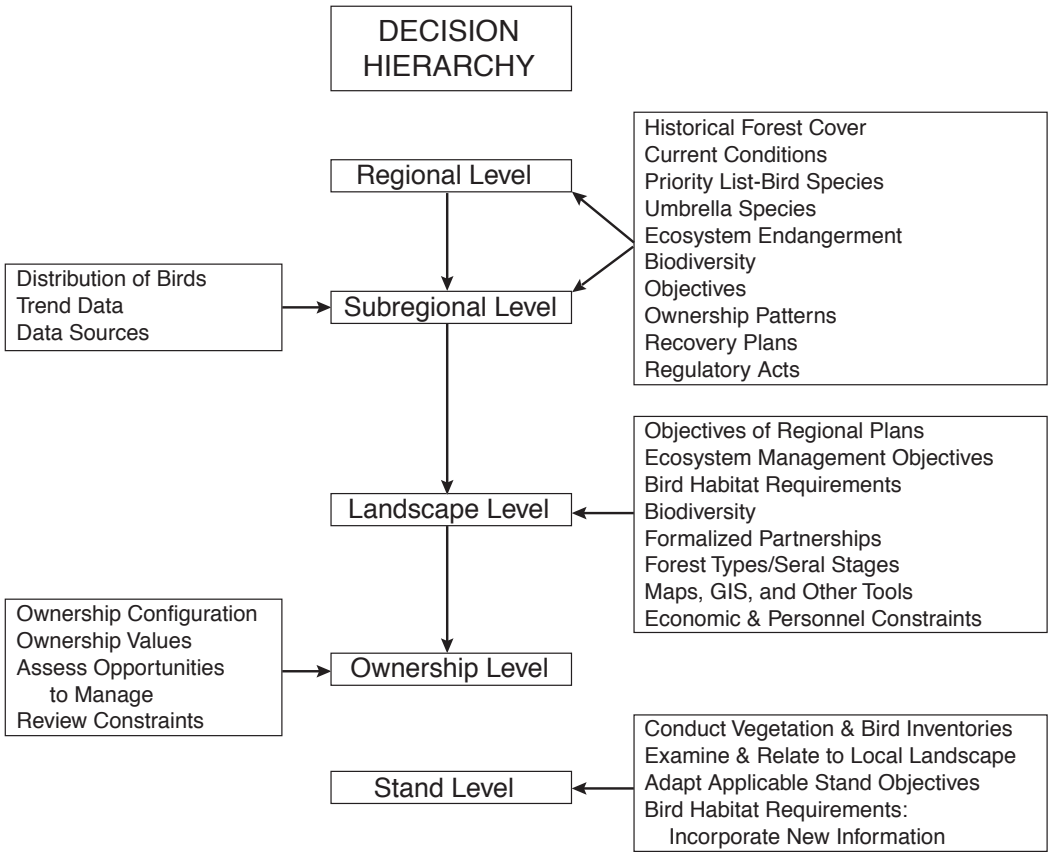

Figure 1—Decision hierarchy for managing forest-associated birds.

process, management decisions on a particular level are designed to complement the objectives and goals of those levels above it in the hierarchy; thus, this process is basically a "top-down" strategy.

This approach obviously brings the issue of scale into play. Scale is important in the maintenance of individual populations, species richness, and biological diversity. Population viability of many bird species within a regional context is reported to be dependent on large tracts of contiguous habitat that are minimally isolated from similar habitats (Whitcomb and others 1981; Lynch and Whigham 1984; Harris 1984; Jones and others 1985; Verner and others 1986; Thomas and others 1990). Often, area-sensitive species are not present or do not breed successfully in isolated, small, or fragmented tracts of land (Whitcomb and others 1981; Ambuel and Temple 1983; Hayden and others 1985; Robbins and others 1989a; Faaborg and others 1993). The landscape context in relation to a given habitat can have an important effect on avian demography, especially reproductive success and, hence, population health (Martin 1992b). Large scales, such as the regional, subregional, and landscape levels described herein, may impose important top-down constraints in terms of how birds respond on a more local level to habitat modifications such as timber harvesting (Mauer 1993; Thompson and others 1993b).

As the size of an area increases, the number of bird species present generally increases until species accumulation curves reach a plateau (Bond 1957; MacArthur and Wilson 1963, 1967; Galli and others 1976; Robbins and others 1989a). The heterogeneity of habitats, including the diversity of seral stages and microhabitats within an area, also influences bird species richness and presence/absence of individual species. Thus, managers who administer large and diverse properties typically manage more species than those with smaller and more uniform properties, and their lands correspondingly contribute in a more powerful way to the regional pool of biological diversity. When habitats and properties are combined under a particular conservation venture, the overall biological diversity of the total conservation area is increased, thus the project has a greater chance of benefiting more species.

Because species differ in home range or territory sizes, geographic distributions, microhabitat requirements, seasonal habitat uses, and responses to habitat alterations, the complex array of habitat needs can be bewildering (Finch and others 1993b; Block and others 1995). This presents a special challenge to those managers who are responsible for effectively maintaining populations of threatened and endangered species under the Endangered Species Act as well as biological diversity under the National Forest Management Act. By keeping in mind that the loss of an endangered species ultimately means a reduction in biological diversity, it is easier to understand how a management plan to meet both objectives (endangered species and biological diversity)

might be designed using the same approach (Finch and Ruggiero 1993). Because many federal and state agencies are now organizing natural resource management plans and organizational structures in line with the concept of "Ecosystem Management," conservation approaches that integrate Neotropical migratory birds (NTMBs) into ecosystem management objectives are recommended (Finch and others 1993; Finch and Ruggiero 1993; Block and others 1995).

In addition, the foundations of some conservation projects by nongovernmental groups—such as the Wildlands Project whose mission is to "help protect and restore the ecological richness and native biodiversity of North America through the establishment of a connected system of reserves"—rest on many principles established under the broader concept of ecosystem management (for review, see Wild Earth 1995/1996). By prioritizing birds in relation to other natural resources defined in ecosystem management plans, including commodity, cultural, and recreational resources, the commitment of a greater number of stakeholders and disciplines can be gained.

A potential way to maximize benefits to multiple species is through management of high-priority ecosystems. Noss and others (1995) advocate conservation of endangered ecosystems, defining an ecosystem as any assemblage of species and/or habitat features that can be classified at some hierarchical level and delineated on a map. Mappable ecosystems, according to Noss and others, encompass physical habitats, vegetation types, plant associations, and natural communities defined by ecological factors such as age, structure, species composition, geography, and condition. In their review, Noss and others concluded that of the ecosystems showing declines of 70% or more since European settlement, highest losses were among forests and wetlands, followed by grasslands, savannas, and barrens. However, the list of critically endangered ecosystems—those that have declined by more than 98%—is headed by savannas, grasslands, and barrens. This suggests that management strategies which focus exclusively on forest ecosystems and ignore native nonforest ecosystems, regardless of whether the management scale is local, regional, national, or international, are inadequate for conserving total biological diversity of a given area. Nevertheless, forest ecosystems that are endangered should be emphasized in conservation. By ranking ecosystems based on extent of decline, present area or rarity, imminence of threat, and number of threatened and endangered species, Noss and others (1995) identified 21 ecosystems as highly endangered, including the following 11 ecosystems dominated by forests:

- Southern Appalachian spruce-fir forest
- Longleaf pine forests and savannas
- Southwestern riparian forests
- Hawaiian dry forests
- Large streams and rivers (including their riparian forests)
- California riparian forests
- Old-growth eastern deciduous forest
- Old-growth forests of the Pacific Northwest
- Old-growth red and white pine forests
- Old-growth ponderosa pine forests
- Southern forested wetlands

Management strategies that focus on umbrella species, e.g., those with large territories or home ranges such as the Spotted Owl (*Strix occidentalis*), also can be designed to conserve multiple species, including NTMBs (Foreman 1995/1996). Conserving umbrella species usually translates into managing for large, contiguous blocks of habitat and travel corridors; such areas frequently encompass the habitat and seasonal needs of numerous smaller species, some of which also may be identified as endangered or of high priority. If carefully designed, the recovery plans for umbrella species, many of which are large, threatened, or endangered carnivores, could protect numerous NTMB species, endangered ecosystems, and regional biological diversity as a whole.

Regional and Subregional Levels

At regional and subregional scales, multi-forest, statewide, multi-agency, and/or multi-owner analyses and assessments are necessary. Consequently, land managers should be familiar with historical forest cover, current condition and extent of the forest, and ownership patterns in the region and subregion in which their holdings are located. Spatial patterns of ecosystems as well as the ranges of birds within the region should be identified. Regional and subregional plans should establish objectives for the amount, distribution, and pattern of vegetation types taking into consideration the above factors. We recommend that land managers view land holdings in a regional context to determine where they best fit into regional and subregional plans. For example, we know that many forest-associated species of migratory birds are sensitive to forest fragmentation (Whitcomb and others 1981; Lynch and Whigham 1984; Wilcove 1985; Robbins and others 1989a). Thus, a regional goal might be to maintain large tracts of relatively undisturbed or older forest in close proximity to other forest fragments (e.g., Robbins and others 1989a) or to tie into large region-wide systems of interconnecting forested habitats that encourage movement of birds within appropriate habitats (Harris 1984; Saunders and Hobbs 1991). We recommend that travel corridors be as wide as possible to discourage invasion of the corridor interior by edge predators and cowbirds. Information sources currently available are shown in the Appendix.

Conservation priorities are being developed for bird species at state, subregional, and regional levels (Carter and Barker 1993; Carter and others, this proceedings; Hunter and others 1993a,b; Rosenberg and Wells, this proceedings, 1995; Smith and others 1993; Thompson and others 1993a). Managers should consider these priorities when setting ownership objectives, and should determine the relative contributions of the region and subregion to the national or global sustainability of these resources. Managers also should recognize and incorporate the distribution and population trends of bird species on a physiographic level. For example, data from the North American Breeding Bird Survey (Peterjohn and others 1995) are available to examine population trends by physiographic regions. Partners in Flight regional coordinators should have this information for land managers to use.

Landscape Level

At the landscape level, we suggest that managers address objectives for assemblages of birds on landscapes that are thousands or perhaps tens of thousands of hectares in size. Objectives of regional plans should be considered to help tie various landscape approaches together. Landscape objectives should reflect forest types (plant species composition, successional age, vegetation structure, habitat heterogeneity); patterns of habitat across the landscape (patch configuration and shape, patch size, distance between patches, amount of nonforest edge, juxtaposition of habitats); feasibility of alternatives (including site quality and potential); and forest cover (historical, current, and possible future). Nonforest land also should be part of the assessment. Objectives that incorporate activities and goals of neighboring landscapes should be integrated into the regional and subregional framework or context. Considerations at the landscape level should include minimum area requirements for forest interior and area-sensitive species as well as the needs of edge species. Maintaining biodiversity should be a priority and can be achieved by incorporating configurations (distribution, size, type of patches) designed to mimic natural disturbance regimes caused by fire, climate, and insect infestations.

Public lands in the continental U.S. make up about 30% of the total land base (Miller 1988). Consequently, public forests often are surrounded by diverse mosaics of private lands including small and large tracts of forested, nonforested (agricultural, industrial use, residential use, etc.) areas. These non-dominant land uses and/or nonforested land uses must not be neglected when evaluating objectives for the landscape. Land managers must consider management activities not only within their own land boundaries, but also land use practices and decisions outside their lands that may influence the landscape. To meet landscape-level objectives as specified in regional plans, cooperation and coordination of all ownerships across the landscape are essential. Maps that display configuration information such as size, type, and distribution of habitat patches in the landscape will aid in planning across ownerships.

The knowledge of land composition in terms of number and types of land uses and physiognomy (spatial arrangements of land uses as discussed by Dunning and others [1992])is critical, as lands can have similar composition but vary in physiognomy. The composition of the surrounding landscape mosaic will help determine how much and what types of timber and wildlife management practices are feasible within the forest boundaries. The landscape pattern will determine where within those forest boundaries those practices are best implemented. Therefore, managers should incorporate the dynamic nature of the landscape into management plans, so that a certain proportion of land is maintained in each desired habitat type, even if the locations of those habitats change with time (see Harris 1984, p. 127-144). Landscape-level management requires understanding the structure (composition and arrangement of elements) and function (characteristic ecological processes or habitat values) of the area surrounding the management area, and appreciating how these features might vary spatially and temporally. Landscape studies can form a bridge in the spatial hierarchy between habitat studies that focus at the stand scale and larger scale regional and biogeographical studies (Freemark and others 1995).

Ownership Level

At the ownership level, ownership configuration including patch sizes, composition, structure, and location must be determined. Once the configuration is established, then opportunities for managing birds in this ownership can be assessed. Such management should include establishing goals for target amounts of forest type, forest age-class, and vegetation structure that incorporate vertical and horizontal components. By considering constraints that may exist for the property such as deer use, insect infestation, current timber market, and local and federal regulations, the landowner will determine which objectives and management strategies are viable, and can make an informed selection. Land management of individual ownerships should be coordinated with other ownerships and objectives whenever possible. Private landowners can have a definite role in forest bird conservation within the context of their land ownerships and management objectives (Wigley and Sweeney 1993).

Stand Level

Stand-level management requires that bird inventories and vegetation analyses be conducted for the stands under consideration. Standards for conducting bird inventories have been developed, including the design and implementation of a monitoring program to help assess output of the management activities (Ralph 1992; Manley and others 1993). The context of the stand in relation to the local landscape should be evaluated to help determine the objectives for the stand. The manager should incorporate current knowledge of the effects of various silvicultural treatments relating to stand-level effects on birds (DeGraaf and others 1993; Dickson and others 1993; Hutto and others 1993; Thompson and others 1993a) and temporal versus spatial scale factors. Managers need to be cognizant of new information on bird habitat requirements and habitat relationships. Stand-level decisions should be made in the context of other factors such as ownership, land condition and potential, and constraints. Alternatives need to be assessed by considering the objectives that have been established for the landscape.

Tools

Numerous resources are available to the manager to aid in evaluating strategies and alternatives for NTMB conservation. Several major proceedings that provide valuable insight into the ecology and management of NTMBs and include articles on forest-associated species recently have been published (Martin and Finch 1995; Finch and Stangel 1993b; Hagan and Johnston 1992). Regional references also are available such as Hamel (1992b) for the Southeast, DeGraaf and Rudis (1986) and DeGraaf and others (1992) for the Northeast, and Dobkin (1992) for the Northern Rockies and Great Plains. Hamel provides a qualitative assessment of bird-habitat relationships by identifying the suitability of broadly defined seral stages (grass/forb, shrub/seedling,

sapling/poletimber, sawtimber) for land birds found in each forest type in the Southeast. Habitats are considered optimum, suitable, or marginal for each bird species. Hamel also provides appendices with a list of species and the forest interior conditions they require (e.g., big trees, forest interior, extensive forest, and minimum tract size). Managers can use such references to help define desired future conditions that are necessary to support high priority species (appendix).

Examples

If the manager has a forested area that is surrounded by heavily urbanized or agricultural land, he/she may want to plan a lower impact use such as uneven-aged harvesting or perhaps limited recreational activities rather than a higher impact use such as even-aged management, if the primary objective is to manage for forest-dwelling birds. In a situation where the surrounding landscape is highly forested, a manager may be able to increase timber production and/or use even-aged harvesting methods, given that large expanses of forest are not limited in the landscape. A manager may want to consider aggregating harvested areas within the forest into compact shapes to minimize adverse edge effects (Franklin and Forman 1987; Robinson and others 1993). For most species we do not know the optimal size of cut areas within the forest matrix, and more work is needed to discover these relationships (Hunter 1987; Rudnicky and Hunter 1993). If an objective is to manage for early successional species, then maintaining large tracts of mature forest may offer insufficient habitat. In this situation, assessing the general habitat suitability of each landscape element outside of the management area is particularly important. Managers can then evaluate what is available and what may be lacking for high- priority species, whatever their habitat needs. Petit and others (1995) provide a detailed example of how a manager may proceed in the assessment.

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Appendix: Potential data sources for the landbird manager. For more comprehensive descriptions of bird databases, see Butcher and others (1993).

General Literature

University and governmental libraries

Scientific journals and magazines

Biological indices and annual reviews

University presses and other presses specializing in bird literature

Published proceedings of workshops and symposia

Final reports of agencies

Published and unpublished reports of nongovernmental organizations

Recent ornithological literature (supplement to The Auk)

Wildlife Review (U.S. Fish and Wildlife Service)

National Bird Databases

Bird Banding Laboratory (USGS)

Breeding Bird Survey (USGS)

Breeding Bird Censuses (Journal of Field Ornithology Supplements)

Christmas Bird Counts (National Audubon Society—American Birds)

Monitoring Avian Productivity and Survivorship Program (MAPS) (DeSante and others 1993)

BBIRD (Bird Breeding Biology Database) (BBIRD contact is Tom Martin, Montana Fish and Wildlife Cooperative Research Unit, University of Montana, Missoula, MT.)

Nest Record Program (Cornell Laboratory of Ornithology)

Local and Regional Bird and Habitat Inventories

Much of this information should be available in the future in a summarized format from the Partners in Flight Regional Coordinators.

Breeding bird atlases by state

GAP Analysis Project by state (USGS BRD, Scott and others 1993)

Environmental Monitoring and Assessment Program (EMAP) (Environmental Protection Agency, Preston and Rubic 1992)

USDA Forest Service
- Forest Inventory and Analysis (FIA)
- Continuous Inventory of Stand Conditions Program (CISC)
- Forest Health Monitoring Plots
- Wildlife Habitat Program
- Local Bird Monitoring Sites

State Natural Heritage Programs

State wildlife agencies

Various federal agencies (e.g., U.S. Fish and Wildlife Service, USGS-Biological Resources Division, Bureau of Land Management, USDA Forest Service, Bureau of Reclamation, Department of Energy, Corps of Engineers, Tennessee Valley Authority)

Bird observatories

Conservation organizations

Faculty at academic institutions

Agencies and organizations of Canada and Latin America

Private individuals

A Strategy for Maintaining Healthy Populations of Western Coniferous Forest Birds

Sallie J. Hejl

Abstract—Current knowledge of the distribution, habitat relations, and population trends of most birds inhabiting western coniferous forests is rudimentary, and the quality of knowledge varies among species and areas. Cumulatively, individual, correlative, research projects from the Rocky Mountains indicate that: Habitat changes due to recent logging practices are detrimental for most permanent residents and many migrants but are beneficial for other migrants; some species are positively affected by silviculturally induced landscape changes and some are negatively affected; and fire suppression negatively affects birds associated with habitats created by high- and low-intensity fires. Little is known, however, about the impacts of management practices on the demographics of particular species. In addition, U.S. Fish and Wildlife Breeding Bird Surveys (BBS) point out 10 western forest species that have declined in the past 24 years, but cannot indicate the causes of these declines. BBS data also are limited in that substantive information has been obtained for only 50% of western coniferous forest birds, and many of the birds most likely to be negatively affected by logging or fire management are not sampled well by BBS. Until we have more concrete, specific information on the effects of management on all species, I recommend a strategy to help maintain western coniferous forest birds. The strategy is composed of three stages: (1) to maintain, mimic, and restore natural vegetation patterns and processes, (2) to ensure that the specific habitat components required by sensitive species are created and/or maintained, and (3) to monitor the habitats and individual sensitive species in future years. This process is illustrated with an example from managers of the Lolo National Forest. Both logging and prescribed fire are used in this example to recreate natural vegetation patterns across a landscape which had been logged previously in many different ways. The three-stage process would be the same in other forest cover types elsewhere in the West, but the details of the management treatments used would differ depending on the natural vegetation, current condition, and the natural disturbance processes for that particular area. Finally, while all species found in western coniferous forests should be considered in the creation of the North American Bird Conservation Plan, I suggest particular attention be paid to declining species, uncommon species, and those negatively affected by logging and fire suppression.

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In developing a North American Bird Conservation Plan, many western coniferous forest birds and habitats emerge as high priority species and habitats based on particular review criteria (e.g., population trend information for each bird species; historic losses, current threats, and conservation potential for each habitat) and processes established by each State Working Group of Partners in Flight. To ensure the maintenance of healthy populations of forest birds, managers would need to know: (1) the current distribution of each species, (2) the current distribution of vegetation characteristics important to each species (e.g., age classes of each forest cover type, structural attributes such as snags and downed logs), and (3) the effects of all disturbance regimes—both human-induced and natural—on the distribution and demographics of each bird species within each habitat and in various parts of its geographic range. Managers are not likely ever to have more than a small amount of this information. This paper summarizes the current state of knowledge about coniferous forest birds in western North America and illustrates a management strategy that can help forest managers maintain healthy populations of western coniferous forest birds.

Current Knowledge About Western Coniferous Forest Birds

Knowledge of current distribution, habitat relations, and population trends of most western coniferous birds is rudimentary, and the quality of knowledge varies among areas (Hejl and others 1995). (I am not considering or reviewing information on the more-studied, known, or suspected threatened and endangered species.) Key information sources are individual research projects and the Biological Resource Division Breeding Bird Surveys (BBS). Both sources are valuable but both have limitations. Most research projects have examined the effects of disturbance regimes on bird species through correlative studies based on count data, not through examination of demographics or causality. In contrast, BBS is a monitoring program that indicates population trends and is not habitat- or treatment-specific.

Effects of Logging on Western Coniferous Forest Birds

Cumulatively, individual research projects indicate that some species are affected positively and some negatively by logging. This information results primarily from correlation analyses between bird presence or abundance on manipulated and non-manipulated habitats, primarily

forest stands. For example, reviewing literature on the effects of silvicultural treatments on forest birds in the Rocky Mountains, Hejl and others (1995) found that 26 species were less abundant in treated areas than in unlogged areas, whereas 15 other species were generally more abundant in the treated areas. Not surprisingly, species that were more abundant in unlogged areas were associated with mature and old-growth forests; almost all resident and about half the migrant species are in this category. Most species associated with logged areas are migrants, most of which are known to be associated with open conditions. In addition, in the Rocky Mountains, mature-forest associates generally appear to be less affected by partial logging than by clearcutting. The data to support this conclusion are not very robust, however, because few studies have examined the effects of logging other than clearcutting. Correlational studies in other areas, e.g., Raphael and others (1988) in northwestern Douglas-fir, also suggest that many mature forest species, such as bole-foragers, are negatively affected by logging, while open-forest species, such as ground/brush foragers, are affected positively. These results are consistent across habitats and geographic areas for some species—for example, White-breasted Nuthatch (*Sitta carolinensis*) and Brown Creeper (*Certhia americana*)—but not all, e.g., Townsend's Solitaire (*Myadestes townsendi*) and Hermit Thrush (*Catharus guttatus*) (Hejl 1994; Hejl and others 1995).

Knowledge of the effects of silviculturally induced landscape changes (e.g., from clearcutting, strip-cutting, and partial logging) on bird populations is even more rudimentary, although some good correlative studies have been conducted (Wetmore and others 1985; Rosenberg and Raphael 1986; Verner and Larson 1989; Lehmkuhl and others 1991; Keller and Anderson 1992; Hejl and Paige 1994; McGarigal and McComb 1995; Schmiegelow and others 1997). These studies show that some species are more abundant in fragmented areas, whereas some are less abundant. For example, in Douglas-fir forests in California, bird species richness increased significantly in more fragmented stands and 20 species were associated with edges; 18 species, however, avoided edges, and some species clearly showed negative responses to fragmentation, e.g., Spotted Owl (*Strix occidentalis*), Pileated Woodpecker (*Dryocopus pileatus*), and Winter Wren (*Troglodytes troglodytes*) (Rosenberg and Raphael 1986). Similarly to stand-based studies (Hejl and others 1995), 35% of the residents were associated with unfragmented forest interiors, whereas only 11% of migrants showed negative responses to fragmentation (Rosenberg and Raphael 1986). In cedar/hemlock forests in northern Idaho, 16 species were more abundant in areas fragmented by clearcutting, and 3 species—Brown Creeper, Winter Wren, and Golden-crowned Kinglet (*Regulus satrapa*)—were more abundant in continuous areas (Hejl and Paige 1994). In general, Brown Creeper (Keller and Anderson 1992; Hejl and Paige 1994; but see Rosenberg and Raphael 1986) and Winter Wren (Rosenberg and Raphael 1986; Lehmkuhl and others 1991; Hejl and Paige 1994; McGarigal and McComb 1995) are negatively affected by various types of fragmentation caused by logging, while Olive-sided Flycatcher (*Contopus borealis*) (Rosenberg and Raphael 1986; Hejl and Paige 1994; McGarigal and McComb 1995) and Pine Siskin (*Carduelis pinus*) (Rosenberg and Raphael 1986; Lehmkuhl and others 1991; Keller and Anderson 1992; Hejl and Paige 1994) are positively affected. These generalizations stem from count data from landscapes modified in many different ways, and provide only an indication of the importance of forest fragmentation to these species. Indeed, in most cases, teasing apart the effects of fragmentation, or changes in landscape pattern, from the effects of logging per se is difficult.

In contrast to these correlative studies, Schmiegelow and others (1997) used an experimental approach to understanding changes in bird numbers in response to changes in landscape patterns. Comparing pre- and post-harvest measurements of bird populations in old, boreal mixed-wood forests, these researchers found that fragmentation had a significant negative effect on seven species in isolated fragments (isolated by clearcutting on all four sides) and six species in connected fragments (isolated on three sides by clearcutting with the fourth side connected to a riparian buffer strip). In contrast, fragmentation has a positive effect on three species in isolated and two species in connected fragments. Many species were temporarily crowded into isolated fragments for one year after the treatment. Considering this, some of the species that seem positively affected by fragmentation in many of the correlative studies mentioned above may also be exhibiting this initial crowding effect, and may actually be negatively affected by fragmentation in the long-term (also suggested by Rosenberg and Raphael 1986).

We are just beginning to understand the relationships between western forest birds and silviculturally induced changes in landscape patterns from these few correlative studies and one experimental study. As McGarigal and McComb (1995) and Schmiegelow and others (1997) acknowledged, all of these results must be interpreted within the scope and limitations of each study. For example, in the study of Schmiegelow and others, the fragmentation experiments were embedded in a landscape where large areas of old, mixed forest are still available, potentially dampening any local-scale impacts. Landscape studies conducted at different landscape scales and embedded in different matrices are even harder to generalize from than stand-level studies.

These generalizations about the effects of logging on birds result from pooling data across coniferous forests and are based on a relatively small number of correlative studies measuring bird presence and abundance in various habitats (e.g., 19 stand-level studies about logging in the Rocky Mountains). Little is known about the specific relationships between birds and logging. At best, correlative studies provide an indication of how bird densities would be affected by habitat manipulation, but such studies cannot reveal the actual processes involved in any noted changes.

Indeed, if a species is consistently absent from manipulated areas that it occupied prior to the manipulation, for example, when many studies are compared as in Hejl and others 1995, then that species probably has been negatively affected by that manipulation. But, on any one particular study, an absent species also could have been affected by another manipulation in the landscape, or affected cumulatively by several manipulations of which this manipulation was just one, or simply could be exhibiting natural population fluctuations (Hejl and others 1988). We are

even less certain if change in density reflects changes in its demographics (via nesting success, overwinter survival, and so forth; see Tobalske 1992; Hitchcox 1996; Hejl and Holmes, this proceedings). It is clear, however, that a substantial change in the distribution or habitat use of a species in response to a treatment is just as important as its demographics. We need all three sets of information (distribution, habitat use, and demographics) to know how to maintain species, and we have little information on distribution and habitat use, and almost none on demographics, for most western forest birds.

Effects of Fire on Western Coniferous Forest Birds

Forest fires are the primary agent of natural disturbance in the West; birds, therefore, evolved with forest fires. Understanding the effects of fire on birds is difficult, because fires vary in intensity, duration, frequency, location, shape, and extent, and few studies have been conducted in burned habitats (Hejl and others 1995). High-intensity fires often create habitat for primary and secondary cavity nesters. In the Rocky Mountains, woodpeckers (migrants and residents), flycatchers (migrants), and seed-eaters (migrants) all benefit from the habitat created by high-intensity fires one to two years after the fire (Hutto 1995). Moderate- and low-intensity fires show less dramatic immediate effects (Hejl 1994). Low-intensity fires may be most important in maintenance of park-like forests, resulting in habitat for birds that prefer open forest, e.g., Purple Martin (*Progne subis*). Because overall acreage burned has declined—for example, the acreage burned by low-intensity fires has declined by at least an order of magnitude in many forest systems (McKelvey and others 1996)—it is reasonable to assume that bird species associated either directly with fires, or with fire-maintained forest structures, have been negatively affected by fire suppression.

Salvage logging of burned forests can further increase or decrease the quality of burns for individual bird species. American Kestrel (*Falco sparverius)* and Lewis' Woodpecker (*Melanerpes lewis*) may benefit from partial logging (Saab 1997), and Tree Swallow (*Tachycineta bicolor)* may benefit from clearcutting when a few snags are left behind (Caton 1996). Many cavity nesters, however, may be negatively affected by logging, as demonstrated in the following studies: Eight species nested in partially logged but not in clearcut post-fire forests (Caton 1996); few Black-backed Woodpeckers (*Picoides arcticus*) and Three-toed Woodpeckers (*P. tridactylus*) nested in the partially logged portions of burned forests, whereas many did in unlogged portions (Hitchcox 1996; Saab 1997; Hejl, unpublished data); and nesting success for Northern Flickers (*Colaptes auratus*) was lower in logged than in unlogged burns (Hitchcox 1996).

Population Trends of Western Coniferous Forest Birds

In contrast to habitat-relationship studies, population trend data derived through BBS point out 10 forest species that likely have declined in the past 24 years (e.g., Band-tailed Pigeon, *Columba fasciata*, and Olive- sided Flycatcher), but do not indicate how or why these birds have declined (Hejl 1994). BBS data are limited also in that substantive information has been obtained for only 50% (57 of 113) of western coniferous forest birds. Many of the species that are most dramatically and negatively affected by many forms of logging and/or the absence of fire, for example Black-backed Woodpecker (Hutto 1995), Pileated Woodpecker (Bull 1987; Raphael and others 1988), Purple Martin (Brawn and Balda 1988), and Brown Creeper (Keller and Anderson 1992) are inadequately sampled by BBS and therefore not monitored by this program. Unfortunately, simply adding more BBS routes does not solve this problem for most of these species, 51 of which are found in such low densities, or have such low detectabilities, that population trends cannot be derived from BBS data (Hejl 1994). Current BBS statisticians recommend analyzing only those species whose average detections are greater than or equal to 1.00 detection/route (John Sauer, personal communication), and these 51 species currently average less than this level. Sampling optimal habitat for these species may help us to determine trends for some of them, but that approach is unlikely to determine this information for all. While the continued existence of old-growth forests, snags, burns (especially unlogged burns), and interior forests probably is very important for the maintenance of many species (Hejl 1994), our current monitoring programs often do not adequately sample these habitats or the species about which we should be most concerned.

A Strategy for Maintaining Healthy Populations of Western Coniferous Forest Birds

This strategy is a three-stage management process for maintaining western coniferous forest bird populations: (1) Maintain, mimic, and restore natural vegetation patterns and processes, (2) ensure that the specific habitat components required by sensitive species are created and/or maintained, and (3) monitor the habitats and individual sensitive species in future years. The process is based on the idea that we do not know every habitat requirement for every species, but we can assume that species present today evolved under natural processes in natural habitats, and that by preserving these processes and habitats, we should be able to maintain healthy populations of the species that are associated with them.

The first stage includes three steps: (a) Maintain all habitats, for example forest cover types and successional stages, and all habitat components, for example snags, (b) strive to mimic presettlement ("natural") proportions and distributions of forest types, successional stages, and habitat components, either by retaining or restoring them within their range of variation, and (c) allow or reintroduce natural disturbance patterns, for example, let fires burn or use prescribed fire, leaving many burned areas unlogged (Hejl and others 1995). Sweden has recently begun using a similar strategy in boreal forests (Fries and others 1997). The second stage entails comparing the proposed future vegetation to the needs of each sensitive species (as determined by an examination of the literature) that would potentially use

habitats in the area, and ensuring that an adequate amount and kind of vegetation remains or is created. The third stage is to use standardized methods to monitor the habitats and sensitive species in an area, preferably before and at several-year intervals after the treatments are applied.

A Case Study

The following description of the strategy in operation on the Lolo National Forest (LNF) is an example for a forest in which I have worked, and for which I know the ecosystems well. Application of the strategy, however, should be the same on any area. If the natural patterns in a given area differ from my example, then the patterns in the target area should be mimicked. The strategy does not imply that one type of habitat is superior to another, for example, that old growth is more important than early successional habitat. Rather, the strategy strives to maintain each type of habitat in a proportion similar to its historical existence.

The LNF is using this strategy for a timber sale in the Moccasin Ecosystem Management area (J. M. Hillis, personal communication, Lolo National Forest, Building 24, Fort Missoula, Missoula, MT 59801). The area is composed of three coniferous cover types. Much of the lower elevation is covered with ponderosa pine (*Pinus ponderosa*)/Douglas-fir (*Pseudotsuga menziesii*) forests. These pine/fir forests last underburned in 1919, and most of the largest trees were cut in 1960. The existing forest is fairly young. The middle elevation is covered by Douglas-fir/western larch (*Larix occidentalis*) forests. These were underburned in some areas and had stand-replacing fires in others, with the last fires in 1910 and 1919. Big trees were selectively logged out over the years. Patches of young Douglas-fir and young western larch remain, with some large larches spread in pockets throughout the area. The upper elevations are mainly lodgepole pine (*Pinus contorta*), in which many fires occurred in the 1800s and 1900s, until 1919. Much of the area was clearcut in 40-acre patches in 1970.

Based on the literature and current and old (1937) aerial photos, managers on the LNF compared the vegetation patterns that exist today with patterns they believed to occur historically. They determined that forest composition and structure in all three areas likely varies from presettlement times, and from what would exist today had these areas been governed solely by natural processes. Based upon presettlement patterns, the lower elevations were covered primarily with large stands (hundreds to thousands of acres) of old-growth ponderosa pine, which underburned every 5 to 25 years (Arno 1976; Arno 1980; Gruell and others 1982; Gruell 1983; Arno 1988; Hejl 1992; Losensky 1993; Arno and others 1995a). The middle elevations consisted of a mixture of even-aged and uneven-aged Douglas-fir and western larch, with scattered stands of large larch throughout. Fire frequency varied from 15 to 80 years, and from low to high intensity, with patch sizes varying from fairly small to fairly large depending upon local topography (Arno 1980; Barrett and others 1991; Hejl 1992; Losensky 1993; Barrett 1994). The upper elevations were composed of a mosaic of primarily young lodgepole pine stands of varying sizes and shapes. High-intensity fires most likely occurred every 20 to 200 years and ranged from 100 to 1,000 acres (Arno 1980; Barrett and others 1991; Losensky 1993; Barrett 1994). All of the areas would have more standing dead trees (snags) and large downed logs than they do now had natural processes been allowed to continue.

For the first stage of the strategy, the suggested treatments were: (1) Lower elevations: Remove much of the Douglas-fir, but leave some large Douglas-fir; leave any large- or medium-sized ponderosa pine; and underburn periodically to encourage the recreation of parklike old-growth ponderosa pine stands. (2) Middle elevations: Remove some pole-sized Douglas-fir and thin the pole-sized larch to encourage some patches of parklike old-growth larch stands. (3) Upper elevations: Burn the entire area as it stands without logging it.

For both economic and political reasons, a compromise approach actually was employed for the upper elevations: Log large lodgepole pine from the leave strips of highly fragmented areas; leave the medium and small trees; and then burn the entire landscape to recreate a large, early seral community with much standing dead and downed woody debris.

Restoring or recreating "old-growth" ponderosa pine in the lower elevations requires manipulation (Arno and others 1995b; Arno and others 1995a)—both logging of understory trees and conducting periodic prescribed burns. Decades of fire suppression have changed the natural disturbance patterns and have allowed the build-up of duff and understory Douglas-fir. In general, historically and currently, old-growth and younger ponderosa pine forests require frequent, periodic underburns to favor ponderosa pine over Douglas-fir. Not all old-growth or young forests would require this level of manipulation to recreate presettlement patterns. Other old-growth forests, for example western redcedar (*Thuja plicata*)/western hemlock (*Tsuga heterophylla*), and some northern Pacific Northwest Douglas-fir do not require the same frequency of underburns to retain their character (Arno 1980; Hemstrom and Franklin 1982; Agee 1991) and are not likely to require logging of any sort. Also, as much or more early successional habitat exists now than did historically, so the concern on the LNF was to increase old growth, not early seral communities. That scenario may not always occur. If early successional forests are less common than historically, then this strategy calls for increasing those habitats.

Variation in treatment is an important concept in the mimicking of natural disturbance patterns and processes. While the maintenance of variation needs to be included in the treatment of each of these habitats, the maintenance of variation in stand age, stand structure, and patch size probably is particularly important in the middle-elevation larch/fir habitat in this case study.

For the second stage in this case study, the needs of three sensitive species were considered. Flammulated Owls (*Otus flammeolus*) require large ponderosa pine trees, large snags, pockets of Douglas-fir, and a fairly open stand (McCallum 1994a,b). Recreating old-growth ponderosa pine stands should meet these needs. Pileated Woodpeckers need large snags (especially ponderosa pine and larch in this area) (McClelland 1977; Bull 1987). Some snags exist but more are needed in the future at lower and middle elevations. Recruiting older stands of ponderosa pine and larch will meet this need in the long-term. Black-backed Woodpeckers may be

dependent on stand-replacing fires in the Rocky Mountains (Hutto 1995). Appropriate habitat will be created in the upper elevations by the large, landscape level fires, which will recruit fire-killed dead stands, as long as enough medium and large trees (for snag recruitment) or medium and large snags in suitable densities and patch sizes are left for nesting and foraging in the area.

For the final stage of the strategy, all habitats and the three sensitive bird species will be monitored in future years. Optimally, these animals would be sampled for presence/absence and abundance before the treatment, then, using the same methods, every few years after the treatment. The vegetation also should be monitored to see if the management methods used can successfully recreate presettlement patterns of forest types, successional stages, and habitat components.

In this example, based on information available at the time this management plan was created, mimicking natural vegetation patterns and processes appears to meet the known needs of the sensitive species in this area, some in the short-term, others in the long-term. In other cases, such mimicking may not meet the needs for specific sensitive species. Then, compromise prescriptions may be needed, in which natural disturbance patterns are modified to ensure that the specific requirements of sensitive species are provided. These modifications may be required if humans have recently created new habitats or microhabitats that are solely or preferentially used by some sensitive species, and which would not exist if the landscape were managed only to mimic presettlement patterns. Another issue would be if habitats are so greatly changed that natural conditions or proportions cannot be restored quickly or at all.

The proposed strategy is most applicable in relatively natural areas (where land use has not changed the land base to alternative uses, e.g., housing and agricultural land) and where adjoining landowners agree with the principles discussed above. It may be most applicable to western forests because they are extensive and publicly owned. In areas of alternative uses or where landowners do not agree with these suggestions, one alternate strategy is to learn the needs of each species and to try to maintain appropriate habitat for each. A second alternate strategy is to modify my suggestions and use just a portion of them (e.g., learn the needs of known sensitive species and maintain appropriate habitat for these species, or maintain a certain number of natural structures per unit area), resulting in less certain effects (e.g., potentially missing the needs of those species that are sensitive, but which we do not recognize yet, or maintaining the appropriate distribution of a structure for one species, but not for others).

The principles of the strategy can be used on any land base. They are easiest to use at a large landscape scale, for example the basin level, depending on the natural scale of the patterns and processes involved. Plans could be made at the basin level, with individual projects being treated so they fit into the "big picture" of the desired landscape. Public and private landowners could form partnerships and work together using this strategy. Landowners could work together to decide how each could help to create the optimal landscape. In this process, each landowner could help provide a certain portion of each successional stage for each habitat, depending on what currently exists in their land base, what historically existed, and the economic needs of that landowner.

Because neither vegetative complexes nor the requirements of species are static (Hejl 1992), I suggest revising this strategy after habitats have been restored to more natural conditions. Managing for presettlement patterns provides for a short-term restoration of "natural" conditions, but it does not allow for the evolution of these habitats or species. Managing for process would allow for perpetuating patterns, but we cannot restore natural patterns via natural processes in many cases. Because we are constrained in our use of natural process, we need steps two and three to help us provide for the species most likely to be sensitive to our human-induced disturbances, and to make sure that this strategy is working. The concern of creating a static situation will have to be addressed in the future, once habitats are restored.

Finally, I advise moderation in following these recommendations. My suggestions are based on discussions with (and therefore often the intuition of) many naturalists, managers, and scientists, but they are not substantiated by data from designed experiments. I suggest manipulating only a portion of a habitat at a time, and then monitoring to see if desired outcomes are actually achieved (adaptive management). If the desired outcomes are not achieved, future management activities in these habitats should be designed differently.

Final Thoughts

Lubchenco (1995) suggested ingredients for useful communication of scientific information for constructing good policy to maintain biodiversity: What is known; the certainty with which it is known; what is not known; what is suspected; the limits of the science; probable outcomes of different policy options; key areas where new information is needed; and recommended mechanisms for obtaining high-priority information, for example, research or adaptive management. In the body of this paper, I have generally described what we currently know about the relationships between western coniferous forest birds and logging, fire, and fire suppression, and the limits of what we know. Additionally, I have suggested a management strategy, for implementation at the project level, that can be used until we find out more specifics on the effects of each management and natural process on each species, especially potentially sensitive species. I have not yet described the probable outcomes of different policy options; key areas where new information is needed; and recommended mechanisms for obtaining high-priority information, for example, research or adaptive management. Too many different policy options exist to enumerate all of the probable outcomes. Key areas where new information is needed include more information on the distribution, habitat use, and demographics of any species suspected to be sensitive to a particular logging practice or fire suppression, including knowledge at the landscape scale. We also need comparisons between the effects of land management practices (including the treatments used to mimic presettlement patterns) and natural disturbance patterns and processes

on forest birds. Information could be obtained either through research or adaptive management. Well-designed monitoring of management practices (adaptive management) can give us useful information; carefully constructed experimental studies (research), however, will be required to address many questions.

Besides the potentially declining species indicated by BBS (Hejl 1994), all of the knowledge described herein points to particular concern for two groups of western coniferous forest birds: Uncommon species, and species most likely to be negatively affected by logging and fire suppression (most resident species and many migrants). Both sets of species should be emphasized in the North American Bird Conservation Plan. Uncommon species are a concern because neither BBS nor individual research projects have good data on whether these species are declining and/or are affected by particular land management processes. Resident species as a group are of special concern because in general, they are negatively affected by many types of past logging and by fire suppression—the two most common practices by which humans have affected western coniferous forests. Resident species also may use these habitats year-round, and therefore may be more affected by our management treatments in the winter (potential population "crunch" time) than during summer. Therefore, I suggest that the plan carefully consider guidelines for uncommon and potentially sensitive species, especially residents. Further, while the monitoring of sensitive species on the project level was suggested in the three-step management strategy for individual projects, I also highly recommend large-scale, Westwide monitoring for all species, especially uncommon and potentially sensitive species, which would necessitate new emphases for rare, nocturnal, or otherwise poorly monitored species or habitats—50% of all forest birds—being included in the plan.

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Bird Conservation Planning in the Interior Low Plateaus

Robert P. Ford
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Abstract—The Interior Low Plateaus (ILP) is a 12,000,000 ha physiographic province that includes middle Kentucky, middle Tennessee, and northern Alabama. Spatial analysis of Breeding Bird Atlas data has been used to determine relationships between the nature of high priority bird communities and broad features of the habitat. A standardized vegetation classification using satellite imagery, Geographic Information Systems (GIS), GAP Analysis, and Breeding Bird Atlas data, were used to develop landscape-level habitat models for the ILP. The objectives of this effort were to: (1) identify centers of abundance for species and/or species assemblages within the ILP, (2) identify and prioritize areas for potential acquisition and/or public-private partnerships for conservation, (3) identify areas with the highest potential for restoration of degraded habitats, (4) identify specific lands managed by project cooperators where integration of nesting songbird management is a high priority, and (5) identify areas that require more intensive breeding bird inventories. Sites have been prioritized by each of the above objectives, as well as by each state agency for effective implementation.

Bird Conservation Areas (BCAs) can be identified over the landscape of a physiographic area using geographic information system (GIS) technology, breeding bird atlas data, Partners in Flight (PIF) species prioritization scores, and land management partnerships. The physiographic area is a useful geographic scale at which to set conservation and management objectives, because physiographic areas often have similar land forms and land uses, have similar bird distribution patterns and bird conservation needs, and transcend traditional political boundaries, such as state lines. The objectives of this paper are to describe the method we used for the first phase of bird conservation planning in a specific physiographic area—the Interior Low Plateaus (ILP)—and to present the results, including the identification of potential BCAs for bird species assemblages that nest in the ILP's mature hardwood forests, early successional forests or old fields, and open lands.

The ILP encompasses more than 12 million ha in southern Ohio, Indiana, and Illinois; central Kentucky; central Tennessee; and northern Alabama. The rolling topography of this area has been dominated historically by oak-hickory forests, with areas of rock outcrops and glade habitats, prairies, and barrens (Martin and others 1993). All habitats now are highly fragmented. Currently, this project includes only Kentucky, Tennessee, and Alabama; the remainder of the ILP will be incorporated later. Distinct subdivisions within the current scope of the project include the Bluegrass region and Shawnee Hills in Kentucky; the Western Highland Rim, Eastern Highland Rim, and Central Basin of Tennessee; and the Tennessee River Valley of Alabama (fig. 1). These subdivisions serve as distinct conservation planning units. About 95% of the land base consists of non-industrial forest lands, open lands for agriculture (pasture), and urban areas. Public lands and lands managed by the forest products industry make up less than 5% of the total area (Vissage and Duncan 1990).

The Tennessee Conservation League, state affiliate of the National Wildlife Federation, has served to facilitate PIF objectives in the ILP with leadership from state wildlife agencies and the forest products industry. A steering committee developed to provide oversight, direction, and implementation included representatives of the Alabama Department of Conservation and Natural Resources, Game and Fish Division; Champion International Corporation; Kentucky Department of Fish and Wildlife Resources; Tennessee Department of Environment and Conservation; Tennessee Conservation League; Tennessee Ornithological Society; Tennessee Valley Authority; Tennessee Wildlife Resources Agency; U.S. Fish and Wildlife Service; U.S. Forest Service; Westvaco Corporation; and Willamette Industries Incorporated. In addition, a technical working group was formed that included land managers and biologists from the above groups.

Methods

The first phase conservation planning objectives were (1) to identify centers of abundance for species and species assemblages by subdivision within the ILP, (2) to identify specific lands managed by the project's current cooperators where integration of nesting songbird management is a high priority, (3) to identify areas with the highest potential for restoration of degraded habitats, (4) to identify and prioritize areas for potential acquisition and/or public-private partnerships for conservation, and (5) to identify areas that require more extensive breeding bird inventories.

Tools and Information

The conservation planning objectives were accomplished by using the best available information from vegetation maps generated by interpretation of satellite imagery from

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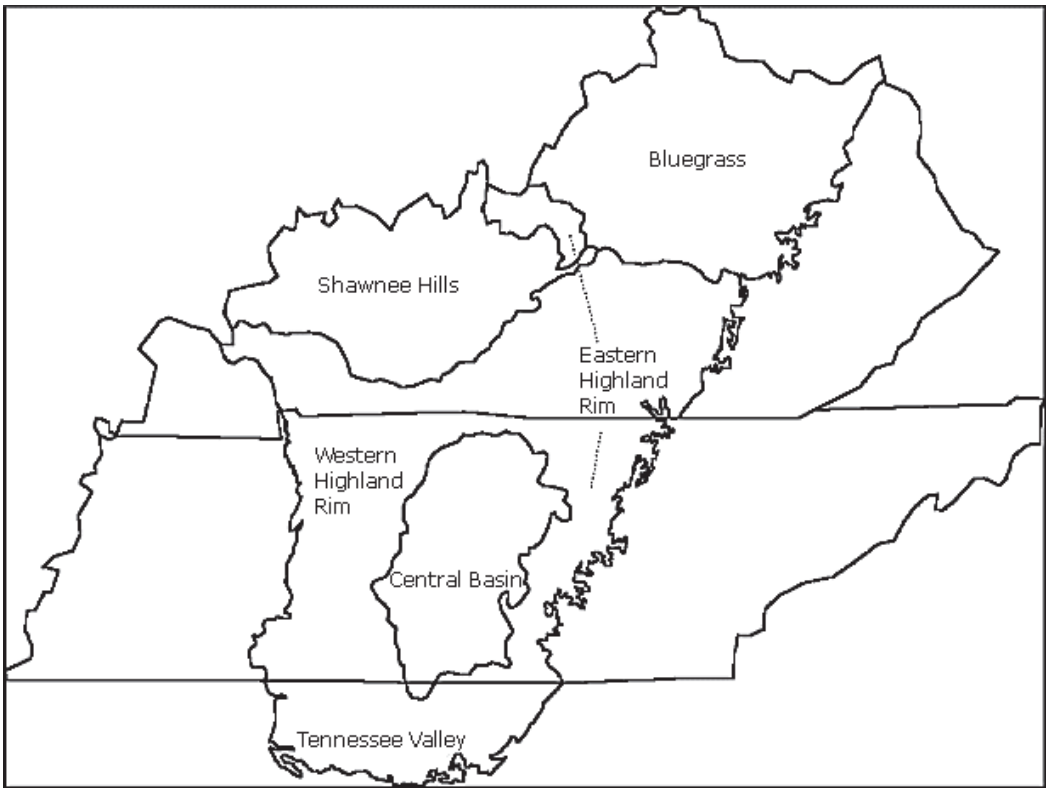

Figure 1—Interior Low Plateaus and its subdivisions in Kentucky, Tennessee, and Alabama.

the Landsat Thematic Mapper; data from each state's breeding bird atlas; PIF species prioritization values (Carter and others, this proceedings); and known boundaries from public and private cooperators' lands. This process was modified from the Gap Analysis protocol (Scott and others 1993). A standard vegetation classification and habitat patch size distribution, including areal coverage and spatial location information, were fundamental layers of information. For this planning phase, the satellite imagery was processed using GIS (ARC INFO) to provide broad landcover categories that included deciduous forest, coniferous forest, mixed forest, wetlands, agriculture, open water, and urban areas. These analyses were completed in Tennessee by the Tennessee Gap Analysis (Jones and others 1995) and Biodiversity (Reid 1993) projects, and in Alabama by the Tennessee Valley Authority. This process is not complete in Kentucky, although Gap Analysis has been initiated by the Kentucky Department of Fish and Wildlife Resources and Murray State University.

Breeding bird distribution and relative abundance were documented in the ILP by breeding bird atlas projects in each state. Tennessee (Nicholson, in press) and Kentucky (Palmer-Ball 1996) have completed breeding bird atlas projects; observers have completed about 70% of the coverage for a breeding bird atlas in northern Alabama. Generally, these atlas projects followed national protocols. One breeding bird atlas block was designated for a sixth of each of 820 USGS 7.5 minute topographic maps in the ILP. During the atlas periods, over 95% of the atlas blocks were completed. For this analysis, we used breeding bird atlas information from 810 of the topographic maps. Vegetation maps based on GIS technology were available for all of middle Tennessee and northern Alabama, but not available for most of Kentucky at the time of this analysis. Although the coverage for breeding bird atlas and vegetation mapping were incomplete at the time of this writing, the analysis has provided preliminary results, clarification for future planning needs, and a test of the process. Although observer effort differed among states, results provided sufficiently consistent data for this process in the ILP. Breeding bird species, bird species assemblages, and habitats were prioritized using the PIF concern scores for the ILP (Hunter and others 1993a; Carter and others, this proceedings). Finally, the boundary maps of current cooperator lands were included in the GIS.

Conservation Planning Process

Of the 15 species for which prioritization scores exceeded 23 in the ILP, six species were typical of mature hardwood forests, six of old fields and early successional forests, and three of open lands. To more fully represent these habitat types, we selected a species assemblage that included species with concern scores of 19 or above. Birds within each assemblage were selected to represent different habitat conditions within the broad habitat category, and loosely followed management assemblages as described by Block and others (1995).

Three bird species were chosen to represent the species assemblages within each of three broad habitat groups (table 1). The mature hardwood forest bird species assemblage was represented by Cerulean Warbler, Worm-eating Warbler, and Black-and-white Warbler. Both Cerulean Warbler and Worm-eating Warbler were of high concern score for PIF (Hunter and others 1993a); although Black-and-white Warbler scored of moderate concern, this species was included because of its area sensitivity (Hamel 1992b). The early successional forest and old field bird species assemblage was represented by Prairie Warbler, Blue-winged Warbler, and Yellow-breasted Chat, all of which scored 23 or above. The open lands bird species assemblage was represented by Grasshopper Sparrow, Dickcissel, and Loggerhead Shrike, all of which scored 23 or above. Nine additional species that were too rare or locally distributed to fit into a species assemblage were listed for single species management or monitoring priority.

Breeding bird atlas blocks were then identified in which at least two of the three species of each assemblage had been recorded. Each of the blocks were placed in one of four conservation planning categories based on proximity to cooperator lands, inventory needed, and landscape habitat characteristics. These categories were designed to set direction for management and maintenance of existing populations on or near current cooperator lands, and to identify additional locations where management or restoration of habitats will be a priority.

The first category includes atlas blocks on which all three species of the assemblage were recorded and cooperator lands are present. The conservation objective here is to work with traditional land management objectives to sustain or increase target populations. The second category includes atlas blocks on which all three species in the assemblage occur and cooperator lands are nearby; that is, no more than three atlas blocks (12 miles) away. The conservation objective here is to identify the best opportunity for public-private partnerships to increase core bird populations. The third category includes atlas blocks on which all three species occur and vegetation maps indicate that habitat cover will sustain populations, yet the block is far-removed-from cooperator lands (greater than three atlas blocks away). The conservation objective here is to conduct further bird inventories and to search for opportunities for public-private partnerships. Conservation and management actions include an increased opportunity for biologists and land managers to cooperate with nearby landowners to investigate populations and recommend management options to sustain or increase the sizes of core populations. The fourth category includes atlas blocks on which only two of the three species within an assemblage were recorded, and which are far removed from cooperator

Table 1—(A) Species assemblages selected for each of three broad habitat types in the Interior Low Plateaus physiographic province and; (B) bird species of single species management or monitoring priority. The number represents the Partners in Flight concern score in the Interior Low Plateaus (Hunter and others 1993).

A. Species assemblage	Scientific name	Concern score
Mature hardwood forest		
Cerulean warbler	*Dendroica cerulea*	28
Worm-eating warbler	*Helmitheros vermivorus*	23
Black-and-white warbler	*Mniotilta varia*	20
Early successional or old field		
Blue-winged warbler	*Vermivora pinus*	25
Prairie Warbler	*Dendroica discolor*	27
Yellow-breasted Chat	*Icteria virens*	23
Open lands species assemblage		
Loggerhead Shrike	*Lanius ludovicianus*	24
Dickcissel	*Spiza americana*	23
Grasshopper Sparrow	*Ammodramus savannarum*	25
B. Single species priorities		
Species scoring >24, site-specific management recommendations		
Swainson's Warbler	*Limnothlypis swainsonii*	25
Bewick's Wren	*Thryomanes bewickii*	30
Henslow's Sparrow	*Ammodramus henslowii*	25
Bachman's Sparrow	*Aimophila aestivalis*	24
Species scoring 19-23, site-specific monitoring recommendations		
Black-billed Cuckoo	*Coccyzus erythropthalmus*	22
Bell's Vireo	*Vireo bellii*	22
Sedge Wren	*Cistothorus platensis*	23
Lark Sparrow	*Chondestes grammacus*	21
Willow Flycatcher	*Empidonax traillii*	20

lands. The conservation objective here is to prioritize for further bird inventory and monitoring.

Conservation plans for priority atlas blocks that are far removed from any cooperator's land depend on whether two or three species in an assemblage have been recorded there. Blocks having all three species, and where existing vegetation maps from GIS indicate that habitat patch size or land-use patterns would sustain populations of the species assemblage, will be prioritized for cooperative management agreements or incentive programs. Atlas blocks on which two of three species occurred, and where vegetation maps indicate that habitat size or land use is marginal to sustain populations, will be explored for restoration opportunities. Known locations of rare and locally distributed species (see table 1) will be prioritized for management or monitoring, and will be placed into one of the above categories as the planning process continues.

Results

The mature hardwood forest bird species assemblage (Cerulean Warbler, Worm-eating Warbler, Black-and-white Warbler) occurred in 46 of 810 (6%) atlas blocks in the ILP; two of these three species occurred in 72 of the 810 blocks (9%) in the region (fig. 2). This species assemblage was most common in the Western Highland Rim, which accounted for 50% of the blocks in which all three bird species of the assemblage occurred and 53% of those with at least two of the three bird species. The Eastern Highland Rim ranked second among subdivisions for the distribution of the mature hardwood forest bird species assemblage; approximately 11% of the atlas blocks with this assemblage occurred in Kentucky's Eastern Highland Rim.

The remaining hardwood species assemblage locations were scattered widely, often along the transition between subdivisions, commonly along a forested elevation gradient, such as between the Eastern Highland Rim and Cumberland Plateau. Other locations were at the edges of the Bluegrass Region and the Shawnee Hills and near the Ohio River or its tributaries.

Each atlas block with the mature hardwood forest species assemblage was assigned to a conservation category (table 2). Twelve atlas blocks were placed in the existing category, nine of which are in the Western Highland Rim. There were 16 atlas blocks with the bird species assemblage in the close-to cooperator category, 18 atlas blocks in the far-removed-from cooperator lands category, and at least two of three species occurred in 72 atlas blocks and were in the increased inventories category. The designation of blocks in the last two categories remains unclear because of the current lack of a GIS vegetation map in Kentucky.

The early successional or old field bird species assemblage (Blue-winged Warbler, Prairie Warbler, Yellow-breasted Chat) occurred throughout the ILP with nearly uniform frequency; observers recorded all three species in 126 of 810 (16%) atlas blocks. Two of three species occurred in 379 of 810 (47%) blocks (fig. 3). Approximately 43% of the 126 blocks that had all three of these birds are in the Western Highland Rim. Otherwise, the species assemblage was evenly distributed among the Eastern Highland Rim (17%), Bluegrass Region (17%), and Shawnee Hills (15%). The species assemblage occurred least frequently in the Central Basin

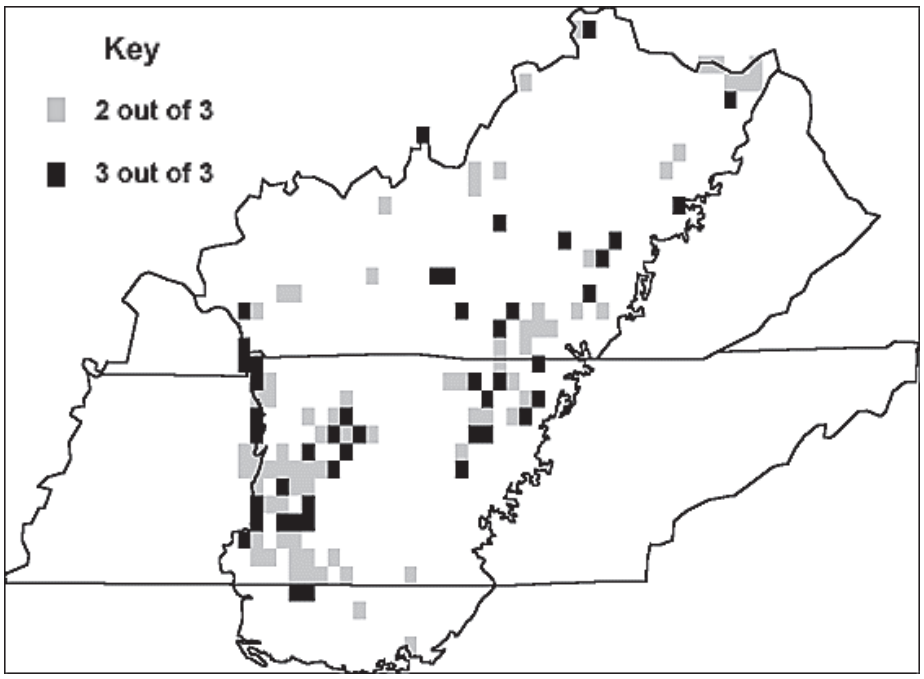

Figure 2—Mature hardwood forest bird species assemblage (CEWA, WEWA, and BAWW) distribution in the Interior Low Plateaus.

Table 2—Conservation categories defined with recommended conservation actions.

Category	Definition	Conservation action
Existing cooperators land	All three species occur in an Atlas block that includes cooperators lands.	Work with traditional management objectives for recommendation to sustain or increase local populations.
Close to cooperators land	All three species occur in an Atlas block within 12 miles (3 Atlas blocks) of cooperators land.	Identify best opportunity for public-private partnerships to increase core bird population area.
Far removed from cooperators land	All three species occur in an Atlas block greater than 12 miles from cooperators lands and vegetation maps indicate habitat patch size will sustain populations.	Prioritize for further bird inventories, opportunities for public-private incentive programs and partnerships for management.
In need of increased inventories	At least two of three species occur in an Atlas block and vegetation maps indicate patch size will not sustain populations.	Prioritize for further bird inventories, opportunities to restore habitat blocks with incentive programs and partnerships for habitat restoration.

(7%). Although these birds were widely distributed, notable gaps include much of the agricultural lands in the Tennessee Valley of northern Alabama, parts of the Shawnee Hills, the Western Highland Rim in Kentucky, and parts of the Bluegrass region.

Blocks were distributed evenly among existing, close-to cooperator, and far-removed-from cooperator conservation categories (table 3). Early successional forest or old field habitat was the only habitat for which the percentage of existing blocks was higher than that of the close-to cooperator category, probably because of the acreage and management of cooperating forest products industries. This species assemblage occurred in all subdivisions except the Tennessee Valley. The Western Highland Rim had the highest number of blocks with the species assemblage (21). The blocks in the increased-inventory category were widespread and occurred uniformly across the region.

The open lands bird species assemblage (Grasshopper Sparrow, Dickcissel, and Loggerhead Shrike) occurred on 108 of 810 blocks (13%); two of these three species occurred on 177 of 810 (21%) blocks (fig. 4). The 108 blocks where all three species occurred were most widely distributed in the Eastern Highland Rim and the Shawnee Hills (32% and 30% respectively), in Kentucky. The Western Highland Rim in

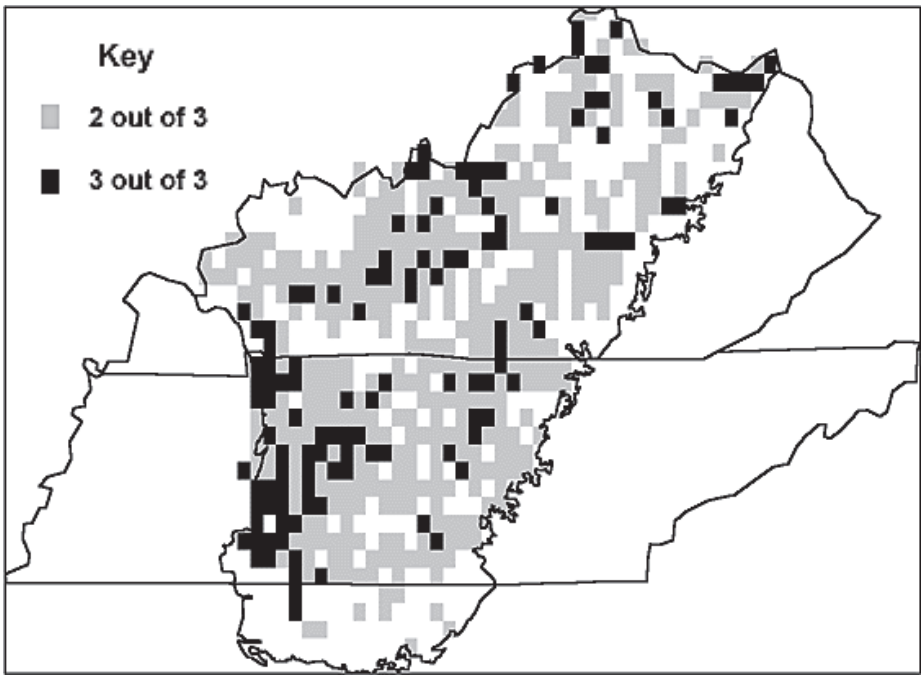

Figure 3—Early successional or old field bird species assemblage (BWWA, PRAW, and YBCH) distribution in the Interior Low Plateaus.

Table 3—Preliminary assignment of mature hardwood forest bird species assemblage to conservation categories by subdivision in the Interior Low Plateaus. In the existing category all three species occurred in a Breeding Bird Atlas block which also had cooperator lands. In the close to cooperator category, all three species occurred in a Breeding Bird Atlas block within 12 miles of cooperator lands. In the far removed category, all three species occurred in a Breeding Bird Atlas block greater than 12 miles from cooperator lands. In the category for increased inventory, two of the three species occurred in a Breeding Bird Atlas block. The objective of the process is to move the highest possible number of sites into the existing category through increased partnerships and cooperative land management.

	Shawnee Hills	Blue-grass	Western Highland Rim	Eastern Highland Rim	Central Basin	Tennessee Valley	Total
Existing	0	0	1	9	2	0	12
Close to cooperator	1	1	8	6	0	0	16
Far removed from cooperator	3	1	6	8	0	0	18
Increased inventories	4	11	37	20	0	1	73
Total	8	14	60	36	0	1	119

Kentucky had a relatively high percentage of the blocks with all three species (23%). The remainder of blocks for the open lands species assemblage occurred in the Central Basin of Tennessee and the Bluegrass Region of Kentucky. Areas containing historically prairie, barren, or glade habitats (see Martin and others 1993) were compared to atlas locations for this species assemblage. At least 29 occupied blocks occurred in the historical area of the Kentucky Barrens, four in Tennessee's Central Basin, and eight in Tennessee's barren habitats (a total of 41 or 38% of 108).

Sixteen (6%) of the open lands bird species assemblage blocks occurred in the existing-conservation category, 40 (14%) were in the close-to cooperator category, 52 (18%) in the far-removed category, and 177 (62%) in the increased-inventory category (table 4). Of the three broad habitat types, birds of the open lands species assemblage occurred the least frequently in atlas blocks with existing cooperators lands. However, the species assemblage occurred in five blocks with existing cooperators lands in the Shawnee Hills and in seven in the Eastern Highland Rim.

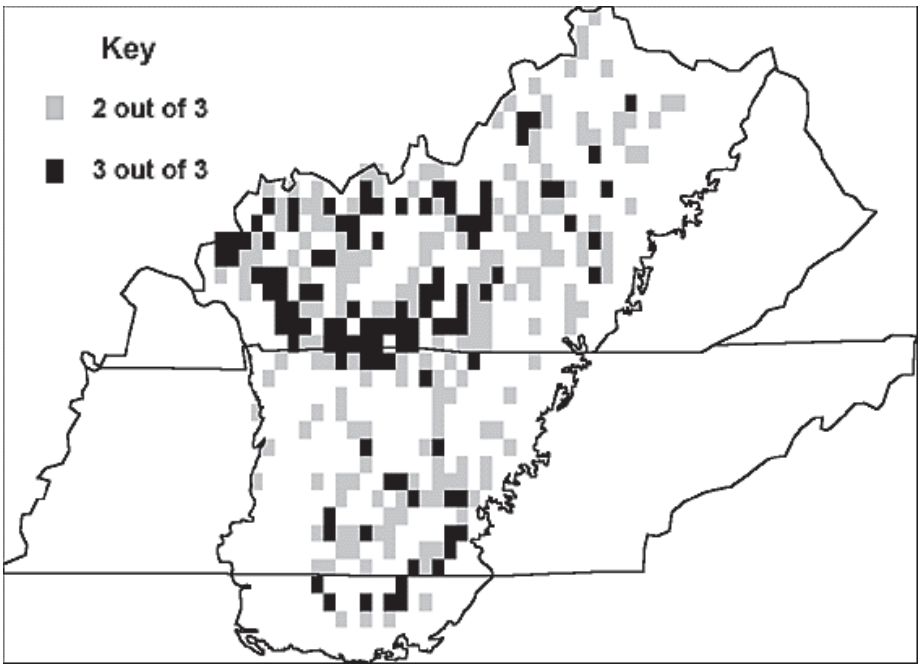

Figure 4—Openland bird species assemblage (LOSH, DICK, and GRSP) distribution in the Interior Low Plateaus.

Table 4—Preliminary assignment of old field and/or early successional forest bird species assemblage to conservation categories by subdivision in the Interior Low Plateaus. In the existing category all three species occurred in a Breeding Bird Atlas block which also had cooperator lands. In the close to cooperator category, all three species occurred in a Breeding Bird Atlas block within 12 miles of cooperator lands. In the far removed category, all three species occurred in a Breeding Bird Atlas block greater than 12 miles from cooperator lands. In the category for increased inventory, two of the three species occurred in a Breeding Bird Atlas block. The objective of the process is to move the highest possible number of sites into the existing category through increased partnerships and cooperative land management.□

	Shawnee Hills	Blue-grass	Western Highland Rim	Eastern Highland Rim	Central Basin	Tennessee Valley	Total
Existing	6	5	21	3	4	0	39
Close to cooperator	3	6	15	6	2	0	32
Far removed from cooperator	10	11	18	10	3	0	52
Increased inventories	78	61	71	104	65	3	382
Total	97	83	125	123	74	3	505

Discussion

Bird conservation planning for the PIF initiative has emphasized a multiple species as opposed to a single species approach (Finch and Stangel 1993b), a planning process to be developed by physiographic area (Hunter and others 1993b; Carter and others, this proceedings) with implementation by states (Williams and Pashley, this proceedings), and an approach to stop population declines before species become critically endangered. Within the ILP physiographic area planning unit, BCAs are continuous blocks of habitat of sufficient size and quality to support healthy populations of all of the birds within one of the three species assemblages. The conservation strategy for existing sites should be management and maintenance to sustain existing populations. Habitat restoration and consolidation will be required to turn marginal areas into functioning BCAs.

Bird species assemblages of three broad habitat types in the ILP were placed into conservation and management categories based primarily on geographic relationship to current cooperator lands. A conservation and management action was associated with each category. This process was designed to be hierarchical, with a goal to move the maximum number of areas into the "existing" category. Species assemblages that occur close to existing cooperators lands are higher in the hierarchy because of opportunities for targeted technical assistance programs. Areas harboring full species assemblages that are far removed from existing cooperator lands and areas in need of increased inventory, where only two of the three species of an assemblage occurred, will be examined for opportunities to maintain or create viable BCAs.

The mature hardwood forest bird species assemblage was the most limited in the ILP, which represented a dramatic reduction in recent years (Mengel 1965; Nicholson, in press; Palmer-Ball 1996). This species assemblage occurred most commonly in the Western Highland Rim of Tennessee, where a management and maintenance strategy has been undertaken to sustain existing populations and secure 50 sites across the landscape within 25 years. These areas are designed to be approximately 4,000 ha of forested lands, open to a variety of ownerships and forest land management, and are based on core bird populations. Management recommendations for cooperator lands integrate bird management into current management objectives of the cooperator (Ford 1995). Many of the areas within the Shawnee Hills, Bluegrass region, Eastern Highland Rim, and Tennessee Valley, where forest birds are fewer, will require habitat restoration and consolidation in order to achieve long term security. This species assemblage was not a historical component of the inner Central Basin avifauna (Ford and Hamel 1988).

The old field and early successional forest bird species assemblage was the most widespread in the ILP, most commonly on the Western Highland Rim. The relatively high number of atlas blocks where this and the mature hardwood forest bird species assemblage occurred reflects the existing managed forest landscape in this subdivision. However, increasing development from residential and other pressures will require a strategy to maintain forest cover in the Western Highland Rim. This strategy is being implemented by forest products industry cooperators who maintain patches of early successional forests in the context of large blocks of mature forest. This species assemblage occurred in certain successional stages of cedar glades and barrens as well, particularly in the Central Basin, and parts of the Shawnee Hills, where habitat maintenance and restoration will be recommended.

The open lands bird species assemblage was scattered primarily in the Shawnee Hills and Western Highland Rim of Kentucky and the southeast section of the Eastern Highland Rim in Tennessee and Alabama. Although these spe-

cies may have occurred infrequently in native prairies and glades of Kentucky (Palmer-Ball 1996), these locations reflect the historical distribution of barrens, prairies, and glade habitats, as well as an increase in pasturelands. The open lands bird species assemblage occurs infrequently on cooperator lands because the cooperators primarily manage forest lands. This species assemblage offers an opportunity to better manage areas that were historically prairies, barrens, or other open lands of the region. In addition, some habitat consolidation may be pursued to increase partnerships among landowners that manage large acreage of pasture lands.

The next steps in this process include:

- Increase field inventories to verify occurrences of species assemblages on current cooperator lands.
- Develop habitat management recommendations for cooperating land managers.
- Decide on criteria to prioritize areas for restoration and/or increased inventories.
- Test the predictive value of landscape habitat models for the occurrence of species assemblages.
- List the assumptions used in this planning process and develop them as research projects.
- Include nonbreeding birds in this process.
- Further coordinate project recommendations with existing state priorities for bird conservation, management, and monitoring.

Acknowledgments

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4. Population and Habitat Assessment: Monitoring Bird Populations Over Large Areas

Pileated Woodpecker

4. Section Overview—Population and Habitat Assessment: Monitoring Bird Populations Over Large Areas

John R. Sauer
Robert J. Cooper

Monitoring provides essential information about status and change in bird populations. For Neotropical migrant birds (NTMBs), the North American Breeding Bird Survey (BBS) has been particularly influential in documenting regional population change (e.g., Robbins and others 1989b), and often is cited as justification for management actions. However, as with most bird surveys, the design of the BBS, and the geographic scale of the information, often limits its use either in evaluating the response of bird populations to management, or in identifying causes of population change.

In the study of NTMB population change, limitations of the landscape-scale BBS data are all too apparent. Adequately documenting patterns of change in populations using survey data is often difficult due to controversy about methods and limitations of the count-based survey design (e.g., Böhning-Gaese and others 1993; James and others 1995; Sauer and others 1996a; Link and Sauer 1997). Also, analyses of population change from the BBS often end with frustrating statements about the survey's inability to establish causes of population change (e.g., Peterjohn and others 1995), clearly emphasizing the lack of linkages of the data collection to management. Many monitoring programs (1) are too poorly designed to allow us to adequately evaluate population change; (2) provide data collected at the wrong scale for appropriate management; and (3) are difficult to interpret unless their data are collected in a specific management context, for example, in conjunction with an experimental design or adaptive management. Developing additional monitoring programs, and fitting BBS information into management contexts, will improve our ability to understand bird population dynamics. The collection of monitoring papers in this volume outline some innovative approaches to gathering information using designs and scales appropriate for management.

Design of surveys, and connecting survey design to management objectives, is the primary concern of several of the papers. Johnson discusses some of the challenges associated with developing a local or regional monitoring program. Often, if objectives are not well defined before the survey is initiated, the results will not be useful for any objective. Methods need to be chosen appropriate to the stated objectives, and principles of experimental design must be followed if monitoring is to be used to assess the consequences of management activities. Nichols suggests that retrospective studies based on monitoring results often do not lead to "reliable knowledge." Instead, monitoring is most useful when incorporated into experimentation or adaptive management, in that it then allows us to evaluate population responses to management actions. Often, management for birds involves habitat management, and Twedt and Loesch advocate habitat monitoring using Geographic Information Systems as an essential element of bird conservation planning. Evans and Rosenberg describe their efforts to develop acoustic monitoring programs, and document some initial successes of the procedure.

Scale-specific monitoring and integration of monitoring programs is addressed by several papers. Sauer uses information from the BBS to argue that monitoring data often do not interpolate from regional to local scales, and that management needs at each scale require scale-specific monitoring. Sauer, Hadidian, Droege, Handly, Williams, Swarth, Didden, and Huff describe a monitoring program for birds in urban environments of Washington, DC. Urban areas are generally not well monitored by the BBS, but data from these areas often play an important role in defining public and scientific perceptions of bird population change. Hamel, Brunswig, Dawson, and Staten review several case studies of monitoring at local and regional scales, documenting the benefits of several programs in the southeastern United States. Downes describes the Canadian Landbird Monitoring Strategy, which is designed to provide information on status and trends of bird populations for species and geographic scales of management interest. The Strategy extends beyond counting birds, to include monitoring demographic parameters such as survival and productivity, monitoring habitats along with count data from the BBS, and information transfer and educational activities associated with bird monitoring. Handel describes regional research and monitoring for landbirds in Alaska, with the goal of combining count data and demographic data to develop a comprehensive monitoring program within logistical and physical constraints imposed by the large area of interest and limited access by roads. A variety of research and management questions were specified, and monitoring at several geographic scales has been implemented to provide information to address the questions.

These papers indicate a clear advance in monitoring. Rather than simply documenting population change using methods with unknown sampling properties, the authors suggest that

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reliable information can be derived only from sampling with well defined goals, statistically valid sampling methods, and with a clear experimental or adaptive management context. They also express the need for scale-specific information, and information on demography rather than just counts of birds. Following these recommendations should result in clarification of the causes of population changes in landbird populations.

Statistical Considerations in Monitoring Birds Over Large Areas

Douglas H. Johnson

Abstract—The proper design of a monitoring effort depends primarily on the objectives desired, constrained by the resources available to conduct the work. Typically, managers have numerous objectives, such as determining abundance of the species, detecting changes in population size, evaluating responses to management activities, and assessing habitat associations. A design that is optimal for one objective will likely not be optimal for others. Careful consideration of the importance of the competing objectives may lead to a design that adequately addresses the priority concerns, although it may not be optimal for any individual objective. Poor design or inadequate sample sizes may result in such weak conclusions that the effort is wasted. Statistical expertise can be used at several stages, such as estimating power of certain hypothesis tests, but is perhaps most useful in fundamental considerations of describing objectives and designing sampling plans.

This paper presents a personal view on the topic of monitoring birds over a large area, such as a national park, forest, or wildlife refuge. My ideas derive from several years experience as a consulting statistician in a natural resource management agency. In recent years, especially, I have been asked by managers for help in establishing surveys for nongame birds. Most of my experience is with U.S. Fish and Wildlife Service managers, who are responsible for fairly large areas such as national wildlife refuges, as well as groups of smaller units such as waterfowl production areas. My limited interactions with land managers in other agencies suggest that their concerns are essentially similar. My emphasis here is on the statistical (especially the design) aspects of monitoring, rather than on the field methodology. Thus, I will not concentrate on questions such as whether point counts should be used in lieu of line transects. Useful references about field methodology include Ralph and Scott (1981), Verner (1985), and Ralph and others (1993) for birds; Lancia and others (1994) discussed methods of population estimation for wildlife more generally.

When establishing a monitoring program, many questions arise: What should be done? When should it be done? How should it be conducted? Who should do it? Where should sites be located? Why should it be carried out? And, especially for administrators, how much will it cost?

The major point of my paper is that the "Why" question is overriding and should be clearly addressed first. Understanding—and agreeing to—the objectives of a monitoring program will facilitate addressing the remaining issues. Knowing why something is to be done will dictate answers to the other questions (Roberts 1991; Usher 1991). As Green (1984:298) said, "environmental biologists tend to worry too much about the statistical methodology and too little about the question."

When asked by managers to help design a monitoring scheme for birds, I often become a reflective listener, but aggressively so. I first ask them why they want to monitor birds, and when they tell me, I ask more questions. If they say they want to know what is happening to bird populations on the area they manage, I ask why they want to know, and what is the area of concern, and do they care what is happening elsewhere. If they say they want to know what effect their management actions are having, I ask them why, and which practices are of concern, and how much land they affect. While such inquisitions can prove irritating to the managers, and remind them of youngsters who respond to every answered question with another "Why?", I have found that the process does tend to refine the manager's thinking. He or she will eventually settle on one or more specific needs that should be addressed. And that usually leads to answers to the other questions.

In several recent workshops with U.S. Fish and Wildlife Service land managers, I asked them why they wanted to monitor birds, in this case nongame birds. Responses ran the gamut. A number of managers wanted to contribute to broad-scale, coordinated monitoring and research efforts. They expressed an interest in conducting North American Breeding Bird Survey (Peterjohn 1994) routes, or supporting MAPS (Monitoring Avian Productivity and Survivorship) (DeSante and others 1993b) stations, or contributing to the U.S. Forest Service's bird monitoring plan (Manley 1993). Others more generally wanted to provide better information on distribution of birds or their habitat affinities, or to identify threats to their viability.

Some managers indicated an interest in local-scale issues. Managers wanted to assess the value of their area to nongame birds. Others wanted to determine when and how their area is used by different species. Some U.S. Forest Service managers indicated that monitoring of nongame birds is required by laws or regulations.

Several managers' interests were tied to the general "health" of their managed areas. Some managers wanted to monitor nongame birds to indicate habitat quality and environmental health. (See Temple and Wiens [1989] for an interesting discussion of using birds as bio-indicators.) Others mentioned monitoring indicator species. Several managers viewed nongame birds as part of the ecosystem approach, recently adopted by the U.S. Fish and Wildlife Service and other federal agencies (Malone 1995).

Beyond the objectives listed above, three reasons were most consistently mentioned for monitoring in managed

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areas, and these will be the focus of the remainder of this paper. These were (1) to get presence/absence information for species, (2) to monitor population trends, and (3) to evaluate the effects of specific management actions. I tried to demonstrate to the managers that the optimal monitoring design will vary, depending on which objective is paramount. As we treated each objective, we discussed various methods available to meet the objective and evaluated the advantages and disadvantages of each method.

Obtaining Presence/Absence Information

If the primary objective is to learn which species use the area, possibly by season, a variety of methods can be employed. Point counts (Ralph and others 1995b), transects (Mikol 1980; Seber 1982), territory mapping (Hall 1964; Val Velzen 1972), nest searching, and other systematic methods will provide information about species using the area. But these methods are labor-intensive relative to the information obtained.

A more suitable method is to conduct aggressive searching of all habitats on the site. Mist-netting (Karr 1981) might be used to augment the database. Nocturnal surveys will improve the chance of detecting owls, rails, goatsuckers, and certain other species that are more active at night. Playing recorded calls and listening for responses is valuable for certain secretive species (Johnson and others 1981). Adding observations of species detected incidental to other activities also will be useful. Managers should develop a system for staff and visitors to record such sightings, verify them, and add them to the data base. Also, there may be historical data that can be included, although old occurrence records may tell little about current presence.

Addressing this objective lends itself to a cooperative effort with the local birding community, either individuals or organized clubs. The best information on the bird species using an area can be obtained by encouraging active and proficient birders to cover the area. Managers might make it a contest to see how many species can be found. Birders should visit all habitat types, as long as they do no damage and do not interfere with management activities, and visiting birders should be encouraged to share their sightings.

"Big Days," on which birders attempt to find as many species as possible during a single 24-hour period, can be encouraged, with the proviso that sightings need to be restricted to the area of concern. I suggest that such activities, conducted during the various seasons for several years, would provide an excellent list of species using the site. That list could then be augmented by incidental observations and species found during other surveys.

This objective ties in nicely with atlas projects, which are intended to determine the breeding distribution and reproductive status of breeding birds. These are usually done by state or province, and many states have recently completed or are currently conducting atlas projects. Smith (1990) discussed techniques for atlas projects.

A key consideration is that records of birds need to be verified, especially for unlikely species. One advantage of using proficient birdwatchers is that they are better able to recognize the species. Many state birding societies have developed systems to evaluate unusual sightings. Photographs or other evidence may be required in certain circumstances. I suggest using those systems to verify species records for managed sites. Also, some thought should be given to indicating the relative abundance of, or likelihood of a bird watcher finding, each species.

A final word about this objective: when pressed, managers generally acknowledge that learning which species use their site is *not* their foremost objective. As more effort is devoted to meeting the objective, the longer this list of species will become. Eventually any species added will be a rarity, especially one whose normal range is distant from the site. The value of a list of extralimital species is questionable. Although managers—and visiting birders—like to know which species are likely to be found on a site during a particular season, managers usually need information addressing the other two major objectives.

Monitoring Bird Population Changes

Many managers indicated that they wanted to know how bird populations on their areas were changing over time. For that objective, the *ad hoc* procedures recommended above are not very suitable. General references on ecological monitoring include Goldsmith (1991) and Spellerberg (1991). One of the most important considerations for monitoring is that the system needs to be repeatable. Except in very unusual situations, results of a monitoring effort in any year will provide but an index to the population size of each species. It is useful to have the index close to the actual population size (that is, to monitor a large fraction of the population), but it is far more important to have the index strongly correlated with the population size (Johnson 1995).

Some guidelines will help ensure that an index is accurate. The advice is simple to state but not always easy to follow. Repeatability demands that standardized methods be used. Protocols must be written down, understood by the participants beforehand, and adhered to closely. Observers vary in their abilities (Faanes and Bystrak 1981; Sauer and others 1994b). For this reason, it is best to use the same observer for as many years as possible. If it is necessary to change observers, careful training will minimize the disruption in the monitoring scheme (Kepler and Scott 1981; Hanowski and Niemi 1995).

For monitoring purposes, it is probably best to use the same locations for counts in all years. A system with some old and some new locations each year might offer somewhat better statistical properties, but I doubt that it is worth the effort. Observations should be made in all major habitats. As a rough guide to sample sizes, I would place sampling locations in each habitat in proportion to the area of that habitat on the site, times the (expected) density of birds in the habitat. Simply stated, put more effort in more common habitats or habitats with a lot of birds. Also, areas of special importance to birds (e.g., breeding colonies, special habitats) should be monitored, even if their areal extent is small.

I have not discussed the actual bird survey methods. Territory mapping can be used, but again is labor-intensive

and restricted to small areas. Mist-netting may be useful in certain habitats, but I would suggest point counts or line transects as methods that detect large numbers of birds and, most importantly, are repeatable.

The point count method, the current favorite among bird survey methods, has a number of advantages over other techniques (Ralph and others 1995b). It does not, however, provide estimates of abundance or density. Density estimates can be made if distance sampling is used (Buckland and others 1993), or if a fixed-radius circle is employed in the point count such that all birds within that radius are detected and none beyond the radius are included.

A question often arises about the use of roadsides as routes for point counts or other survey methods. Certainly, if one is interested in getting an accurate count of each species on the site, those species that favor roadsides will be detected more often from roadside counts than their actual abundance would indicate (Rotenberry and Knick 1995). The opposite would be true, of course, for any birds that avoid roads (although Keller and Fuller [1995] found no such pattern in second-growth forest). Is this a problem if monitoring change is the objective? No, not if detectability remains more-or-less constant from year to year. A systematic roadside survey may, as an example, record 10 percent of all Mourning Doves (*Zenaida macroura*)—which favor roadsides—on the area, but only 3 percent of all Baird's Sparrows (*Ammodramus bairdii*)—which do not. So using survey results to compare numbers of Mourning Doves and Baird's Sparrows would be misleading. But, as long as those percentages remain roughly the same from one year to the next, the survey will adequately portray changes in the population size of either species.

Offsetting the potential bias of roads is their convenience. Routes that follow roads offer logistical advantages. During the same amount of time, one might be able to conduct only a third as many counts off-road than along a road, and even fewer if the terrain is difficult. Moreover, the extent of the roadside bias will depend on the kind of road; a narrow trail winding through a habitat will pose less of a problem than a freeway (Hutto and others 1995).

One remedy is to conduct some on-road counts and some off-road counts in similar habitat, and compare both the numbers of birds detected and the amount of time needed to carry out the surveys. Analysis of resulting data should be informative. My suspicion is that, in most cases, the logistic convenience will more than outweigh any roadside bias. If important habitats do not have roads or trails through them, then the sampling design needs to be augmented to incorporate those habitats. Also, routes along roads would not be feasible in smaller areas.

A final thought on monitoring: To be of most value, monitoring should be conducted as part of a larger effort, so that trends on the site can be compared with those off-site. Related to this point is my opinion that monitoring bird populations may not be sensitive to effects of management actions taken on the site (Roberts 1991). Monitoring is useful when the questions to be asked cannot be anticipated (Hamel and others, this proceedings). If responses to known actions are desired, alternatives preferable to general monitoring are available (Cooper and others, this proceedings).

Evaluating Effects of Management Actions

Managers manage. Whether by their own direct actions, the activities of cooperators, or passive inaction, managers cause changes on the lands for which they are responsible. They want and need to know what effects they are having on target as well as nontarget species. This objective was rated as most important by the managers I talked with. Some suggestions follow, directed toward assessing the effects of management actions on nongame birds (which historically have been nontarget species for most managers).

First, a general monitoring scheme is unlikely to detect changes in bird populations due to management actions unless either the monitoring program is very intensive, the actions have very marked consequences, or a lucky event has occurred. Most often, management practices—such as prescribed burning, grazing, or cutting timber—affect only part of the area during any particular year. Unless the bulk of a species are in the affected area, only a fraction, say 15%, of the birds may be affected. And fluctuations of that magnitude are common in most bird populations and well below the level likely to be detected under routine monitoring.

To identify effects of a management action, it is better to focus on the species and habitats likely to be affected by the action. (Also, consider how the treatment might affect the species: density, species composition, productivity.) Sampling should be heavy in areas to be treated and in similar areas that will not be treated (control, or comparison, areas). Samples should be taken before the treatment, and for several years following. Sites to be treated and sites to be used for comparison should be selected randomly from a set of similar sites. A number of independent treatments should be applied, affording some replication. These three features—treatments and controls, randomization, and replication—form the basis of sound experimental design (Fisher 1947).

It may be useful to pause here and contrast three scientific approaches: experimental, observational, and sample survey. In an experimental approach (e.g., Cochran and Cox 1957; Milliken and Johnson 1984), one is interested in the effect of some treatment, such as grazing, on some variable, such as the density of a particular bird species. The process is manipulative: the unit is treated or perturbed by the experimenter. He or she then can select control sites, randomize the treatment and control, and replicate. In an observational study (Cochran 1983), one likewise is interested in a treatment effect, but the process is passive: the treatment is applied by someone else (or

nature) and control sites may not be available, randomization is not feasible, and replication may not be possible. In a sample survey (e.g., Cochran 1977; Williams 1978), interest lies not in a treatment effect but in some population feature, for example, the density of Baird's sparrows in grazed fields in North Dakota. Hurlburt (1984) termed such surveys "mensurative studies." Like an observational study, the process involved in a sample survey is passive.

The experimental approach is stronger than an observational approach for understanding effects of a treatment (Skalski and Robson 1992, a book that is useful more generally than for mark-recapture studies, as its title would suggest). Experiments are, unfortunately, more demanding and frequently impractical or even impossible. In such situations, the observational approach and some other techniques offer partial remedies. An observational study arises largely because one cannot assign treatments and controls. One useful tool for resulting data is matching, trying to find a unit that is as similar as possible to the treated unit except for the application of the treatment. Another tool is statistical control, essentially trying to control for other variables during the analysis, rather than during the design. Instead of randomly assigning treatments and controls, one measures a number of other variables—such as soil type, precipitation, and vegetation, in our example—and attempts to statistically adjust for their effects. Cochran (1983) is a valuable reference for this approach.

Sometimes a treatment will be applied, but the investigator has no hand in where it will be done; randomization is impossible. Perhaps, as an example, a timber sale will result in major tree-removal in a certain area, and that area is predetermined. Suppose there is interest in understanding the effects on bird populations. A BACI (Before and After, Control and Impact) design may be appropriate (Skalski and McKenzie 1982, Stewart-Oaten and others 1986). The idea here is to measure bird populations before and after the timber cutting, and in similar (control) areas as well as in the treated (impact) area. The methodology was developed in the ecological literature for situations such as power plant sitings, and has been described by Eberhardt (1976), Green (1979), and Stewart-Oaten and others (1986), among others.

A related method is intervention analysis. In that approach, some event has occurred (such as banning DDT) and interest lies in detecting if a change in some variable (such as the number of Bald Eagles *[Haliaeetus leucocephalus]* in an area) occurred coincidentally with the event. Intervention analysis uses time-series methods to determine if such a change took place (Box and Tiao 1975). It is used when the investigator has no control over the event and the study generally is designed after the event, rather than before (Eberhardt and Thomas 1991). The method requires a rather long series of measurements both before and after the event, which limits its applicability. BACI, intervention analysis, and related methods require assumptions and analyses based on models to separate true effects from confounding influences of space and time (Skalski and Robson 1992:162). As such, they are inferior to manipulative experiments.

Randomization is important in an experimental setting in the context of assigning treatments to sample units. That aspect of randomization is far more important than another way randomization is used: to select points at which a response is measured. For example, suppose one is interested in the immediate effects of burning a grassland on densities of Sprague's Pipits (*Anthus spragueii*). Ideally, one should have a number, say 20, of similar fields and randomly choose 10 of those fields to burn. The remaining 10 fields are left unburned to serve as controls, or as a basis of comparison to the burned fields. One (or more) point count is made in each field. This approach is how randomization (and replication) should be used, and provides a sample size of 10 in each of the two groups. The error degrees of freedom for a t test would be $20 - 2 = 18$, and would likely provide some strong inferences about the treatment effect.

Contrast this to the situation in which one field is burned and one left idle, but that 10 point counts of Sprague's Pipits are made in each field after the treatment. The points are selected randomly within each field. Here randomness may help us get a good estimate of Sprague's Pipits on each field (or it may not; a systematic sample would probably be preferable), but it does nothing to ensure that the field selected for treatment did not differ in some important way from the field selected for the control; a random selection of fields to which to apply the treatment would have done that. Also, this randomization does not increase the sample size for the comparison of burned versus unburned fields; there is one sample per treatment, the error degrees of freedom are $2 - 2 = 0$, and a t test (or any other test) cannot validly be conducted. Treating the 10 point counts done within each field as sample units would be a fine example of pseudoreplication (Eberhardt 1976; Hurlbert 1984). Eberhardt and Thomas (1991) also noted the common error of confusing control of treatments with control of the observational process.

Occasionally the other essential component of the experimental approach, replication, is not achieved. (Sometimes it is impossible, but too often it is simply overlooked.) Suppose the densities of Baird's Sparrows are 10 per 100 ha in a grazed field and 20 per 100 ha in an ungrazed field. What does that tell us about the effect of grazing on Baird's Sparrows? Almost nothing; the fields may differ in other important aspects (the probability of which could be reduced by randomization, or the effects adjusted for by careful analysis of measured covariates). And, equally importantly, the difference may be due to chance; had two other identical fields been considered, densities might have been 20 per 100 ha in the grazed field and 10 per 100 ha in the ungrazed one.

This possibility is one reason why replication is so important; it tends to average out the effects of random events, so that treatment effects stand out. If replication at a single site is impossible, meta-analysis may—and I emphasize may—offer a potential remedy. Meta-analysis was designed to reach an understanding about the value of some parameter (in our case, treatment effect) from numerous studies in which the parameter has been estimated. Each study produces an estimate of the parameter, along with a measure of its uncertainty, such as standard error. Meta-analysis basically is an analysis of analyses, in which the individual studies form sample units for the larger study. The methodology was not developed for situations in which the individual studies themselves were not replicated and did not estimate standard errors, but perhaps it could be adapted for such situations. For example, if densities of Baird's Sparrows on grazed and ungrazed fields were measured for a number of sites in the mixed-grass prairie, some general conclusions might be reached, even if no single site replicated the comparison sufficiently to produce reliable answers to the question. One danger is that, at each site where grazed and ungrazed fields were compared, the field where grazing had been applied might differ in some fundamental way from the ungrazed field. This is a problem that randomization is designed to alleviate; meta-analysis can address only the lack of replication. Some references on meta-analysis are Hedges and Olkin (1985), Gurevitch and Hedges (1993), and Arnqvist and Wooster (1995).

Replication within a study is important, but replication of studies in space and time is far more important (Hawkins 1986). To know that the density of Baird's Sparrows was higher in an ungrazed field than in a grazed field at one site in one year is useful, perhaps. Knowing that the result is general, that it holds for mixed-grass prairies in general, is far more valuable. This more universal conclusion can be reached only by replicating the study in areas throughout the mixed-grass prairie and in multiple years. Quoting Eberhardt and Thomas (1991:57), "Since truly definitive single experiments are very rare in any field of endeavor, progress is actually made through sequences of investigations."

Compromise Designs

Typically, managers, like the rest of us, want it all. They want to know what species occur on their areas, they want to monitor population changes, and they want to know the consequences of their management activities. As described above, the optimal design for any single objective will be suboptimal, and perhaps nearly worthless, for another objective. Can a compromise design be developed that will allow all objectives to be met to some degree, even if not optimally?

I suggest the answer is yes, and offer some thoughts. The core of such a design would focus on monitoring, with incremental work to address more directly the other two objectives. Suppose a general monitoring scheme is in place, following guidelines mentioned above. It might be a series of point counts, mostly along secondary roads or trails, possibly with some off-road points for comparison. All important habitats (importance due to either areal extent or use by birds) should be covered. Most critically, the monitoring protocols should be clearly described and followed closely in each year. This plan would directly address the monitoring objective.

For the checklist objective, results of the monitoring can be supplemented with incidental information gathered during other activities and with records provided by visiting birdwatchers. Extra efforts such as mist-netting, playbacks, and nocturnal surveys may add species not otherwise detected. And cooperating with local or state birding groups to use a system of verifying records and to develop checklists will likely prove worthwhile.

To assess the changes in bird populations due to management actions, I suspect that the routine monitoring scheme by itself will prove inadequate. But results of that scheme can form the basis of a useful evaluation. I would suggest augmenting the monitoring design by adding more sampling points in areas to be affected by the management actions and in areas not to be affected. The basic criteria of experimental design should be met if at all possible: control and treated sites, random assignments of treatments, and replication. So if a treatment is planned for a particular site (preferably, the site had been randomly chosen for the treatment, and it is only one of several replicates), the number of sampling points at that site and at others similar to it (comparison sites) should be increased. Those sampling points should be surveyed both before the treatment is applied and for several years after, depending on how long the treatment is likely to have an effect. Results of the basic monitoring scheme may prove useful (1) for selecting sites that are relatively similar, to use as potential treatment and control sites in the experiment; (2) for understanding the variation in counts so that necessary sample sizes can better be determined; and (3) as part of the sample used to estimate the effect of the treatment.

Conclusions

At the early stages of learning which species are using an area, developing a checklist of species present is a valuable endeavor. An intensive effort by cooperating birdwatchers, augmented by recording of incidental observations, can produce the desired list in relatively short order. A system for verifying sightings of unusual species should be adopted.

For long-term monitoring, point counts or similar methods are applicable. They should be conducted in all important habitats. I suspect that roadsides can be used for routes, if they are appropriately distributed, but any biases can be evaluated in a comparative study. The most critical concern is that the monitoring be systematic and repeatable; standardized protocols, strictly adhered to, and a training program for observers will help to ensure the quality of the program.

If the effects of management on bird populations are to be evaluated, the three foundations of experimentation should be assured: treatment and control sites, randomization of treatment, and replication. Emphasis should be on areas to be treated and on similar areas left untreated. Some partial remedies, briefly mentioned above, may be helpful if one or another cannot be met.

Managers should also consider the importance of habitats on their areas, and the species for which their areas are important. The manager of a refuge containing unusual fen wetland habitat, or a small stand of old-growth trees, should give special emphasis in a monitoring plan to bird species that rely on those habitats. And a manager of a refuge in the mixed-grass prairie should ensure that bird species that require such grasslands, such as the Baird's Sparrow, are monitored before concerning him- or herself with widespread and more common species that do not need those habitats, such as Brown Thrashers (*Toxostoma rufum*), for example. In that sense, the monitoring plan should mirror the management priorities.

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Monitoring Is Not Enough: On the Need for a Model-Based Approach to Migratory Bird Management

James D. Nichols

Abstract—Informed management requires information about system state and about effects of potential management actions on system state. Population monitoring can provide the needed information about system state, as well as information that can be used to investigate effects of management actions. Three methods for investigating effects of management on bird populations are (1) retrospective analysis, (2) formal experimentation and constrained-design studies, and (3) adaptive management. Retrospective analyses provide weak inferences, regardless of the quality of the monitoring data. The active use of monitoring data in experimental or constrained-design studies or in adaptive management is recommended. Under both approaches, learning occurs via the comparison of estimates from the monitoring program with predictions from competing management models.

Monitoring, the activity of making periodic assessments of state variables reflecting system dynamics, has become popular among those studying ecological populations and communities. In the case of bird populations, monitoring programs in North America include efforts to monitor population size (e.g., the North American Breeding Bird Survey [Sauer and Droege 1990], the Audubon Christmas Bird Counts, and numerous other surveys); and the vital rates (survival and reproductive rates) responsible for changes in population size (e.g., the MAPS program [DeSante and others 1995] and BBIRD [Conway and Martin, this proceedings]).

When faced with a difficult management decision, decisionmakers frequently exhibit a form of displacement behavior or stalling tactic by asking for additional information, without thinking sufficiently clearly about exactly what kinds of information will be most useful in making the decision. I believe that some monitoring programs have been established as a result of such displacement behavior with the vague hope that future retrospective looks at monitoring results will somehow lead to a reduction in future uncertainty and to an understanding of population dynamics and responses to management.

In this paper, I express the view that monitoring can be very useful in helping us to understand and manage bird populations. However, I argue that this utility is dependent upon using monitoring results in conjunction with models and hypotheses about system behavior as part of a scientific process such as experimentation or adaptive management (Walters 1986). In the absence of a scientific context, I believe that monitoring, by itself, is not likely to lead to good understanding or management (Nichols 1991a). In this sense, I tend to agree with the following provocative statement by Krebs (1991:3), "Monitoring of populations is politically attractive but ecologically banal unless it is coupled with experimental work to understand the mechanisms behind system changes." I will try to provide a basis for such views about monitoring and, in the process, identify explicit roles for monitoring data in management and research programs.

Management Requisites and the Role of Monitoring

I believe that four fundamental requirements exist for the informed management of any animal population or community (Nichols and others 1995). First, the manager must develop explicit goals for the management process. These goals should be translated into an objective function that specifies the relative values of different specific objectives and the costs of management actions (Nichols and others 1995; Williams 1996; Conroy, this proceedings). Second, the manager must have the ability to implement different management actions relevant to attainment of management objectives. In the example of migratory bird management, relevant actions would most likely involve habitat management, but also could include control of predators or nest parasites. Third, at each decision point, the manager must have access to information about the state of the managed system and about other goal-related variables. For migratory birds, system state would likely include population size(s) and, possibly, related quantities. The fourth requisite for informed management is knowledge about the response of the managed system to alternative management actions. In an uncertain world, this "knowledge" is typically represented by hypotheses or models about the dynamics of the managed system.

Monitoring programs are important to the third and fourth management requisites listed above. They are clearly important as the primary source of information about the state of the managed system. In single-species management, we must know something about the population size at time t to make an informed decision about how to manage at that time. Monitoring programs directed at the population variables of interest provide such information for management. The other role of monitoring programs is to provide data that can be used to develop our "knowledge" of system

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dynamics and responses to management. It is with respect to this acquisition of knowledge that I claim "monitoring is not enough."

Approaches to Learning

Retrospective Analyses

Monitoring data have been used in various ways to help us understand the managed system. Perhaps the most commonly used approach is the retrospective analysis of time-series data produced by monitoring programs (Nichols 1991a). Monitoring programs may yield annual estimates of quantities such as population size over some relatively long time period (e.g., 20 years), and it is commonly thought that such trajectories lead almost immediately to an understanding of underlying population dynamics. It is a common practice to use such data with correlation and regression analyses to investigate possible relationships between population size and various environmental and management variables. The problem with this approach is that it is unlikely to yield "reliable knowledge" (Romesburg 1981), because there typically will be multiple *a posteriori* stories or models that provide reasonable explanations for any observed time series. Indeed, Pirsig (1974:107) suggested that "The number of rational hypotheses that can explain any given phenomenon is infinite."

The potential for being misled by retrospective analysis exists for all kinds of observations (Platt 1964; Romesburg 1981) but is probably especially large for time series of estimates of population size and related variables. One reason for this is that population size is not observed but is estimated, often with large sampling variances and sometimes with bias. Temporal variation in point estimates of population size is thus not equivalent to temporal variation in the underlying population (Link and Nichols 1994). Stories and hypotheses developed to explain the variation in a series of population estimates may not be adequate to explain the real variation in the underlying quantity of interest.

Another difficulty in drawing inferences from retrospective analyses of population trajectory data involves the stochastic nature of population processes. Death, for example, is typically viewed as a simple stochastic process. If a population has 100 animals at time t and if each of these animals has a probability of 0.3 of dying during the interval $(t, t + 1)$, then we do not expect exactly 70 animals to be alive at time $t + 1$. Instead the number of survivors will be a binomial random variable with expected value 70, but with likely realized values of 68, 73, 65, etc. Reproductive processes and movement also are viewed as stochastic in nature, leading to the view of a population trajectory as a single realization of a (likely complicated) stochastic process. We should not expect to be able to observe a single realization of an unknown stochastic process and infer much about the process (Nichols 1991a). This is analogous, in some sense, to being handed a loaded coin, being permitted to flip it once, and then being asked to specify the probability of obtaining heads.

Another difficulty associated with inferences from retrospective studies of population monitoring data involves problems with using correlation analysis to draw inferences about the functional relationship between variables represented by time series. A clear example of such problems involves the existence of trends and monotonicity in many environmental covariates that potentially influence bird populations. Metrics of human-related environmental variables such as habitat fragmentation, habitat degradation, and pollutant levels will frequently tend to show an increasing trend over time. Correlation analyses involving two variables, each of which shows a time trend, will tend to indicate association, although this may have nothing to do with any functional relationship between the variables. In fact, the problem of conducting association analyses of two time series extends beyond the case of monotonic trends, and such analyses frequently lead to inappropriate inferences (Yule 1926; Barker and Sauer 1991).

The conclusion I draw from this consideration of problems associated with inferences from retrospective studies is that such analyses should not form the basis for our knowledge of population dynamics and responses to management. Instead, I suggest that we restrict our use of retrospective analyses of monitoring data to the generation of hypotheses about population dynamics and responses. We can then use scientific processes such as experimentation and adaptive management to distinguish between competing models.

For those who do not find these arguments convincing, I recommend readings on the history of efforts to investigate the effects of hunting regulations on waterfowl populations in North America (Anderson and Burnham 1976; Nichols and others 1984; Nichols 1991b; Smith and Reynolds 1992). These efforts employed retrospective analyses of estimates of population size, survival rates, hunting mortality rates, and reproductive rates produced by some of the best large-scale animal monitoring programs in the world, yet have not led to the general acceptance of a single model of waterfowl population dynamics and responses to hunting (Nichols and others 1995).

Experiments and Constrained Studies

Monitoring data also can be used in conjunction with studies designed specifically to test hypotheses about responses of animal populations to management actions. We begin with competing hypotheses or models about population dynamics and responses to management. We try to discriminate among them by applying different treatments (e.g., different management actions) to birds inhabiting different portions of the landscape. If monitoring programs are in place for the treated areas, then differences in response variables (e.g., population size) between areas treated in different ways may provide the basis for inference about management effects (i.e., may help us decide which model provides the best approximation to reality).

Inferences are strongest for true manipulative experiments (Hurlburt 1984; Skalski and Robson 1992). Such experiments are characterized by replication and randomization in the assignment of different treatments to experimental units. Replication refers to the application of treatments to multiple experimental units as a means of estimating the experimental error or error variance (the variance among experimental units to be expected in the absence of treatment differences; i.e., the variance associated

with all factors except the different treatments). Randomization refers to random assignment of treatments to experimental units. Randomization protects against systematic differences among experimental units receiving different treatments and represents an effort to insure that any systematic post-treatment differences among experimental units treated differently can be attributed to the treatments themselves.

In ecological studies in general, and studies of managed populations and communities in particular, manipulative experiments are frequently difficult to perform. In such instances, we may be forced to use study designs that lack replication, randomization, or both of these features. Such constrained designs are considered in some detail by Green (1979) and Skalski and Robson (1992). Inferences resulting from such studies will typically be stronger than those resulting from retrospective analyses, yet not as strong as those based on manipulative experimentation (see examples in Nichols and Johnson 1989).

The important point is that studies, whether they are true manipulative experiments or constrained studies, can be designed to take advantage of monitoring programs. We begin with different *a priori* hypotheses about population dynamics and responses to management. The monitoring programs provide the estimates of potential response variables that are used to distinguish among competing hypotheses, and test for effects of the studied treatments (typically management actions). In such studies the short-term objectives of management are temporarily set aside in an attempt to learn something about the response of the studied system to management practices (see Conroy, this proceedings and Cooper and others, this proceedings for examples of such studies). However, any knowledge of system response will be useful in making subsequent management decisions and, through the reduction of uncertainty, will be beneficial to long-term management objectives.

Adaptive Management

Adaptive management (Walters 1986) presents another approach to using monitoring data to help us distinguish among competing hypotheses. Under this approach, however, we do not temporarily set aside short-term management objectives to learn something about the managed system. Instead, adaptive management represents an approach to dealing with the so-called "dual control problem" of simultaneously meeting short-term management objectives and learning about the managed system to reduce uncertainty so that future objectives can be better met.

Adaptive management requires five components that are closely related to the four requisites for informed management listed earlier in this paper:

1. The objective function is simply a formal specification of management objectives.

2. Management options are actions that are available to the manager and that are potentially relevant to attainment of management objectives.

3. The monitoring program provides information on system state variables and other goal-related variables.

4. The model set is a set of competing models about system dynamics and response to management actions.

5. A measure of uncertainty is required for each model in the model set. These measures are probabilities that sum to one and reflect our relative faith in the different models.

At a decision point, t, the monitoring program provides information about the state of the managed system. Given this state, given the objective function, and given the members of the model set with their respective measures of uncertainty, we derive the management action that is optimal with respect to the weighted (by the measures of uncertainty) predictions of the different models. This action is implemented and drives the system to a different state at the next decision point, $t + 1$. This new state is estimated via the monitoring program, and this estimate is used to update or revise our measures of uncertainty. If the new state of the system corresponds closely to the prediction of a particular model, then the probability associated with that model is increased. If the new state of the system deviates substantially (relative to other models) from the prediction of a model, then the probability associated with that model is decreased. At time $t + 1$, the optimal decision is again derived given the new state of the system and the new model weights. The process of adaptive management proceeds in this iterative fashion. Our measures of uncertainty change through time and reflect learning about system responses. This learning leads to a reduction in uncertainty that improves our ability to meet management objectives (Conroy, this proceedings; Nichols and others 1995; Walters 1986; Williams 1996).

Conclusions

Population monitoring has two explicit roles in the process of managing an animal population. First, it provides information about the state of the managed population at each time period for which a management decision is needed. Second, monitoring can contribute to our knowledge of effects of management actions on populations. Three different approaches to the use of monitoring data to aid understanding of animal population dynamics and responses to management were discussed. It was concluded that the most common approach, using monitoring data in retrospective analyses, is not likely to yield "knowledge" in which we can be confident and on which we will be willing to base management decisions. Instead, retrospective analyses of monitoring data can be used to develop hypotheses and models of animal populations and management responses.

Monitoring data can then be used in conjunction with either experimental or constrained studies, or adaptive management, to estimate population responses to management. These estimated responses can be compared with predictions of competing models, and results of these predictions can then be used to distinguish among the different models. The key to the use of monitoring data with experimental or constrained studies, or adaptive management, is the existence of *a priori* hypotheses about system dynamics and response. When the roles of monitoring data are made explicit in this manner, it becomes easier to design monitoring programs to meet management needs.

Combining Information From Monitoring Programs: Complications Associated With Indices and Geographic Scale

John R. Sauer

I feel that some biologists at this conference have been too optimistic about the use of indices of abundance (Kenneth H. Pollock *in* Ralph and Scott 1981: p. 510).

Abstract—To adequately monitor Neotropical migratory birds, information must be collected to assess population change at local, regional, and continentwide scales. I suggest that large-scale survey results (such as those derived from the North American Breeding Bird Survey) should not be used to predict population attributes on parks, refuges, and other protected areas. These areas are often managed, and generally contain habitats that can be poorly sampled in large scale surveys, hence local bird populations might be quite different from those sampled in the large-scale surveys. Furthermore, we are limited in our capabilities to combine information from local surveys with large-scale survey data. Most surveys of bird populations collect indices of abundance which are often not comparable among surveys due to habitat and region specific differences in probabilities of detecting birds. In assessing the effects of management, it is important to understand the limitations of monitoring at different geographic scales and to design programs to monitor at the scale at which management is conducted.

Conservation of Neotropical migratory bird populations requires information on population responses to land management at several different scales: At a very local scale, such as within the plot on which management is conducted; at an intermediate scale, such as a refuge or forest containing a series of plots; and at regional levels, such as flyways, states, or the physiographic strata used in the North American Breeding Bird Survey (BBS, Peterjohn 1994). Point counts or other survey methods that produce an index to population size often are crucial components of monitoring programs at all these levels (e.g., Ralph and others 1995a). Of course, monitoring population size by itself is not sufficient for assessing effects of management (Nichols, this proceedings). Direct estimates of productivity and survival are more likely to provide insights into factors influencing population change (Temple and Wiens 1989). However, the difficulties in implementing demographic monitoring programs at large scales suggest that monitoring population size will play a critical role in assessing the effect of management actions.

Often, large-scale surveys such as the BBS are considered to be primary methods of monitoring population size, with smaller-scale surveys (e.g., within national forests or in forest plots, Ralph and others 1995a) providing supplemental information that can contribute to a continentwide program. A frequent assumption is that information from surveys can be combined to form a composite index, and that information from the BBS can be applied at any geographic scale to address management issues. Unfortunately, both of these assumptions usually are false.

In general, large-scale surveys (as exemplified by the BBS) do not provide adequate information for addressing local issues, and local surveys do not provide a valid sample frame for addressing regional issues. These generalizations may be correct for two primary reasons. First, the habitats managed by most land managers are not random samples from regional habitats, hence, the relative abundances and trends of birds in these local areas may not be representative of regional patterns. Second, counts from large-scale and local surveys provide only an index to the population. It is difficult to combine information from surveys unless the relationship between the indices and the actual population sizes associated with each survey are known (or at least estimated without bias).

In this paper, I use examples from the BBS to discuss limitations of our present monitoring procedures, and to identify some crucial issues in monitoring at different scales. I suggest that technical difficulties with combining information from different surveys will limit our ability to integrate information among geographic scales, and that survey data should be viewed as addressing management issues at the scale at which they are collected.

Can Breeding Bird Survey Results Provide Valid Predictions of Trend and Relative Abundance at Low Geographic Scales?

The temptation to use BBS data to predict relative abundance and population trends of birds on refuges or other land management units is overwhelming when BBS data are displayed as GIS coverages that purport to map population trends rangewide for species (Sauer and others 1995). A simple overlay of the map onto the area of interest could provide a local estimate of trend for a species, if the regional results are valid for the lower scale. The consistency of

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regional patterns of population change for many species (e.g., Wood Thrush, *Hylocichla mustelina)* suggests that regional patterns often might be generally applicable to habitats within the region.

Unfortunately, there is no capability for habitat-specific analyses within the sample units of the BBS. Large-scale surveys provide extensive results at the expense of local specificity. Indices of abundance from these surveys often are aggregate, based on large sample units (e.g., in the BBS: 50 3-minute point counts/24.5 mi survey route), and represent a composite index for habitats encountered in the landscape.

At the scale at which the data are collected, relative abundance estimates from BBS data are correlated with a variety of landscape-level attributes. Flather and Sauer (1996) found associations among bird data from BBS routes and measures of percentage cover, edge, and other landscape metrics estimated from raster images of high-altitude photographs. Most traditional analyses of BBS data estimate trends or other components of population change using the route as the sample unit, and aggregate route trends to estimate regional patterns of population change. At this scale, maps of relative abundance from the BBS show reasonable qualitative views of bird distributions (Sauer and others 1995).

Certainly, counts from pieces of each sample unit could be considered habitat-specific, and used as dependent variables for habitat-specific analyses. However, BBS stop locations often are difficult to assign unambiguously to habitats, hence the definition of a population or area associated with individual stops is not a trivial task. Also, data from individual stops tend to be very limited, and the 50-stop aggregate was originally chosen to ensure that many species would be represented on each survey route. These difficulties emphasize that the BBS was not designed for low-scale, habitat-specific analyses.

The landscape-level nature of BBS data means that using the information for management at local scales is difficult. Most refuges and parks exist because they contain some unique habitat features, such as high mountains, roadless areas, wetlands, or continuous forests. These features ensure that little BBS data will actually be available for the area due to inaccessibility. Additionally, habitats in protected areas rarely experience the changes that occur outside the boundaries of the areas. Therefore, BBS data from surrounding routes will not provide representative information for these protected areas.

Consequently, the BBS forms a regional context for evaluation of bird population trends in local areas and specialized habitats, but should not necessarily be considered a valid predictor of local trends. If changes in population of a migratory species are being caused by factors on the wintering grounds, then local trends might be consistent with regional trends; however, if changes are being influenced by local habitat factors, then local trends might be very different from regional patterns. Of course, if a refuge or park is acting as a source population for a region, population dynamics for that region will be greatly influenced by the dynamics within the source. Without understanding the causes and habitat-specificity of population change, we cannot reasonably assess whether a local site will be consistent with regional patterns of population change.

Can Local Surveys be Incorporated Into Large-Scale Analyses?

Partners in Flight and other programs have resulted in development of many local surveys in areas that are not explicitly sampled by the BBS (e.g., Howe and others 1995). Often, we assume that these data can contribute to the large-scale view of population change (e.g., Ralph and others 1995a).

Federal properties in the United States such as national wildlife refuges and national parks are good examples of areas that generally are not sampled by the BBS. The enormous regional differences in relative size and dispersion of these properties suggest that land holdings of different agencies present different problems for analysis. Some properties, such as Bureau of Land Management or Forest Service holdings in the western United States, are incorporated into the landscape-level results of the BBS, as BBS routes are conducted on established roads in and adjacent to the properties. Because the lands make up a large part of the landscape, they are part of the random sample.

To estimate trends specifically for these properties, it seems reasonable to consider them as separate strata in a stratified sampling design. Independent trend information could be estimated for the areas, and they could be combined with BBS as additional strata after eliminating overlapping BBS data. Because most independent surveys have not been conducted for enough years to provide long-term trends, few opportunities exist to develop composite trends from BBS and local survey results. Difficulties with sampling methods discussed below also may complicate development of composite results from BBS data and these strata.

In addition, because the sizes of many federal holdings are very small relative to the BBS strata, a composite result based on area weights may not adequately incorporate the information from those lands. For example, large continuous forests in national forests in the Appalachians form a relatively small portion of the land area in the eastern United States, hence, they likely will be only a minor part of an area-weighted composite result. However, these lands might play major roles as bird population sources, and many managers might desire that these areas be given more weight in analyses of BBS data. Unfortunately, weighting results to appropriately incorporate relative abundance and area is one of the most controversial aspects of existing BBS analyses (Peterjohn 1994), and adding new strata to the analysis with even more weighting factors will tend to undermine the credibility of the results.

Some investigations have attempted to post-stratify BBS survey routes in an attempt to develop sub-strata for analysis of habitat-specific trends (e.g., Ponderosa Pine (*Pinus ponderosa*) habitats in the southwestern United States, or areas with high cattle use versus areas of low cattle use, (Sauer, unpublished analyses). Although abundances of birds on BBS routes reflect underlying habitat characteristics along the routes (Flather and Sauer 1996), post-stratification of BBS routes is not an efficient strategy for analysis. The reclassification of route data generally results in small sample sizes, and leads to statistical tests having low power to detect differences among the sub-strata.

Complications Associated With Combining Results From Surveys That Collect Index Information

As noted above, combining information from different surveys is problematic if index data are collected. Point counts, such as those used in the BBS, are a population size index, and do not represent an actual population size. Instead, the counts underestimate the population size, that is, the likelihood that any observer actually counts all birds of any species present on a survey route is small. In the eastern United States, BBS observers probably count only an average of 50 percent of the individuals present of any species (Sauer and others 1994a). Although we can only speculate about the extent of the undercount, it likely differs among survey methods, regions, and habitats (e.g., higher proportions of the birds are observed in open habitats than in habitats with dense vegetation, Sauer and others 1994a).

Observers also tend to differ greatly in counts they collect, even under similar circumstances of counting (Sauer and others 1994b). At least for some species, evidence exists that observers have gotten better at counting over time, and that they now count a higher proportion of the birds present (Sauer and others 1994b).

The potential for differences in detection probabilities are intrinsic in any survey that does not explicitly estimate the proportion of birds that are detected (Lancia and others 1994). Any analysis of count data must at least consider the consequences of inconsistencies in the undercount (Sauer and others 1994a). Standardization of counting procedures (e.g., Ralph and others 1995a) does not eliminate the problem (Barker and Sauer 1995). One important consequence of this deficiency is that a count-based estimate of regional population size is flawed. In BBS analyses, even estimating a mean abundance for a route is not trivial. Commonly used estimates of bird abundance such as mean counts on the route are biased by observer changes and trend over time (Flather and Sauer 1996).

Combining the results of surveys from different regions requires estimates of the populations in each region. If the surveys use methods of data collection that lead to different undercounts, reconciling their results may be difficult. For example, individuals of many species with low abundances can be attracted by playing recordings of their calls. Some biologists advocate special surveys in which the observer plays recordings of calls and counts the responses. However, these special surveys would be conducted only in habitats with high probabilities of encountering the species, and over a limited part of the species range. Any attempt to combine these results with BBS data would require that we know how the index derived from the special survey relates to the BBS index. These relationships can be established only by estimating the size of the undercount associated with each survey, and adjusting survey results to a consistent index level.

Conclusions

The BBS provides a large-scale view of bird populations and monitors many species of birds with sufficient precision to provide some confidence in the results (Peterjohn and others 1995). However, attempts to use BBS information to provide insights into local management actions is likely to lead to imprecise and inaccurate results. Also, studies designed specifically for local areas may not be easy to combine with the large-scale results provided by the BBS. However, both kinds of information are needed for assessment of management actions.

Because managers cannot rely on the landscape-level results of the BBS to provide them with reliable information on local consequences of management actions, they must design surveys at the appropriate scale to monitor change. Adaptive management provides a reasonable framework for monitoring in the context of uncertainty about population responses (Nichols, this proceedings). Another alternative involves using BBS data as a "control," and developing local monitoring programs in management "treatments" that are then used to test for differences in local area and regional population changes. Because of the technical considerations of combining different indices, local information should not be considered as part of a regional monitoring program without an understanding of the relative detection probabilities of the indices collected in each survey.

Unfortunately, much of the literature on monitoring has suggested that all information collected can be fit into a composite nationwide program. Perhaps a more productive view would be to consider the need for habitat-specific or species-specific programs in areas where management occurs, and to design experiments to assess the consequences of the management.

An Overview of the Canadian Landbird Monitoring Strategy

C. M. Downes

Abstract—In 1992, Canada formally agreed to work toward retention of its biological diversity upon signing the Convention on Biological Diversity in Rio de Janeiro. Recently, data from a number of studies have documented long-term declines in populations of some species of landbirds. In response to the growing concern over landbirds and the need for data to develop sound conservation plans, the Canadian Wildlife Service (CWS) developed the Canadian Landbird Monitoring Strategy (in consultation with other federal government departments, provincial/territorial governments, and non-government organizations). The Strategy is intended as a stepping stone toward a more effective system for monitoring landbirds in Canada. It provides a framework to integrate monitoring activities that are conducted by both government and conservation organizations, and recommends a suite of surveys selected to provide data on the status, population trends, and population dynamics of landbirds. Such an approach has proved successful in encouraging cooperation and communication among organizations, promoting the thorough evaluation of survey techniques, identification of data gaps, and the development of regional monitoring strategies. The Strategy has helped encourage volunteer participation by publicizing the need for volunteers and providing summaries of the major monitoring activities, thus allowing volunteers to select the surveys most suited to their skills and interests.

To develop sound conservation strategies for birds, an understanding of their status, population trends, and the causes of population change is required. A variety of monitoring programs in Canada, coordinated by various government and non-government organizations, currently gather data on landbirds (see Downes and Welsh 1997 for overview). In 1994, the Canadian Wildlife Service (CWS) released the Canadian Landbird Monitoring Strategy, developed in consultation with other federal and provincial government departments, non-government organizations, and professional and amateur ornithologists (Canadian Wildlife Service 1994).

The Strategy was developed in response to the need to provide a more integrated approach to monitoring among organizations, and to maintain a coordinated system of surveys, which would ensure that sufficient data on landbird population changes are obtained. The Strategy is currently (1999) undergoing thorough revision, and will be updated regularly as new information is gathered and progress is assessed. The Strategy addresses the Canadian government's national and international interests in monitoring wildlife populations. For instance, the Canadian Biodiversity Strategy (1995) contains directives for the development and implementation of monitoring programs and the conservation of habitat. Responsibilities for monitoring are also outlined in A Wildlife Policy for Canada (Wildlife Ministers' Council of Canada 1990) drafted with participation from the federal, provincial, and territorial governments, aboriginal organizations, wildlife professionals, and the general public. The Wildlife Policy recognizes the need for a national program for monitoring the status of, and trends in, biodiversity.

Goals and Objectives

The goals of the Strategy are:

- Collect information to assess the health of landbird populations.
- Identify species or species groups that are a priority for intensive study and/or conservation action.
- Ensure that data and trends are accurate, current, and readily available to wildlife managers and the public.

The first focus of the Strategy is to ensure that sufficient data are collected on the population status of birds. However, surveys providing information on productivity, survivorship, and bird/habitat associations are also included, because these data contribute to an understanding of the causes of population change, and they are important in environmental assessments and the development of habitat management plans.

Information on population status can be obtained most effectively by breeding- or winter-season surveys, where the source population of the birds being monitored can be defined. However, for those birds that breed and winter in inaccessible areas, migration-season surveys may provide the only way to obtain indices of population change. Distribution data on birds in all seasons are needed for the identification of critical habitat and habitat management initiatives. Breeding season and winter distribution of birds are relatively well known in southern Canada, however, data are scarce or lacking in the northern parts of provinces, the territories, and during migration.

Evaluations of current surveys indicate that several categories of birds are not well monitored; these include nocturnal birds, diurnal raptors, and birds breeding in northern or remote areas. Adequate coverage of some species in these groups may be obtained if participation in current surveys is increased; others may require new surveys that are designed to monitor a specific habitat or season. Rare or uncommon species are unlikely to be adequately monitored by surveys designed to cover common birds.

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Status of Surveys Recommended in the Strategy

Of the many surveys now active in Canada, those listed below were selected to form the core of the Strategy. Surveys were classified according to the type and accuracy of information gathered, and species and geographic coverage. Surveys classified as "Key Surveys" are the highest priority. Those classified as "Complementary Surveys" appear to provide necessary data but have not yet been fully evaluated.

Key Surveys

Breeding Bird Survey (BBS)—The BBS is the core survey in the Strategy. The BBS is designed to detect and measure changes in bird populations. In Canada, the BBS has been conducted since 1966, and routes are now run in all provinces and territories, although most are located in the southern parts of the provinces. In 1995 more than 440 routes were run in Canada by some 300 volunteers. Data are now sufficient to calculate national population trends for some 267 species (Downes and Collins 1996; Dunn and others 2000). Participation in the BBS has steadily increased over the last several years in response to recruitment efforts. Telephone surveys of current and potential participants were conducted in target provinces over the last few years to increase participation and improve feedback to participants. Currently, the CWS is investigating ways in which habitat classification of BBS stops can be incorporated into the BBS methodology. Habitat data should increase the ability to associate changes in bird populations with changes in particular habitats. Biological Resource Division of the U.S. Geological Survey and the CWS are reviewing the statistics used to produce population trends from BBS data.

Migration Monitoring Network: Intensive Sites—Because few roads traverse much of Canada's large boreal forest and Arctic land mass, running sufficient numbers of BBS routes in those areas to monitor bird populations is difficult. Much work has focused on developing alternative methods of monitoring. In 1993, a joint United States and Canada workshop on monitoring birds during migration recommended that a series of intensive long-term migration monitoring sites be established with emphasis on monitoring birds breeding in northern Canada and Alaska (Blancher and others 1994) which may not be well monitored by other programs. The migration monitoring program is designed to generate counts of migrating birds that can be used in long-term population monitoring. Sites are located at bird observatories or banding stations, and follow standard protocols. Recommended protocols for running sites are outlined in Hussell and Ralph (1996). Six bird observatories are now running migration monitoring stations as part of the Canadian Migration Monitoring Network: Long Point (Ontario), Thunder Cape (Ontario), Whitefish Point (Michigan), Delta (Manitoba), Last Mountain Lake (Saskatchewan) and Beaverhill (Alberta). In 1995, eight other stations were run on a trial basis (3 in British Columbia, one in Ontario, one in Quebec, one in Maritimes, two in Alberta).

Checklist Surveys—Checklist surveys are standardized programs in which birders record sightings of birds by locality. The data are compiled in a central database and can be used to examine seasonal and geographic distribution, year-to-year and long-term variations in population, and breeding status of birds. Checklist surveys may be particularly useful in documenting status of birds in remote areas where a small human population precludes surveys that rely on repeated observations or highly standardized techniques. In such regions it may be a better use of resources to establish a checklist program than to concentrate on more intensive types of monitoring that can cover only a few sites. Checklist surveys are also useful in gathering information during migration for species that are difficult to monitor during the breeding season (Cyr and Larivée 1993; Dunn, Larivée, and Cyr 1996). In 1994, a Canada/United States committee produced guidelines on standard methodologies that were developed to ensure that data from different checklist surveys are compatible and comparable across North America (Dunn 1995).

In Canada, the checklist survey technique was pioneered by Quebec's "EPOQ" program ("Etude des populations d'oiseaux du Québec," or "Study of bird populations in Quebec"). EPOQ began in the 1950s, and currently maintains a database of over 2 million observations from some 3,600 observation sites with about 10,000 new checklists added annually. Data analyses from EPOQ have produced a number of papers on population trends of Quebec birds and a seasonal atlas of bird distribution (e.g., Cyr and Larivée 1993; Cyr and Larivée 1995). Such surveys are now gaining in popularity. In 1993, the Alberta Federation of Naturalists began a checklist survey that has now run successfully in Alberta for the last two years. In 1995 a pilot checklist survey was run in the Northwest Territories by the CWS. Because of the small population size and remoteness of much of the NWT, emphasis was placed on the participation of research camps, ecotour groups and visitors, as well as the local communities. Results from the pilot year were promising, and the NWT survey will be run at a more intensive level in 1996. Preliminary discussions with naturalist groups in Manitoba and Saskatchewan show there is interest in starting checklist programs in these provinces.

Breeding Bird Atlases and Distribution-Mapping Projects—Breeding Bird Atlases are designed to provide information on distribution and, to a lesser extent, relative abundance of breeding birds. Atlases have been completed in Ontario (Cadman and others 1987), Quebec (Gauthier and Aubrey 1995), Alberta (Semenchupk 1992), Saskatchewan (Smith 1996), and the Maritimes (Erskine 1992). Three volumes of the Birds of British Columbia (Campbell and others 1990) have been published, and publication of the fourth volume is anticipated in 2000 (Campbell and others, in preparation). The Birds of Yukon, focusing on distribution and status, is scheduled for publication in 2000 with over 100,000 sight records in the database. Manitoba is currently working on a publication of bird distribution and status. Publication in 2001 is anticipated. A checklist of birds of the Northwest Territories was published in 1995 based on the compilation of published and unpublished records (Sirois and McRae 1995).

Forest Bird Monitoring Program (FBMP)—The FBMP monitors population changes of birds in interior forest habitat and describes species-habitat associations. The program relies on volunteers using 10-minute point counts to count birds at several (usually 5) listening stations. The program also records information on habitat. The FBMP is active in Ontario. It began in 1987, and by 1995, 160 sites were monitored. The first analyses of results are in preparation (Welsh and others 1997). The establishment of forest bird monitoring in Alberta, Manitoba, and Saskatchewan is now being considered.

Christmas Bird Counts (CBC)—The CBC is included in the Strategy as a key survey because it provides information on early winter bird distribution. The CBC also may be valuable in corroborating population trends of species monitored by other surveys, and may provide trends for species not covered by other surveys, such as those that breed in the Canadian north (Dunn and Sauer 1997). Because CBCs are conducted in teams, the counts also serve as a training opportunity and introduction to surveys for less-experienced volunteers. Approximately 230 counts are run annually in Canada.

Complementary Surveys

Monitoring Avian Productivity and Survivorship (MAPS)—MAPS is a cooperative effort among public agencies, private organizations, academic institutions, and individual bird banders in North America to operate a network of constant-effort mist-netting and banding stations. MAPS was established in 1989 by The Institute for Bird Populations, Point Reyes, California, to provide long-term demographic data on landbirds to help identify the causes of change in bird populations documented by other major programs (DeSante and others 1993b). MAPS is designed to provide annual estimates of post-fledging productivity, adult survivorship recruitment, and population size for certain species. All MAPS stations follow a standardized method that includes: Constant-effort mist netting and banding throughout the breeding season, point counts, and vegetation mapping (DeSante and Burton 1994a).

In 1995, 24 MAPS stations were operating in Canada: BC (1), Alberta (6), Saskatchewan (1), Manitoba (1), Ontario (10), Quebec (2), New Brunswick (2), and Yukon (1). The Institute for Bird Populations is conducting an evaluation of the results from the six years that MAPS has been running. In Canada, the outcome of this evaluation will be used to decide whether this program should be incorporated as a "Key Component" of the Strategy, aimed at providing needed long-term information on the productivity and survivorship of target landbird species.

Nest Records Schemes—Nest Records Schemes provide information on breeding distribution and breeding biology of nesting birds. The schemes rely on participants finding nests and reporting information on clutch sizes, breeding success, distribution, and habitat of nesting birds. In Canada, all provinces have active programs. Although the Nest Records databases appear to be promising sources of information on productivity and survivorship of landbirds, their ability to do so has not yet been evaluated. A thorough evaluation of this program is difficult because the majority of data have not been entered into computers. Evaluations may be possible in BC where the data for passerines has been computerized, and in Ontario, where volunteers are beginning to input data. A final decision on the inclusion of the Nest Record Scheme as a "Key Survey" in the Strategy awaits the results of such an evaluation.

The Nest Records Scheme in the Maritime provinces began in 1960 and now contains over 40,000 records. The CWS office in Sackville, New Brunswick maintains the data and produces an annual report (Erskine 1994). In Quebec, the Nest Records Scheme began in the late 1960s, and the database now contains over 22,000 cards. The cards are maintained at the Canadian Museum of Nature, Vertebrate Division (Gosselin 1994). In Ontario, the Royal Ontario Museum in Toronto maintains the database. The scheme started in 1956 and now contains over 110,000 cards (Peck 1994). To date, about 5,000 nest record cards have been entered into computers. The Manitoba Museum of Man and Nature maintains the data for the three prairie provinces and some cards from the Northwest Territories. The scheme began in the late 1950s and now has a database of approximately 45,000 cards. Most of the data are available only as hard copies, although portions of the Manitoba data are now being entered into computers (Copeland 1993). The British Columbia Nest Records Scheme began in 1955.

Setting Monitoring Priorities

In Canada, a scheme for setting priorities for monitoring, research, and management related to Ontario birds has been developed (Dunn 1997). This scheme will be used as an outline for setting priorities at the national level.

Promotion and Education

Most of the surveys described above rely heavily on volunteer participation. In Canada the pool of committed, highly skilled birders is relatively small, and many volunteers already are overtaxed. If programs are to expand and continue into the future, a means of training and encouraging new recruits must be provided. Appropriate feedback and encouragement to current volunteers is equally important.

In the last several years a series of training and recruitment workshops have been held in BC, Alberta, Manitoba, Saskatchewan, and Ontario. Some workshops have been aimed at a technical audience including members of provincial and federal wildlife management agencies and parks, while others were oriented to the general public. Topics covered include the design of regional and local monitoring programs, recruitment of volunteers for the various surveys, and training in survey methods and bird identification.

Resource material to assist participants in identifying birds by song has been developed. The CWS contracted Cornell University and Monty Brigham to produce a series of cassettes and compact disks of bird songs for each of seven biogeographic regions in Canada. Cornell University and Microwizard were asked to adapt their computer learning program to work with the regional compact disks. The computer programs allow the user to practice and test their

bird song identification. The cassettes were distributed to all BBS and FBMP participants. The computer programs were distributed to BBS coordinators and placed in other selected areas where volunteers could access them.

The BIRDQUEST program, developed by CWS and the Canadian Nature Federation, is an educational program designed to introduce participants to the ecology of wild birds and to develop identification skills. The program is geared toward children, who qualify for a badge and certificate as they advance from the beginner level through the advanced level. Graduates of the advanced level must be able to identify their local birds by sight and sound, among other requirements, and should be well-equipped to participate in monitoring surveys.

In Ontario, a coalition of government and non-government organizations have cooperated in developing the Ontario Wildlife Watcher's Program, designed to promote participation in surveys of birds and other wildlife, and to promote partnerships among government, nongovernment agencies, and volunteers. This program offers incentives to survey participants such as badges and an annual report (Environment Canada 1995).

Bird Trends is a new newsletter published by the CWS to report the results of ornithological surveys. The first and sixth volumes (Hyslop 1991; Kennedy 1998) summarized the results of national and regional landbird surveys. The newsletter is available to a wide audience of professional and amateur birders; it provides feedback to volunteers on the results of surveys, and ensures that sources of data are well known.

Conclusion

The Canadian Landbird Monitoring Strategy is meant to be a stepping stone toward a more effective system for monitoring Canadian landbirds. To date, such an approach has been effective in promoting participation in surveys, encouraging the evaluation of current techniques, the development of standardized methods, and the development of regional monitoring strategies that tie into the national strategy. The Strategy was prepared by the CWS with extensive input from stakeholders in various provincial and territorial governments, other federal government departments, nongovernment organizations, and members of the public. A revised version of the Canadian Landbird Monitoring Strategy was published in 2000 (Downes and others 2000).

Conservation Planning and Monitoring Avian Habitat

Daniel J. Twedt
Charles R. Loesch

Abstract—Migratory bird conservation plans should not only develop population goals, they also should establish attainable objectives for optimizing avian habitats. Meeting population goals is of paramount importance, but progress toward established habitat objectives can generally be monitored more easily than can progress toward population goals. Additionally, local or regional habitat objectives can be attained regardless of perturbations to avian populations that occur outside the geographic area covered by conservation plans. Assessments of current avian habitats, obtained from remotely sensed data, and the historical distribution of habitats should be used in establishing habitat objectives. Habitat planning and monitoring are best conducted using a geographic information system. Habitat objectives are assigned to three categories: maintaining existing habitat, restoring habitat, and creating new or alternative habitat. Progress toward meeting habitat objectives can be monitored through geographic information systems by incorporating georeferenced information on public lands, private lands under conservation easements, corporate lands under prescribed management, habitat restoration areas, and private lands under alternative management to enhance wildlife values. We recommend that the area and distribution of habitats within the area covered by conservation plans be reassessed from remotely sensed imagery at intervals appropriate to detect predicted habitat changes.

Arresting declining populations of Neotropical migratory birds will, in many cases, require migratory bird conservation plans that include regional and local management actions. Bird conservation plans developed for physiographic areas or smaller local areas will likely focus on maintaining or increasing populations of specific bird species (Mueller and others, this proceedings). Progress toward population goals set by these bird conservation plans, however, will be difficult to evaluate. In some cases, established population goals, especially those for migratory birds, may be unreachable by actions undertaken solely within the geographic boundaries covered by the conservation plan. For example, factors outside established boundaries may adversely impact some species. Even when population goals can be attained by conservation efforts within defined geographic boundaries, assessing progress toward population goals may be difficult. Monitoring bird populations and their demographics over large geographic areas and over extended time periods can be a Herculean task in terms of personnel and financial resources (Sherry and Holmes, this proceedings).

Fortunately, many species of concern to managers are closely linked to specific habitat types (Hamel 1992b; Hunter and others 1993b). Often, behavioral and spatial relationships exist which allow quantifiable breeding bird populations to be associated with specified areas of designated habitat types. We recommend that bird conservation plans establish habitat objectives that enhance the likelihood of achieving avian population goals. To be effective, habitat objectives must be achievable regardless of external impacts on bird populations. Once established, habitat objectives provide benchmarks that usually can be measured, evaluated, and achieved more easily than population goals.

Determining Baseline Habitat Data

After habitats critical to migratory bird species of concern within a planning unit have been identified, the availability of these habitats should be assessed. At landscape scales, this assessment can be achieved through remote sensing technologies such as satellite imagery. Remotely sensed data can be obtained at scales from 1 km to less than 10 m using panchromatic, multispectral, infrared, or radar sensors. Choice of scale and sensor often are dictated by cost and the extent and location of desired coverage. Planners should consult with experts in remote sensing or geographic information systems (GIS) to ascertain the advantages of different imaging systems.

Managers planning at local scales have additional options for assessing avian habitats, including aerial photography and videography. When available, archived and current management records might provide accurate and detailed descriptions of habitats. Finally, ground reconnaissance should be used to delineate habitats or to verify habitat assessments from other sources.

Whether at landscape or local scales, information about avian habitats must be organized in a format that is conducive to planning and ultimately to monitoring. A GIS format is appropriate because remotely sensed data are available in digital form and can be imported directly. Additionally, these digital data must represent habitat types that are derived via computerized classification procedures. Other

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habitat data, such as photographs, management records, and ground reconnaissance, can be entered into a GIS by scanning or by digitizing maps.

For example, in the Mississippi Alluvial Valley, the extent and distribution of bottomland hardwood forest (critical habitat for avian species of concern in the Mississippi Valley [Mueller and others, this proceedings]) were classified from Thematic Mapper imagery (fig. 1). We suggest using this type of data on avian habitats as baseline data from which to establish habitat objectives. In many states, digital habitat data derived from Thematic Mapper imagery are currently or soon will be available for wildlife conservation planning through statewide "Gap analysis" projects (Scott and others 1993).

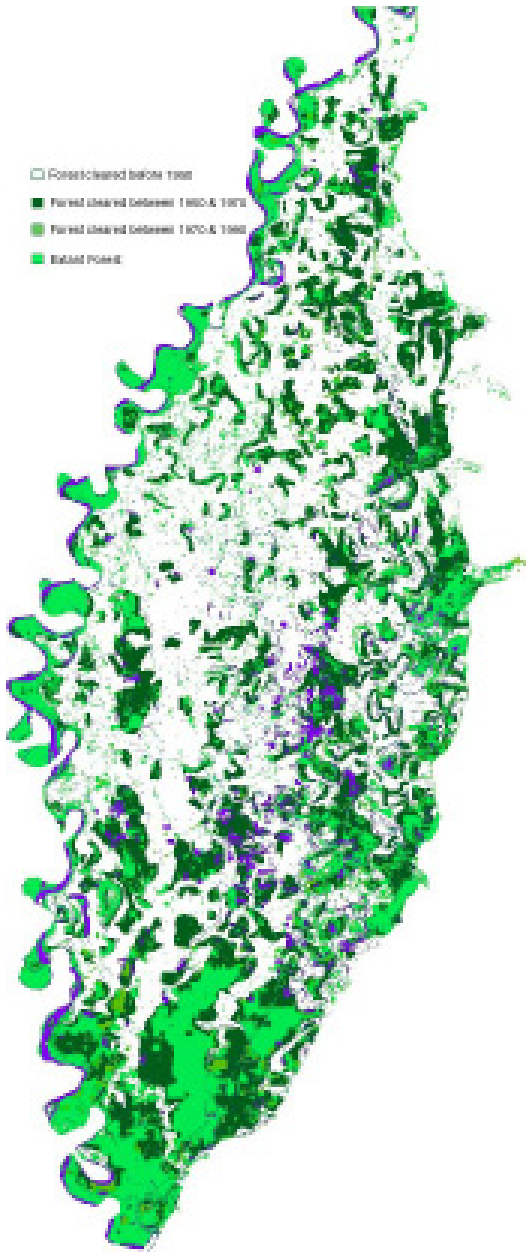

Figure 1—Distribution of forested habitat within the Mississippi "Delta," that portion of the Mississippi Alluvial Valley between Vicksburg, MS, and Memphis, TN, circa 1992, circa 1976, and circa 1957.

Establishing Habitat Objectives

The area and distribution of habitat objectives can be established from a direct assessment of hypothesized habitat needs (Mueller and others, this proceedings) or indirectly based on the needs of previously identified population goals (Loesch and others 1994; Loesch and others, this proceedings). Regardless of how established, habitat objectives can be categorized as: Maintaining existing habitats, restoring former habitats, or creating new or alternative habitats. All categories should be considered when formulating habitat objectives.

For example, to ensure continuation of extant habitats, management plans may suggest maintaining current habitat conditions (e.g., uneven-aged timber harvest) or they may compensate for habitat change by replacing existing habitat with habitat at other sites (e.g., even-aged, rotational timber harvest). Even maintaining existing habitats may be a significant challenge in areas where urban encroachment is fragmenting existing avian habitats.

Before restoring habitat, examining the historical distribution of habitats is useful. Although remotely sensed data are available for only about the past 30 years, cartographic data may be obtained for much earlier periods. Historical land surveys, topographic maps, or aerial photographs might reveal dramatic changes in avian habitats compared to current conditions. When conservation plans include restoring former habitats, historical information can be an important guide to developing logical and achievable restoration objectives. Other factors also may indicate where restoring habitat is practical. For example, soil type often determines what plant communities will thrive, thereby defining avian habitats. Similarly, water-control projects (i.e., dams and levees) have altered the hydrology of many ecosystems to the extent that restoration of historical habitats is not feasible. Thus, inclusion of soil type and hydrologic data in a GIS will provide important ancillary information for identifying areas for habitat restoration.

In areas where maintaining and restoring endemic avian habitat are not feasible, creating new habitat, establishing alternative habitat, or implementing management practices that promote avian use of existing habitats may be practical solutions. For example, in the Mississippi Alluvial Valley, replacing conventional row crops with short-rotation agroforestry provides breeding, migration, and wintering habitat for migratory forest birds while continuing to provide income for landowners. Another alternative incorporates water-control structures within existing agricultural fields to retain water on harvested croplands, thereby providing foraging habitat for wintering waterfowl without restricting farm operations during the growing season.

Monitoring Progress Toward Habitat Objectives

After habitat objectives have been established, data added to the GIS will aid in monitoring progress toward these objectives. On a landscape scale, for example, the areas of public land ownership (e.g., national wildlife refuges, state

wildlife management areas, national forests, state parks, etc.) and management (e.g., natural areas, wildlife management, multipurpose management, etc.) can be incorporated into the GIS (fig 2). Similarly, private lands enrolled in conservation easements (e.g., Ducks Unlimited), in government programs (e.g., Conservation Reserve or Wetland Reserve), or maintained for long-term economic return (e.g., corporate timber holdings and private grazing land) can be added to the GIS (fig. 3). The area and location of these dedicated conservation lands, in relation to habitat objectives, directly affects our ability to maintain existing avian habitats. Additionally, these lands provide opportunities to restore former habitats and can serve as areas to focus habitat restoration.

Projects to restore habitats often are part of larger conservation efforts; therefore managers should ensure that the areas influenced by their restoration project are accurately delineated on georeferenced maps or geocoded (e.g., by

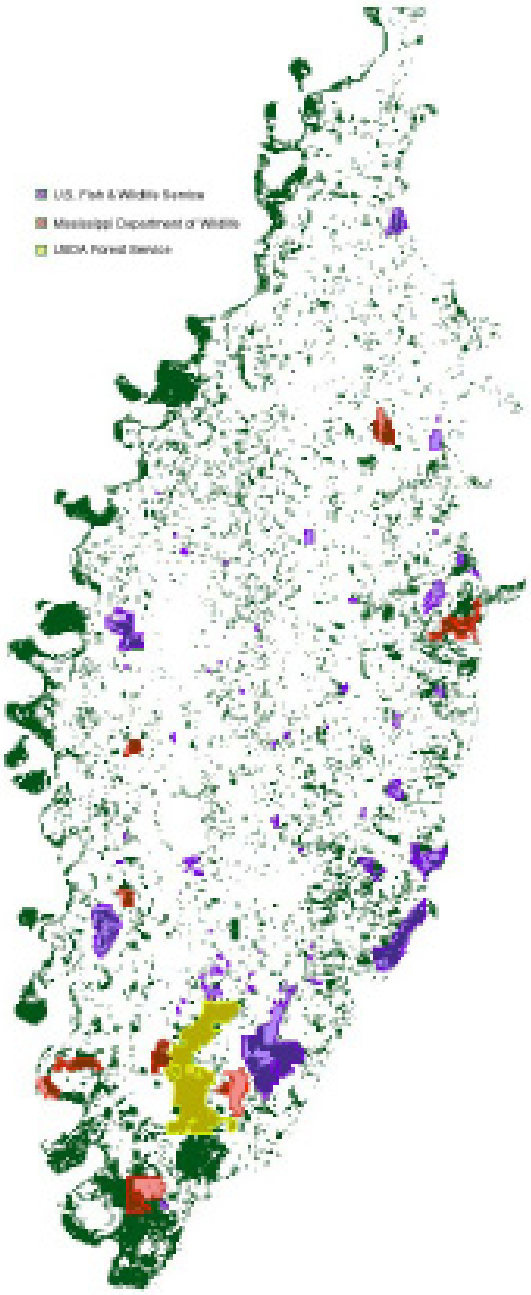

Figure 2—Location of public lands within the Mississippi "Delta," that portion of the Mississippi Alluvial Valley between Vicksburg, MS, and Memphis, TN.

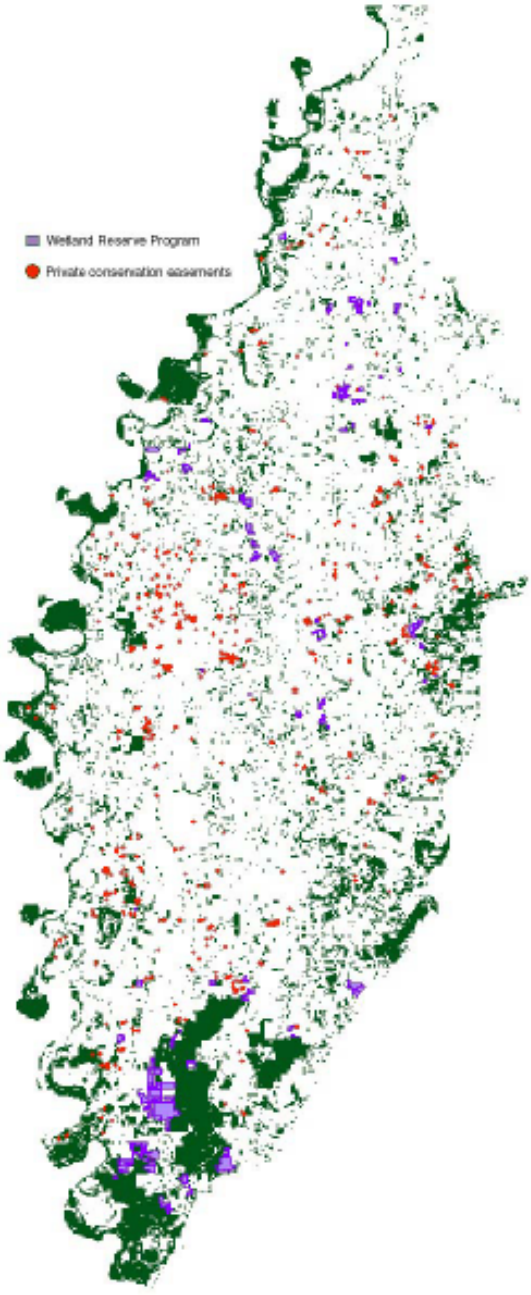

Figure 3—Lands enrolled in the Wetland Reserve Program and private lands under cooperative agreements (e.g., Mississippi Partners projects) to manage wildlife within the Mississippi "Delta," that portion of the Mississippi Alluvial Valley between Vicksburg, MS, and Memphis, TN.

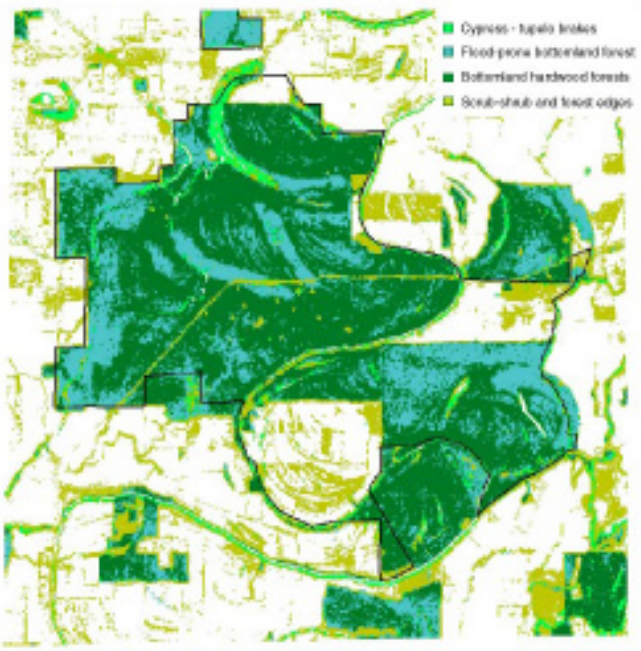

Figure 4—Four forest classes derived from 1992 Thematic Mapper imagery of the northern portion of Tensas River National Wildlife Refuge, LA. Black line depicts refuge boundary.

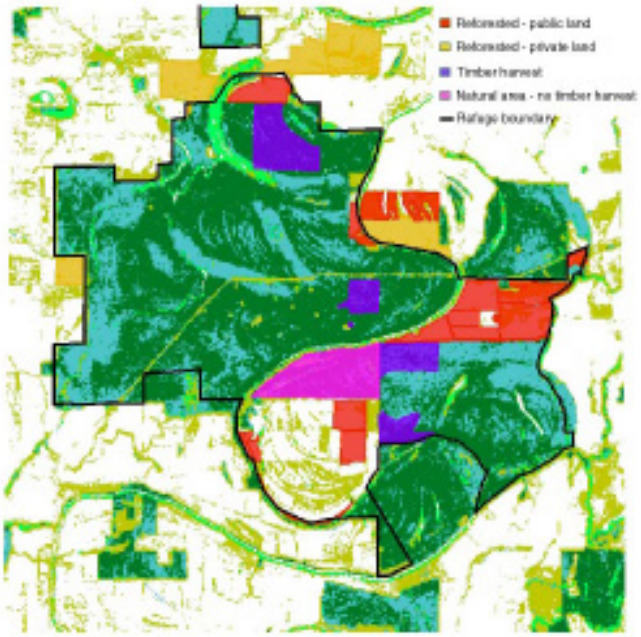

Figure 5—Areas of reforestation, areas of timber harvest, and areas of unmanaged forest on the northern portion of Tensas River National Wildlife Refuge, LA.

global positioning systems). When private landowners restore habitat, they should be encouraged or assisted in geocoding the area impacted, and these data should be incorporated into the habitat-monitoring database. When alternate land management or conservation enhancements are developed, such as installation of water-control structures, the lands affected should also be incorporated into the GIS (fig. 3).

On a local scale, similar data can be incorporated into migratory bird conservation plans for wildlife management areas or other management units (fig. 4). Habitat objectives within the management unit can be established in concert with habitat objectives set at a landscape scale and restored or modified habitat can be added to the GIS (fig. 5).

Identification of public and private managed lands, inclusion of restoration areas, and identification of areas under alternative management may be sufficient to monitor progress toward achieving migratory bird habitat objectives at local scales. However, to monitor progress toward habitat objectives at landscape scales, we recommend using remote sensing to periodically update habitat data.

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Lying in Wait for Partners in Flight: Some Experiences Monitoring Birds in Southeastern Bottomlands

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Michael R. Dawson
Mike Staten

Abstract—Partners in Flight stimulated a group of researchers and managers in the Southeast to produce a guide to design and conduct monitoring activities using point counts. Monitoring birds in the Southeast, however, predates the appearance of Partners in Flight. Some observers have been monitoring bird populations on fixed study plots as part of ongoing management activities for several years. Monitoring on the Francis Beidler Forest, a National Audubon Society/Nature Conservancy sanctuary in South Carolina, demonstrates how an ongoing program, developed to support management and information and education activities, can provide unanticipated benefits. When Hurricane Hugo radically altered the forests of the Sanctuary, it created an opportunity to compare the bird communities of the Sanctuary before and after the hurricane. Elsewhere, the experience of Anderson Tully Company indicates how monitoring birds, in support of timber management activities, provides an important new training and evaluation tool for a private industrial timber company. A powerful and hopeful take-home message to southeastern land managers has been that getting started is the most difficult, but also the most important part of a monitoring program, and that regardless of the available effort, a commitment to monitor will provide useful results over the long term. The Partners In Flight process has brought managers and research biologists together in the realization that some activities are more widely useful than others, and this has improved our common understanding of the populations and management of birds in the Southeast.

Our charge is to examine the state of the art in monitoring. This usually is construed to mean the most advanced possible practice of the art; our purpose here is to examine the state of the art as it currently is practiced by managers in the Southeast, in the hope of demonstrating activities that are within the grasp of every manager. We believe that the success of the North American Bird Conservation Strategy depends more upon the activities of all managers than on those of practitioners on the so-called cutting edge.

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We describe three separate monitoring activities. First, we outline the strategy adopted for monitoring by the Southeast Management Working Group, and its realization in the monitoring plans of the National Forest System and the U.S. Fish and Wildlife Service in the South. Second, we outline the experience of the managers of a private, nonprofit organization, the National Audubon Society, in monitoring birds on the Francis Beidler Forest. We here address monitoring the unintended consequences of management by examining bird response to a catastrophic natural disturbance. Third, we describe the experience of a private, industrial timber company, Anderson Tully Company, in monitoring birds on their extensive holdings in the Mississippi Alluvial Valley. This permits us to examine the unintended outcomes of monitoring.

Case Studies

Case 1—Southeast Management Working Group, Partners in Flight: Monitoring Strategy for the Region

The Southeast Management Working Group has produced a strategy and set of standards for conducting monitoring of birds in the South (Hamel and others 1996). Based primarily on experience developed in the Mississippi Alluvial Valley (Smith and others 1993), and consistent with the suggestions of Ralph and others (1993), the strategy indicates to individual managers how they might establish a monitoring program using point counts. The strategy provides managers with step-by-step guidelines to determine the intent of the monitoring program, the level of detail sufficient to meet the intent of the program, and the sample sizes of counts sufficient to answer particular questions.

Our experience in the Southeast suggests that basic bird lists are unavailable for most properties. We believe that such lists are the keys to successful monitoring, inventory, and public education involving birds; hence we encourage managers to develop bird lists.

For properties with bird lists, we suggest that managers determine what sort of information is necessary for them to carry out their management tasks successfully. The step-by-step process outlined in the strategy guides the manager to assess whether information on presence-absence, relative abundance, or demography is the intent of the monitoring activity. Detailed instructions allow the

manager to determine the number of point count samples required to address two basic questions related to differences in numbers of birds. First, we address the question "have bird communities on my property changed over the years?" Second, we address the question "have bird communities responded to management treatments that I have applied?" Our "Quick-and-Dirty" estimation of sample size starts with these questions, proceeds through the development of an estimate of variability derived from a pilot sample of counts, describes the estimation of the power available from a given sample of counts, and details how to determine a sufficient number of point counts to address a given question with a particular defined precision. Unfortunately, no magic number of counts can be named to satisfy every need.

Application of this process has resulted in the deployment of broad-scale monitoring schemes on U.S. Fish and Wildlife Service properties (R. Coon, personal communication) and on U.S. Forest Service properties (Gaines and Morris 1996) in the Southeast. Importantly, the schemes developed by these two public agencies are within reasonable reach of what managers across the region can endorse and carry out. An unintended benefit of this process has been the development of a commercially available software package that supports the data standards developed for the Southeast (Guddanti 1994).

All of these activities have taken place in the 1990s, with growing recognition of the impetus and value of becoming a Partner in Flight. Yet monitoring of birds is not a new idea in the South, although it has been a fairly low priority in many quarters. Nevertheless, some managers truly have been lying in wait for Partners in Flight. We present two additional case histories illustrating how the development of a monitoring program that is responsive to the information needs of the land manager can provide unintended benefits to the manager, including scientific information, public education, and revenue.

Case 2—The Francis Beidler Forest: Monitoring Response to Natural Catastrophe

The Francis Beidler Forest, a sanctuary jointly owned by the National Audubon Society and The Nature Conservancy, is managed by the National Audubon Society primarily as a place where 1000-year-old baldcypress (*Taxodium distichum*) trees can grow in peace. At purchase in 1973 the sanctuary consisted of about 3,600 acres (1,500 ha) nearly evenly divided between old-growth bottomland hardwood forest, especially cypress-tupelo (*Nyssa aquatica*) stands, and similar stands that had been selectively logged during the 1960s.

To learn more about their land, NAS put a single person in the field for 10 mornings per year, and established two objectives for a bird monitoring program. First, they wanted to track fluctuations in populations of breeding birds on the property as one measure of forest health and to develop a bird species list for forest visitors. Second, they decided to compare populations on the old-growth with those on the cutover portion of the tract. To address these two objectives, Beidler Forest staff set up two 8-ha spot-mapping plots on sites of matching topography, with one in the old-growth portion, and the other in the cutover portion of the tract. After initial sampling of each tract in 1979, an alternating schedule was adopted in which one of the plots was sampled each year.

A total of 16 censuses have been conducted, eight on each of the plots. Fifty-seven species have been recorded on at least one of the censuses, 50 on the cutover plot, and 49 on the old-growth plot. Seven species occur at different densities on the two plots, five of which are Neotropical migratory birds (appendix). Four of these species have significantly greater densities on the cutover and three on the old-growth plot, indicating that neither habitat on the Beidler Forest is better for all the species of the sanctuary. Among the species more abundant on the cutover plot is the Swainson's Warbler (*Limnothlypis swainsonii*) whose population peaked on the cutover plot in 1979, 12 years after the initial harvesting of much of the canopy of the stand.

These data have been useful to Beidler Forest managers in their own right, but are not the major story of the bird monitoring program there. On the night of 21 September 1989, Hurricane Hugo visited the Low Country of South Carolina, bringing 150 mph (240 kph) winds and extensive destruction to the forests on the sanctuary. Among the very few positive remnants after the storm was the opportunity to compare the populations of bird species on the sample plots before and after the storm. These comparisons provided Beidler Forest staff with quantitative information to demonstrate to their visitors the actual effects of the storm on the birds of the Beidler Forest. Densities of five species were shown to be different on the Beidler Forest after the storm by Wilcoxon 2-sample tests; each is a Neotropical migratory bird. Densities of Yellow-billed Cuckoos (*Coccyzus americanus*; $Z = -2.11$, $P < 0.05$), Chimney Swifts (*Chaetura pelagica*; $Z = -1.97$, $P < 0.05$), Wood Thrushes (*Hylocichla mustelina*; $Z = -2.86$, $P < 0.01$), and Northern Parulas (*Parula americana*; $Z = -2.95$, $P < 0.01$) declined, while those of Blue-gray Gnatcatcher (*Polioptila caerulea*; $Z = 2.7$, $P < 0.01$) increased. Among species whose densities did not differ significantly after the storm were the Yellow-throated Warbler (*Dendroica dominica*) and Northern Cardinal (*Cardinalis cardinalis*). Because baldcypress trees were particularly resistant and hence relatively unchanged by the winds of the storm (N. Brunswig, unpublished data), we expected that birds associated with cypress stands, such as Yellow-throated Warblers, would be affected less than others by the storm. Northern Cardinals, on the other hand, increased on the old-growth plot to numbers typical of their use of the cutover plot before the storm. These birds are associated with shrubby understory in the forest, which increased dramatically after the storm.

The effects of Hurricane Hugo on the bird community of the Beidler Forest could not be evaluated were it not for the foresight of managers to institute a monitoring program. The techniques used were put into practice long before a larger scale program like Partners in Flight, and so do not use the same standards as currently employed in the Southeast. Nevertheless, they serve the needs of the manager and have provided some valuable information on bird community response to a very infrequent natural perturbation that was, otherwise, a disastrous event for the sanctuary.

Case 3—Anderson Tully Company: Monitoring Provides Unexpected Benefit of Information Transfer

Anderson Tully Company is a private timber company engaged in production of large sawtimber trees (Staten and Hodges 1997). The company, founded in 1889, owns lands in the Mississippi Alluvial Valley from Illinois to Louisiana. It maintains a set of permanent 0.2-acre (0.08-ha) plots on which are measured timber inventory variables for their timber management activities. Plots, classified into one of 11 forest site types, are sampled every five years.

Because a large proportion of their land is leased to hunt clubs, over time the company's wildlife management staff bolstered the list of inventory variables by adding measures of presence of four browse plants important for white-tailed deer (*Odocoileus virginianus*): dewberry (*Rubus* sp.), honeysuckle (*Lonicera* sp.), greenbrier (*Smilax* sp.), and trumpetcreeper (*Campsis radicans*), as well as measurements of live and dead cavity trees.

During a 1990 field trip for the Arkansas Chapter of The Wildlife Society to company lands in eastern Arkansas, the land manager noticed that a considerable store of information about bird occurrence existed among his wildlife staff. Excited about the variety of birds on company lands, he decided to add information about bird occurrence to the standard inventory. Concern also existed about potential conflicts between bird populations and certain management activities.

The company's wildlife staff developed protocols for adding a continuous habitat inventory to the timber inventory. The approach represented a hybrid of available effort and desired coverage. A randomly selected subset of 65 of the permanent plots was chosen for wildlife habitat monitoring, comprising five plots in each of nine forest site types on company lands, and ten plots in each of the two most common types ("Riverfront hardwoods-Dry site," and "Upland Hardwoods-Good site"). Within each permanent wildlife monitoring plot, extent of downed woody vegetation, both long wood and top materials, and stumps are measured. A set of 20 1-yd^2 (0.84-m^2) subplots also is sampled for understory vegetation. Each of these 65 plots became the center for a star of five bird point count stations, spaced 200 m apart.

The first sampling of these 325 point count stations was conducted in 1994. A standard 10-minute count was conducted at each of the points. Vegetation sampling on bird point count stations involved a visual determination of the actual forest site type, as well as estimation of percent coverage by the vegetation and the two most frequent species in vegetation layers. General layers involved ground cover, midstory, and overstory. Within each of these layers, field crews determined whether to separate coverage into three or fewer sublayers. Field effort for this monitoring activity involved a four-person crew for six field weeks.

Company plans call for resampling on the same 5-year interval as the timber inventory plots. Point count data will be prepared and summarized to the standards of the Southeast Management Working Group.

To train their staff to conduct this monitoring activity, Anderson Tully Company wildlife biologists realized that no simple field guide, complete with a set of tapes of songs of breeding birds, existed for the birds of bottomland hardwoods. Furthermore, existing larger treatments, such as Hamel (1992b), did not present relationships of birds to standard habitat structures in a quickly understood visual manner. Consequently, company biologists and foresters compiled a book, complete with species accounts, identification, habitat and other details of species biology, and a narrative and visual summary of proposed silvicultural and structural habitat use for each of 71 species (Staten 1994). An audiotape or compact disk of songs of these species also was prepared. The book and tape are available from the company, and proceeds from the sale will be used to support the company's research activities.

The story, however, does not stop here. In the process of developing this guide, establishing monitoring activities, and training company biologists for this work, an interesting thing happened. The consciousness of not only company biologists, but of the company's entire forest management field staff, has expanded to include knowledge of birds as a part of the store of knowledge about company lands. Field foresters bring questions of bird identification to biologists; through this interaction and the combined understanding of forest structure and bird response on company lands, a practical understanding of silviculture for songbirds on company lands is emerging. At periodic department managers' meetings, the land manager now conducts "field tests" in which field managers make point counts of birds, and compare their counts to those of company biologists to improve the quality of the general knowledge of birds among all company field personnel. We propose that the experience of this one timber company can be instructive to others interested in, or apprehensive about, adding specific songbird activities to their land management program.

Summary

We have attempted to show, through three different examples, how monitoring activity must meet the recognized needs of the land manager of a property. Our examples indicate that well-designed monitoring activities can meet efficiently the objectives of information gathering necessary to the land management activities of a particular agency or property owner. They further show that monitoring designed for a specific purpose can incidentally provide outstanding opportunities for responding to natural or planned disturbances, for training staff, for educating clientele among the general public, and for increasing income.

Several additional points can be made. First, in monitoring birds on a given property, benefits will accrue to the managers who invest time in working with their neighbors to develop and implement a monitoring scheme. Our current understanding of the effects of landscape factors on bird distribution clearly indicates this common-sense notion. Second, successful monitoring activities can be developed through a step-by-step, adaptive process in which it is not necessary to try to "run before one can walk." Third, monitoring activities that are integrated into the ongoing staff training, public information, and decision-making processes of the agency or institution will satisfy not only the intended objectives. They also will put the enterprise in

a position of preparedness, of "lying in wait" for a future that promises unexpected opportunities.

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Appendix: Summary of bird occurrence on two 8-ha plots on the Francis Beidler Forest, SC, 1979-1995.

Species	Cutover plot	Old-growth plot
	n = 8	
Great Blue Heron, *Ardea herodias*	0.02 ± 0.04	0.0 ± 0.0
Great Egret, *Casmerodius albus*	0.01 ± 0.04	0.0 ± 0.0
Little Blue Heron, *Egretta caerulea*	0.01 ± 0.04	0.0 ± 0.0
Green-backed Heron, *Butorides striatus*	0.09 ± 0.2	0.0 ± 0.0
Yellow-crowned Night-Heron, *Nycticorax violaceus*	0.05 ± 0.05	0.05 ± 0.05
White Ibis, *Eudocimus albus*	0.04 ± 0.05	0.04 ± 0.05
Wood Duck, *Aix sponsa*	1.6 ± 4.4	5.6 ± 6.7
Turkey Vulture, *Cathartes aura*	0.0 ± 0.0	0.02 ± 0.05
Red-shouldered Hawk, *Buteo lineatus*	2.4 ± 4.6	5.7 ± 6.0
Northern Bobwhite, *Colinus virginianus*	0.0 ± 0.0	0.01 ± 0.04
Mourning Dove, *Zenaida macroura*	0.04 ± 0.05	0.05 ± 0.05
Yellow-billed Cuckoo, *Coccyzus americanus*	39.0 ± 23.8	30.9 ± 17.0
Eastern Screech-Owl, *Otus asio*	0.0 ± 0.0	0.01 ± 0.04
Barred Owl, *Strix varia*	0.1 ± 0.2	0.2 ± 0.2
Chimney Swift, *Chaetura pelagica*	1.6 ± 4.3	12.6 ± 11.1
Ruby-throated Hummingbird, *Archilochus colubris*	0.02 ± 0.05	1.4 ± 4.0
Red-headed Woodpecker, *Melanerpes erythrocephalus*	1.6 ± 4.4	4.9 ± 9.2
Red-bellied Woodpecker, *Melanerpes carolinus*	73.7 ± 37.5	79.3 ± 34.9
Downy Woodpecker, *Picoides pubescens*	28.2 ± 23.5	44.3 ± 21.8
Hairy Woodpecker, *Picoides villosus*	0.0 ± 0.0	4.3 ± 8.3
Pileated Woodpecker, *Dryocopus pileatus*	22.0 ± 8.6	26.0 ± 12.9
Eastern Wood-Pewee, *Contopus virens*	0.0 ± 0.0	1.4 ± 4.0
Acadian Flycatcher, *Empidonax virescens*	91.0 ± 27.8	95.5 ± 53.6
Great Crested Flycatcher, *Myiarchus crinitus* [b]	38.2 ± 28.2	109.6 ± 34.0
Blue Jay, *Cyanocitta cristata*	0.02 ± 0.05	0.06 ± 0.05
American Crow, *Corvus brachyrhynchos*	3.2 ± 5.7	5.0 ± 9.2
Fish Crow, *Corvus ossifragus*	1.6 ± 4.3	0.06 ± 0.05
Carolina Chickadee, *Parus carolinensis*	32.4 ± 24.4	35.8 ± 17.5
Tufted Titmouse, *Parus bicolor*	125.4 ± 63.7	113.8 ± 17.4
White-breasted Nuthatch, *Sitta carolinensis* [b]	3.2 ± 5.7	47.1 ± 24.9
Carolina Wren, *Thryothorus ludovicianus*	104.9 ± 46.4	99.7 ± 49.5
Blue-gray Gnatcatcher, *Polioptila caerulea*	344.1 ± 129.6	304.1 ± 91.4
Wood Thrush, *Hylocichla mustelina*	18.5 ± 17.8	8.5 ± 11.2
Gray Catbird, *Dumetella carolinensis*	0.8 ± 2.2	1.4 ± 4.0
Brown Thrasher, *Toxostoma rufum*	1.5 ± 4.4	0.0 ± 0.0
White-eyed Vireo, *Vireo griseus* [b]	151.2 ± 56.7	49.9 ± 28.2
Yellow-throated Vireo, *Vireo flavifrons*	12.4 ± 18.6	7.7 ± 14.1
Red-eyed Vireo, *Vireo olivaceus*	121.1 ± 32.1	111.7 ± 47.5
Northern Parula Warbler, *Parula americana*	147.4 ± 59.2	160.1 ± 115.4
Black-throated Blue Warbler, *Dendroica caerulescens* [c]	0.04 ± 0.05	0.01 ± 0.04
Yellow-throated Warbler, *Dendroica dominica* [b]	10.1 ± 12.2	52.7 ± 24.2
Pine Warbler, *Dendroica pinus*	0.01 ± 0.04	3.5 ± 9.9
American Redstart, *Setophaga ruticilla*	0.0 ± 0.0	0.01 ± 0.04
Prothonotary Warbler, *Protonotaria citrea*	101.8 ± 32.8	83.6 ± 39.4
Swainson's Warbler, *Limnothlypis swainsonii* [b]	20.9 ± 30.4	1.4 ± 4.0
Ovenbird, *Seiurus aurocapillus* [c]	0.04 ± 0.05	0.02 ± 0.05
Louisiana Waterthrush, *Seiurus motacilla*	0.01 ± 0.04	0.0 ± 0.0
Kentucky Warbler, *Oporornis formosus*	3.1 ± 5.7	0.02 ± 0.05
Common Yellowthroat, *Geothlypis trichas*	0.02 ± 0.05	0.7 ± 2.0
Hooded Warbler, *Wilsonia citrina* [b]	102.3 ± 37.0	23.9 ± 25.6
Yellow-breasted Chat, *Icteria virens*	0.01 ± 0.04	0.0 ± 0.0
Summer Tanager, *Piranga rubra*	10.9 ± 10.1	26.7 ± 14.3
Northern Cardinal, *Cardinalis cardinalis* [b]	72.9 ± 17.3	37.2 ± 37.7
Indigo Bunting, *Passerina cyanea*	0.0 ± 0.0	0.7 ± 2.0
Eastern Towhee, *Pipilo erythrophthalmus*	1.5 ± 4.4	0.0 ± 0.0
Common Grackle, *Quiscalus quiscula*	1.2 ± 3.2	0.05 ± 0.05
Brown-headed Cowbird, *Molothrus ater*	3.1 ± 8.7	4.3 ± 11.9

Density ± S.D., in pairs/100 ha[a].

[a]Partial territories and visitor species quantified as by Hamel (1992).
[b]Species densities differ between the plots by Wilcoxon 2-sample test at P = 0.05.
[c]Transient species recorded only as visitors during migration.

DC Birdscape: A Program for Monitoring Neotropical Migratory Birds in Washington, DC

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Abstract—Urban and suburban habitats often contain a variety of Neotropical migratory birds, but are poorly sampled by programs such as the North American Breeding Bird Survey. DC Birdscape was developed to inventory and monitor birds in Washington, DC. Birds were surveyed using a systematic sample of point counts during 1993-1995. Results indicate that species richness of Neotropical migratory birds varied among land-use categories, and that maximum species richness occurred in parkland habitats. Although DC Birdscape has provided relevant information on bird distribution and species richness, it is unclear whether the information is of sufficient management interest to support its continuation as a long-term monitoring program.

Neotropical migratory birds (NTMBS) tend to be associated with forests during the breeding season, leading many biologists to discount the importance of urban and suburban habitats for these species. However, information on population changes in NTMBs from urban parks has been influential in creating the perception of long-term declines in the species (Terborgh 1989), and the increasing extent of suburbia has caused urban habitats to appear near many areas that are surveyed by the North American Breeding Bird Survey (BBS; Peterjohn and Sauer 1993) that formerly were rural. The always-expanding suburban and urban centers provide experimental and management opportunities, because urban planners often have the opportunity to manipulate the extent and structure of woodlot fragmentation (Dawson and others 1993). As many people encounter birds only in urban and suburban habitats, monitoring and managing birds in these areas will benefit the species and increase public awareness of management for NTMBs.

Washington, DC, contains a surprising number of urban parks and other habitats that support migrating and breeding NTMB species. Parks are of particular interest, and long-term data exist from Breeding Bird Censuses for some parks in Washington (Terborgh 1989), but how changes in these parks relate to regional bird population changes is unclear. To provide a regional context for the park data, a consortium of groups—including the Audubon Naturalist Society, the Biological Resources Division (then the U.S. Fish and Wildlife Service), and the National Park Service—worked together to design and implement a monitoring program for birds in Washington. Because the Washington region has a large concentration of amateur and professional ornithologists who have participated in Atlases and Christmas Bird Counts in the city, we felt that volunteer birders could be used as surveyors in the program. Here, we provide a brief summary of the project. A more extensive analysis is available in Hadidian and others (1997).

Methods

Field Methods

Bird sampling was conducted using single, 5-minute point counts on a systematic grid. Most of the sampling occurred in 1993, but additional counts were conducted in 1994 and 1995 to fill in gaps in coverage and to provide more intensive coverage in parks and other areas of particular interest. Here we present results from the initial 1993 survey only. The study area was metropolitan Washington, DC, on which a Geographic Information System (GIS) was used to define a grid with uniformly spaced intersections (nodes) at 500 m intervals (Hadidian and others 1997). Bird sampling was conducted at the 617 of these nodes that could be reached by observers.

To assist observers in locating points, field maps were created by using GIS to combine point locations with cartographic data. Maps were designed to show no more than nine points (the number of sample points that could be covered easily in one day), and to provide location information at a

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reasonable scale. Experienced observers were assigned between one and ten map areas to be surveyed between 31 May and 30 June. Surveys were conducted between 0600 and 0930 on mornings when conditions permitted (no steady rain, and calm or low wind conditions). Time, weather conditions, and species and numbers of bird detected were recorded at each point.

Data Analysis

The initial intent of the program was to map bird species distributions within the city, to define associations between bird species distributions and land use in the city, and to provide information that could be used in conjunction with repeated surveys to assess bird population change.

To accomplish the first two goals, we used the GIS to associate the bird survey locations with coordinates on a map (to allow mapping) and with land-use at the locations. Seven land-use categories (Residential-low density, Residential moderate density, Residential-high density, Commercial, Public and Institutional, Parklands, and Industrial-Airport) were summarized from land-use classes developed by the District of Columbia Office of Planning and digitized for analysis (table 1). Survey locations were then overlaid onto the land-use categories for analysis.

In point count-based surveys, observers almost never count all of the birds at the points. To analyze the data, we must assume that the proportion of birds missed at each point is consistent among points, an assumption that generally is not true (Barker and Sauer 1992). In surveys involving many observers, for example, it is likely that observer and habitat differences in detection rates of birds could invalidate comparisons based on numbers of birds counted (Barker and Sauer 1995). Consequently, we used relative abundance data only for map construction. Maps were made of distributions of birds using the count data from the sample points (Hadidian and others 1997).

Although comparisons of relative abundance from point counts can be biased by visibility differences, species richness can be estimated from count data using mark-recapture models (Burnham and Overton 1979). These statistical methods allow estimation of number of species present at each point (or land-use category) even if species are not encountered during sampling, and are generally applicable to the analysis of point count data (Nichols and Conroy 1996). We used the capture-recapture procedure to estimate species richness by land-use category for species categorized as Neotropical migratory species as defined in Peterjohn and Sauer (1993), then compared species richness among land-use categories, using a Chi-square test (Sauer and Williams 1989).

Table 1—Land use categories used in DC Birdscape project, with brief explanations about uses, estimated species richness of Neotropical migratory birds, and standard errors of the species richness estimates. Estimated species richness and its standard error also are provided for all habitats combined.

Category	Species richness	SE
Residential-low density (single family detached and semi-detached houses)	31	5.5
Residential-moderate density (row houses)	11	2.5
Residential-high density (multiple-unit housing, mid and high-rise apartments)	18	7.4
Commercial (low-high density shopping and service areas)	6	1.4
Public and institutional (land and facilities of federal and district government)	21	3.2
Parkland (district and federal parks, recreation centers, and open space)	39	3.7
Industrial-airport (industrial land and national airport)	9	2
Total	46	4.2

Results

Ninety-one species were observed at points sampled in 1993. The largest number of points were located in Parkland (171 points), while only 21 points were located in High-density residential areas. See Hadidian and others (1997) for a detailed analysis of species richness for a variety of species groups and habitats.

Species Richness of Neotropical Migratory Birds

The estimated total species richness of NTMBs in the Washington, DC, metropolitan area was 46 (±4 SE) (table 1). The estimated species richness for all species was 115 (±8 SE), closely matching the documented species total from anecdotal sources.

Estimated species richness of NTMBs differs greatly ($P < 0.001$) among land-use categories in Washington, ranging from 6 in Commercial areas to 39 in Parklands. In Hadidian and others (1997), we document other aspects of species richness, and assess the association between size of land-use category and species richness.

Relative Abundance Maps

Maps have been produced for a variety of species, and these maps provide the first quantitative information about relative abundance for the species within Washington, DC. They will be made available to urban planners and the public through publications, Internet home pages, and other outlets. See Hadidian and others (1997) for examples of relative abundance maps produced from DC Birdscape. Point maps of species distributions are available over the Internet (http://www.mbr-pwrc.usgs.gov/dcbirds/dcbird.html).

As expected, patterns of relative abundance for most species reflect the availability of habitat. For example, Parks and other forested areas contain Wood Thrush *(Hylocichla mustelina),* while other areas generally do not.

Discussion

Is DC Birdscape a Monitoring Program?

DC Birdscape originally was intended to provide a systematic sample of bird species' relative abundances and distributions throughout the metropolitan area. From these data, associations among land-use categories, other habitat features, and abundances provided information for land managers on possible consequences of land use changes on bird communities. The data also provided an extensive view of bird distributions within the region for public use. Most participants in the planning of the study believed that it would be repeated after several years, to allow for monitoring of changes, but no organization committed itself to planning future surveys.

Although DC Birdscape clearly has the potential to monitor population change, several conditions should be met before a decision can be made to repeat the survey.

1. It must be documented that the information is of use to managers. If information about bird population changes in the urban area is not likely to be used by urban planners and bird population biologists, then the program should not be repeated. Goals must be developed for the repeated survey, and support must be obtained from potential users of the data. Of course, this is an interactive process, and making land managers and planners aware of the existence of the data is an essential function of the organizers.

2. The efficiency of the survey to estimate population change must be evaluated. If the estimates of population change from the repeated survey are extremely imprecise, the data will be useless for management. Several methods exist to assess the efficiency of the survey. Replicate counts at the sample locations can be used to assess within-year variation in counts (Link and others 1994), or replication of a subset of points in a future year could be used to provide pilot information on population change. These evaluations should be conducted before any long-term program is implemented.

3. An administrative structure must be developed to support the survey. Biologists hate bureaucracies, which generally stifle innovation and divert funds from operational programs. However, DC Birdscape has been greatly hampered because it lacks a coherent source of funding. Most of the work on the project has not been officially supported, leading to analyses not being completed on schedule. To continue the survey, a source must be identified to fund staff for organizing the fieldwork, collating the data, and conducting analyses.

How Could DC Birdscape Contribute to Large-Scale Monitoring Efforts?

If the survey provided estimates of population change for Washington, DC, the information would be useful in several contexts. The Washington region has a variety of land management agencies that monitor parks, military lands, and other areas. Most managers are interested in changes in bird populations on their lands. The GIS component of DC Birdscape provides explicit information about the association of points with land-use information. This information can be used to determine associations between changes in land use and changes in bird populations. Although these associations do not necessarily imply cause and effect relationships, managers can use them to determine post-hoc effects of changes in land use.

Although the area monitored by DC Birdscape is small relative to the extensive coverage provided by monitoring programs such as the BBS, the information from the more intensive, explicitly georeferenced program could provide valuable additional information. Information from the survey could be combined with the more extensive information by considering the area as a separate strata, although some technical issues need to be resolved in combining the indexes from the surveys.

Surveys such as DC Birdscape also play a role in bridging the gap between local studies, such as Breeding Bird Censuses (BBC; Johnston 1990) in individual woodlots, and large scale programs such as the BBS. The BBS often is criticized because it is large scale and landscape level, hence using the information to address local issues is difficult. Local surveys, such as the BBC, have only a local context that does not allow assessment of large-scale patterns of population change. DC Birdscape, with its local and regional components, could play a valuable role in reconciling patterns of population change in single sites with regional patterns of population change.

Boreal Partners in Flight: Working Together to Build a Regional Research and Monitoring Program

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Abstract—Boreal regions of western North America regularly support breeding populations of 130 species of landbirds, including 68 Nearctic-Neotropical migrants. Primary conservation concerns within the region include increased timber harvesting, insect outbreaks, fire suppression, mining, impacts of military training activities, urbanization, and recreational activities. Under auspices of Partners in Flight, biologists, land and resource managers, and conservationists from Alaska and western Canada have combined efforts to develop a regional research and monitoring program for landbirds. An experimental monitoring program has been under way during the past four years to test the relative statistical power and cost-effectiveness of various monitoring methods in Alaska. Joint efforts currently include the Alaska Checklist Project on National Wildlife Refuges, 75 Breeding Bird Surveys along the road system, 122 Off-road Point Count routes, 27 Monitoring Avian Productivity and Survivorship banding sites, and 8 migration banding stations. The ultimate goal is to design a comprehensive monitoring program that is sensitive to changes in population size, survival rates, and productivity, but robust enough to accommodate logistical constraints that arise when working in vast, roadless areas with limited funds and staff. Primary challenges that must be faced to assure the long-term future of such a program are obtaining long-term commitment from resource agencies in the region, integrating this program with other national and regional programs that address those species and habitats that are inadequately monitored by established techniques, and developing cooperative research, monitoring, and management programs at the landscape level.

Boreal regions of northwestern North America support a rich diversity of terrestrial breeding habitats for birds. Coastal tundra blankets the northern and western fringes of the continent. Taiga and mixed forests of spruce (*Picea glauca* and *P. mariana*) and hardwoods cover large expanses of the interior, whereas old-growth coniferous forests tower along the southern coasts. Shrub thickets line riparian corridors and lower hillsides throughout the region, while alpine tundra cushions the peaks. Alaska's diverse terrestrial habitats host large breeding populations of landbirds, which converge from wintering areas across all continents of the globe except Antarctica. More than half of the 130 species of landbirds breeding in Alaska, however, winter in the Neotropics.

Boreal Partners in Flight had its inception in November 1991, when a small group of biologists held a workshop on landbirds at the Fourth Alaska Bird Conference in Anchorage, Alaska. We were concerned with the alarming downward trends in populations of Nearctic-Neotropical migrants which had been studied elsewhere on the continent (cf., Keast and Morton 1980; Rappole and others 1983; Robbins and others 1986, 1989b; Terborgh 1989; Hagan and Johnston 1992). We knew very little about the landbirds that rely on northern areas each year to breed, so we decided to combine our efforts to determine the status of boreal populations.

In March 1992 we had our first meeting of Boreal Partners in Flight, which is now a formally recognized working group of national Partners in Flight and includes over 100 members from Alaska and Canada. Our closest working relationships are among Alaska, Yukon Territory, and British Columbia. Our coalition includes representatives from all the major federal land and resource managers in Alaska and Canada, state and provincial agencies, universities, Native corporations, and local environmental consulting firms. Nongovernmental organizations such as the Alaska Bird Observatory, the Alaska Natural Heritage Program, and local chapters of the National Audubon Society play key roles. The foundation of the program, however, relies on the commitment of individuals. Boreal Partners in Flight includes biologists, land managers, teachers, and birders—a diverse, active, and dedicated group.

Conservation Concerns in Alaska

To be successful, a conservation plan must be based on sound, scientific information on the status of populations, species' habitat requirements, and the ecological processes that affect the populations and their habitats. One of the first tasks we set for Boreal Partners in Flight was to establish a regional Research and Monitoring Program in Alaska to address these information needs. We focused our initial efforts on landbird species that winter south of the United States-Mexico border, in keeping with the international program, but have since expanded our focus to include all landbirds that breed regularly in Alaska and northwestern Canada. In addition to those changes that are occurring on wintering grounds, Boreal Partners in Flight has identified seven major issues within Alaska that need to be addressed to assure the health of boreal landbird populations.

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Timber Harvesting

Timber harvesting is the primary factor that is likely to influence breeding populations throughout Alaska within the next twenty years. Harvest of old-growth coniferous forests in southeastern Alaska has been of growing concern since 1954, when two long-term sale contracts began in the Tongass National Forest. Other areas of specific concern include the Chugach National Forest, Haines State Forest, Cape Yakataga, and large Native corporation holdings within and adjacent to national parks, refuges, and forests in southeastern and southcoastal Alaska. Although only 7% of productive old-growth forests within Tongass National Forest had been harvested as of 1993, an estimated 52% of the productive forests in southeastern Alaska under state or private ownership had been removed (J. Rice, U.S. Forest Service, personal communication).

Mature white spruce forests on state and private lands on the Kenai Peninsula in southcoastal Alaska have been harvested heavily for chipped wood during the past several years, and mixed forests of spruce and hardwoods within the Tanana River Valley in central Alaska are being harvested increasingly to supply saw timber, fiber products, and pulp (L. Fortune, Alaska Department of Natural Resources, personal communication).

Three primary issues associated with timber harvesting have been identified as of special concern for landbird populations:

1. Effects of the removal of trees, changes in habitat configurations, and revegetation treatments.
2. Effects of road-building—which accompanies timber harvesting—including fragmentation of forested habitats, increased human access, and changes to drainage patterns.
3. Effects of log-transfer activities in estuarine areas.

Insect Outbreaks

A widespread infestation of spruce beetles (*Dendroctonus rufipennis*) currently exists in coniferous and mixed coniferous-deciduous forests of southcoastal and east-central Alaska. Natural changes in forest structure and composition have the potential to affect populations of many landbird species. Under the Federal Emergency Salvage Law (Public Law 104-19, § 2001), the Chugach National Forest has proposed to salvage timber in several different areas that would include not only trees that have been infested, but also healthy trees in nearby areas. Other land management agencies and private landowners in the region are also faced with decisions about how to respond to actual or potential infestations. Several questions need to be addressed to guide management decisions:

1. What would be the long-term effects of this natural insect outbreak on avian populations if no management treatment were applied? How would the structure and composition of forest habitats and avian community structure be altered?
2. What would be the effect of different types of management treatments on populations of landbird species? How would population and community dynamics be affected by timber harvests of various patch sizes, fragmentation of habitats, and changes in forest structure through different revegetation treatments?
3. How are the dynamics of outbreaks of spruce bark beetles and other insects being altered by increased rates of fire suppression throughout boreal regions?

Fire Suppression

As the human population has increased in Alaska, human habitations have become increasingly dispersed across areas that previously were uninhabited. A policy of protecting human property has led to increasing attempts to suppress natural fires, which are an important aspect of boreal forest ecology, particularly in central Alaska (Dyrness and others 1986). Fire is an important factor not only in determining a dynamic mosaic of forest types throughout the boreal region, but also in allowing regeneration of an unproductive monospecific stand to an uneven-aged stand of mixed species (Kelsall and others 1977; Chandler and others 1983; Dyrness and others 1986; Bonan 1992). Fire suppression in other areas of North America has led to changes in avian communities primarily from changes in the structural diversity and composition of vegetation (see Rotenberry and others 1995 for review). Two areas of research need to be addressed:

1. How are ecological processes and avian communities in the boreal region being altered with recent changes in the fire regime? This requires study beyond the changes that occur after a single fire. Not only must one examine the effects of patchiness, intensity, and season of an individual fire, but one must look at cumulative effects on the ecological community of the dynamics that result from a series of fires over a longer time period.
2. What methods, patch sizes, seasonal timing, and frequency of prescribed burning can be used to mimic the patterns and processes wrought previously by natural fires in boreal regions?

Mining

Placer mining is of particular concern in central Alaska and to some extent in the other parts of the state, primarily because of the loss of riparian habitat and alteration of the hydrology of the streams (A. Morkill, Bureau of Land Management, personal communication). Throughout the boreal region, undisturbed riparian areas support corridors of shrub thickets, which are often surrounded by black spruce taiga forests. Taiga forests are relatively depauperate in terms of avian breeding density and species richness, whereas tall shrub habitats are comparatively rich (Spindler and Kessel 1980). Several topics of research need to be addressed:

1. What have been the cumulative effects on landbird populations of destruction of riparian habitat, which has occurred extensively across federal and state lands since the turn of the century?
2. What are the effects on landbird communities of settling ponds and uncontrolled revegetation that has occurred on old tailings piles throughout the region?
3. During the reclamation process that is now legally mandated, how can the geomorphological properties of the

streams be stabilized so that natural vegetative communities can be restored? What guidelines can be developed to aid miners in the restoration process?

Impacts of Military Overflight and Training Areas

There are 21 Military Overflight Areas (MOAs) in Alaska, which encompass 170,000 square kilometers, or 11% of the land in Alaska. The MOAs include large tracts of forests, shrublands, interior wetlands, and tundra in southwestern and central Alaska, which support breeding populations of a diverse array of avian species (Kessel and Gibson 1978). These areas are used by the two fighter wings stationed in Alaska for routine training operations and Major Flying Exercises, which include approximately 21,000 low-level flights annually. In addition, these and other military training areas are exposed to the use of ordnance. Several issues are of concern regarding the use of these vast areas for training:

1. What are the effects on birds of sonic booms and increased noise levels associated with low-level flight?
2. What are the effects of exploded and unexploded ordnance on avian habitats within the region, both directly from fire and explosions, and indirectly from contamination of soil and water?

Urbanization

Spreading out along the road corridors throughout central and southcoastal Alaska is a progressive loss of landbird habitat due to urbanization. Specific issues include direct loss of forested and wetland habitats due to development, and fragmentation of forests due to road-building. Specific questions that need to be addressed include:

1. How are survival and productivity of breeding birds affected when displaced to other areas due to loss of habitat? Do they move to adjacent areas and, if so, how are population dynamics altered in these areas with increased densities of nesting birds?
2. How does fragmentation of breeding areas influence northern breeding birds? Are predation rates increased? Are any of these species area-sensitive?

Increases in Recreational Activities

As resident human populations and tourism increase within the boreal region, disturbance increases in urban and remote areas due to recreational activities. Disturbance includes intrusion of humans into previously undisturbed areas, proliferation of trail systems and subsequent erosion, and building of roads and facilities necessary to support recreational activity. The effects of such changes on boreal landbird populations are unknown.

A Boreal Landbird Research and Monitoring Program is needed to determine the current status of boreal populations and to develop recommendations for their management. This paper describes some of our goals, the obstacles we face, what tools we are using to accomplish our goals, where we hope to head in the future, and some of the roadblocks we see to long-term success. It focuses on our work in Alaska and the neighboring Yukon Territory.

Where Did We Begin?

Our first step was to assess where we were. Our only monitoring tool at the time was the North American Breeding Bird Survey (BBS), but the data had been collected so sporadically in our region of interest that they could not be analyzed statistically except for a handful of species (J. Sauer, Biological Resources Division, U.S. Geological Survey, personal communication). From 1968-1991, a total of 57 fifty-stop routes had been established in Alaska. Among these, 15 (26%) had been run only once and only 8 (14%) had been repeated for more than 5 years sequentially (B. Peterjohn, Biological Resources Division, U.S. Geological Survey, unpublished data). A consistent effort was not established until 1982, when the Nongame Wildlife Program of the Alaska Department of Fish and Game assumed leadership of the program in Alaska, so no long-term data were available for any routes in the state. In addition, observers frequently changed between years, further reducing the number of routes that could be analyzed for population trends. We identified two basic problems with the existing status of the BBS in Alaska:

1. Turnover of individual observers within Alaska was high, resulting in a crippling lack of continuity in the program.
2. The road system is very limited within boreal regions, leading to a small, geographically biased sample. Most of the routes that had been run were clustered along the primary road corridors between east-central and southcoastal Alaska (fig. 1). Roads are virtually nonexistent throughout the rest of Alaska.

Initial Goals

Our initial goals for a research and monitoring program were to be able to provide answers to some very basic questions:

1. How are landbirds distributed across the landscape within the western boreal region of North America? With what habitats are they associated?
2. Are breeding populations in boreal regions declining, stable, or increasing? Are these trends in accordance with continental trends?
3. If populations are changing, what are the causes? Are there management actions that can be taken on boreal breeding grounds to slow or reverse declines in populations?

Next, we identified characteristics necessary for a research and monitoring program to answer these questions effectively:

1. The program must be able to detect significant changes in populations with enough lead time for action.
2. It must be able to relate changes in habitat to their effects on bird populations.

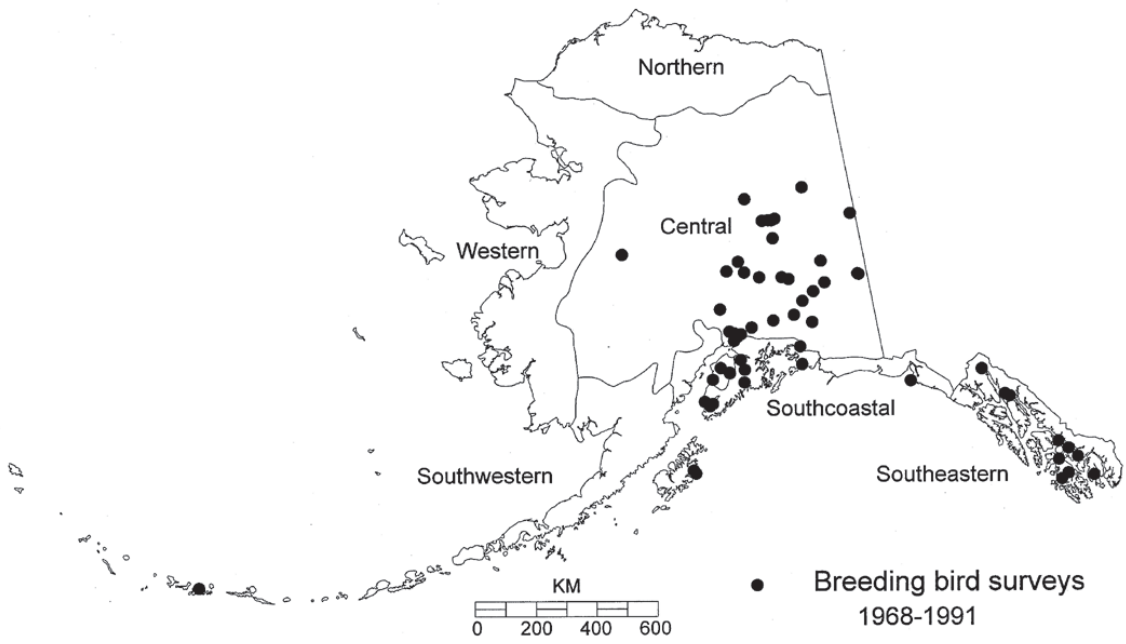

Figure 1—Location of standard 50-stop North American Breeding Bird Survey routes in Alaska that had been censused at least once between 1968 and 1991.

3. It must help us to understand the causes for changes in bird populations. Without such knowledge, there would be no basis for action.

4. It must be efficient in terms of monetary costs, staffing, training, and logistics.

5. It must provide feedback at several different levels, including local, regional, national, and continental.

Obstacles

Establishing a regional monitoring program required overcoming several major obstacles. First was the size of the state and the immense logistical problems and costs in sampling remote areas. Alaska alone encompasses 1.5 million square kilometers, and is about one-fifth the size of the rest of the United States. Access to most of the region is restricted to small plane, helicopter, or boat.

One factor that aided our efforts was the fact that about 68% of the land in Alaska is under some type of federal or state jurisdiction with natural resource responsibilities (table 1). These lands are distributed widely across the state, and all agencies have some type of authority to inventory and monitor wildlife populations. Therefore, one of our first objectives was to establish a program across these lands and to determine what role they might play in supporting viable breeding populations of landbirds.

Two other major obstacles existed: first, different legislative mandates and authorities among the agencies involved, and second, different funding levels among agencies, and therefore differing abilities to participate in the program. To overcome these obstacles, we refocused our efforts to undertake a pilot project to determine what methods might work in boreal regions, and what sample sizes and funding levels would be required to carry out such a program. The ultimate goal was to use these baseline data to develop recommendations for a cohesive, regional program to which all partners could contribute.

Building a Research and Monitoring Program

Building the initial structure for a regional research and monitoring program has been an entirely grassroots campaign. We have relied on the energy, enthusiasm, and knowledge of individuals scattered across the region, including many volunteers, to make it work. Several key tools have helped make the initial phase so successful.

Consensus

Everything has been done with group consensus. Each year we elect a Chair, Vice-chair, Secretary, and Regional Coordinators to help organize our efforts. The entire group meets once or twice a year at different locations around the state. We have informal workshops and organize smaller groups to accomplish various tasks. At our annual meeting we set specific objectives for the upcoming year, agree upon deadlines, and identify individuals responsible for accomplishing each objective.

Regional Organization

We set up regional working groups that work closely together to deal with similar scientific questions as well as common logistical problems. We have divided the state up into six biogeographic regions that are based on the distributional patterns of birds (Kessel and Gibson 1978), and we use

Table 1—Amount of land in Alaska under jurisdiction of federal and state agencies with major responsibility for natural resource management. Note that areas are approximate because of ongoing conveyances.

Resource land units[a]	Area (km^2)	Percent of Alaska
Bureau of Land Management public lands and National Petroleum Reserve-Alaska	356,100	23.5
National Wildlife Refuges	309, 200	20.4
National Parks and Preserves	218,500	14.4
National Forests	114,100	7.5
State Parks	20,900	1.4
State Refuges	12,100	0.8
Department of Defense training areas	6,100	0.4
Other	481,800	31.7
Total	1,518,800	100.0

[a]Sources: Bureau of Land Management, Alaska Regional Office; U.S. Fish and Wildlife Service, Alaska Regional Office; National Park Service, Alaska Regional Office; USDA Forest Service, Chugach National Forest; Alaska Department of Natural Resources; Alaska Department of Fish and Game; Fort Richardson Army Base, Department of Public Affairs.

these to stratify our sampling (fig. 1). By looking at regional needs without respect to jurisdiction, we are able to distribute sampling efforts more efficiently than if individual agencies assumed the task separately. For example, by combining survey data collected in black spruce forests from three refuges and a park in central Alaska, we can monitor landbird populations across a broader area with only a quarter of the resources from each land unit.

Standardization

Gathering and coding of data are carefully standardized. National programs are adopted where possible. Data can then be analyzed at various hierarchical levels: The specific land unit, the habitat type, the biogeographic region within Alaska, or Alaska in comparison with other continental regions. Key data fields are identified that must be collected by all cooperators; additional fields are identified to answer specific research questions at designated areas.

Coordination of Data Collection and Analysis

For each aspect of the program, an individual or organization is assigned to coordinate allocation of sampling efforts, collection of data, statistical analysis, and reporting. This model affords the efficiency that can be gained by centralization, but disperses the effort required across several different agencies and organizations. Consensus is necessary to determine how much effort should be allocated statewide to each project.

Discretionary Seed Money

Several of the federal agencies have had modest amounts of funding that could be distributed to various projects across the state where it was most needed. Often, these small amounts made a huge difference as to whether a particular group could participate in the program. For example, small allocations allowed smaller refuges and parks to set up banding efforts in northwestern Alaska, which supports large breeding populations of Nearctic-Neotropical migrants, but whose regional ecology is poorly understood. Discretionary funds also were contributed by several agencies to fund jointly the production of a compact disc of Alaska Bird Songs by the Cornell Library of Natural Sounds (1996). This product could not have been funded by a single agency, but will serve to train observers across the state to census birds.

Tiered Structure

We set up a tiered structure to the program, which consists of several different projects requiring different levels of time, funding, and expertise. In the pilot phase, individuals have contributed at whatever level possible, given their available resources, capabilities, and motivation; these individuals have been organized according to the stratified framework that we have identified regionally. After analysis of these initial data, we will make recommendations about how efforts should be allocated optimally within each tier to monitor different parameters of population dynamics.

Research and Monitoring Program Structure

Here is an overview of the pilot projects we have established, listed roughly in ascending order of the time, money, and expertise required to establish and run them.

Alaska Checklist Project

This project has been organized by the Alaska Migratory Bird Management Office of the U.S. Fish and Wildlife Service, and tested thus far on national wildlife refuges in Alaska (Andres 1995). Individuals collect standardized data on the relative seasonal abundance of birds on a township basis. It is an easy way to add to our knowledge of distributional patterns, and is an important means by

which to train observers. Data can be collected in conjunction with other ongoing projects, so this effort requires no added logistical costs.

North American Breeding Bird Survey

Participation on established BBS routes has increased, and several new routes have been set up through the organizational efforts of the Alaska Migratory Bird Management Office of the U.S. Fish and Wildlife Service. We now have 75 routes regularly run within the state, including 7 routes along rivers, on which observers navigate by boat instead of car, and one route that is traversed on a four-wheeler (fig. 2). Through these innovations, we have increased coverage in roadless portions of the state.

Off-Road Point-Count Program

As part of a cooperative research project of the Alaska Biological Science Center, Biological Resources Division, U.S. Geological Survey, we have established an off-road point-count program across the state to test methodology for monitoring bird populations in the vast roadless areas of the region (Handel 1993b,c). We are investigating the relative importance of time of day, time of season, interannual variability, and observer variability in detection of different species across the six biogeographic regions of the state using standardized point-count methodology (Ralph and others 1993). We have established 122 twelve-point routes that are stratified by region and habitat (fig. 2). We also have conducted surveys at an additional 283 individual points for a total of 1,747 across the state. At each point we collect standardized data on habitat (Handel 1993a). Both BBS and Off-road Point Counts require more time, money, and expertise than the Checklist Program, but provide information on population trends.

Monitoring Avian Productivity and Survivorship (MAPS)

We currently have 27 stations at 17 locations across Alaska and the Yukon Territory participating in the MAPS program organized by The Institute for Bird Populations (fig. 3). This project requires more time and money than any of the surveys, and also requires banding expertise. It does, however, provide additional information on regional productivity and survivorship, which helps us to understand the factors influencing changes in population size (DeSante and others 1993b).

Migration Stations

We have had eight stations banding during spring or fall migration or both since the inception of Boreal Partners in Flight (fig. 3). This project is the least standardized of any of our efforts, and also requires the greatest amount of resources. At this point, efforts are under way to investigate seasonal and interannual variability at different locations. This pilot project should shed light on the timing and pathways of migration for various species, and possibly population trends and regional productivity. The Alaska Bird Observatory and Alaska Peninsula National Wildlife Refuge have helped to organize this project and summarize regional data each year.

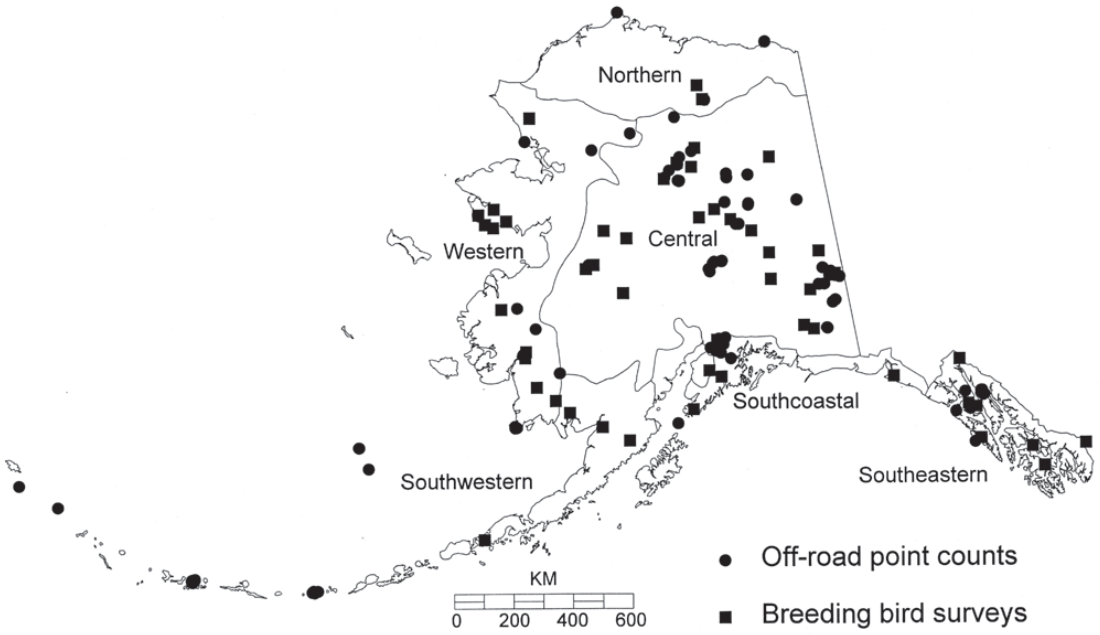

Figure 2—Location of 12-stop Off Road Point Count routes and 50-stop North American Breeding Bird Survey routes that have been surveyed in Alaska since 1992.

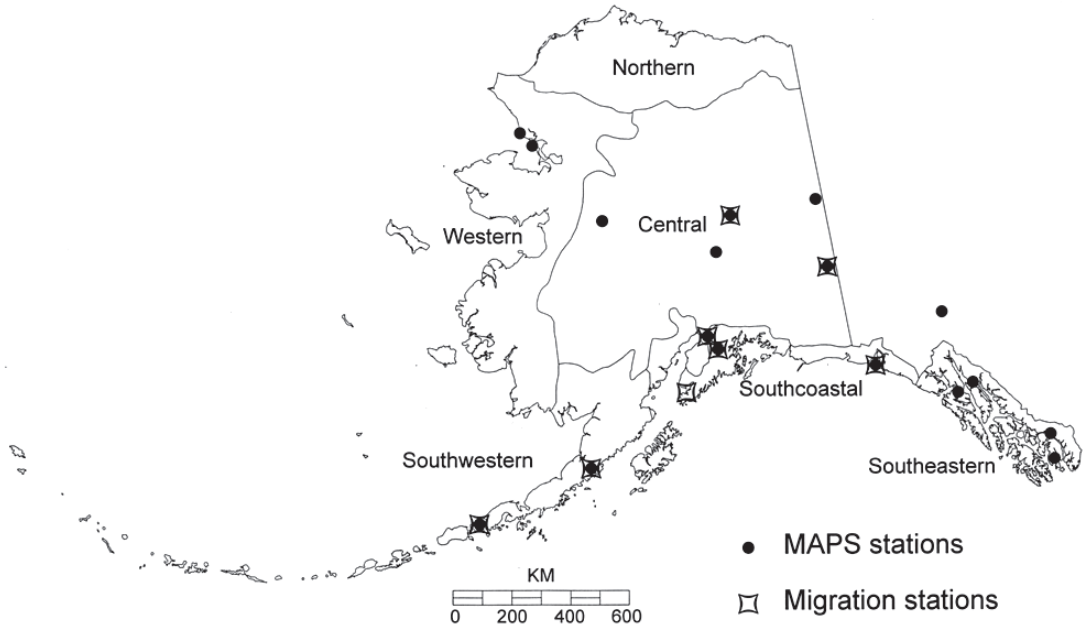

Figure 3—Location of mist-netting stations that have been established in Alaska since 1992 as part of the Monitoring Avian Productivity and Survivorship (MAPS) program and to monitor migration of landbirds.

Specific Studies

A number of studies have been conducted within the past few years as a direct result of Boreal Partners in Flight. For example, studies of the breeding ecology and habitat requirements of Townsend's Warblers (Matsuoka 1996; Matsuoka 1997a,b) and Olive-sided Flycatcher (J. Wright, Alaska Department of Fish and Game, personal communication) were initiated because of particular concerns about the status of these Nearctic-Neotropical migrants. An important role of Boreal Partners in Flight is to identify species, habitats, or issues of management concern and to identify potential studies of highest priority in the region.

Where Do We Hope to Go From Here?

Experimental Design

Our next step will be to analyze data collected during the pilot phase of this program and to refine the design of our monitoring program. We will be looking at sample size requirements, statistical power, and sources of variability, including observer effect, in relation to the costs involved with different types of projects.

Concordance

We also will be analyzing data from various aspects of the integrated program to see how concordant the results are. We will investigate combining measures of population trends from Breeding Bird Surveys and Off-road Point Counts into a comprehensive, single data set. This approach could greatly increase statistical power to detect population changes.

Habitat-Based Program

Another goal is to have the entire program habitat-based. Changes in amounts and configuration of breeding habitats can influence species composition, abundance, and productivity. Our monitoring program will be much more sensitive to changes in populations if it can account for the effects of large-scale changes due to fire, insect outbreaks, succession, and human influences. Management actions should be scaled to mimic the natural patch dynamics that occur across landscapes in response to such disturbances (Rotenberry and others 1995).

Because the state is so vast and most areas are too remote to monitor bird populations directly, we will be using remotely sensed vegetation data to aid our monitoring efforts. The EROS Alaska Field Office of the U.S. Geological Survey is currently developing a Geographical Information System that maps vegetation classes across the state at a resolution of 1 km, based on a composite Normalized-Difference Vegetation (or "Greenness") Index from satellite data (M. Fleming, U.S. Geological Survey, personal communication). Features such as large fires can be readily discerned and measured. Maps such as these can be produced over various time intervals to detect long-term changes in the configuration and amounts of different habitats and to aid us in stratification.

Feedback

We feel that it is very important that feedback from the research and monitoring program be provided immediately to land managers and other decision-makers. Although we have concentrated a lot of effort on determining the proper *input* to our program, an equally important aspect of its

design will be the *output*. We believe that providing information within a local, regional, national, or continental context is a real strength of this approach. The Alaska Biological Science Center has been developing an interactive resource information system so that land managers, biologists, and the public can have immediate access to survey data via the Internet <http://www.absc.usgs.gov/research/bpif/bpif.html>.

Trigger-Points

As we progress in our design of the program, we will be incorporating trigger-points for management actions. Key to the success of a conservation plan is an understanding of the processes that contribute to the patterns we observe. It is not sufficient to know that populations have declined by a certain percentage over a certain period of time. One must understand the causes contributing to the decline in order to determine proper corrective actions. The feedback system will provide information both on when management actions should be taken and what actions, if any, will be effective.

Potential Roadblocks

The primary goal of our efforts is to establish a long-term research and monitoring program for populations of birds that rely on boreal regions of western North America. Our initial efforts have proven productive, but two major roadblocks may prevent us from accomplishing our final goal. First of all, the grassroots effort that has taken us so far in our initial phase may be viewed as a potential weakness in the long term. By relying on efforts of individuals who voluntarily have assumed extra duties with little or no compensation, we risk tremendous losses to integrity of the program should they leave, particularly if they are replaced with individuals with no personal motivation to continue.

Second, certain individuals have assumed responsibility for coordination of data collection and analysis during the initial phase. For none of the projects is this a long-term funded responsibility. Without some long-term commitment to coordination, analysis, and feedback, the projects are doomed to failure.

Recommendations for Success

I make three recommendations for long-term success of our program and others like it. First, a long-term commitment must be made by every federal and state agency with land-management responsibility to continue to support coordinated, cooperative efforts to study and monitor landbirds. This commitment must be made in two ways. First, mandates must be incorporated into management plans to guarantee that the projects will continue regardless of turnover of personnel. Next, these mandates must be supported with adequate funding for training, regional coordination, field efforts, data analysis, and feedback. By coordinating efforts of a large number of cooperators, we will maximize the efficiency of our programs.

Second, this program must be integrated with other research and monitoring programs. Although the program began with an emphasis on Nearctic-Neotropical migrant landbirds, the goals of Boreal Partners in Flight have since broadened. For example, Alaskan tundra and boreal forests provide breeding grounds for 37 species of shorebirds and support the majority of the western hemispheric population for at least 12 of these species (Gill and Senner 1996). Over 75% of Alaska's breeding shorebird species winter in the Neotropics (Gill and others 1994) and are vulnerable, like many landbirds, to the rapid changes in habitat that are occurring at southern latitudes. One goal of Boreal Partners in Flight is to develop a comprehensive research and monitoring program that examines entire ecosystems and the species that they support. The program must incorporate the fact, however, that these are not closed systems because of the migratory nature of the birds. Partnerships must be extended across international boundaries, not only to Neotropical countries, but also to those nations within Australasia, Oceania, Europe, and Africa with which Alaska shares landbird and shorebird populations.

Finally, efforts must be expanded to involve more private landowners and to develop cooperative management plans at the landscape level. Wildfires and spruce beetles do not recognize property lines. Natural disturbances such as these are best managed with cooperative, integrated efforts across broad geographic regions. The impacts of human-caused disturbances such as logging and urbanization are still poorly understood in boreal habitats. Information on the effects of such disturbances on landbird populations at the landscape level needs to be gathered and management recommendations must be made available to all landowners, both public and private. By working together, regardless of affiliation, we can accomplish much more than we ever imagined. We must keep the momentum going.

Acknowledgments

I thank all the dedicated members of Boreal Partners in Flight for their commitment to building this international program. Members of the Western Working Group and the National Working Groups were instrumental in providing inspiration and guidance. I thank B. Peterjohn and J. Sauer for data from the North American Breeding Bird Survey, and A. Morkill, J. Rice, L. Fortune, J. Wright, P. Martin, T. Doyle, B. McCaffery, B. Andres, E. Campbell, and many others for insights on conservation concerns in Alaska. D. Robertson and K. Milton are thanked for their assistance with the figures.

Acoustic Monitoring of Night-Migrating Birds: A Progress Report

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Kenneth V. Rosenberg

Abstract—This paper discusses an emerging methodology that uses electronic technology to monitor vocalizations of night-migrating birds. On a good migration night in eastern North America, thousands of call notes may be recorded from a single ground-based, audio-recording station, and an array of recording stations across a region may serve as a "recording net" to monitor a broad front of migration. Data from pilot studies in Florida, Texas, New York, and British Columbia illustrate the potential of this technique to gather information that cannot be gathered by more conventional methods, such as mist-netting or diurnal counts. For example, the Texas station detected a major migration of grassland sparrows, and a station in British Columbia detected hundreds of Swainson's Thrushes; both phenomena were not detected with ground monitoring efforts. Night-flight calls of 35 species of migrant landbirds have been identified by spectrographic matching with diurnal calls recorded from known-identity individuals; call types of another 31 species are known, but are not yet distinguishable from other similar calls in several species complexes. Efforts to use signal-processing technology to automate the recording, detection, and identification of night-flight calls are currently under way at the Cornell Lab of Ornithology. Automated monitoring of night-flight calls will soon provide information on migration routes, timing, and relative migration density for many species of birds. Such information has application for conservation planning and management, as well as for assessing population trends.

Most species of North America's migrant landbirds make their transcontinental flights at night, and many species give short vocalizations while they fly. By aiming microphones at the night sky, a volume of sky—with dimensions dependent on microphone design—can be monitored for calls (Graber and Cochran 1959). A variety of microphone and recording station designs have been used for this purpose, depending on the specific monitoring goals and the recording environment (Graber and Cochran 1959; Dierschke 1989; Evans 1994). In many regions of North America, a recording station may detect thousands of calls during a single migration night (Graber and Cochran 1960; Evans 1994). Species known to give night-flight calls include the warblers (*Parulinae*), sparrows (*Emberizinae*), cuckoos (*Cuculidae*), rails (*Rallidae*), herons (*Ardeidae*), and Catharus thrushes. Groups not known to give regular vocalizations in night migration are the vireos (*Vireonidae*), flycatchers (*Tyrannidae*), and orioles (*Icterinae*). If a monitoring protocol is consistently maintained, an array of microphone stations can provide information on how the species composition and number of vocal migrants vary across time and space. Such data have application for monitoring avian populations and identifying their migration routes. In addition, detection and classification of distinctive call-types is possible with computers (Mills 1995; Taylor 1995), thus information on bird populations might be gained automatically. In this paper, we summarize the current state of knowledge for identifying night-flight calls to species; present selected results from four ongoing studies that are monitoring night-flight calls; and discuss the implications of this research for conservation of migratory landbirds.

Methods

Field Recording

Pressure Zone Microphones (PZMs) designed by Evans were used in conjunction with high-fidelity video cassette recorders (hi-fi VCRs) to enable directional sound pickup and inexpensive recording of avian night-flight calls over long periods. The microphones were designed to be especially sensitive in the two-to-nine kilohertz range, and to reject land-born environmental noise. Hi-fi VCRs allowed 8-10 hours of continuous 2-channel recording of sound from the night sky, and could be programmed for regular nightly operation. Recording sites were chosen in areas relatively free of vegetation to minimize wind and insect noise; several microphones were operated in open fields that were relatively free of insect song. Most sites included a building with A. C. power on which microphones could be positioned to provide unobstructed access to the sky, and someone living either at the site or close enough to assist in operating the recording equipment by changing tapes once per day.

From 1991 through 1994, a line of stereo recording stations was operated across central New York State during fall migration (fig. 1). Four sites were operated in 1991 (A, B, I, and O); five sites were operated in 1992 (A, B, M, I, and O); seven sites in 1993 (C, A, B, I, R, O, and J) and seven in 1994 (C,A,B,I,R,N,O). Six of these sites were located at residences (C, A, M, R, N, and J), two on old barns (B and O), and one was operated by battery in a short-grass field (I). In addition, recording stations were operated in southern Texas at Laguna Atascosa National Wildlife Refuge during the spring migrations of 1994-1996, at the southern end of Vancouver Island in British Columbia during spring and fall of 1995, and in eastern Florida during the springs of 1989, 1991,

In: Bonney, Rick; Pashley, David N.; Cooper, Robert J.; Niles, Larry, eds. 2000. Strategies for bird conservation: The Partners in Flight planning process; Proceedings of the 3rd Partners in Flight Workshop; 1995 October 1-5; Cape May, NJ. Proceedings RMRS-P-16. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

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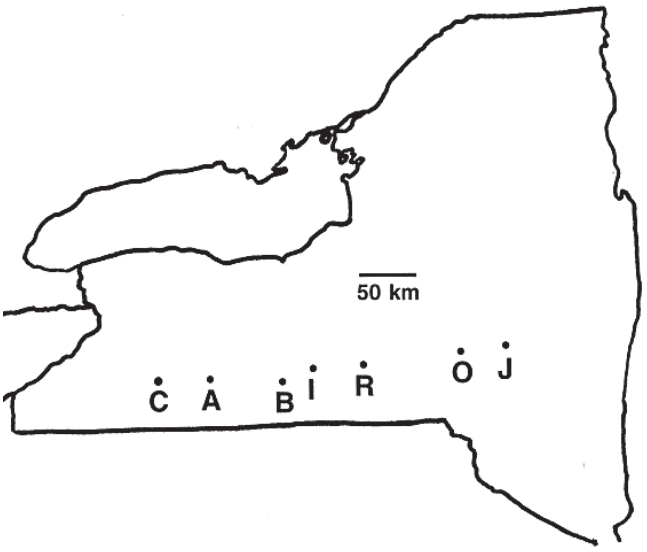

Figure 1—Location of night-flight call recording stations across New York State. Letters are from the closest town to each recording station. C = Cuba; A = Alfred; B = Beaver Dams; I = Ithaca; R = Richford; O = Oneonta; J = Jefferson.

1993, 1995, and 1996. Recordings were made either every night or when weather conditions were conducive to migration. At the sites in New York State, microphones were positioned 0.6 meters apart on an east-to-west line, with the east microphone angled 20 degrees from vertical toward the southeast, and the west microphone angled 20 degrees from the vertical toward the southwest. This positioning helped to dispel rainwater and shielded the microphones from direct buffeting by northerly winds.

The sensitivity pattern of a microphone design was determined using a ground-based eight-channel microphone array (Evans and others, in preparation). Eight microphones were laid out within a 75 meter by 75 meter area, four at the corners of the area and four at the corners of a 30 meter by 30 meter square centered in the interior of the larger square. This layout enabled calls from birds flying in the vicinity of the array to be picked up by all eight microphones. It also allowed the approximate point of origin of a night-flight call to be determined by analyzing its varying arrival times at the different microphones. By plotting such locations for hundreds of night-flight calls, the shape of a microphone's detection pattern and its range of detection for different species became evident. The detection range is defined here as the distance within which a call can be detected by the microphone and still be identified to species by spectrographic analysis or by ear. This range varies due to differing call loudness among species, the distinctiveness of their acoustic signatures, and variables in the recording environment.

The eight channel study revealed that the microphone design used in New York State, Texas, and part of the Florida study had a maximum above-ground detection range of 300 meters for a wide range of warblers and sparrows. Furthermore, the maximum horizontal cross-section of sky that a single microphone had for detecting such calls was approximately 250 meters. The calls of Catharus thrushes, which are louder than warbler and sparrow calls, were detectable to 600 meters above a recording site, and a single microphone covered an approximate 1,000 meter cross-section of sky; the stereo setup covered an approximate 1,500 meter cross-section.

Call Detection and Analysis

Calls were detected on the recordings by listening through headphones (Evans) and by signal analysis software written in the Bioacoustics Research Program at the Cornell Laboratory of Ornithology (Mills 1995). This software was designed to detect short high-pitched call notes, which range in frequency from 5-9 kHz. All sound analysis employed the software program Canary (Charif and others 1995). Spectrographs of calls presented in this paper were made from calls digitized with a 22254 Hz sampling rate and processed using a 256 point FFT, 128 point frame size, 87.5% overlap, and Hanning window (frequency resolution 86 Hz, time resolution 0.72 msec, analysis bandwidth 700 Hz).

Recordings were analyzed by interpreting bird call sequences to derive a minimum number of individuals passing (MIP). The MIP technique is based on human interpretation of the sequences of bird calls on audio recordings. The human listener considers time delays between calls, amplitude differences between calls, stereo location of calls, and expected bird flight speeds in conjunction with the pickup pattern of the microphone(s), to interpret a minimum number of individuals passing over (Evans and Mellinger 1999).

In this paper, for MIP analysis on warbler night-flight calls from Florida, we assumed that calls from the same species (or species complex) occurring within one minute of each other were from the same individual. Calls occurring more than one minute apart were interpreted to be from different individuals. This formula is based on an estimated minimum bird flight speed of 20 km/hour (330 meters per minute) and a maximum horizontal pickup pattern of 250 meters. Note that our estimates of the number of calling individuals are probably low, because most birds probably pass through the pickup zone in less than one minute, and because two individuals could call within one minute.

Based on similar calculations, our MIP analysis of thrushes assumed that calls more than two minutes apart were from different individuals, and both stereo analysis of time delays and amplitude differences were used to discriminate individuals within two minute periods. Thrush calls are louder than warbler and sparrow calls, so they can be heard over a larger region of sky.

Identification of Nocturnal Flight Calls

A long-standing impediment to the development of night-flight call monitoring has been call identification. The night-flight calls of many species, such as warblers and sparrows, are like single cricket chirps, typically between 0.05 and 0.25 seconds long. Their high frequencies (5-9 kHz) make them especially difficult for the human ear to distinguish.

Since 1985, Evans has systematically determined the type of night-flight call given by most species in eastern

North America. Three techniques were used to acquire this information (see Evans 1994). First, structural details of night-flight calls were compared with diurnal calls of known identity through spectrographic analysis (fig. 2). The diurnal calls were typically recorded from birds in visible flight, and such calls were considered as likely to be the same call type used during night migration. The other two methods of call determination consisted of correlating the seasonal timing and geographic range in which various types of night-flight calls were recorded with known timing and migration ranges for each species.

All identifications of recorded night-flight calls used in the analyses described here were performed by aural comparison, or by visual comparison of spectrographs, to diurnal calls of verified identity for each species.

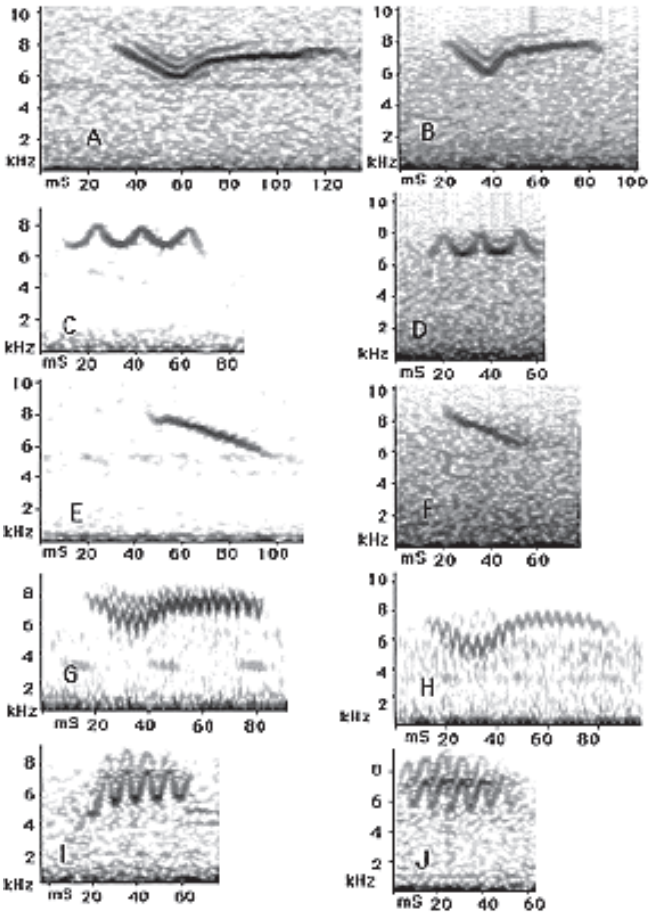

Figure 2—Identification of nocturnal flight calls through spectrographic comparison with diurnal calls for selected species migrating along the east coast of Florida. A = Presumed night-flight call of American Redstart; B = Diurnal flight note of American Redstart; C = Night-flight call of species complex #5; D = Diurnal flight note of Blackpoll Warbler; E = Night-flight call of species complex #4; F = Diurnal flight note of Parula Warbler; G = Presumed night-flight call of a Black-and-White Warbler; H = Diurnal flight note of a Black-and-White Warbler; I = Presumed night-flight call of a Common Yellowthroat; J = Diurnal flight note of a Common Yellowthroat.

Results

The night-flight calls of 35 migrant landbird species in eastern North America are now known to be distinguishable either by ear or by spectrographic analysis (table 1), and evidence exists for the type of call given by 31 additional migrant species (W. Evans and M. O'Brien, unpublished data). The calls of these latter species are not yet distinguishable from one or more other species with similar call-types (table 2). In addition, many species of shorebirds and waterfowl, as well as herons, bitterns, gulls, terns, and rails, give vocalizations at night that may be recognized by their similarity to the birds' typical diurnal calls.

Following are selected results from four pilot studies in North America where night-flight call monitoring has been in operation. These results illustrate the progress being made in the areas of species identification, counting techniques, comparisons with ground-based surveys, and the biology of nocturnal migration.

Species Identification and Counting: Caribbean Migrants in Florida

To begin the complex process of sorting out species identifications and counting techniques, we initially searched for a geographic region that was relatively well-known, in terms of bird migration, and where nocturnal migration was limited to relatively few common species. We found such a region on the east coast of Florida. An outstanding historical database exists for east-central Florida, due to compilations by Cruickshank (1980) and Taylor (1976). This includes 25 years of visual migration observations and extensive information from tower-kills, both of which define migration periods and relative abundance patterns for many species of migrants. The data show that the majority of passerine migrants during spring in eastern Florida are species known to winter in the Caribbean Islands or which fly over the Caribbean enroute from South American wintering grounds. Such species include Common Yellowthroat (*Geothlypis trichas*), Ovenbird (*Seiurus aurocapillus*), Blackpoll Warbler (*Dendroica striata*), American Redstart (*Setophaga ruticilla*), Cape May Warbler (*Dendroica tigrina*), Black-throated Blue Warbler (*Dendroica caerulescens*), Black-and-white Warbler (*Mniotilta varia*), Northern Parula (*Parula americana*), Northern Waterthrush (*Seiurus Novaboracensis*), Connecticut Warbler (*Oporornis agilis*), Bobolink (*Dolichonyx oryzivorus*), and Bicknell's Thrush (*Catharus bicknelli*). Because of these well-known migration patterns and the relatively simple species composition, we established a recording station on the east coast of Florida to determine the night-flight call identities of these Neotropical migrant species.

During five spring migrations, this recording station recorded over 50,000 calls of migrating birds. Basic evidence for the identity of these species' night-flight calls was compiled by spectrographically matching migratory contact notes from observed birds during the day with distinctive night-flight calls (fig. 2). Identities were then further corroborated by matching the seasonal time of occurrence of the tentatively identified call-types with the migrational databases compiled by Cruickshank and Taylor (Evans, in

Table 1—Migratory landbird species in eastern North America with known nocturnal flight calls distinguishable by ear or by spectrographic analysis. Note that calls of other species are known, but are not yet distinguishable from similar species (see table 2).

Species	Vocalization
Upland Sandpiper (*Bartramia longicauda*)	rapid "tu tu tup" series (variable)
Long-billed Curlew (*Numenius americanus*)	Cur-lee flight call
Black-billed Cuckoo (*Coccyzus erythropthalmus*)	guttural "chuckle"
Yellow-billed Cuckoo (*Coccyzus americanus*)	kakakowlp call (variable)
Red-headed Woodpecker (*Melanerpes erythrocephalus*)	"queeer" note
Red-breasted Nuthatch (*Sitta canadensis*)	"aah, aah, aah" notes
Veery (*Catharus fuscescens*)	short whistled note
Gray-cheeked Thrush (*Catharus minimus*)	short whistled note
Bicknell's Thrush (*Catharus bicknelli*)	short whistled note
Swainson's Thrush (*Catharus ustulatus*)	short whistled note
Hermit Thrush (*Catharus guttatus*)	short whistled note
Wood Thrush (*Hylocichla mustelina*)	shortwhistled note
Chestnut-sided Warbler (*Dendroica pensylvanica*)	short, high "tseep"
Cape May Warbler (*Dendroica tigrina*)	short, high "tseep"
Black-throated Blue Warbler (*Dendroica caerulescens*)	short, high "tseep" (often doubled)
Palm Warbler (*Dendroica palmarum*)	short, high "tseep"
Black-and-white warbler (*Mniotilta varia*)	short, high "tseep"
American Redstart (*Setophaga ruticilla*)	short, high "tseep"
Ovenbird (*Seiurus aurocapillus*)	short, high "tseep"
Northern Waterthrush (*Seiurus noveboracensis*)	short, high "tseep"
Common Yellowthroat (*Geothlypis trichas*)	short, buzzy "tzzp"
Canada Warbler (*Wilsonia canadensis*)	short, high "tseep"
Rose-breasted Grosbeak (*Pheucticus ludovicianus*)	short whistled note
Dickcissel (*Spiza americana*)	buzzy flight note
Indigo Bunting (*Passerina cyanea*)	buzzy flight note
Painted Bunting (*Passerina ciris*)	buzzy flight note
Blue Grosbeak (*Guiraca caerulea*)	buzzy flight note
American Tree Sparrow (*Spizella arborea*)	short, high "tseep"
Chipping Sparrow (*Spizella passerina*)	short, high "tseep"
Savannah Sparrow (*Passerculus sandwichensis*)	short, high "tseep"
Grasshopper Sparrow (*Ammodramus savannarum*)	short, high "tseep"
Henslow's Sparrow (*Ammodramus henslowii*)	a high descending "zeee"
Lincoln's Sparrow (*Melospiza lincolnii*)	a buzzy "zee"
Swamp Sparrow (*Melospiza georgiana*)	a buzzy "zee"
Bobolink (*Dolichonyx orizivorus*)	pink flight note

preparation). One important discovery was the probable night-flight call of Bicknell's Thrush (Evans 1994), a high-priority species for monitoring along the Atlantic Coast.

A 15 minute sample of analyzed one channel audio data from this Florida station shows the temporal occurrence of calls from different species and species complexes (fig. 3). Analysis of this calling sequence using the MIP method revealed that a minimum of seven Ovenbirds, seven individuals in the species complex #5 (table 2), two individuals in species complex #4, two Common Yellowthroats, and two American Redstarts passed over the recording station during the 15 minute period. In addition, detection of single calls from a Black-throated Blue Warbler, Northern Waterthrush, and Black-and-white Warbler during the 15 minute period were interpreted as evidence for the passage of at least one individual of each of these species. On this evening, winds were southwesterly at 10-20 km/hr and the sky was clear. Given these conditions, birds were assumed to be heading northward and not circling.

Comparisons With Ground-Based Banding and Surveys

In 1994, a nocturnal flight call monitoring station was established at Laguna Atascosa National Wildlife Refuge (LANWR) in south Texas. The study was conducted in part to supplement information on migration gathered from a United States Fish and Wildlife Service (USFWS) banding operation at the refuge. Data from this study are still being analyzed, but early results have revealed valuable information.

The most common passerines detected acoustically were very different from the most common species detected by mist-netting. For example, the banding data included large numbers of White-eyed Vireos (*Vireo griseus*) and Yellow-breasted Chats (*Icteria virens*), two species that are not known to give calls in night migration. At the same time, the acoustic technique revealed large flights of Savannah Sparrows (*Passerculus sandwichensis*), Grasshopper Sparrows

Table 2—"Complexes" of bird species for which call-type is known but which are not yet definitely distinguishable from other species with similar call-types. All these calls are short, typically less than 1/10th of a second in duration and high pitched, between 5 and 9 kHz.

Species complex	Vocalization
I	
Prothonotary Warbler (*Protonotaria citrea*) Clay-colored Sparrow (*Spizella passerina*) Swainson's Warbler (*Limnothlypis swainsonii*)	A nonsibilant, rising "tseep" note
II	
Blue-winged Warbler (*Vermivora pinus*) Golden-winged Warbler (*Vermivora chrysoptera*) Louisiana Waterthrush (*Seiurus motacilla*)	A buzzy "kzeen" of "kzeep" note
III	
Tennessee Warbler (*Vermivora peregrina*) Nashville Warbler (*Vermivora ruficapilla*) Orange-crowned Warbler (*Vermivora celata*) Black-throated Green Warbler (*Dendroica virens*) Vesper Sparrow (*Pooecetes gramineus*) Yellow-rumped Warbler (*Dendroica coronata*) White-crowned Sparrow (*Zonotrichia leucophrys*)	A sibilant, rising "tseet" or "tsee" note
IV	
Pine Warbler (*Dendroica pinus*) Northern Parula (*Parula americana*) Field Sparrow (*Spizella pusilla*) Yellow-throated Warbler (*Dendroica dominica*) Prairie Warbler (*Dendroica discolor*)	A descending "tsew" note
V	
Cerulean Warbler (*Dendroica cerulea*) Blackburnian Warbler (*Dendroica fusca*) Magnolia Warbler (*Dendroica magnolia*) Worm-eating Warbler (*Helmitheros vermivorus*) Blackpoll Warbler (*Dendroica striata*) Yellow Warbler (*Dendroica petechia*) Bay-breasted Warbler (*Dendroica castanea*) Connecticut Warbler (*Oporornis agilis*)	A buzzy, "zeet" note
VI	
Fox Sparrow (*Passerella iliaca*) Song Sparrow (*Melospiza melodia*) White-throated Sparrow (*Zonotrichia leucophrys*)	A high, "tseep" note
VII	
LeConte's Sparrow (Ammospiza leconteii) Sharp-tailed Sparrow (*Ammospiza* ssp.)	A high downslurred "tsee" note

(*Ammodramus savannarum*), and Dickcissel (*Spiza americana*) whereas none of these species were netted (Evans and Mellinger 1999).

An exciting finding from the acoustic station at LANWR was the detection of Black Rails (*Laterallus jamaicensis*) in night migration from mid-April through early May 1994. Black Rails are not known to breed or winter in southernmost Texas, so detection of their night-flight calls at LANWR suggests that the species may still be a Neotropical migrant wintering somewhere along the east coast of Mexico.

A second comparison between acoustic monitoring and ground-based data comes from New York State. In this case, a comparison is made between nocturnal flight call data for another commonly detected migrant, the Gray-cheeked Thrush, with data from two banding stations in west-central New York. One banding station, operated by Elizabeth Brooks near Alfred, NY, was located approximately 1 mi. from the acoustic station at Alfred (station A; fig. 1). The other banding station was at the Braddock Bay Bird Observatory, located approximately 60 miles north of station A. During the fall migrations of 1990-1994, the banding station at Alfred netted an average of <1 Gray-cheeked Thrush per year, while from 1986-1995, the station at Braddock Bay averaged 22 per season (ranging from 7 to 53 per year). In 1991, 1992, 1994, and 1995, the acoustic station at Alfred detected 206, 210, 220, and 139, respectively. (Due to equipment failure, the last week of September 1995 was missed; a likely reason for the lower total). Of further interest is the consistent seasonal timing of Gray-cheeked Thrush passage revealed by the acoustic data (fig. 4). Peak passage occurred

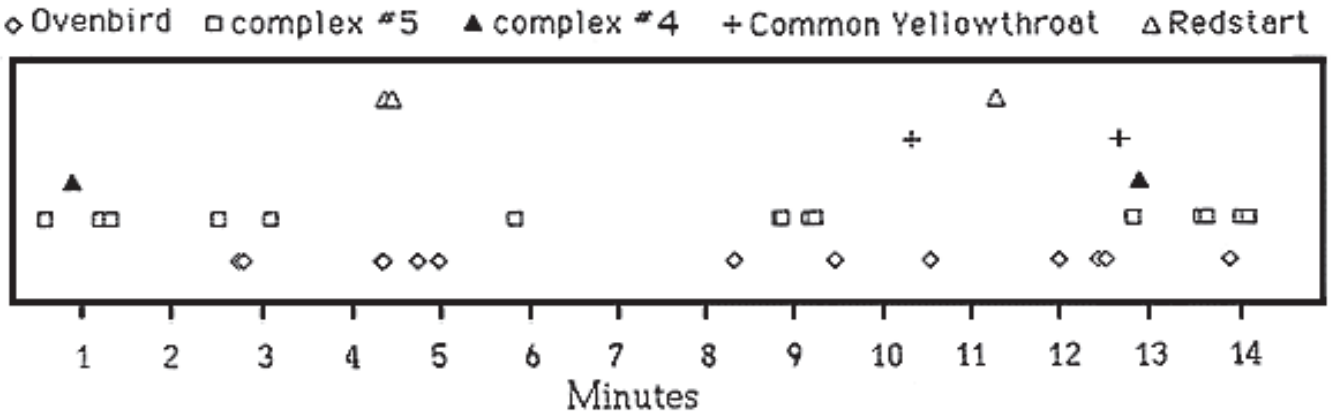

Figure 3—Example of the minimum individuals passing (MIP) technique applied to five warbler species in a 15 minute sequence from one audio channel, recorded 7 May 1989 on the east coast of central Florida. See text for discussion of MIP.

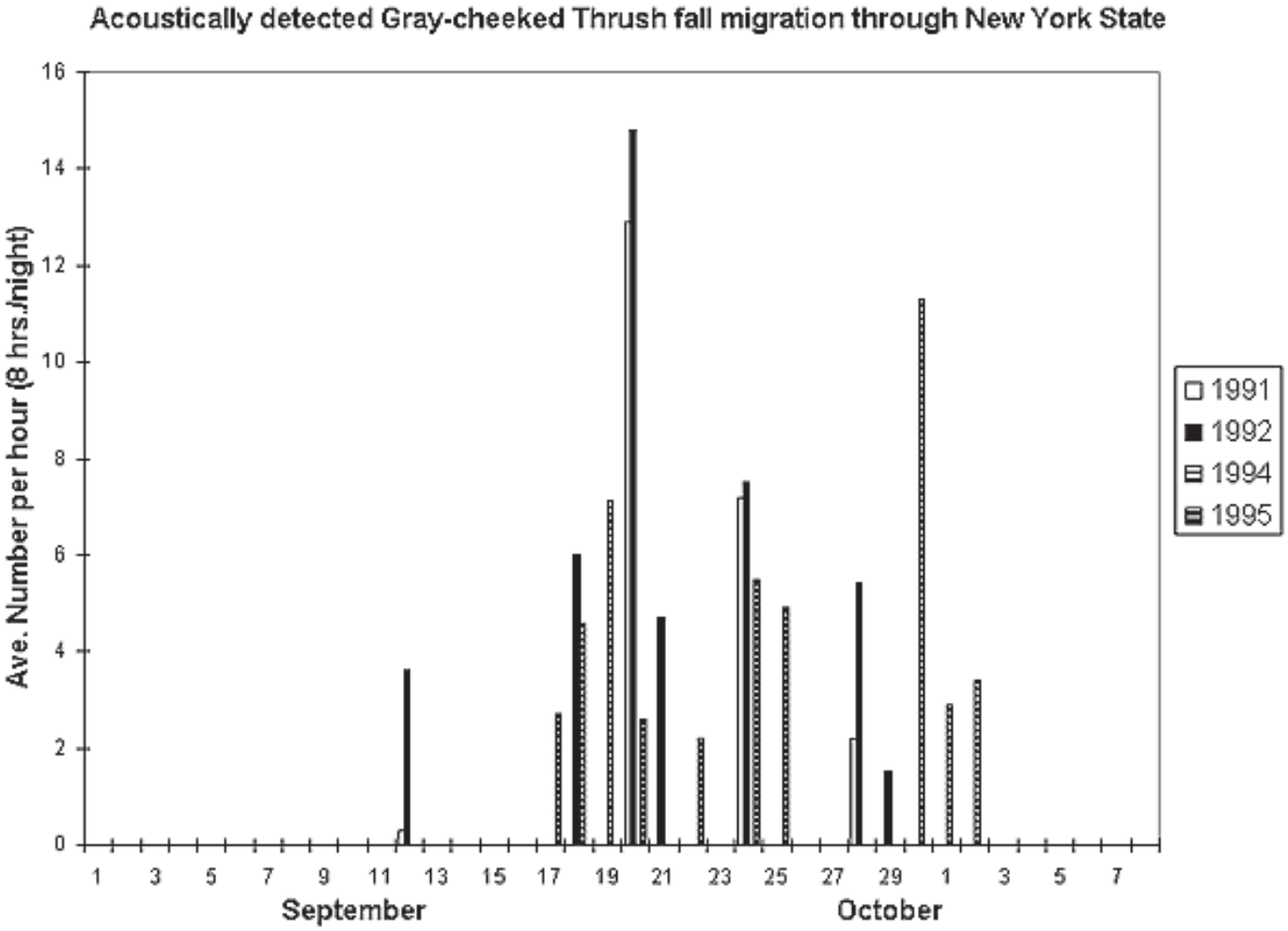

Figure 4—Average number of Gray-cheeked Thrushes per hour (8 hours of monitoring per night) detected at acoustic stations A and B during the fall migrations of 1991, 1992, 1994, and 1995.

each year during a 2-week period from 17 September to 2 October, and the bulk of their migration occurred on only 4 to 6 nights each season.

A third comparison between acoustic monitoring and ground-based data comes from British Columbia, where nocturnal-flight call monitoring was incorporated into a nongame avian-monitoring program by Rhonda Millikin of the Canadian Wildlife Service (CWS). In addition to acoustic monitoring, the program used mist-netting, transects, estimated totals, and radar with a goal to monitor species composition and density of avian migration across British Columbia. A primary focus of this research is to determine locations of migratory funnel points for establishing long-term monitoring stations.

Identities of night-flight calls of migrant passerines in western North America are not well known. However, calls of species such as Swainson's Thrush are similar to their calls in eastern North America. Acoustic monitoring in BC during fall 1995 revealed results similar to those from NY, regarding the number of individuals monitored by a single recording station compared with mist net data. During four migration nights when the acoustic technique was used, 495 Swainson's Thrushes were detected using the MIP technique, whereas only 20 Swainson's Thrushes were mist-netted during the entire fall migration period. The mist net operation involved 10-15 nets running for six hours a day in riparian habitat.

Documenting Broad-Front and Other Migration Patterns

The potential of the acoustic technique for detecting large numbers of individuals is even more promising when an array of recording stations is used. Since 1991, experiments with an array of stations across New York State have uncovered many interesting aspects of avian night migration. Foremost is the revelation of broad-front density correlations in night migration; i.e., the density of calling individuals of certain species shows similar temporal patterns (seasonal and within-night) across broad geographic areas (Evans and Mellinger 1999). These patterns are illustrated for the Veery (*Catharus fuscescens*) on a typical fall migration night in upstate New York (fig. 5). Note the similar hourly pattern of Veery passage within two pairs of stations, both about 40 km apart (fig. 1).

Based on the estimated 1,500 meter cross-section of sky that each stereo microphone station censuses for Catharus thrushes, interpolation of the Veery passage across New York State on the night of 28-29 August 1993 (fig. 5) yields an estimated minimum southward passage of 28,000 Veerys across the 300 km line of recording stations. Expanding the technique to the whole season yields a 1993 estimated minimum detected passage of 175,000 Veerys across the 300 km transect, based on season totals detected at stations across New York State from 1991-1994.

Discussion

Every technique for monitoring avian populations is subject to limitations and biases involving detectability of birds, amount of area covered, observer variability, and standardization of analyses (Ralph and Scott 1981; Ralph and others 1993). For example, the number of birds detected by a banding station varies with factors such as number of nets, duration of daily operation, regional geography, and local habitat characteristics. Similarly, the equipment and environmental variables associated with an acoustic monitoring station, and the method for interpreting the number of passing individuals from calling data, affect the number of individuals detected. Although the limitations and biases of acoustic monitoring are still not completely understood, certain aspects of the technique can be controlled carefully, increasing the potential for standardization and largely eliminating observer variability. Overall, we believe that the biases associated with acoustic monitoring at night are not greater than those inherent in diurnal censusing or mist-netting. In fact, the most serious impediments to widespread application of a night-flight call monitoring program are the shear volume of data that can be collected in a short time, and the number of hours required to analyze these data. Ongoing research is therefore focusing on computerized automation of data collection and analysis, which will greatly reduce both data-processing time and human-induced biases.

Even given the large number of variables and uncertainties, it is clear that this new technique can detect enormous numbers of migrating birds and can provide information not possible to obtain through more conventional methods. The data from the Texas acoustic monitoring station illustrate how the biases of both acoustic monitoring and banding complement one another in giving a more accurate representation of migration through a region. Each technique detected species that the other missed. Notable regarding the acoustic technique is the detection of relatively rare and secretive species like the Black Rail, a species for which we have little population or migration information.

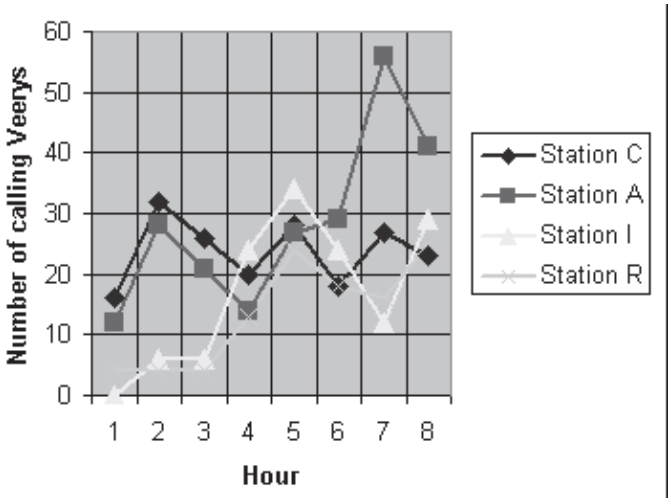

Figure 5—Temporal and geographic comparison of Veery numbers detected by acoustic monitoring at four recording stations in New York State (see fig. 1) during the night of 28-29 August 1993. Recording began at all stations simultaneously at 2030 EDT and continued for 8 hours.

The acoustic stations at Alfred, NY, and Vancouver Island, BC, detected more than an order of magnitude more thrushes than were detected by mist-netting. Furthermore, results from the New York State array reveal that many species migrate in broad geographic fronts with spatially related density gradients. This suggests that acoustically detected numbers aloft may be interpolated between properly spaced inland monitoring stations, resulting in even greater monitoring power.

The MIP counting technique, which theoretically compensates for variable calling rates of birds, is most likely conservative, and additional work toward understanding night-flight calling behavior will likely lead to more sophisticated MIP analysis and higher MIP totals. For example, further work characterizing flight altitudes and average flight speeds of small passerines by radar in different regions and weather conditions should lead to more accurate MIP calculations.

Acoustically determined numbers of migrants with MIP are tallied with certain assumptions. MIP considers that migrants typically progress in some consistent direction, as opposed to circling. Whole-season surveillance radar studies support this assumption (e.g., Graber 1968), but certain weather conditions, especially combined with the presence of artificial lighting, can cause circling. The possibility of circling birds must be evaluated before applying MIP.

A second assumption is that the apparent broad front density of migration of certain species, for example Veery, allows interpolation between recording stations. Further studies are needed to understand the validity of such interpolation, and to determine the appropriate interstation distances within a transect.

A final assumption is that an acoustic station can census calling species consistently through time, despite inevitable variations in flight altitude, wind conditions, migration routes, and calling behavior. Although this assumption is difficult to prove, one of the strongest pieces of evidence lies in the empirical results from the New York State monitoring stations. These data indicate consistent season totals and migration timing for species amid the variables of multiple seasons (e.g., Gray-cheeked Thrush data in this paper).

Results from several of the pilot studies demonstrate the importance of weather and geographic factors in affecting the monitoring potential at different sites, and suggest that some sites may be better than others for acoustic monitoring at particular seasons. For example, the station in British Columbia detected few calls in spring but heavy calling in fall, while concurrent surveillance radar studies indicated heavy migration over the recording station during both seasons. However, radar studies also indicated that birds were flying higher in spring, above the range of the recording equipment (R. Millikin, personal communication). In spring, birds must cross the 30 km wide Juan de Fuca Strait before flying over the recording station on southern Vancouver Island. In fall, migrant landbirds funnel southward down Vancouver Island. Birds may fly at higher altitudes in spring migration across the Juan de Fuca Straight than they do in their fall flight down Vancouver Island. Further research on microphone designs will define the altitudes at which migrants can be acoustically censused, but a site like the southern end of Vancouver Island generally appears not to be a good location to acoustically study migration during spring.

As a second example of the effects of weather, the acoustic station on Florida's east coast detected large flights only under specific wind directions in spring. On east to southeast winds only light calling was detected, whereas large flights predictably occurred when winds were from south to west, tending to "wind-drift" migrants against the coast. Under these latter conditions, the birds apparently prefer to fly at low altitudes and to hug the coastline during their northbound flight, instead of flying out over the Atlantic Ocean. Although these weather and geographic variables may appear as serious limitations of the acoustic monitoring technique, we believe that knowledge of such variation can be used to select sites that maximize the consistent monitoring of large numbers of migrants.

In the New York State array, relatively consistent acoustic patterns have been revealed for the 1991-1994 fall migrations, amid a wide range of seasonal weather variables (see also Evans and Mellinger 1999). One advantage of an inland, east-west running transect of recording stations is that it can account for variations in the flow of migrants due to variable seasonal weather conditions. In one season, some migrants may pass over the east side of a recording-station transect; in another year these migrants might pass over the western side. Therefore, an east-west running transect of stations may act as a "recording net," able to more consistently monitor the flow of migration amid seasonal weather variations than a single station can.

The question most frequently asked regarding this emerging technique involves species identification and problems associated with non-calling or non-detected individuals. We believe that the issue of species identification has been addressed partly through careful comparisons with calling birds of known identity, and through the use of modern spectrographic analysis. Our knowledge of call identities and variations within species will be refined as field recordists continue to work in new areas of North America, and as computer-analysis techniques become more sophisticated. In the short term, inclusion of a call-type in a complex of similar species does not preclude our ability to monitor these species at certain geographic localities or times of year. For example, some calls in figure 3 are placed in the species complex #5, which includes at least eight species. However, considering extensive diurnal migration observations made along the east coast of Florida during early May (Cruickshank and Taylor databases), the likely callers are Blackpoll Warbler and to a lesser extent, Connecticut Warbler. Similarly, all the calls placed in species complex #4 (fig. 3) are most likely from Northern Parula because other species in this complex are not known to be regular migrants at this time of year in eastern Florida.

The problem of noncalling or "missed" birds is potentially more troubling, but may be resolved through innovative comparisons with radar data (Gauthreaux, personal communication). As with other monitoring techniques, we seek a consistent index of species abundance. Therefore, even if we cannot reliably estimate the probability that a given bird calls while passing over a recording station, acoustic monitoring still will be useful if the number of birds detected is positively correlated with the number of birds aloft. However, comparisons and calibrations with other techniques are complicated by the presence of individuals

of abundant, non-vocal species. For example, on nights when large numbers of Gray Catbirds (*Dumatella carolinensis*) and Red-eyed Vireos (*Vireo olivaceus*) are migrating, close correspondence between acoustic and radar data might not be expected, because neither species is known to give night-flight calls.

Another barrier to widespread use of the night-flight call monitoring technique is the large amount of data analysis involved. Thousands of calls may occur over a monitoring site in a single evening, and hundreds of hours of tape may be generated in even a limited study. One of the great potentials of the acoustic-monitoring technique is now being developed—the use of signal processing technology to automatically extract and classify calling information from recorded tapes. Recent work toward this goal has been carried out by the Cornell Laboratory of Ornithology's Bioacoustics Research Program (Mellinger and Clark 1993; Fristrup and Watkins 1994; Mills 1995; Taylor 1995). Automated detection of call notes and classification into species or complexes of species will make large-scale analysis of flight-call data possible.

In conclusion, we believe that acoustically monitoring night-flight calls of migrating birds offers enormous potential for improving understanding of migration routes, migration timing, and species composition at specific sites. Ultimately, we believe the technique will help us to monitor population changes of certain migratory species. Careful selection of recording sites can minimize the effects of geography or local weather, and inland transects of recording stations can lead to consistent monitoring. Acoustic monitoring is promising for its ability to detect species that are difficult to study by other means; for example, the migration of secretive grassland birds (Evans and Mellinger 1999), the passage of boreal-nesting species such as Gray-cheeked Thrush (Blanchard and Droege 1993) or the movements of special-concern species such as Bicknell's Thrush (Evans 1994). This new methodology will be especially valuable when used in conjunction with other, more conventional techniques, such as mist-netting and diurnal counts. The information that can be derived from acoustic monitoring is qualitatively different, however, from that obtained by other methods.

As humans, our ability to study the species-specific movements of nocturnal migrants always has been dependent on what we encounter on the ground, during the day. As such, we traditionally may have missed the bulk of the true migration, which passes undetected overhead. The emerging techniques we describe here, especially if combined with exciting new avian detection capabilities of Nexrad radar (Larkin 1991; Gauthreaux 1996), will open a wide window into one of the great mysteries of nature.

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5. Population and Habitat Assessment: Demographic Approaches

American Redstart

5. Section Overview—On the Need for Demographic Approaches to Answer Questions About Conservation and Management of Migratory Landbirds

Robert J. Cooper
Nadav Nur

In the preceding section, emphasis was placed on monitoring birds over large areas, and the monitoring method emphasized was the point count. Indeed, point counts are useful when a large area must be surveyed, or if all that is required is a simple list of the species present. However, it is becoming increasingly clear that for many objectives pertinent to research and management, we must know something about the demographic parameters of bird populations. By demographic parameters we mean vital rates such as productivity and survival, and estimates of population increase or decrease obtained from vital rates (Noon and Sauer 1992). Point counts do not provide these data. Moreover, presence/absence, or abundance, can be a misleading indicator of habitat quality (Van Horne 1983). For example, forest fragments occupied by a species may not be suitable breeding habitat if the individuals detected are mostly unmated males (Gibbs and Faaborg 1990), or if pairs present consistently produce no young (i.e., a sink; Pulliam 1988). Any attempt to relate population viability to landscape characteristics or to alternative management practices is also meaningless without some estimate of the vital rates of the populations in question. That sentiment is echoed by many of the papers in this section.

Those readers unfamiliar with demographic field work might initially believe such studies to be beyond their means in terms of both money and expertise. However: (1) demographic information can often be obtained without nest finding and monitoring, which are especially labor-intensive; (2) standardized protocols have been worked out and now exist for several approaches to demographic monitoring; and (3) with all the demographic studies recently initiated, more and more people are gaining the required skills in nest finding and mist-netting. The British Trust for Ornithology has demonstrated, for Britain, that demographic monitoring is feasible and yields valuable insights (Baillie 1990; Peach and others 1991).

There are several general approaches used in demographic studies. Three such methods—intensive nest monitoring and netting, nest monitoring alone, and constant-effort mist-netting—are represented in this section. A fourth method, using behavioral cues as an index to reproductive success, is not covered here but is useful when working with species whose nests are extremely difficult to find (Vickery and others 1992).

Approaches

Intensive Nest Monitoring and Netting

In the intensive approach, investigators work on plots or study areas of various sizes, attempting to find and monitor as many nests as possible in the area. In addition, because it is recognized that many species are capable of producing >1 brood in a season, adult birds are captured using mist nets and then uniquely marked with a set of color bands. Thus, multiple broods can be assigned to the correct female. Color banding adults also allows annual survival to be estimated by resighting or recapturing banded birds that have survived each year (Marshall and others, this proceedings). Examples of this approach represent some of the best population ecology work published to date on Neotropical migrant species. They include Nolan (1978), Holmes and others (1992), Sherry and Holmes (1992), Roth and Johnson (1993), and others. Most studies are long term (>5 yrs).

Intensive studies, discussed in this section by Sherry and Holmes, are ideal in many ways because productivity is measured directly instead of indirectly using mist-netting or reproductive success. Drawbacks are cost and the need to focus on a relatively small area (<50 ha). Studies that compare, say, several different treatments with replicates of each treatment become extremely expensive and logistically challenging, usually requiring collaboration among several partners (Cooper and others, this proceedings).

Nest Monitoring Alone

Clearly, an important component of annual productivity is nesting success, defined as the likelihood of a nest producing $\geq$1 conspecific young. Many studies have therefore examined just this component of reproductive success. This approach is best exemplified by the Breeding Bird Inventory and Research Database (BBIRD) effort. Discussed in this section by Conway and Martin and by Hejl and Holmes, BBIRD is a database that includes data on thousands of nests from numerous locations nationwide. Most of the data are collected according to a standardized protocol (Martin

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and others 1997) on one or more plots between 20 and 50 ha in size. Data collected by most contributors include nesting success, habitat measurements taken at and around the nest as well as at random sites within study plots, and point counts taken at those same random points. Many but not all contributors employ BBIRD protocols to study questions relative to habitat fragmentation or management practices, among others (e.g., Cooper and others, this proceedings).

For someone initiating a project that includes estimation of productivity, utilizing BBIRD protocols has several advantages. First, although methods will have to be fine-tuned for each specific project, a standardized set of variables has already been established. These include standardized methods for point counts and habitat measurement, which also yield valuable information. Many aspects of logistics (e.g., number and size of plots, crew size and makeup) have also been worked out. Therefore, the investigator does not have to start from scratch. Also, much of the BBIRD program revolves around nest monitoring and measurement. Thus, it follows the spirit of intensive studies in that productivity of individual nests is assessed directly. A drawback is that BBIRD protocols do not include mist-netting and banding birds, so that while nesting success and productivity of individual nests are assessed, seasonal productivity is not.

One potential drawback to nest monitoring studies is that investigators may expend effort to find and monitor as many nests of as many species as possible, usually on several plots. This can present a problem in that most species will be represented by only a few nests which, while they contribute to the overall database, are too few to make any sort of population inference in that particular study. Effort expended on those species may detract from effort perhaps better spent on well-represented species (Hejl and Holmes, this proceedings). As a result, sample sizes (i.e., number of nests per species) within plots are often not adequate to estimate parameters of interest such as nesting success (Hensler and Nichols 1981; Nur and others 1999). This problem sometimes can be overcome by focusing effort on the nests of a few focal bird species and ignoring the rest (Hejl and Holmes, this proceedings).

Last, conclusions based on nesting success alone can be misleading because it is only one component of annual productivity. However, if additional information, such as the length of the breeding period and the time between nesting attempts (successful and unsuccessful), is known, then models such as those developed by Pease and Gryzbowski (1995) can estimate annual productivity. These models also take into account the fact that brood parasitism precludes renesting as long as the nest is active, which in some instances can significantly modify estimates of annual productivity.

Constant-Effort Mist-Netting

Constant-effort mist-netting takes an approach that is different from the above two. It entails capturing birds in mist nets using standardized procedures and drawing inferences about productivity and survival from the numbers and ages of birds captured both among and within years. In the U.S.A., it is best exemplified by the Monitoring Avian Productivity and Survivorship (MAPS) program, discussed in this section by DeSante, Rosenberg and DeSante, and Nur and others. Nests are generally not monitored (although doing so as a check on productivity estimates is encouraged). Rather, assessment of productivity is based on captures of hatch-year (HY) birds in mist nets. Typical protocols call for ≥10 12-m nets to be operated throughout the breeding season, once every 10 days, but in some cases mist nets are run more often (Nur and Geupel 1993a). The method assumes that the intraspecific ratio of HY birds to adult birds is an index to the productivity for that species in that area (Nur and Geupel 1993a). It therefore bypasses outcomes of individual nests and instead assesses seasonal output only.

The method has several advantages. First, it provides assessment of production of young of the year, integrated over a potentially large area (the catchment area of the nets). Second, the productivity index incorporates mortality of newly fledged young (generally, only independent young are caught in nets, two or more weeks after fledging; Nur and Geupel 1993a). And, third, annual survival of adults can be assessed on the basis of capture-recapture analysis (example in Nur and others in this section).

There are other advantages. First, a smaller crew is needed. In some locations, a single experienced bander can operate all the nets. Also, the system lends itself to training new banders by giving them experience in removing birds from nets and banding them while the supervisor is nearby. More than a few ornithologists decided on their career while under the careful tutelage of an experienced and patient bander. Also, the system lends itself to public demonstrations of field work with migratory birds, meeting outreach and education needs along with monitoring and research. Last, protocols call for point counts and additional habitat measurements, although these are not as extensive as BBIRD habitat measurements.

The chief disadvantage of constant-effort mist-netting involves problems with small numbers of captures in some habitat types. In particular, HY birds are often captured in bunches or else are not captured at all. While results are promising from scrub-shrub habitats, in which mist nets cover most of the vertical extent of the vegetation (see Nur and others in this section), similarly detailed data are lacking from forest habitats. Given the clumped nature of captures, this is not surprising. This effect can be ameliorated by analyzing data from captures over a larger scale. In fact, the MAPS program is really not designed to provide productivity estimates on a small scale (e.g., a 20-ha plot; DeSante, this proceedings), but rather on a regional scale.

Discussion

When deciding on a demographic approach, the most important consideration is the objective of the project (Ralph and others 1993; Johnson, this proceedings). A research project will have a different set of objectives than a monitoring or outreach project. Cost is nearly always a consideration, too. Each of the approaches summarized above has advantages and shortcomings; these are discussed in greater detail in some of the papers in this section. It is always a good idea to discuss potential methods with those investigators currently using them and perhaps visit a site where the methods are being used.

Whereas the intensive approach might be considered superior because it provides the most information, logistical constraints may override its usefulness. For those facing such practical considerations, it is perhaps useful to consider the two standardized methods, nest-monitoring and constant-effort mist-netting, to be components of the intensive approach. Nest monitoring and constant-effort mist-netting complement each other to some extent (Nur and Geupel 1993a). Thus, one might start out by using either BBIRD or MAPS protocols, depending on preference, and endeavor to integrate the other approach into the study at a later date.

A cautionary note is also in order. There are problems associated with estimation of demographic parameters that potential investigators need to be aware of. Survival estimation is problematic because of the tendency of long-distance migrants to disperse far from the site where they were first captured. Although still alive, they are indistinguishable from dead birds if not resighted. This problem, discussed here by Marshall and others, is so severe for hatching-year birds dispersing from their natal site that first year survival is hardly ever estimated. Estimation of productivity also is problematic because it can vary greatly both within and among years (e.g., Wilson and Cooper 1998). Reproductive success estimated from nests monitored during only a small part of the breeding season, or from only one year, can therefore be very misleading.

Using standardized approaches is valuable for several reasons. Large data sets from nationwide sources promote collaboration. Indeed, some demographic questions are only answerable over large scales by the joint analysis of several data sets. For example, variation in population parameters across a species' range, regional patterns of productivity or survival, or other regional comparisons are only possible with large data sets such as these. Robinson and others (1995b) provide an excellent example of what can be accomplished by combining data sets from several locations (Robinson and Morse discuss linking local and regional demographic studies in this section). In this case, the authors verified what had long been suspected, that reproductive success of forest interior bird species is inversely related to the degree of fragmentation in the surrounding landscape. However, this result was based on data from the midwestern U.S.A. only. It remains to be seen if the rest of us can work collaboratively to combine data for other regions of North America. Standardized databases such as these can facilitate this objective if the daunting organizational obstacles can be overcome.

Patterns of Productivity and Survivorship From the MAPS Program

David F. DeSante

Abstract—The Monitoring Avian Productivity and Survivorship (MAPS) Program is a cooperative, continentwide program of constant-effort mist-netting and banding designed to provide: (1) annual indices and long-term trends in adult population size and post-fledging productivity for target landbird species from capture rates of young and adult birds; and (2) annual estimates and long-term trends in adult population size, adult survivorship, and recruitment into the adult population from modified Cormack-Jolly-Seber analyses of mark-recapture data. Here I investigate patterns in productivity indices and survival-rate estimates obtained at two spatial scales (a large sub-continental region—eastern North America; and a single physiographic province—the Sierra Nevada) from data from the four-year (1992-1995) pilot MAPS program. Productivity indices for species groups from eastern North America varied as a function of nest location (in descending order: cavity, ground, open-cup tree, and open-cup shrub nesters) and migration strategy (in descending order: permanent residents, temperate-wintering migrants, and Neotropical-wintering migrants). These patterns agree with those found by direct nest-monitoring and those predicted from theoretical considerations, and were robust with respect to both time and space (being similar in each of the four years and similar whether data were included from only the 61 stations operated during each of the four years or from all stations operated each year, which increased from 81 stations in 1992 to 203 stations in 1995). The same general patterns of productivity as a function of nest location and migratory strategy also were found at the smaller spatial scale of the Sierra Nevada physiographic province. In addition, survival-rate estimates for Neotropical migrants tended to be higher than those for temperate migrants and permanent residents at both spatial scales, again in agreement with current life-history theory. These results suggest that patterns of productivity and survivorship generated by MAPS data reflect real population processes at large and varying geographic scales.

Recent analyses of data from the North American Breeding Bird Survey (BBS) and other large-scale, long-term monitoring programs suggest that many species of landbirds, including a number of Nearctic-Neotropical migratory species, have undergone pronounced population declines over the past three decades, and that these declines may be accelerating, at least in the eastern and central parts of the continent (Robbins and others 1989b; Terborgh 1989; Peterjohn and others 1995, 1996). Indeed, these analyses have provided much of the impetus for the establishment and growth of the Neotropical Migratory Bird Conservation Initiative, "Partners in Flight."

Despite the general success of large-scale monitoring programs, such as the BBS, in describing geographic and temporal patterns of avian population trends and identifying potentially declining species, such monitoring programs provide little information as to factors responsible for population declines and even less direction as to appropriate management actions to reverse declines (Peterjohn and others 1995; DeSante and Rosenberg 1998). This is because they provide no information about the stages of the life cycle that control the population changes (Temple and Wiens 1989), and thus fail to distinguish problems caused by productivity factors that operate on the breeding grounds from those caused by mortality factors that may operate primarily on the wintering grounds and migration routes (DeSante 1992b; Sherry and Holmes 1995). Clearly, critical data on primary demographic parameters (productivity and survivorship) are needed to determine the factors responsible for the population declines in Neotropical migratory birds and to identify conservation and management actions to reverse the declines (DeSante 1995).

The Monitoring Avian Productivity and Survivorship (MAPS) Program was established by The Institute for Bird Populations to provide these critical data (DeSante and others 1993b, 1995). MAPS uses standardized, constant-effort mist-netting and banding during the breeding season at a continentwide network of stations, and was patterned after the British Constant Effort Sites Scheme (Baillie and others 1986; Peach and others 1996; Peach and Baillie, in press) that has been in operation since 1981.

The specific objectives of MAPS are to provide, for a suite of target landbird species (including both Neotropical- and temperate-wintering species) and at multiple spatial scales: (1) annual indices of adult population size and post-fledging productivity from data on the numbers and proportions of young and adult birds captured; and (2) annual estimates of adult survivorship, adult population size, and recruitment into the adult population from mark-recapture data on the adult birds captured. These demographic indices and estimates are to be used to describe temporal and spatial patterns in the demographic parameters of the target species, and to model interrelationships between demographic parameters and environmental variables including weather and landscape-level habitat characteristics (particularly those resulting from management actions).

The major long-term goal of MAPS is to use the demographic information generated on target species to aid in: (1) identifying proximate demographic causes of population changes in these species; (2) identifying conservation strategies and management actions to reverse population

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declines; and (3) evaluating the effectiveness of the conservation strategies and management actions implemented. Indeed, monitoring primary demographic parameters may be the most judicious way to determine whether management actions are working effectively (DeSante and Rosenberg 1998). This is because management actions affect primary demographic parameters directly, and these effects can potentially be observed over a short time period (Temple and Wiens 1989). Because of buffering effects of floater individuals and density-dependent responses of populations, substantial time lags may occur between changes in primary parameters and resulting changes in population size or density (DeSante and George 1994). Moreover, because of the vagility of most bird species, local variations in population size may be masked by recruitment from a wider area (George and others 1992) or accentuated by lack of recruitment from a larger area (DeSante 1990).

Additional long-term goals of MAPS are to: (1) forge cooperative partnerships among federal and state agencies, nongovernmental organizations, researchers, and independent banders to use public lands for long-term avian monitoring efforts; and (2) provide a means for direct public participation in landbird conservation efforts by encouraging banders to collect rigorous mark-recapture data. These two objectives are addressed elsewhere in this proceedings (Burton and DeSante). Whether MAPS can achieve its major long-term goal depends upon whether temporal and spatial patterns in demographic parameters of target species generated from MAPS data reflect actual population processes at the scale of interest. Criticism of MAPS has primarily been twofold: (1) because of constraints on locations where long-term mist-netting is practical and permissible, stations are not sited by a probability-based sampling strategy—thus, inferences regarding productivity indices and survival-rate estimates cannot be made beyond the sample of stations; and (2) with regard to productivity indices, the populations sampled at MAPS stations are not clearly identified due to limitations on our knowledge of bird dispersal patterns—thus, the adequacy of productivity indices based on the proportion of young captured is not well known.

This paper documents the growth of the MAPS Program from 1989 through 1996, and describes, at two geographic scales (a large semi-continental scale—North America east of the Rocky Mountains and north of Mexico; and a smaller regional scale—the Sierra Nevada physiographic province as defined by the BBS), patterns of productivity with respect to nest location and migration strategy and patterns of survivorship with respect to migration strategy. I show that patterns generated by these data are temporally and spatially consistent both with patterns expected from ecological theory and with patterns generated from other empirical data.

Methods

Data Collection

The overall design of the MAPS Program and the methods used to collect data were outlined in DeSante and others (1993b, 1995) and were described in detail in DeSante and Burton (1997). Briefly, MAPS stations were established in 20 ha study areas where long-term mist-netting was practical and permissible. Typically, about 10 permanent net sites were distributed opportunistically (at locations where birds can be captured efficiently) but rather uniformly throughout the central 8 ha of the study area, and one 12 m, 30 mm-mesh mist net was erected at each net site.

Stations were operated in a standardized manner, typically for six hours per day, beginning at sunrise, for one day per 10-day period, and for 8-12 consecutive 10-day periods, depending on latitude, from May 1 to August 28 (MAPS protocol was changed in 1997 to minimize captures of fall migrant individuals: the last two 10-day periods, August 9-28, were eliminated). To minimize captures of spring migrant individuals and subsequent net avoidance by permanent resident and early arriving summer resident individuals, starting dates for MAPS stations were delayed until the time when most spring migrant individuals of the target species have moved through the study area; thus, starting dates were later at more northern latitudes.

Each bird captured was marked with a uniquely numbered aluminum leg band and all birds captured (including recaptures) were identified to species, age, and (if possible) sex. The times of opening and closing each net and beginning each net run were recorded each day so that effort could be calculated for each 10-day period and standardized between years. A separate record was kept of all species seen or heard within the boundaries of each station on each day of operation, to determine, for each year, whether the species was a summer resident and probable breeder at the station.

Data Analysis

Methods of data analysis were described in detail in DeSante and others (1993b) and DeSante and Burton (1994b). Very briefly, after computer entry and proofing, capture data were run through verification programs that: (1) checked the validity and ranges of all coded data; (2) compared the species, age, and sex determinations against the aging and sexing criteria used, and flagged discrepancies or suspicious data; (3) screened data for unusual band numbers or band sizes; and (4) screened all records of each band number for inconsistent species, age, or sex determinations. All inconsistencies, discrepancies, or suspicious data were examined in detail and corrected if necessary.

Following procedures pioneered by the British Trust for Ornithology in its CES Scheme (Baillie and others 1986; Peach and others 1996), I used the proportion of young (hatching-year) birds in the catch [# young/(# young + # adults)] during the entire MAPS season (May 1 to August 28) each year as the annual index of post-fledging productivity. For productivity (or survivorship) analyses in any given year, I included only stations that were operated for at least five periods, at least three of which occurred during the earlier portion of the season (when adults predominate in the catch) and at least two of which occurred during the later portion of the season (when young birds predominate in the catch).

I investigated patterns of productivity from eastern North America over the four years, 1992-1995, by two approaches: (1) the constant-stations approach, in which I pooled data

from the 61 stations east of the Rocky Mountains that lay within the breeding range of the species and that fulfilled the above criteria during every one of the four years; and (2) the variable-stations approach, in which I pooled data from all stations east of the Rocky Mountains that lay within the breeding range of the species and that fulfilled the above criteria in any of the four years. The numbers of stations from which data were pooled using this latter approach were 81 in 1992, 109 in 1993, 169 in 1994, and 203 in 1995.

I included species in productivity analyses from eastern North America for which at least 50 aged individuals were captured during each of the four years at all stations that were pooled each year. I classified each species by nest location (cavity nester, open-cup tree nester, open-cup shrub nester, ground nester) using information from Ehrlich and others (1988), and by migration strategy (permanent resident, temperate-wintering migrant, Neotropical-wintering migrant) using information from AOU (1983) and DeSante and Pyle (1986). I excluded Brown-headed Cowbird (*Molothrus ater*) from these analyses because it is a brood parasite, and an appropriate nest location classification could not be assigned. I also excluded Cedar Waxwing (*Bombycilla cedrorum*) and American Goldfinch (*Carduelis tristis*), because adults of these species begin nesting in eastern North America substantially later than other species and, unlike all species that were included, pre-breeding adults often were captured in sizeable flocks during the MAPS data-collection period. For this reason, productivity indices for these two species likely would be biased low compared to all other species.

For the Sierra Nevada analyses, I used the variable stations approach; that is, I pooled data for each species each year from all stations within the Sierra Nevada physiographic province that lay within the breeding range of the species. I included species in this analysis for which a total of at least 100 aged individuals were captured during the four years at all stations that were pooled each year. I classified species by nest location and migration strategy as described above. I excluded House Wren (*Troglodytes aedon*), Orange-crowned (*Vermivora celata*) and Nashville (*V. ruficapilla*) warblers, and Lesser Goldfinch (*Carduelis psaltria*) from these analyses because large numbers of individuals of these species, especially juveniles, undergo up-mountain drift after the breeding season. Therefore, productivity indices for these species likely would be biased high compared to all other species.

I calculated maximum-likelihood estimates of annual adult survival rates from four years (1992-1995) of mark-recapture data pooled from stations that were operated in every one of the four years. I used a modified time-constant Cormack-Jolly-Seber analysis (Pollock and others 1990) that incorporated the transient model described by Pradel and others (1997) into the computer program SURVIV (White 1983). The transient model allows estimation of the time-constant proportion of resident birds among newly captured individuals, as well as estimation of the time-constant recapture probability. In order for the estimate of proportion of residents to be biologically meaningful, I pooled only data from stations where the species was known to be a regular breeder, that is, where evidence existed that the species was a summer resident in at least three of the four years, 1992-1995. In order to make meaningful comparisons of productivity and survivorship, I recalculated productivity indices for both eastern North America and the Sierra Nevada using the same stations from which survival rates were estimated, that is, stations that were operated during each of the four years 1992-1995 and at which the species was a regular breeder. For analyses from eastern North America, I included species for which a total of at least 200 aged individuals were captured over the four years; for the Sierra Nevada analyses, I included species for which a total of at least 60 aged individuals were captured over the four years. I inferred the statistical significance of differences in productivity indices or survival-rate estimates between groups of species having different migration strategies from non-overlapping 95% confidence intervals.

Results

Growth of the MAPS Program

MAPS grew from 17 stations in 1989 to 38 in 1990, 66 in 1991, 178 in 1992, 236 in 1993, 326 in 1994, 391 in 1995, and 413 stations in 1996 (fig. 1). The substantial growth of the program in and subsequent to 1992 and the increase in the percentage of stations supported at least partially by federal funds was caused by the increased involvement of various federal agencies in PIF, particularly the USDA Forest Service; the USDI Fish and Wildlife Service, National Park Service, and National Biological Service (now Biological Resources Division of USGS); and the USDoD Departments of the Navy and Army. The distribution of the 413 stations operated in 1996 is shown in figure 2.

Patterns of Productivity from Eastern North America

Annual (1992-1995) productivity indices (proportion of young in the catch) and nest-location and migratory-status classifications are presented for each of the 43 species

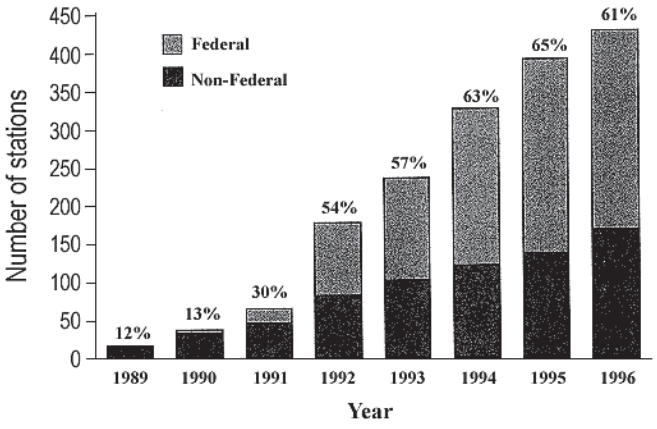

Figure 1—Growth of the Monitoring Avian Productivity and Survivorship (MAPS) program from 1989 to 1996 and percentage of stations for which at least some federal support was received.

Figure 2—Map of North America showing the distribution of the 413 MAPS stations operated in 1996 (as determined by the 10-minute block in which the station was located). Thus, an individual square mark can include multiple stations. Clusters of stations (indicated by clusters of square marks), in fact, can include up to 14 stations.

included in this analysis in appendix 1. In terms of nest type, they included 8 cavity nesters, 12 open-cup tree nesters (hereafter, tree nesters), 14 open-cup shrub nesters (hereafter, shrub nesters), and 9 ground nesters. In terms of migratory status they included 7 permanent residents, 13 temperate-wintering migrants (hereafter, temperate migrants), and 23 Neotropical-wintering migrants (hereafter, Neotropical migrants). For 36 of these 43 species, a total of 50 or more aged individuals were captured each year at the 61 stations that were operated during each of the four years.

The relationship between productivity and nest-location is shown for each of the four years in figure 3. In general, for both the constant- and variable-stations approach, cavity nesters showed the highest productivity indices, followed by ground, tree, and shrub nesters in that order. This pattern was found in 7 of 8 year-approach cases; in the only exception (1994, constant-station), the order was cavity, tree, ground, shrub nesters. Indeed, cavity nesters showed significantly higher productivity than shrub nesters in all 8 year-approach cases, and significantly higher productivity than tree nesters in 5 of the 8 year-approach cases, including all four years using the variable-stations approach.

The relationship between productivity and migration strategy is shown for each of the four years in figure 4. Permanent resident species showed the highest productivity indices and Neotropical migrants the lowest, while temperate migrants were intermediate. This pattern was consistent in all 8 year-approach cases. Indeed, permanent resident species showed significantly higher productivity indices than Neotropical migrants in all 8 year-approach cases.

In addition, for most groups, using either the constant- or variable-station approach, productivity increased from 1992 to 1993, increased again from 1993 to 1994, and decreased from 1994 to 1995. This exact pattern was found in 5 of 8 nest

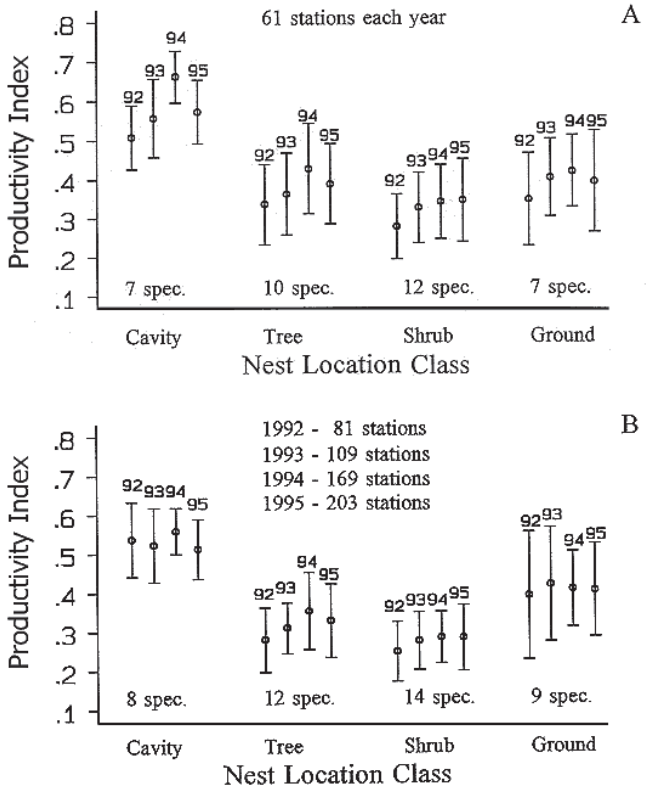

Figure 3—Productivity indices for 1992 through 1995 for species in eastern North America (all stations pooled east of the Rocky Mountains lying within the breeding range of the species) as a function of nest location from: (A) constant-stations and (B) variable-stations analyses (see text). Shown are the means and 95% confidence intervals. The number of species included and the number of stations from which data were pooled are shown for each year and nest-location group.

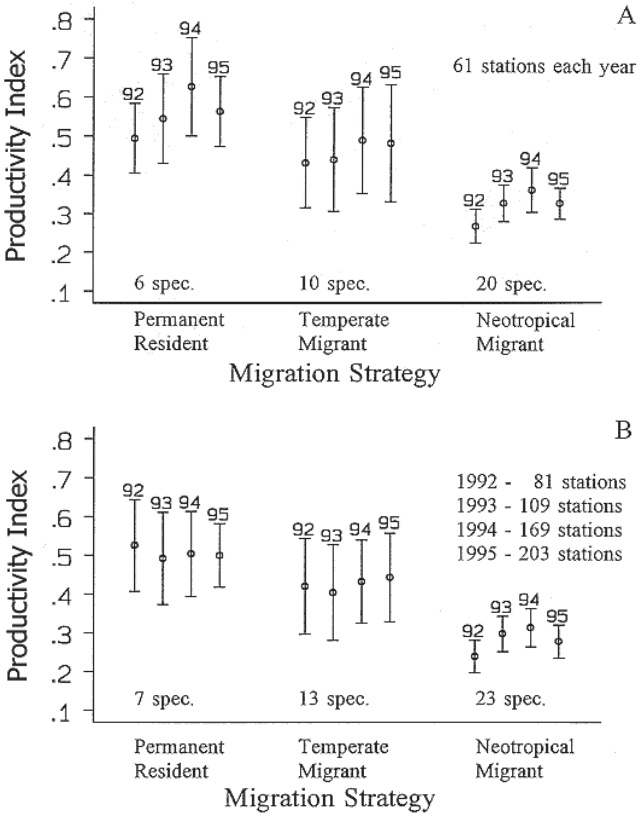

Figure 4—Productivity indices for 1992 through 1995 for species in eastern North America (all stations pooled east of the Rocky Mountains lying within the breeding range of the species) as a function of migration strategy from: (A) constant-stations and (B) variable-stations analyses (see text). Shown are the means and 95% confidence intervals. The number of species included and the number of stations from which data were pooled are shown for each year and migration-strategy group.

location-approach cases (fig. 3) and in 4 of 6 migration strategy-approach cases (fig. 4). In 4 of the other 5 cases, only 1 of the 4 years was different than the above-mentioned sequence.

Patterns of Productivity From the Sierra Nevada□

Annual (1992-1995) productivity indices for species groups in the Sierra Nevada physiographic province (appendix 2; fig. 5) showed the same patterns with respect to nest location and migration strategy as did productivity indices for analogous species groups from the eastern United States. That is, cavity and ground nesters tended to show higher productivity indices (with the 4-year mean for cavity nesters being slightly higher than that for ground nesters), while tree and shrub nesters tended to show lower productivity indices (with the 4-year mean for shrub nesters being lower than that for tree nesters; fig. 5A); and permanent residents tended to show the highest productivity indices, followed by temperate migrants and then Neotropical migrants (fig. 5B). In fact, 4-year mean productivity indices for permanent resident species were significantly higher than those for Neotropical migrants.

These patterns also tended to be consistent over time, despite the fact that the number of stations increased from 9 to 14 during the four years. Indeed, productivity indices decreased from 1992 to 1993, increased from 1993 to 1994, and decreased from 1994 to 1995 for all 7 species groups. The pattern of permanent residents higher than temperate migrants higher than Neotropical migrants held for all years except 1993, when the pattern was permanent residents higher than Neotropical migrants higher than temperate migrants. Similarly, both cavity and ground nesters showed higher productivity indices than both tree and shrub nesters during all four years.

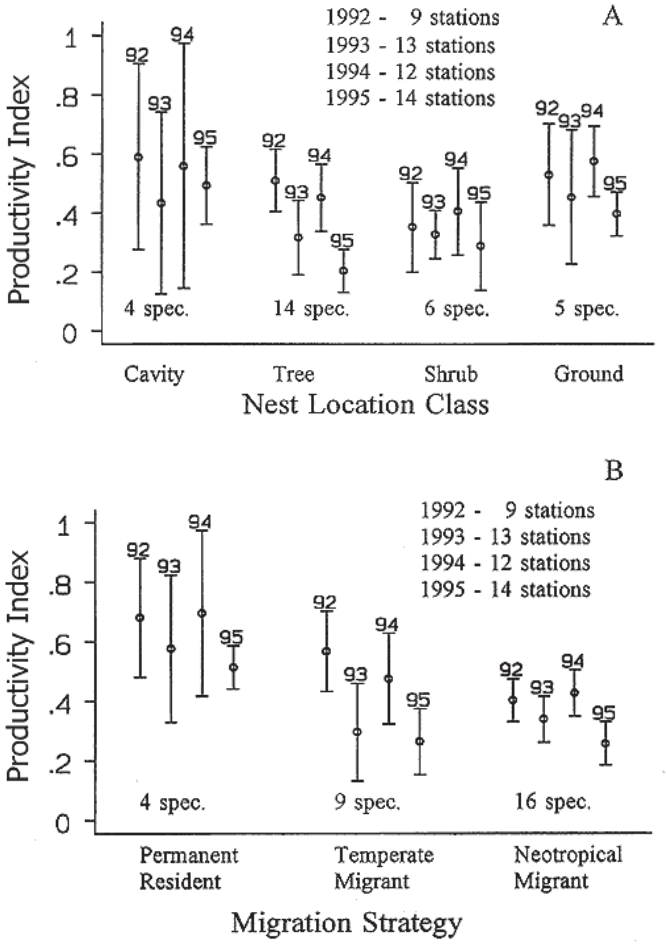

Figure 5—Productivity indices for 1992 through 1995 for species in the Sierra Nevada (all stations pooled in the Sierra Nevada physiographic province lying within the breeding range of the species) using the variable stations approach as a function of (A) nest location and (B) migration strategy. Shown are the means and 95% confidence intervals. The number of species included and the number of stations from which data were pooled are shown for each year and nest-location or migration-strategy group.

The Relationship Between Patterns of Productivity and Survivorship

In marked contrast to mean annual productivity indices (fig. 6A), annual time-constant adult survival-rate estimates tended to be higher for Neotropical migrants than for any other migration-strategy species group (fig. 6B; appendix 3). This was true both for eastern North America and for the Sierra Nevada. Indeed, the similarities between the two areas in both productivity indices and adult survival-rate estimates as a function of migration strategy are striking.

Discussion

Patterns of MAPS productivity indices from eastern North America indicate that cavity-nesting species tended to have higher productivity indices than any other nest-location group, and that tree and, especially, shrub nesters had the lowest productivity indices. These patterns also were reflected in MAPS data from the Sierra Nevada where cavity and ground nesters also tended to have higher productivity indices than tree and shrub nesters. These patterns agree well with analogous results on the percentage of nests lost to predators and the percentage of nests fledging at least one young as determined by direct nest monitoring (Martin 1995). Cavity nesters, for example, generally experience low rates of both nest predation and cowbird parasitism; moreover, they often have larger clutch sizes than the other nest-location groups. Ground nesters often experience relatively low rates of cowbird parasitism but rather high rates of nest predation. Tree and shrub nesters generally experience high rates of both cowbird parasitism and nest predation. Shrub nesters, in particular, experience high rates of nest predation from both terrestrial and arboreal nest predators.

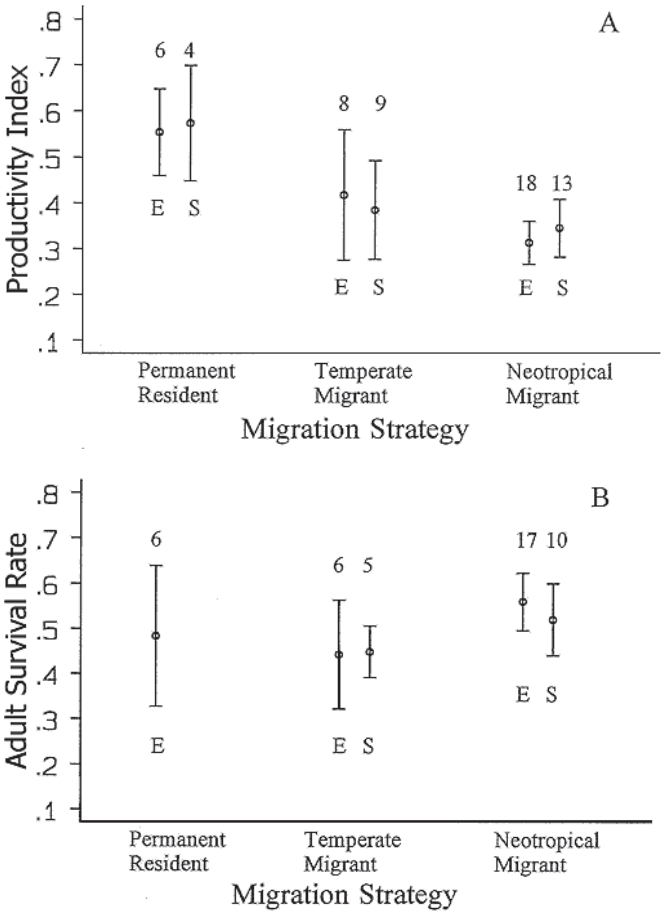

Figure 6—(A) mean (1992-1995) productivity indices and (B) time-constant (1992-1995) annual adult survival-rate estimates from MAPS for species in eastern North America (E) from data pooled from 61 stations operated during each of the four years; and the Sierra Nevada physiographic province (S) from data pooled from 7 stations operated during each of the four years as a function of migration strategy. Shown are the means and 95% confidence intervals. The number of species are shown for each migration-strategy/geographical-area group.

Also interesting was the relationship in both eastern North America and the Sierra Nevada between productivity indices and migration strategy: Permanent resident species showed the highest productivity indices while Neotropical migrants showed the lowest. Greenberg (1980) previously provided both empirical and theoretical evidence for this pattern. The reason for it may lie, at least partially, with the length of breeding season available to each of the three groups of species. Permanent resident species often begin nesting earlier in the spring than the other groups and, because they are not constrained by the need to molt, store fat, and migrate before the summer ends, can extend breeding later into the summer than the other groups. As a result, permanent resident species can more easily produce multiple broods and can have greater opportunities to make multiple re-nesting attempts (Whitcomb and others 1981; but see also Martin 1995). In contrast, Neotropical migrant species tend to arrive late in spring and leave early in fall and, thus, have a relatively short time available to produce multiple broods or make multiple renesting attempts (Whitcomb and others 1981; Martin 1995).

It also is important to note that the patterns of MAPS productivity indices presented here as a function of nest location and migration strategy were robust over time; that is, the same patterns tended to occur in each of the four years, 1992-1995, although the temporal patterns differed between eastern North America and the Sierra Nevada. Moreover, for eastern North America at least, the same patterns occurred each year regardless of whether data were included from only the 61 stations that were operated during every one of the four years, or from all of the stations that were operated each year, which nearly tripled from 81 stations in 1992 to 203 in 1995, indicating that these patterns were robust over space as well as time. This important result suggests that, while MAPS productivity indices may be biased, the biases tend to remain consistent over time and space. This is a fundamental requirement for any large-scale, long-term monitoring program.

In addition, the fact that patterns of productivity indices from MAPS for various nest-location and migration-strategy groups reflected patterns obtained from direct nest-monitoring as well as patterns predicted from theoretical considerations, suggests that biases in MAPS productivity indices also may remain fairly consistent among species. Indeed, the general agreement between patterns of MAPS productivity indices and patterns of reproductive success

estimated from direct nest monitoring or predicted from theoretical considerations suggests that MAPS-generated patterns of productivity may well reflect real ecological processes operating at large but variable geographic scales. The fact that Neotropical migrants tended to have lower productivity indices than the other three groups is interesting in view of the tendency for many Neotropical migrants to be experiencing greater population declines than many species of the other three groups (Peterjohn and others 1995).

These results should not be construed to suggest that low productivity is necessarily the cause of the negative population trends for many Neotropical migrants. It is important to note that population trends result from the interaction between productivity and survivorship. Species having low productivity (such as, perhaps, many Neotropical migrants) can have stable or positive population trends if their low productivity is at least balanced by a high survival rate. Thus, simultaneous survivorship information is needed along with productivity information to provide real insight into the causes of population trends and to identify appropriate management actions to reverse population declines. This is exactly what MAPS purports to do.

It is of considerable interest, therefore, that MAPS data suggests that Neotropical migrants in both eastern North America and the Sierra Nevada tend to have higher survival rates than permanent residents and temperate migrants. This also agrees with limited empirical data and theoretical considerations suggested by Greenberg (1980). Indeed, the apparent trade-off between productivity and survivorship, as illustrated by MAPS data, is fundamental to much of modern life-history theory (Martin 1995).

The two major criticism of MAPS have been that: (1) large-scale inferences regarding productivity indices and survival-rate estimates cannot be made beyond the sample of stations, and may not be representative of the region as a whole, because constraints on locations where long-term mist-netting is practical and permissible preclude the use of a probability-based sampling strategy for siting stations; and (2) the adequacy of productivity indices based on the proportion of young captured is not well known, because limitations on our knowledge of bird dispersal patterns preclude the clear identification of the populations sampled at MAPS stations. However, the fact that patterns of productivity with respect to nest location, migration strategy, and time remained consistent over a large geographical area, even when the number of stations under consideration tripled, suggests that patterns from the samples of stations actually may be representative of the pattern from the region as a whole. Moreover, the fact that patterns of productivity from MAPS generally agree well with productivity patterns from direct nest monitoring data and current life-history theory, suggests that productivity indices based on the proportion of young in the catch actually may be adequate to describe ecological processes at large spatial scales.

In summary, patterns of productivity and survivorship from MAPS, when examined at two large but different spatial scales, suggest that the MAPS program has the potential to provide useful demographic information on target species that can aid efforts to guide management strategies for them. This may especially be true when patterns of productivity and survivorship from MAPS are integrated with population trend data from the BBS and other long-term avian monitoring programs and with research results from direct nest-monitoring and habitat-utilization studies. I suggest that the MAPS Program is well suited to serve as one important piece of an integrated monitoring program for North American birds, and that it should continue to serve as an integral part of an effective North American Bird Conservation Program.

Acknowledgments

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Appendix 1: MAPS productivity indices for 1992 through 1995 for eastern North America for species for which at least 50 aged individuals were captured during each of the four years at all stations pooled in eastern North America lying within the breeding range of the species.

		1992			1993			1994			1995				
	Anal. type[a]	No. sta.[b]	No. aged ind.[c]	Prod. index[d]	No. sta.[b]	No. aged ind.[c]	Prod. index[d]	No. sta.[b]	No. aged ind.[c]	Prod. index[d]	No. sta.[b]	No. aged ind.[c]	Prod. index[d]	M[e]	N[f]
Downy Woodpecker	VS	54	177	0.562	81	235	0.518	118	400	0.582	132	412	0.553	R	C
Picoides pubescens	CS	43	140	0.603	46	131	0.577	48	190	0.658	51	195	0.654		
Eastern Wood-Pewee	VS	30	50	0.169	37	59	0.202	46	86	0.151	72	125	0.180	N	T
Contopus virens	CS	[7]													
Acadian Flycatcher	VS	22	70	0.100	30	183	0.186	55	356	0.118	78	43	0.176	N	T
Empidonax virescens	CS	18	63	0.095	13	79	0.166	16	93	0.118	17	84	0.214		
Traill's Flycatcher	VS	23	117	0.138	35	245	0.220	35	272	0.232	57	429	0.235	N	S
E. traillii or *alnorum*	CS	21	112	0.144	23	153	0.320	16	142	0.310	20	141	0.318		
Least Flycatcher	VS	20	123	0.290	22	139	0.398	22	164	0.446	32	184	0.336	N	T
E. minimus	CS	15	96	0.351	16	107	0.414	12	78	0.566	17	64	0.326□		
Eastern Phoebe	VS	22	64	0.593	39	157	0.660	41	138	0.690	45	116	0.607	T	C□
Sayornis phoebe	CS	18	52	0.596	27	119	0.636	22	100	0.722	27	80	0.643□		
White-eyed Vireo	VS	14	63	0.318	31	145	0.261	62	463	0.281	70	578	0.314	N	S
Vireo griseus	CS	13	59	0.288	17	68	0.278	14	62	0.293	15	65	0.332□		
Red-eyed Vireo	VS	53	313	0.070	74	410	0.133	97	595	0.183	120	765	0.139	N	S
V. olivaceus	CS	39	252	0.079	42	293	0.144	42	325	0.205	40	282	0.178		
Blue Jay	VS	34	89	0.308	37	89	0.268	64	135	0.296	75	143	0.241	T	T
Cyanocitta cristata	CS	29	58	0.353	38	56	0.319	27	64	0.409	31	61	0.338□		
Carolina Chickadee	VS	27	114	0.458	42	159	0.439	74	325	0.492	91	366	0.477	R	C
Poecile carolinensis	CS	24	94	0.439	23	104	0.556	25	87	0.782□	21	90	0.564		
Black-capped Chickadee	VS	38	306	0.532	54	491	0.532	68	580	0.589	71	505	0.491	R	C
P. atricapilla	CS	27	228	0.539	33	271	0.598	32	292	0.648	32	270	0.584		
Tufted Titmouse	VS	34	172	0.535	58	291	0.522	95	524	0.535	116	638	0.541	R	C
Baeolophus bicolor	CS	28	156	0.520	28	161	0.627	30	183	0.624	30	198	0.605		
Carolina Wren	VS	35	214	0.504	59	356	0.459	85	416	0.468	113	745	0.495	R	C
Thryothorus ludovicianus	CS	31	202	0.509	33	192	0.585	27	112	0.641	26	136	0.571		
Bewick's Wren	VS	9	60	0.758	13	63	0.704	24	180	0.602	22	165	0.614	R	C
Thryomanes bewickii	CS[g]														
House Wren	VS	25	196	0.357	31	225	0.355	35	253	0.516	34	281	0.326	N	C
Troglodytes aedon	CS	19	127	0.354	18	158	0.321	20	140	0.561	17	132	0.391		
Veery	VS	39	284	0.192	39	350	0.274	44	387	0.289	48	503	0.303	N	G
Catharus fuscescens	CS	30	217	0.238	25	226	0.269	30	232	0.284	26	242	0.270		
Wood Thrush	VS	36	305	0.245	54	472	0.227	75	881	0.297	108	944	0.286	N	T
Hylocichla mustelina	CS	27	257	0.279	31	336	0.247	29	325	0.285	32	294	0.281		
American Robin	VS	50	462	0.522	62	450	0.447	75	544	0.441	85	680	0.465	T	T
Turdus migratorius	CS	41	394	0.523	42	323	0.495	40	302	0.460	40	331	0.439		
Gray Catbird	VS	57	979	0.353	59	1482	0.438	86	1970	0.444	100	1955	0.384	N	S
Dumetella carolinensis	CS	47	845	0.360	41	957	0.420	37	973	0.478	40	988	0.406		
Brown Thrasher	VS	28	84	0.200	33	90	0.232	50	139	0.304	49	138	0.302	T	S
Toxostoma rufum	CS[g]														
Blue-winged Warbler	VS	12	72	0.270	18	114	0.277	34	227	0.304	32	184	0.218	N	G
Vermivora pinus	CS	11	67	0.230	10	67	0.381	12	79	0.432	8	54	0.278		
Yellow Warbler	VS	29	468	0.352	35	566	0.454	39	710	0.382	43	670	0.407	N	S
Dendroica petechia	CS	25	440	0.363	25	469	0.486	23	429	0.411	26	459	0.469		
Chestnut-sided Warbler	VS	16	85	0.248	19	103	0.390	25	147	0.335	30	206	0.261	N	S
D. pensylvanica	CS	14	77	0.274	15	77	0.431	19	85	0.391	17	80	0.246		
Black-and-white Warbler	VS	27	101	0.355	53	176	0.422	72	307	0.413	81	266	0.350	N	G□
Mniotilta varia	CS	24	96	0.332	33	132	0.427	30	153	0.416	32	120	0.326		
American Redstart	VS	35	209	0.232	46	419	0.442	56	507	0.487	69	556	0.380	N	T
Setophaga ruticilla	CS	26	170	0.256	30	251	0.399	35	262	0.457	30	235	0.385		
Ovenbird	VS	51	411	0.328	70	523	0.426	87	687	0.413	115	891	0.435	N	G
Seiurus aurocapillus	CS	34	281	0.384	41	319	0.423	38	311	0.452	39	352	0.472□		
Common Yellowthroat	VS	42	505	0.386	67	849	0.375	93	1148	0.361	109	1106	0.352	N	S
Geothlypis trichas	CS	38	467	0.394	44	579	0.440	39	514	0.451	40	463	0.431		

(con.)

Appendix 1 (Con.)

		1992			1993			1994			1995				
	Anal. type[a]	No. sta.[b]	No. aged ind.[c]	Prod. index[d]	No. sta.[b]	No. aged ind.[c]	Prod. index[d]	No. sta.[b]	No. aged ind.[c]	Prod. index[d]	No. sta.[b]	No. aged ind.[c]	Prod. index[d]	M[e]	N[f]
Hooded Warbler	VS	18	67	0.198	20	131	0.337	43	205	0.338	53	308	0.319	N	S
Wilsonia citrina	CS	15	64	0.192	11	77	0.339	17	63	0.291	12	65	0.357		
Scarlet Tanager	VS	25	53	0.172	33	70	0.259	42	102	0.320	48	89	0.198	N	T
Piranga olivacea	CS[g]														
Eastern Towhee	VS	19	61	0.199	36	109	0.341	44	160	0.401	57	204	0.458	T	G
Pipilo erythrophthalmus	CS	15	52	0.233	20	53	0.305	19	58	0.364	21	60	0.518		
Field Sparrow	VS	26	227	0.411	34	300	0.337	50	506	0.361	53	454	0.237	T	G
S. pusilla	CS	23	193	0.447	21	165	0.413	20	144	0.381	18	135	0.274		
Song Sparrow	VS	31	474	0.566	43	628	0.519	43	606	0.507	53	806	0.539	T	G
Melospiza melodia	CS	27	458	0.569	29	458	0.605	26	347	0.609	28	397	0.616		
Swamp Sparrow	VS	10	60	0.514	13	145	0.405	12	132	0.468	14	192	0.624	T	S
Melospiza georgiana	CS	10	60	0.514	10	93	0.503	6	55	0.627	8	127	0.732		
White-throated Sparrow	VS	10	64	0.327	12	53	0.301	12	95	0.296	24	400	0.391	T	G
Zonotrichia albicollis	CS[g]														
Dark-eyed Junco	VS	8	86	0.871	11	186	0.881	8	86	0.687	14	178	0.713	T	G
Junco hyemalis	CS[g]														
Northern Cardinal	VS	51	391	0.331	75	557	0.275	124	1145	0.261	149	1351	0.330	R	S
Cardinalis cardinalis	CS	44	342	0.358	43	342	0.328	41	326	0.409	42	361	0.401		
Rose-breasted Grosbeak	VS	25	73	0.152	27	97	0.223	42	113	0.339	38	104	0.283	N	T
Pheucticus ludivicianus	CS	16	56	0.180	19	71	0.243	21	52	0.380	19	59	0.296		
Indigo Bunting	VS	34	187	0.206	58	378	0.144	77	541	0.169	91	569	0.097	N	S
Passerina cyanea	CS	26	117	0.286	28	135	0.194	27	96	0.139	22	99	0.195		
Dickcissel	VS	9	84	0.071	14	82	0.146	19	231	0.108	17	117	0.077	N	S
Spiza americana	CS[g]														
Red-winged Blackbird	VS	21	105	0.098	25	80	0.053	26	109	0.115	31	132	0.127	T	S
Agelaius phoeniceus	CS	19	93	0.089	19	61	0.037	17	52	0.096	20	81	0.083		
Common Grackle	VS	26	92	0.383	38	152	0.362	47	167	0.352	38	236	0.350	T	T
Quiscalus quiscula	CS	21	67	0.451	27	114	0.439	24	84	0.529	14	110	0.454		
Baltimore Oriole	VS	20	103	0.306	25	84	0.244	35	121	0.290	35	109	0.333	N	T
Icterus galbula	CS	16	86	0.320	18	58	0.250	17	54	0.362	16	54	0.417		
House Finch	VS	12	140	0.467	14	231	0.451	16	62	0.705	14	94	0.713	T	T
Carpodacus mexicanus	CS	10	119	0.553	13	159	0.656	13	53	0.711	12	91	0.736		

[a]Type of analysis: VS = variable-stations approach; CS = constant-stations approach (see text).
[b]Number of stations within the breeding range of the species and at which at least one aged individual was captured.
[c]Number of aged individuals captured at all stations pooled lying within the breeding range of the species.
[d]Productivity index is given as proportion of young in the catch.
[e]Migration strategy: R=permanent resident; T = temperate-wintering migrant; N = Neotropical-wintering migrant.
[f]Nest location: C = cavity nester; T = open-cup tree nester; S = open-cup shrub nester; G = ground nester.
[g]Species not included in the constant-stations analysis because fewer than 50 aged individuals were captured in at least one of the four years.

Appendix 2: MAPS productivity indices for 1992 through 1995 for the Sierra Nevada for species for which a total of at least 100 aged individuals were captured during the four years at all stations pooled in the Sierra Nevada physiographic province lying within the breeding range of the species.

	1992			1993			1994			1995				
	No. sta.[a]	No. aged ind.[b]	Prod. index[c]	No. sta.[a]	No. aged ind.[b]	Prod. index[c]	No. sta.[a]	No. aged ind.[b]	Prod. index[c]	No. sta.[a]	No. aged ind.[b]	Prod. index[c]	M[d]	N[e]
Red-breasted Sapsucker (*Sphyrapicus ruber*)	9	51	0.357	11	38	0.183	10	51	0.255	9	24	0.375	T	C
Western Wood-Pewee (*Contopus sordidulus*)	9	28	0.400	11	34	0.146	11	62	0.323	9	42	0.191	N	T
Pacific-slope Flycatcher (*Empidonax traillii*)	3	20	0.203	5	33	0.333	7	45	0.267	4	15	0.067	N	S
Cassin's Vireo (*Vireo cassinii*)	8	52	0.465	9	34	0.359	7	42	0.333	6	43	0.372	N	T
Warbling Vireo (*V. gilvus*)	8	123	0.291	13	182	0.161	12	202	0.287	13	138	0.116	N	T
Hammond's Flycatcher (*E. hammondii*)	9	43	0.473	10	39	0.316	11	53	0.340	8	27	0.185	N	T
Dusky Flycatcher (*E. oberholseri*)	8	84	0.249	11	98	0.276	11	139	0.446	10	102	0.177	N	S
Western Flycatcher (*E. difficilis*)	5	24	0.333	5	25	0.135	7	41	0.512	6	28	0.357	N	G
Mountain Chickadee (*Poecile gambeli*)	9	91	0.769	12	66	0.432	11	96	0.438	11	65	0.523	R	C
Red-breasted Nuthatch (*Sitta canadensis*)	9	31	0.739	9	25	0.653	10	46	0.739	8	33	0.515	R	C
Brown Creeper (*Certhia americana*)	8	43	0.496	11	41	0.468	8	74	0.811	12	46	0.565	R	C
Golden-crowned Kinglet (*Regulus satrapa*)	6	29	0.724	8	72	0.760	9	109	0.798	5	22	0.455	R	T
American Robin (*Turdus migratorius*)	9	72	0.507	13	59	0.140	11	72	0.319	14	63	0.159	T	T
Yellow Warbler (*Dendroica petechia*)	8	81	0.477	9	83	0.363	11	95	0.474	8	62	0.307	N	S
Yellow-rumped Warbler (*D. coronata*)	8	201	0.758	12	116	0.273	11	628	0.822	13	113	0.204	T	T
Hermit Warbler (*D. occidentalis*)	8	45	0.647	11	180	0.663	10	272	0.746	11	60	0.417	N	T
MacGillivray's Warbler (*Oporornis tolmiei*)	9	182	0.516	12	238	0.442	12	285	0.614	11	184	0.462	N	S
Wilson's Warbler (*Wilsonia pusilla*)	9	253	0.494	13	274	0.503	12	276	0.591	12	183	0.322	N	G
Western Tanager (*Piranga ludoviciana*)	7	27	0.561	9	32	0.443	10	89	0.539	9	37	0.081	N	T
Chipping Sparrow (*Spizella passerina*)	5	29	0.333	8	75	0.227	9	70	0.357	8	45	0.244	N	T
Song Sparrow (*Melospiza melodia*)	8	119	0.573	10	144	0.576	11	151	0.570	9	110	0.446	T	G
Lincoln's Sparrow (*M. lincolnii*)	8	100	0.542	11	200	0.487	12	233	0.485	11	183	0.399	N	G
White-crowned Sparrow (*Zonotrichia leucophrys*)	2	91	0.462	3	47	0.213	2	56	0.411	3	52	0.346	T	S
Dark-eyed Junco (*Junco hyemalis*)	9	494	0.716	13	495	0.576	12	974	0.730	14	357	0.468	T	G
Black-headed Grosbeak (*Pheucticus melanocephalus*)	5	18	0.254	7	48	0.236	9	64	0.300	5	55	0.055	N	T
Lazuli Bunting (*Passerina amoena*)	6	12	0.216	7	126	0.344	8	61	0.230	7	91	0.374	N	S
Purple Finch (*Carpodacus purpureus*)	6	83	0.293	8	62	0.070	8	108	0.306	5	35	0.086	T	T
Cassin's Finch (*C. cassinii*)	7	57	0.684	8	24	0.085	9	82	0.354	9	31	0.161	T	T
Pine Siskin (*Carduelis pinus*)	7	68	0.769	9	118	0.561	10	209	0.526	8	51	0.137	T	T

[a]Number of stations within the breeding range of the species and at which at least one aged individual was captured.
[b]Number of aged individuals captured at all stations pooled lying within the breeding range of the species.
[c]Productivity index is given as proportion of young in the catch.
[d]Migration Strategy: R = permanent resident; T = temperate-wintering migrant; N = Neotropical-wintering migrant.
[e]Nest location: C = cavity nester; T = open-cup tree nester; S = open-cup shrub nester; G = ground nester.

Appendix 3: Mean productivity indices and time-constant estimates of adult survival probability, recapture probability, and proportion of residents from four years (1992-1995) of MAPS data.

	Num. Sta.[a]	Num. Aged Ind.[b]	Prod. Index[c]	Num. Ad.[d]	Survival Probability[e]		Recapture Probability[f]		Proportion of residents[g]		M[h]
For 32 species for which at least 200 aged individuals were captured over the 4 years (1992-1995) at MAPS stations operated in eastern North America.											
Downy Woodpecker (*Picoides pubescens*)	42	620	0.618	262	0.713	(0.164)	0.447	(0.133)	0.255	(0.098)	R
Acadian Flycatcher (*Empidonax virescens*)	15	300	0.148	275	0.701	(0.142)	0.381	(0.108)	0.462	(0.163)	N
Traill's Flycatcher (*E. traillii*)	13	464	0.235	370	0.606	(0.105)	0.747	(0.105)	0.197	(0.052)	N
Least Flycatcher (*E. minimus*)	11	309	0.406	244	—[i]	—	—	—	—	—	N
White-eyed Vireo (*Vireo griseus*)	14	244	0.287	188	0.731	(0.163)	0.432	(0.129)	0.376	(0.141)	N
Red-eyed Vireo (*V. olivaceus*)	42	1143	0.150	182	0.543	(0.073)	0.406	(0.071)	0.465	(0.104)	N
Blue Jay (*Cyanocitta cristata*)	34	224	0.372	182	0.600	(0.215)	0.561	(0.220)	0.165	(0.091)	T
Carolina Chickadee (*Poecile carolinensis*)	25	321	0.581	160	0.326	(0.200)	0.180	(0.249)	1.000	(1.505)	R
Black-capped Chickadee (*P. atricapilla*)	29	1059	0.592	484	0.455	(0.089)	0.551	(0.107)	0.537	(0.159)	R
Tufted Titmouse (*Baeolophus bicolor*)	29	682	0.588	290	0.464	(0.098)	0.567	(0.116)	0.643	(0.195)	R
Carolina Wren (*Thyrothorus ludovicianus*)	26	617	0.573	282	0.347	(0.085)	0.743	(0.127)	0.546	(0.178)	R
House Wren (*Troglodytes aedon*)	15	539	0.406	324	0.520	(0.144)	0.451	(0.157)	0.344	(0.160)	N
Veery (*Catharus fuscesens*)	23	893	0.264	610	0.535	(0.058)	0.707	(0.063)	0.543	(0.083)	N
Wood Thrush (*Hylocichla mustelina*)	30	1205	0.273	987	0.446	(0.069)	0.559	(0.085)	0.432	(0.097)	N
American Robin (*Turdus migratorius*)	41	1336	0.481	765	0.500	(0.114)	0.155	(0.082)	0.776	(0.440)	T
Gray Catbird (*Dumetella carolinensis*)	41	3739	0.417	2276	0.453	(0.040)	0.488	(0.050)	0.586	(0.082)	N
Blue-winged Warbler (*Vermivora pinus*)	10	259	0.337	193	0.431	(0.141)	0.568	(0.184)	0.441	(0.212)	N
Yellow Warbler (*Dendroica petechia*)	24	1770	0.434	954	0.445	(0.062)	0.495	(0.079)	0.527	(0.113)	N
Chestnut-sided Warbler (*D. pensylvanica*)	10	283	0.282	207	0.727	(0.146)	0.540	(0.115)	0.360	(0.115)	N
Black-and-white Warbler (*Mniotilta varia*)	20	412	0.339	292	0.841	(0.200)	0.190	(0.093)	0.470	(0.255)	N
American Redstart (*Setophaga ruticilla*)	21	840	0.365	562	0.452	(0.123)	0.244	(0.121)	0.606	(0.341)	N
Ovenbird (*Seiurus aurocapillus*)	30	1170	0.430	729	0.521	(0.090)	0.452	(0.096)	0.410	(0.116)	N
Common Yellowthroat (*Geothlypis trichas*)	38	1998	0.432	1217	0.501	(0.057)	0.492	(0.064)	0.482	(0.084)	N
Hooded Warbler (*Wilsonia citrina*)	11	241	0.274	193	0.620	(0.134)	0.436	(0.125)	0.525	(0.187)	N
Eastern Towhee (*Pipilo erythrophthalmus*)	23	214	0.354	135	0.304	(0.152)	0.355	(0.247)	1.000	(0.827)	T
Field Sparrow (*Spizella pusilla*)	22	632	0.376	529	0.523	(0.090)	0.429	(0.095)	0.521	(0.149)	T
Song Sparrow (*Melospiza melodia*)	27	1655	0.600	703	0.374	(0.073)	0.571	(0.106)	0.515	(0.149)	T
Swamp Sparrow (*M. georgiana*)	6	319	0.608	108	—[i]	—	—	—	—	—	T
Northern Cardinal (*Cardinalis cardinalis*)	42	1347	0.374	848	0.596	(0.068)	0.422	(0.063)	0.574	(0.111)	R
Indigo Bunting (*Passerina cyanea*)	27	416	0.216	376	0.452	(0.114)	0.532	(0.143)	0.333	(0.123)	N
Red-winged Blackbird (*Agelaius phoeniceus*)	21	281	0.076	328	0.353	(0.229)	0.454	(0.340)	0.133	(0.131)	T
Common Grackle (*Quiscalus quiscula*)	21	341	0.486	200	—[i]	□—	—	—	—	—	T

(con.)

Appendix 3 (Con.)

	Num. Sta.[a]	Num. Aged Ind.[b]	Prod. Index[c]	Num. Ad.[d]	Survival Probability[e]		Recapture Probability[f]		Proportion of residents[g]		M[h]
For 26 species for which at least 60 aged individuals were captured over the four years (1992-1995) at MAPS stations operated in the Sierra Nevada physiographic province.											
Red-breasted Sapsucker (*Sphyrapicus ruber*)	7	140	0.262	93	0.460	(0.154)	0.357	(0.171)	0.954	(0.535)	T
Western Wood-Pewee (*Contopus sordidulus*)	7	115	0.240	80	0.303	(0.188)	0.462	(0.316)	1.000	(0.863)	N
Willow Flycatcher (*Empidonax traillii*)	2	81	0.254	49	0.641	(0.205)	0.397	(0.177)	0.788	(0.424)	N
Hammond's Flycatcher (*E. hammondii*)	5	107	0.262	71	0.579	(0.273)	0.181	(0.163)	0.985	(0.964)	N
Dusky Flycatcher (*E. oberholseri*)	4	305	0.278	230	0.570	(0.141)	0.564	(0.143)	0.288	(0.112)	N
Cassin's Vireo (*Vireo cassinii*)	2	113	0.250	88	0.377	(0.242)	0.482	(0.346)	0.414	(0.409)	N
Warbling Vireo (*V. gilvus*)	7	518	0.220	384	0.609	(0.116)	0.533	(0.114)	0.281	(0.082)	N
Mountain Chickadee (*Poecile gambeli*)	7	211	0.513	87	—[i]	—	—	—	—	—	R
Red-breasted Nuthatch (*Sitta canadensis*)	5	75	0.667	27	—[i]	—	—	—	—	—	R
Brown Creeper (*Certhia americana*)	5	87	0.506	51	—[i]	—	—	—	—	—	R
Golden-crowned Kinglet (*Regulus satrapa*)	3	85	0.614	27	—[i]	—	—	—	—	—	R
American Robin (*Turdus migratorius*)	7	193	0.296	122	0.367	(0.201)	0.244	(0.216)	1.000	(0.973)	T
Yellow Warbler (*Dendroica petechia*)	5	282	0.401	145	0.607	(0.121)	0.554	(0.123)	0.538	(0.169)	N
Yellow-rumped Warbler (*D. coronata*)	7	803	0.492	199	—[i]	—	—	—	—	—	T
Hermit Warbler (*D. occidentalis*)	6	264	0.552	105	—[i]	—	—	—	—	—	N
MacGillivray's Warbler (*Oporornis tolmiei*)	6	571	0.431	272	0.576	(0.076)	0.710	(0.077)	0.595	(0.111)	N
Wilson's Warbler (*Wilsonia pusilla*)	7	759	0.408	401	0.501	(0.084)	0.640	(0.099)	0.435	(0.106)	N
Western Tanager (*Piranga ludoviciana*)	5	109	0.419	63	—[i]	—	—	—	—	—	N
Chipping Sparrow (*Spizella passerina*)	5	109	0.364	70	—[i]	—	—	—	—	—	N
Song Sparrow (*Melospiza melodia*)	6	394	0.525	165	0.459	(0.113)	0.762	(0.120)	0.627	(0.203)	T
Lincoln's Sparrow (*M. lincolnii*)	7	420	0.458	213	0.444	(0.132)	0.363	(0.152)	1.000	(0.517)	N
White-crowned Sparrow (*Zonotrichia leucophrys*)	2	242	0.358	119	0.472	(0.124)	0.469	(0.144)	1.000	(0.413)	T
Dark-eyed Junco (*Junco hyemalis*)	7	1366	0.636	404	0.483	(0.093)	0.440	(0.103)	0.614	(0.187)	T
Purple Finch (*Carpodacus purpureus*)	2	170	0.186	180	—[i]	—	—	—	—	—	T
Cassin's Finch (*C. cassinii*)	5	152	0.360	95	—[i]	—	—	—	—	—	T
Pine Siskin (*Carduelis pinus*)	3	204	0.365	106	—[i]	—	—	—	—	—	T

[a]Number of stations at which adults of the species were captured.
[b]Number of aged individuals captured during all four years 1992-1995 at all stations pooled where the species was a regular breeder.
[c]Mean productivity index over the four years 1992-1995 given as proportion of young in the catch.
[d]Number of adult individuals captured at all stations pooled where the species was a regular breeder (i.e., number of capture histories).
[e]Adult survival probability presented as the maximum likelihood estimate (standard error of the estimate).
[f]Recapture probability presented as the maximum likelihood estimate (standard error of the estimate).
[g]Proportion of residents presented as the maximum likelihood estimate (standard error of the estimate).
[h]Migration strategy: P = permanent resident; T = temperate-wintering migrant; N = Neotropical migrant.
[i]Species for which data were insufficient to provide estimates for adult survival probability.

Monitoring Survival Rates of Landbirds at Varying Spatial Scales: An Application of the MAPS Program

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Abstract—Survivorship is a primary demographic parameter affecting population dynamics, and thus trends in species abundance. The Monitoring Avian Productivity and Survivorship (MAPS) program is a cooperative effort designed to monitor landbird demographic parameters. A principle goal of MAPS is to estimate annual survivorship and identify spatial patterns and temporal trends in these rates. We evaluated hypotheses of spatial patterns in survival rates among a collection of neighboring sampling sites, such as within national forests, among biogeographic provinces, and between breeding populations that winter in either Central or South America, and compared these geographic-specific models to a model of a common survival rate among all sampling sites. We used data collected during 1992-1995 from Swainson's Thrush (*Catharus ustulatus*) populations in the western region of the United States. We evaluated the ability to detect spatial and temporal patterns of survivorship with simulated data. We found weak evidence of spatial differences in survival rates at the local scale of "location," which typically contained 3 mist-netting stations. There was little evidence of differences in survival rates among biogeographic provinces or between populations that winter in either Central or South America. When data were pooled for a regional estimate of survivorship, the percent relative bias due to pooling "locations" was <1%. With the pooled data, we estimated a 44% annual regional survival rate; this low estimated survival rate was likely due to the presence of transients in the population (Rosenberg and others 1999). Using simulated data, we found that power to detect spatial differences increased considerably with number of years and spatial scale, the latter reflecting larger sample size. Detection of trends at smaller spatial scales required >12 years of monitoring. Detection of spatial patterns and temporal trends in survival rates from local to regional scales will provide important information for management and future research directed toward conservation of landbirds.

Concern over reports of wide-spread declines of neotropical migratory songbirds (e.g., Robbins and others 1989b; Terborgh 1989) motivated the establishment of the Neotropical Migratory Bird Conservation Initiative, "Partners in Flight," an international cooperative program designed to reverse declines in migratory birds (Rogers and others 1993) and landbirds in general (this proceedings). An important component of the initiative is to encourage establishment of monitoring programs, such as *MAPS* (Monitoring Avian Productivity and Survivorship [Desante and others 1993b]) to identify trends in species abundance and demographic parameters affecting these trends (Finch and Stangel 1993b).

Monitoring temporal trends of primary demographic parameters (fecundity, recruitment, and survivorship) that influence population size is especially important (Temple and Wiens 1989; DeSante and Rosenberg 1998), because environmental factors affect these parameters directly, and thus its impacts can be observed over a short time period. Because of buffering effects of transient individuals and density-dependent responses of populations, there may be substantial time lags between changes in primary demographic parameters and resulting changes in population size or density as measured by census or survey methods (Temple and Wiens 1989). Moreover, because of the vagility of most bird species, local variations in population size may often be masked (George and others 1992) or accentuated (DeSante 1990) by varying levels of recruitment from a wider area. Thus, density of a species in a given area may not be indicative of population health, due to source-sink dynamics (Pulliam 1988). Primary demographic parameters are thus critical in understanding population dynamics and are directly applicable to population models that can be used to assess land-management practices (Noon and Sauer 1992).

Demographic parameters of avian populations, such as density (Brown and others 1995), productivity (DeSante and Burton 1994b; Robinson and others 1995b), and survivorship (Burnham and others 1996; Johnson and others 1992), vary spatially and temporally. Estimating these sources of variation is important for understanding dynamics of populations and for detecting trends that may reflect reduced viability (Wilcove and Terborgh 1984). Lack of knowledge on the extent of temporal variation in demographic parameters often leads to incorrect conclusions regarding population health and makes it difficult to argue that specific population declines are noteworthy and deserve additional attention. Although detection of environmental influences on animal populations is difficult, especially considering the "noisy" nature of time-series data, such as estimated population trajectories (e.g., Botsford and Brittnacher 1992), the detection process can be considered a preliminary

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search for patterns to be tested in detailed field studies (Holmes and Sherry 1988; Botsford and Brittnacher 1992; Sherry and Holmes, this proceedings), or to provide information on system state (Nichols, this proceedings). In this sense, monitoring helps direct priorities for applied research. Furthermore, monitoring, if done in an experimental or quasi-experimental manner (Nichols, this proceedings), is necessary to determine the effectiveness of management actions designed to reverse population declines or bring about the recovery of small or threatened populations (Noon 1992).

In 1989, The Institute for Bird Populations initiated *MAPS*, a cooperative effort among federal and state agencies, private organizations, and individual bird banders in North America to operate a continent-wide network of constant-effort, mist-netting stations (DeSante and others 1993b; DeSante and Burton 1994b). The *MAPS* Program was patterned to a large extent after the British Constant Effort Sites (CES) Scheme that has been operated by the British Trust for Ornithology since 1981 (Baillie and others 1986) and that has become one of the cornerstones of the British Integrated Avian Population Monitoring Scheme (Baillie 1990).

An important aspect of monitoring is the ability to detect demographic trends and investigate the scale at which they may be occurring. Regional trends in annual survivorship may occur due to large-scale weather changes or changes in the landscape that are large enough to affect many local populations similarly. Local changes or trends in annual survivorship, such as may occur in a specific national forest, may occur due to changes in the habitat quality, for example, from increased harvest. Understanding the scale over which demographic parameters are changing will thus be informative for identifying future research needed to isolate problems, and, once identified, determining management solutions.

We evaluated the ability of *MAPS* to detect patterns of avian survivorship at different spatial scales. We view the results herein as a preliminary assessment, using a subset of the *MAPS* data. At the time of the symposia, only data through 1995 were available. Our analyses were restricted to Swainson's Thrush (*Catharus ustulatus*), a neotropical migrant that is a common breeder in western and northeastern North America in woodland environments, and winters in Central and South America (Ehrlich and others 1988). We chose data from this species because it was one of the most commonly captured species in terms of both the number of stations in which it was captured and the numbers of individuals captured and recaptured.

Methods

We used data from Swainson's Thrush populations in western North America to investigate patterns of survivorship among spatial scales. We compared variability of survival rates within and among scales. The spatial scales we investigated included: "locations," collections of neighboring stations, similar to the "cluster" (Rosenberg and others 1999), biogeographic provinces, winter-migration scale (populations that winter in either Central America or South America as delineated by Marshall [1988]), and the Western United States, the scale in which we pooled all stations. We used data from Swainson's Thrush that were marked and recaptured at 52 *MAPS* stations during 1992-1994, the only time period in which most stations had three years of data. Stations used in the analyses presented here were located in forest or mixed forest-scrub habitats. Typically, ten permanent net sites were distributed rather uniformly throughout the central 8 ha of the 20 ha study area, but were placed opportunistically at sites where birds could be captured most efficiently. One 12-m, 30-mm-mesh mist net was erected at each net site and the type and location of all nets were kept constant for the duration of the study. The operation of the nets was standardized; most stations were operated for six morning hours, beginning at sunrise, for one day per 10-day period, and for 8-12 consecutive 10-day periods, depending on latitude, from approximately May 1 to August 28. All unbanded birds captured were banded with USFWS bands and an attempt was made to identify all birds captured to age; sex could not be determined reliably for Swainson's Thrush. DeSante and Burton (1994b) provided details of establishment of net sites and their operation.

Mark-recapture was used each year to allow estimation of survival rates. We fit multinomial models to the capture-recapture data using program SURVIV (White 1983). To select the most appropriate model, we used Akaike's Information Criterion (AIC); we tested the significance between general and constrained models with likelihood ratio tests (Burnham and Anderson 1992; Lebreton and others 1992). We compared five models that allowed survival rates (ϕ) to vary among geographical units within a spatial scale (table 1), although each model constrained recapture probabilities (P) to be equal among all stations except for a model that allowed both ϕ and P to vary among locations. A common recapture probability among all stations was deemed appropriate based on earlier model tests (D. Rosenberg, unpublished data; Rosenberg and others 1999). Model $\{\phi_l, P_l\}$ was the most general, and allowed survival and recapture probabilities to vary among locations. Model $\{\phi_l, P\}$ allowed survival probabilities to vary among locations, but constrained recapture probabilities to be equal among all stations (table 1). Model $\{\phi_b, P\}$ allowed survival rates to vary among biogeographic provinces and Model $\{\phi_w, P\}$ allowed survival rates to vary between different wintering-area subpopulations. Model $\{\phi, P\}$ was the most restrictive: survival rates and recapture probabilities were constrained to be equal among all stations. Survival estimates from individual stations had large (>19%, with most >50%) coefficients of variation, and, for some stations, estimates were unobtainable. Thus, we did not consider a model of individual stations, although some locations consisted of a single station (table 2).

To evaluate the statistical power for detecting differences in survival rates and for detecting trends among different spatial scales, we constructed hypothetical populations using the approximate parameter estimates for the regional estimate of survival (0.45) and recapture probability (0.54) from the Swainson's Thrush data (see Results section). We used the average number of individuals captured in the first year (1992) from the Swainson's Thrush data as the number released each year (total of unmarked and marked individuals) for each spatial scale in the simulated populations (Location: n = 45, Biogeographic Zone: n = 130, Winter

Table 1—Comparison of models of annual survival probability for Swainson's Thrush populations in Western North America.

Model[c]	No. of parameters	GOF[a] X^2	df	P	AIC[d]	Likelihood ratio test[b] $\{\phi_l, P\}$	$\{\phi_b, P\}$	$\{\phi_w, P\}$	$\{\phi, P\}$
ϕ_l, P_l	34	47.2	34	0.07	264.6	0.81	0.29	0.36	0.37
ϕ_l, P	18	58.1	50	0.20	243.5		0.05	0.10	0.11
ϕ_b, P	7	77.8	61	0.07	241.2			0.64	0.64
ϕ_w, P	3	80.3	65	0.09	235.7				0.36
ϕ, P	2	81.1	66	0.10	234.6				

[a]Goodness-of-fit (GOF) statistics were used to evaluate model fit; larger P-values represent better fit (Lebreton and others 1992).

[b]Likelihood ratio tests were used to determine significance of differences between the more reduced (simple) model (identified at the top of the column, and serves as the null hypothesis), and all other general submodels (listed under "Model," and serves as the alternate hypothesis). Higher P-values suggest little improvement in model fit with the more general model, and thus the reduced (simple) model is the most appropriate.

[c]Models include survival probabilities that are allowed to vary among locations (ϕ_l), among biogeographic provinces (ϕ_b), between winter ranges (ϕ_w), or that are constrained equal among all stations (ϕ) with a common recapture probability (P). Model $\{\phi_l, P_l\}$ allows recapture probability to vary among locations.

[d]Akaike's Information Criteria (AIC); the minimum value represents the most appropriate model (Burnham and Anderson 1992; Lebreton and others 1992).

Table 2—Summary information on survival estimates among various spatial scales for Swainson's Thrush populations from Western North America.

Scale	No. stations	Biogeographic province	Winter range[a]	Sample size[b]	$\hat{\phi}$[c]	$\widehat{SE}(\hat{\phi})$
Location						
ALAS	2	CE Alaska	SA	20	0.45	0.11
DENA	3	CE Alaska	SA	20	0.37	0.10
ARCA	2	Coastal	CA	67	0.50	0.06
BGSR	1	Coastal	CA	2	0.17	0.11
PALA	1	Coastal	CA	36	0.33	0.07
RFSL	6	Coast Ranges	CA	40	0.33	0.07
SISK	3	Coast Ranges	CA	12	0.55	0.14
SIUS	5	Coast Ranges	CA	230	0.43	0.04
MTBA	5	Cascades\Sierras	CA	80	0.40	0.06
TAHO	1	Cascades\Sierras	CA	2	0.27	0.24
WENA	2	Cascades\Sierras	CA	3	0.47	0.27
WILL	6	Cascades\Sierras	CA	84	0.56	0.05
UMAT	6	Basin-Range	SA	57	0.44	0.07
FLAT	6	Rockies	SA	128	0.40	0.05
GRFA	1	Rockies	SA	3	0	0
MESA	1	Rockies	SA	1	0.50	0.40
TSS	1	Rockies	SA	4	0.33	0.20
Biogeographic Zones						
Central Alaska	5		SA	40	0.42	0.08
Coastal	4		CA	105	0.42	0.05
Coast Ranges	14		CA	230	0.43	0.04
Cascades\ Sierra	14		CA	169	0.49	0.05
Basin-Range	6		SA	57	0.45	0.07
Rockies	9		SA	136	0.39	0.05
Winter Range						
Central America	32			556	0.45	0.03
South America	20			235	0.41	0.04
Western North America	52			791	0.44	0.03

[a]Winter range was determined by Marshall (1988).

[b]Sample size is the number of Swainson's Thrush banded and released in year one (1992).

[c]Survival rates were estimated with a recapture probability (0.54) that was estimated from a model of common recapture probabilities among all subpopulations (table 1).

Range: n = 395, and Regional: n = 790 individuals). We created three hypothetical populations, each with a different survival rate. Two of the three populations were constructed such that they had survival probabilities $\phi = \bar{\phi} + \Delta\phi/2$, $\phi' = \bar{\phi} - \Delta\phi/2$, where $\Delta\phi$ represented the effect size, that is, the difference in survival rates between the populations. The third population was constructed to have the mean survival rate, $\bar{\phi}$. These methods were similar to those in Nichols and others (1982). We investigated $\Delta\phi$ from 0.05 to 0.40, with $\bar{\phi} = 0.45$, and with 3 and 12 years of simulated data. We used the sample sizes (number of individuals banded in year one; assumed to equal the number of releases in each year of the study) listed above for each spatial scale, each reflecting the average number of individual Swainson's Thrushes marked in the first year of sampling. Thus, statistical power comparisons among spatial scales reflect the differences in population size attributed to each scale. We estimated the statistical power of detecting differences among 3 populations at each spatial scale; models permitting geographic variation in were compared to Model $\{\phi, P\}$, in which all stations were constrained to have equal survival probabilities. For all power approximations we used an analytic approach rather than a Monte Carlo simulation approach. We used the parameter values under the various models and protocols (e.g., number of years) to create expected numbers of birds exhibiting each different capture history. The expectations were then entered into SURVIV as data, and estimator bias and statistical power were computed as described by Burnham and others (1987:214-217).

We also evaluated statistical power for detecting trends indicating an exponential decline (0.5, 1.0, and 3.0% annual declines) in survival rates with 12 and 20 years of simulated data. An exponential decline would be one in which the survival rate for a given year was a constant fraction of the previous year's survival rate, such that $\phi_t = \phi_1 * \exp(-ß *[t-1])$, where ϕ_t is the survival rate between year t and $t+1$ ($t = 2 \ldots n-1$; where n is the number of years), ϕ_1 is the survival rate between year 1 and 2, and ß is the annual rate of change in survival (e.g., 0.005 for a 0.5% annual decline). We investigated the power to detect these trends for each spatial scale. Statistical power was determined using the approach of Burnham and others (1987:215-217); the reduced model of equal survival rates among all years (Model $\{\phi, P\}$) represented the null hypothesis, while the alternate hypothesis was Model $\{\phi_d, P\}$, the model with an exponential decline in ϕ, but equal and constant P among all stations and years.

The effect of pooling data when differences among locations are not detected but present was investigated by computing the percent relative bias of the regional survival estimate. We used the estimates for each spatial scale, weighted by number of individuals captured in year one at the scale being investigated to provide a regional (weighted) estimate of survivorship and compared this value to that obtained by pooling all the data and estimating a single regional estimate. If we take the estimates of survival for each Swainson's Thrush population within a geographic scale and treat the estimates as the true survival rate, then percent relative bias can be computed as: $100[\hat{\phi} - \phi]/\phi$, where $\hat{\phi}$ denotes the estimated survival rates of the pooled populations and ϕ denotes the weighted survival rate, calculated as:

$$\phi = \sum_{i=1}^{k} \left(\hat{\phi}_i * R_i\right) \Big/ \sum_{i=1}^{k} R_i$$

where $\hat{\phi}_i$ and R_i are the estimated survival rate and number of individuals marked and released at year one, respectively, for a given *ith* population ($i = 1, 2, \ldots, k$) within a spatial scale (e.g., "location"). We then investigated how bias was related to the increase in the difference in survival rates, $\Delta\phi$, among locations using hypothetical populations. The 3 "populations" were given the same parameter values and years as was done for the power analyses, and percent relative bias was computed as described above.

Results

Survival rate estimates varied widely in both point estimates and coefficients of variation for the 52 stations for which Swainson's Thrush data were obtained, and for which there was at least one recapture. Numbers of individuals captured and marked in year one ranged from 1-76 ($\overline{X} \pm \hat{SE}$, 15.8 ± 2.2 individuals) per station. The coefficients of variation ($\hat{SE}/\overline{X}$, a measure of relative precision) for these estimates were typically >50%; this suggests that these (3 year) estimates were not generally very useful. Therefore, we did not consider the spatial scale of the individual station in further analyses, except in cases where the individual station was equivalent to the "location" because there were no other neighboring stations over which to pool data.

There was a total of 17 locations used in the analyses, with 3.1 ± 0.5 stations/location. Number of individuals captured in the first year of banding ranged from 1-230 (46.4 ± 14.6 individuals) per location. Estimates of annual survival varied considerably among locations (table 2). The coefficient of variation for each location was also fairly large, generally >20%.

We identified 6 biogeographic provinces in which Swainson's Thrush were captured in western North America (fig. 1). Central Alaska included 2 locations, coastal areas in California and the Coast Ranges included 3 locations each, 4 locations were in the mountains of the Cascades and Sierra Nevada, 1 was in the Basin-Range Province, and 4 were in the Rockies. Within the scale of biogeographic provinces, number of individuals captured in the first year ranged from 40-282 (131 ± 35.9 individuals). Survival rate estimates varied from 0.39 to 0.49 (table 2). Coefficients of variation ranged from 9-19% (13.1 ± 1.5%), reflecting considerable improvements in precision over the results at the scale of the location.

Based on work by Marshall (1988), we identified locations which could be separated by the subpopulations assumed to winter in either Central America or South America (fig. 1). Central American wintering populations included 10 locations (556 individuals marked in year 1) and those from South America included 7 locations (235 individuals marked). We estimated 45% and 41% annual survival rates for the Central and South American

wintering populations, respectively. Precision was good for these estimates (table 2): the coefficients of variation was <10%.

The largest spatial scale was that of the entire sampled area of western North America. A total of 791 individuals were captured in the first year of banding. We estimated a survival rate of 44% for this pooled population (table 2), with a 7% coefficient of variation. We estimated a recapture probability of 0.54 ± 0.05; this represented the "pooled" recapture probability estimated in all the previous analyses as well.

The model tests, using both AIC and likelihood ratio tests, suggested the most parsimonious, adequate model was that with a common survival rate among all locations (Model $\{\phi, P\}$), although fit was only marginal for this model (table 2; see Discussion section). Model $\{\phi_l, P\}$ fit the data reasonably well, and likelihood ratio tests of this model against nested models with larger geographic groupings suggested that there was reasonable evidence that survival rates varied among locations (table 2). However, several models had similar AIC and these can be considered as competing models. The complexity of any chosen model is a function of sample size (Burnham and others 1987), so it is not surprising that we failed to detect a more complex model, such as one in which capture probability and survival rates vary geographically. From an analysis of a larger data set, we found that the model that allowed geographic variation in survival rates at the scale of the Physiographic Province best described the data (Rosenberg and others 1999).

Statistical power to detect spatial differences in survival rates increased with number of years (length of study), with greater differences in survival rates between groups (effect size), and with larger spatial scales (sample size). The ability to detect different survival rates between geographic areas was greatest for a scale similar to winter-ranges; with 12 years of simulated data, high power was achieved for small D for the winter-range scale (fig. 2). At the spatial scale of the individual location, adequate power (>80%) was not achifned with 3 years of simulated data until $\Delta\phi$ was approximately 30%. With 12 years of simulated data, adequate power was achieved when $\Delta\phi$ was approximately 10% (fig. 2).

When differences are not detected, but are present, the bias due to pooling heterogeneous samples must be considered. We found that bias of regional estimates is small when pooling data from within spatial scales in which heterogeneity of survival rates is low (fig. 3). However, bias increased with greater differences in survival rates (fig. 2). Fortunately, when large differences existed, the power to detect them was high (fig. 2). Percent relative bias was very low (<0.7%) with the Swainson's Thrush data; if differences existed, but were not detected, pooling these heterogeneous subpopulations would have negligible effects on regional survival estimates.

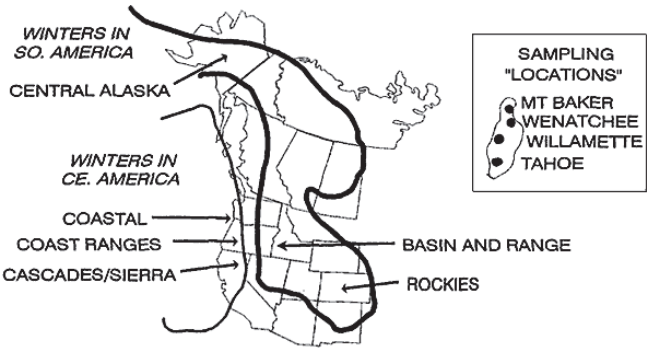

Figure 1—Sampling strategy for estimating survival rates of Swainson's Thrush populations in Western North America. Populations that winter in either Central or South America (Marshall 1988) were pooled for comparisons; these populations were pooled from a collection of biogeographic provinces that included coastal California, Coast Ranges, Cascades and the northern Sierra Nevada, Basin and Range, Rockies, and central Alaska. The subpopulations in the biogeographic provinces were pooled from a collection of "locations," which consist of 1-6 stations, each of which consist of a network of mist nets. For example, Swainson's Thrush in the Cascades/Sierra biogeographic province were part of the central America wintering population, and consisted of four locations (Mt. Baker, Wenatchee, Willamette, and Tahoe). Each of these locations consisted of one or more stations where birds were actually captured (table 2).

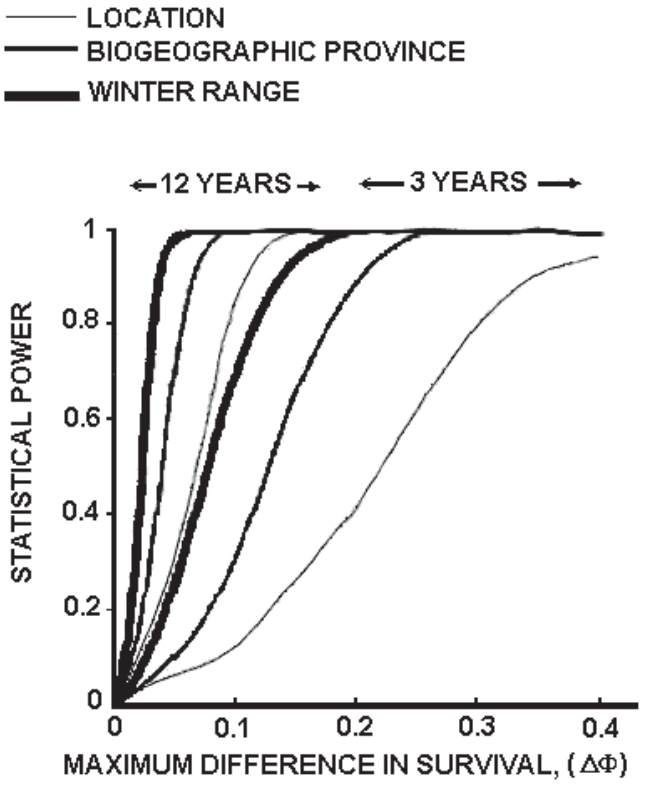

Figure 2—Statistical power to detect differences in survival rates of simulated populations in relation to maximum difference in survival ($\Delta\phi$), number of years of monitoring, and spatial scale. Spatial scale differences in statistical power reflect differences in sample sizes among the spatial scales equivalent to that of location, biogeographic province, and winter range. We estimated the statistical power of detecting differences among 3 populations at each spatial scale using methods of Burnham and others (1987:215); models with geographic variation were compared to Model $\{\phi, P\}$ in which all stations were constrained to have equal survival probabilities.

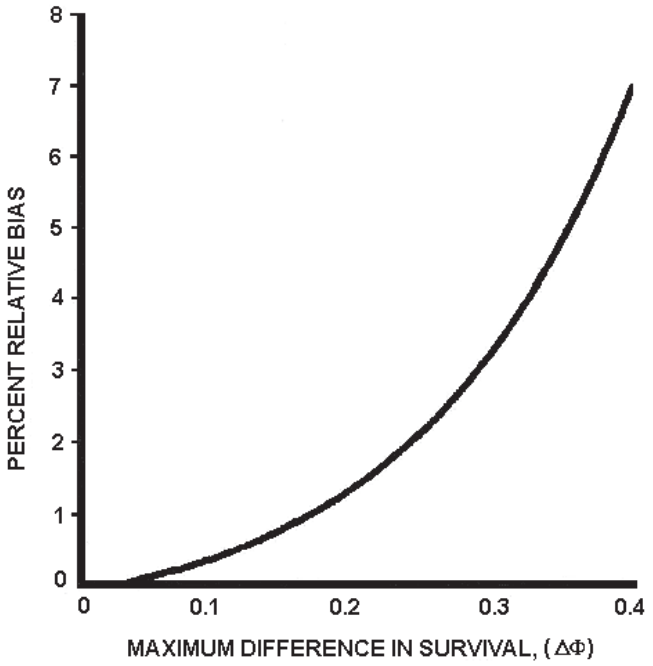

Figure 3—Relationship of percent relative bias due to pooling simulated populations with heterogeneous survival rates. When populations are pooled, but when they have different survival rates, the regional estimate may be biased. Percent relative bias was computed as $100[\hat{\phi} - \phi]/\phi$, where $\hat{\phi}$ denotes the estimated survival rates of the pooled populations and ϕ denotes the weighted survival rate, calculated as

$$\phi = \sum_{i=1}^{k} (\hat{\phi}_i * R_i) / \sum_{i=1}^{k} R_i$$

where $\hat{\phi}_i$ and R_i are the estimated survival rate and number of individuals marked and released at year one, respectively, for a given *ith* population ($i = 1,k$) within a spatial scale (e.g., "location"). We found small bias with relatively small differences in survival rates among simulated populations, but this bias increased rapidly with greater differences among populations.

Although detecting spatial differences in survival rates is interesting and important, one of the primary goals of a demographic monitoring program is to detect trends in these rates. The ability to detect trends at different scales is related to three factors: number of years, effect size (magnitude of decline), and spatial scale (sample size of banded birds). Statistical power was inadequate to detect 0.5% annual declines (i.e., survival rates each year are 0.5% lower than they were the previous year) in survivorship with both 12 and 20 years of data for all sample sizes examined (fig. 4). Statistical power was >80% for detecting 3% annual declines with 12 years of data for the larger spatial scales (fig. 4). Power was increased substantially with 20 years of data. Nevertheless, 20 years of data were necessary to detect 3% annual declines for the spatial scale of location; this demonstrates the difficulty of detecting local trends in survivorship.

Discussion

Survival rates of landbirds may vary spatially and temporally. Examining survival rates in both time and space allows interesting and important management questions to be addressed. Our results suggest that these questions can be explored using a modeling approach with data collected from a monitoring program such as *MAPS*.

We found weak evidence of spatial differences in survivorship for Swainson's Thrush populations in Western North America; the most parsimonious model was that of equal survival rates within Western North America. The statistical power analyses we performed suggested that geographic differences in survival rates would be difficult to detect with three years of data collected from 3 locations. Power would likely have been higher with a larger number of locations, though many locations typically had lower number of captures than we used in the simulations. The results of the power analyses simply demonstrate the difficulty in detecting differences in survival rates with the sample sizes that are typical at small spatial scales with MAPS data (DeSante and Rosenberg 1998). In cases where survival rates vary geographically, but power to detect such differences is low, the regional estimate from a model of a common survival rate among locations would be chosen as the most appropriate.

If geographical differences in survivorship exist (e.g., among locations, biogeographic provinces, etc.), but are not detected, then pooling data may lead to a biased regional estimate. Fortunately, we found that only negligible bias will result when geographic differences in survivorship are low. When differences in survival rates between groups were sufficiently high to result in biased estimates (due to pooling) statistical

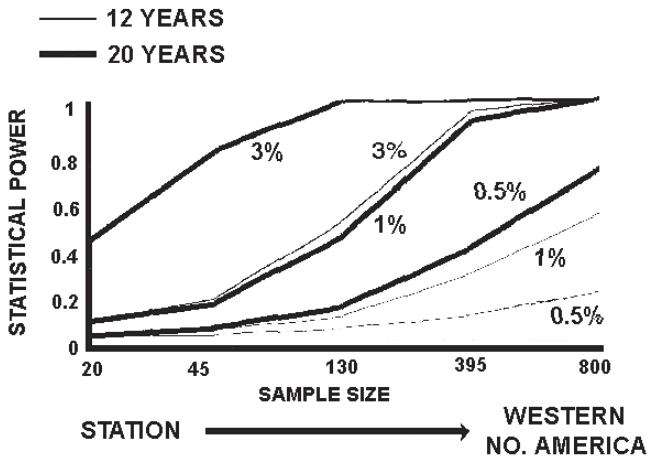

Figure 4—Statistical power to detect exponentially declining survivorship in relation to sample sizes (e.g., number of birds released at year 1), length of monitoring, and percent annual decline for simulated populations. Power was based on the likelihood ratio test of the negative trend model (ϕ_σ, P) against the reduced model of equal survival rates among all years (ϕ, P). Statistical power to detect trends was sensitive to the number of years and sample size; the larger sample sizes were achieved in the field study by pooling among smaller spatial scales, such that a total of approximately 800 Swainson's Thrushes were captured in Western North America.

power was sufficiently high to detect such differences. Similar results were reported by Nichols and others (1982), although they reported lower power to detect geographic differences in survival rates than we did; this is likely due to the much higher capture probabilities used (and estimated from our field study) in our power analyses and the differences between band-recovery data vs capture-recapture models and data. In large-scale studies, geographic differences in survival rates should be evaluated prior to pooling data for a single regional estimate. If geographical differences exist, regional estimates could then be computed as averages of estimates from each geographic area. There was sufficient evidence to warrant concern over pooling all locations with the Swainson's Thrush data; however, bias resulting from this was negligible.

Although we explored only bias resulting from pooling heterogeneous samples, an additional source of bias that may be present in the estimates is that resulting from the presence of transient birds in the sampled population (Pradel and others 1997). Transients will negatively bias survival estimates of resident birds because they, by definition, will not be present at the sampling site in subsequent years (i.e., probability of surviving and being recaptured = 0). For example, in a coastal California site monitored for 7 years, 72% of unmarked Swainson's Thrush were estimated as "transients," resulting in an estimated survival probability for resident birds of 0.61, compared to an estimate of 0.36 when all birds were assumed to be residents (D. Rosenberg, unpublished data). The "transient" model (Pradel and others 1997) requires four sampling periods to provide estimates of annual survival rates of residents, and thus was not used in the analyses presented in this paper because at the time of analyses, only three years of data were available. Use of this model, however, will likely increase the accuracy of survival estimates for resident landbirds at a site when a significant portion of the individuals are transients. In the case of Swainson's Thrush, the transient model fit the data much better ($P = 0.20$) than the model that assumed all individuals were residents ($P = 0.0001$) at a scale equivalent to the "location" in analyses of 1992-1995 MAPS data (Rosenberg and others 1999). The transient model improved the rather poor fit of the nontransient models used in the analyses we reported here (Rosenberg and others 1999). The estimated percent of transients for Swainson's Thrush was 56% (Rosenberg and others 1999). The survival rates for Swainson's Thrush under the transient model (0.63) was much higher than reported here (0.44). The large difference in AIC values between transient and nontransient models (Rosenberg and others 1999) provided strong evidence that transients affected survival rates. Another source of bias of survival rates is emigration (DeSante and Rosenberg 1998). Because we were not able to estimate emigration rates, we do not know how the small study areas of MAPS stations may have biased survival rates. Although models have been developed that allow estimation of survival when movements occur among study areas (e.g., Hestbeck and others 1991), the low probability of movements between stations under the current MAPS study design will likely prohibit the use of these models.

Detecting trends in survivorship will require long-term monitoring. Our results suggest that local trends of even relatively large annual changes will be difficult to detect. Trends that are regional in scope, however, will likely be detected, especially when the number of years of monitoring is large (e.g., >12). Although we were able to detect relatively large annual declines (3%) of survivorship with moderate sample sizes, such declines are unlikely to persist for long periods of time. What may be more important to investigate is the probability of detecting when survival has reached an *a priori* threshold value reflecting a decline (J. Sauer, personal communication). For example, based on a specific productivity, there exists a value of survivorship below which the population can be considered a "sink" rather than a "source" or stable population (Pulliam 1988). The ability to detect when a threshold value is attained may be more important, operationally, than detecting trends. This topic deserves further attention.

The approach we used to evaluate competing hypotheses of variation and trends in survival rates among spatial scales can be a powerful tool to detect environmental variation that directly affects survivorship and thus population dynamics of landbirds. The results highlight limitations and strengths of the sampling methods used in *MAPS*, the only North American program for assessing survivorship of landbirds. The *MAPS* program allowed for large-scale (regional) estimates, but did not adequately estimate rates for local scales with the 3 years of data used in the analyses presented here. Additional years of data will increase power considerably. Large sample sizes, high capture probabilities, and many years of sampling are key to estimating and comparing survivorship among subregional spatial scales.

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The Use of Constant-Effort Mist-Netting to Monitor Demographic Processes in Passerine Birds: Annual Variation in Survival, Productivity, and Floaters

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Geoffrey R. Geupel
Grant Ballard

Abstract—Constant-effort mist-netting (CEMN) has been proposed as a means of assessing demographic processes of avian populations. Such information is necessary to interpret results from monitoring programs (such as the Breeding Bird Survey) that track only abundance and distribution of birds. CEMN is the core methodology for several national monitoring programs, and yet, to date, little work has been done to validate that CEMN accurately measures the demographic parameters which it is purported to measure. To address this need, we use data on three passerine species gathered from long-term studies conducted at the Palomarin Field Station, and compare results obtained from CEMN with those obtained from intensive observations of color-banded individuals. For Song Sparrows (*Melospiza melodia*) and White-crowned Sparrows (*Zonotrichia leucophrys nuttalli*), year-to-year differences in productivity as determined by nest-monitoring correlated well with productivity as assessed on the basis of captures of Hatching Year individuals; this was not the case for Wrentits (*Chamea fasciata*). More than half of all Song Sparrow adults caught were apparently non-territory holding individuals ("floaters"). Territory holders were site-faithful, and relatively likely to be captured more than once in mist nets, whereas non-territory holders were transient. As a result, accurate estimation of Song Sparrow survival was possible only if transient and site-faithful individuals could be distinguished. The most effective criterion to distinguish the two classes appeared to be multiple capture within a breeding season. Song Sparrow adult survival estimated using CEMN (for individuals caught more than once in a breeding season) matched estimates using color band observations (60.0% for both). The abundance of Wrentit and Song Sparrow floaters varied among years; for Wrentits, floater capture rates reflected supply (production of young the year before) and demand (number of breeding vacancies). We conclude by making recommendations for implementation of monitoring programs and for analysis of data so obtained, on the basis of results of our demographic studies. This study demonstrates that important demographic insights can be gained by combining CEMN with studies of breeding success of marked individuals.

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Populations of many North American passerine species appear to be declining at an alarming rate (reviewed in Hagan and Johnston 1992; Askins 1993; Finch and Stangel 1993; Martin and Finch 1995). Migratory species, especially those wintering in the Neotropics, appear particularly threatened, though it is hard to determine the extent of the problems, because data are sparse for many species and for many regions of the continent. As a first step in formulating effective management and conservation responses, we are faced with the challenge of identifying the factors precipitating this decline. This effort requires detailed demographic information that cannot be provided by long-established national monitoring programs, specifically the Breeding Bird Survey.

The four most critical demographic processes underlying population growth and decline are: (1) Adult survivorship, (2) Reproductive success (i.e., production of young or "productivity"), (3) Survival and recruitment of young into the breeding population, and (4) Balance between immigration and emigration (i.e., net immigration). These four components are the most critical because the change in breeding population size from one year to the next, representing decline or recovery of a species, can be directly attributed to a combination of these and only these components. Thus, they are the necessary and sufficient components to explaining population dynamics.

The need for researchers, managers, and agencies to assess primary demographic processes has been enunciated frequently (e.g., Temple and Wiens 1989; DeSante and others 1993b) and is the thrust of several papers in this proceedings (e.g., Robinson and Morse; Sherry and Holmes; Rosenberg and others). To obtain this sort of information on passerine birds, biologists have used a variety of approaches. The three used most commonly (with examples drawn from this proceedings in parentheses) are: (1) Observations of color-banded birds (Sherry and Holmes), (2) Mist-netting (Rosenberg and others), and (3) Nest-monitoring studies (Conway and Martin; Robinson and Morse; Hejl and Holmes). Of these, we focus in this paper on Constant-effort mist-netting (CEMN).

Mist-netting appears to be a potentially powerful and efficient means of collecting critical data on demographic parameters such as annual survival and reproductive success, and is the cornerstone of several monitoring programs, including the Constant Effort Sites (CES) Scheme of the British Trust for Ornithology (Baillie and others

1986; Bibby and others 1992; Peach 1993), and more recently, the Monitoring Avian Productivity and Survivorship (MAPS) program of the Institute of Bird Populations (DeSante and others 1993b; Rosenberg and others, this proceedings). However, the accuracy and validity of inferences derived from mist-netting capture data remain in question, and we are ignorant of the limitations and qualifications of data derived from CEMN. Finally, in the absence of knowledge of the population from which mist-netted birds originate, it is impossible to develop methods of data collection and data analysis that best measure their intended targets.

For these reasons, we have begun a project to investigate the accuracy and validity of inferences drawn from mist net capture data for assessing certain demographic parameters. Knowledge of these demographic parameters, in turn, is of critical importance for interpreting population trends detected by other national monitoring programs, such as the Breeding Bird Survey. The crux of the project is a long-term study of several year-round resident species breeding at the Palomarin Field Station (Point Reyes National Seashore) whose populations have been *simultaneously* studied using two different methodologies: CEMN and detailed observations of color-banded individuals. In this way, we can directly compare parameter estimates (e.g., regarding productivity or survival) obtained with CEMN with estimates obtained using more intensive methods (i.e., observations of color-banded individuals).

Additional objectives of this paper are: (1) to demonstrate the value of CEMN for studying population processes, even when conducted at a single site (in this case the Palomarin Field Station); in this way, this paper complements that by Rosenberg and others (this proceedings) who report on a large-scale, multi-site study of survival using CEMN; and (2) to demonstrate the additional insights gained by studying bird populations using *both* CEMN and nest-monitoring, supporting our contention that the two techniques are complementary rather than redundant.

Methods

Study Species and Study Site

The two principal study species are the Song Sparrow (*Melospiza melodia*) and the Wrentit (*Chamea fasciata*). Ecologically, both species are similar: They are open-cup nesters, insectivorous, and, at our study site, often nest in coastal scrub habitat. Wrentits, unlike Song Sparrows, are primarily restricted to coastal scrub for breeding (Geupel and DeSante 1990); Song Sparrows also breed in moister areas (Shuford 1993). Both species are year-round residents at Palomarin, and in both species, adults appear to disperse very little between years (Nice 1937; Erickson 1938; Johnson 1972; Geupel and Nur, unpublished data) and thus would be well suited for estimating survivorship on the basis of capture/recapture data. For productivity estimates we also include analyses of an additional year-round resident species breeding in the coastal scrub, the White-crowned Sparrow (*Zonotrichia leucophrys nuttalli*).

The field work has been conducted at the Point Reyes Bird Observatory's (PRBO's) Palomarin Field Station, located just within the southern boundary of the Point Reyes National Seashore and adjacent to the Pacific Ocean (see fig. 1 in Nur and Geupel 1993a; also fig. 1 in Johnson and Geupel 1996). On our study site of 36 ha, CEMN has been carried out since 1976, and intensive observations of color-banded individuals have been conducted since 1980. Thus in one study area we simultaneously have carried out CEMN, nest-monitoring, intensive spot-mapping, and behavioral observations of color-banded individuals.

CEMN was conducted using 20, 12-m mist nets erected at 14 netting sites. Eight sites (14 nets) were located on the edge of mixed, evergreen forest habitat. The other six single nets were located in successional coastal scrub habitat, interspersed with introduced grasses. For further description of the study area see DeSante and Geupel (1987).

The net locations are adjacent to and extend across approximately 25% of the 36 ha study plot. The rest of the study plot is within 700 m of the mist net complex. The standardized operation of mist nets is described by DeSante and Geupel (1987) and has continued with little change. In summary, nets were run daily for 6 hours, beginning 15 minutes after local sunrise (weather permitting) from 1 May (1 April prior to 1989) to approximately 25 November, and 3 days per week from December through the end of March (or the end of April, since 1989); further details are in Johnson and Geupel (1996).

Field Methods

The detailed monitoring of individuals was conducted on the 36 ha study plot and has been described elsewhere (Geupel and DeSante 1990). In summary, identities and territory boundaries of color-marked individuals were determined from detailed spot-mapping censuses conducted on a minimum of 3 days per week during the breeding season (1 April-31 July) throughout the 15 years of the study. Concentrated efforts were made to locate and monitor all nest attempts of all territorial pairs on the study area from 1981 through 1985 and 1988 through 1994. No attempt was made to locate nests in 1986, therefore no direct estimates of productivity are available for that year. In addition, nest-finding effort was reduced in 1980 and 1987 compared to other years. However, identification of breeding individuals (territory holders) was not reduced in 1986 or 1987 compared to 1981-1985 or 1988-1994. In 1980, however, fewer than 50% of breeding adults were color-banded, and because the sample of breeders may not be representative, we did not use data from 1980 for adult survival estimation (whether derived from color-banding or mist-netting data). Nearly all successful nests (those fledging one or more young) are found before fledging and their young are individually color-banded (see further details in Geupel and DeSante 1990). Additional individuals are color banded when first caught in mist nets as hatching year (HY) or as after-hatching year (AHY) birds.

Locals are defined as juveniles banded as nestlings and fledged from nests on the study plot. Nonlocals are juveniles first captured and banded in the standard operation of mist nets, and are assumed to have dispersed onto the study area. We attempted to identify all territory holders on or adjacent to the study grid. This allowed us to classify all adults caught in mist nets (as well as those identified by color-bands only)

as territory holders or non-territory holders. We refer to these two groups of individuals as "breeders" and "floaters," respectively (Stutchbury and Zack 1992).

Analysis of Productivity and Survival

The number of HY birds caught as part of a CEMN protocol reflects at least five factors: (1) productivity, as measured in terms of fledged young per breeding pair (or per adult); (2) post-fledging survival of fledglings (note that HY birds are usually not caught immediately after fledging but at least several weeks after fledging. For example, Song Sparrows at this site were first caught in mist nets 10 to 40 days after fledging [Nur and others 1995]); (3) breeding density in the area being sampled by the mist nets, which we refer to as "catchment area"; (4) capture probability for HY birds in the catchment area; and (5) flux of HY birds, i.e., movement of HY birds into and within the vicinity of the mist nets. Note that only (1) and (2) reflect differences in productivity, broadly defined.

To infer patterns in productivity, mist net data have been used in different ways: (a) analysis of total number of HY birds caught; (b) analysis of number of HY birds caught per AHY (After Hatching Year); or (c) analysis of percent of all birds who are HY. Note that (c) is just a transformation of (b) and vice versa, assuming that all birds are classified as HY or AHY (i.e., assuming that the total = AHY + HY).

If one uses (b) or (c) to estimate productivity, then differences in capture rates among AHY individuals (and not just HY individuals) will influence the productivity index. The number of AHY individuals caught reflects: (1) breeding density in the catchment area of AHY individuals; (2) abundance of nonbreeders in the AHY catchment area; (3) capture probability for AHY birds in the catchment area, and (4) flux of AHY birds, both breeder and nonbreeders.

As a result of the factors enumerated above, there are hazards with including the number of AHY birds caught as a measure of productivity. First, the catchment area of HY and AHY can differ markedly (Nur and Geupel 1993b; Nur and others, in press). Hence if breeding density in the HY catchment area should change, without a change in breeding density in the AHY catchment area (or vice versa), the productivity index would be affected, even though no change in actual productivity would have occurred. Second, many AHY birds caught are either nonbreeders (Nur and Geupel 1993a; see below) or transient, i.e., not breeding locally. Hence a change in the capture rates of nonbreeders would be reflected in a change in the productivity index. Pitfalls such as these should be kept in mind in the following analyses of HY and HY/AHY captures.

For both Song Sparrows and White-crowned Sparrows we compare indices of productivity determined from direct observation of nesting and fledging success with indices of productivity determined from mist net capture data. Specifically, we compare HY captures per year with the total number of fledglings produced on the study plot (i.e., the number of young known to have fledged). Additionally, we evaluate whether the proportion of locally fledged young that are subsequently captured in mist nets varies significantly from year to year. If the aim of a monitoring program is to assess the production of fledged young (per year, at one or more sites) by way of mist-netting juveniles, then it would be of concern if the proportion of locally fledged young that are captured should vary between years.

Finally, for Song Sparrows we evaluate whether HY captures alone or HY/AHY captures together provide a better measure of temporal variation in productivity on the Palomarin study plot. We use linear regression analysis for statistical comparison of productivity indices. To analyze capture probability of fledged young we use logistic regression (Cox and Snell 1989), which is appropriate when the outcome is binary (here there are two states: captured or not captured). The statistical test used for logistic regression was the Likelihood Ratio Test (LRT) and its associated test statistic, the Likelihood Ratio Statistic (LRS; Lebreton and others 1992). Under the null hypothesis, the LRS is distributed as a chi-squared random variable with degrees of freedom corresponding to the number of parameters being tested.

To analyze survival rates of adults, we used the statistical program SURGE (Lebreton and others 1992; Cooch and others 1996) and compared survival estimates derived from color-band observations of breeding individuals with estimates derived from mist net capture/recapture data. Capture/recapture analyses such as SURGE allow one to separately estimate a survival probability, as well as a recapture (or, equivalently, a resighting) probability. The latter is defined as the probability that an individual is recaptured (or resighted) at a given time period, given that it has survived to that time period (Nur and Clobert 1988). Statistical tests of survival and recapture probabilities were carried out using the Likelihood Ratio Test. Note also that in this study, mist net data alone cannot establish whether an individual is a breeder (Nur and Geupel 1993a), whereas individuals with well-developed brood patches can be assumed to be breeders, and those without well-developed brood patches are a mixture of breeders and floaters (unpublished data).

Results and Discussion

Evaluation of Productivity Indices

Productivity of Song Sparrows and White-crowned Sparrows—The greater the number of Song Sparrows known to have fledged from the study plot in a given year, the greater the number of HY birds caught in mist nets that year (fig. 1A; $R^2 = 0.802$, $P = 0.0001$, $N = 12$ years; capture rates adjusted in all cases for number of net-hours each year). The relationship was remarkably tight. For White-crowned Sparrows, as well, the number of fledglings produced on the study plot correlated well with the number of HY birds caught (fig. 1B; $R^2 = 0.673$, $P = 0.0011$, $N = 12$ years). For both species, data from 1980 and 1987 were excluded because of low effort at nest-finding (see above); however, the relationships still were significant, even when such data were included.

Among locally fledged young of both species, the proportion that was subsequently captured in mist nets varied significantly among years (LRT, using logistic regression; table 1). This finding is ambiguous: Annual variation in the proportion of locally fledged young that are subsequently captured may reflect differences in the probability of capture among

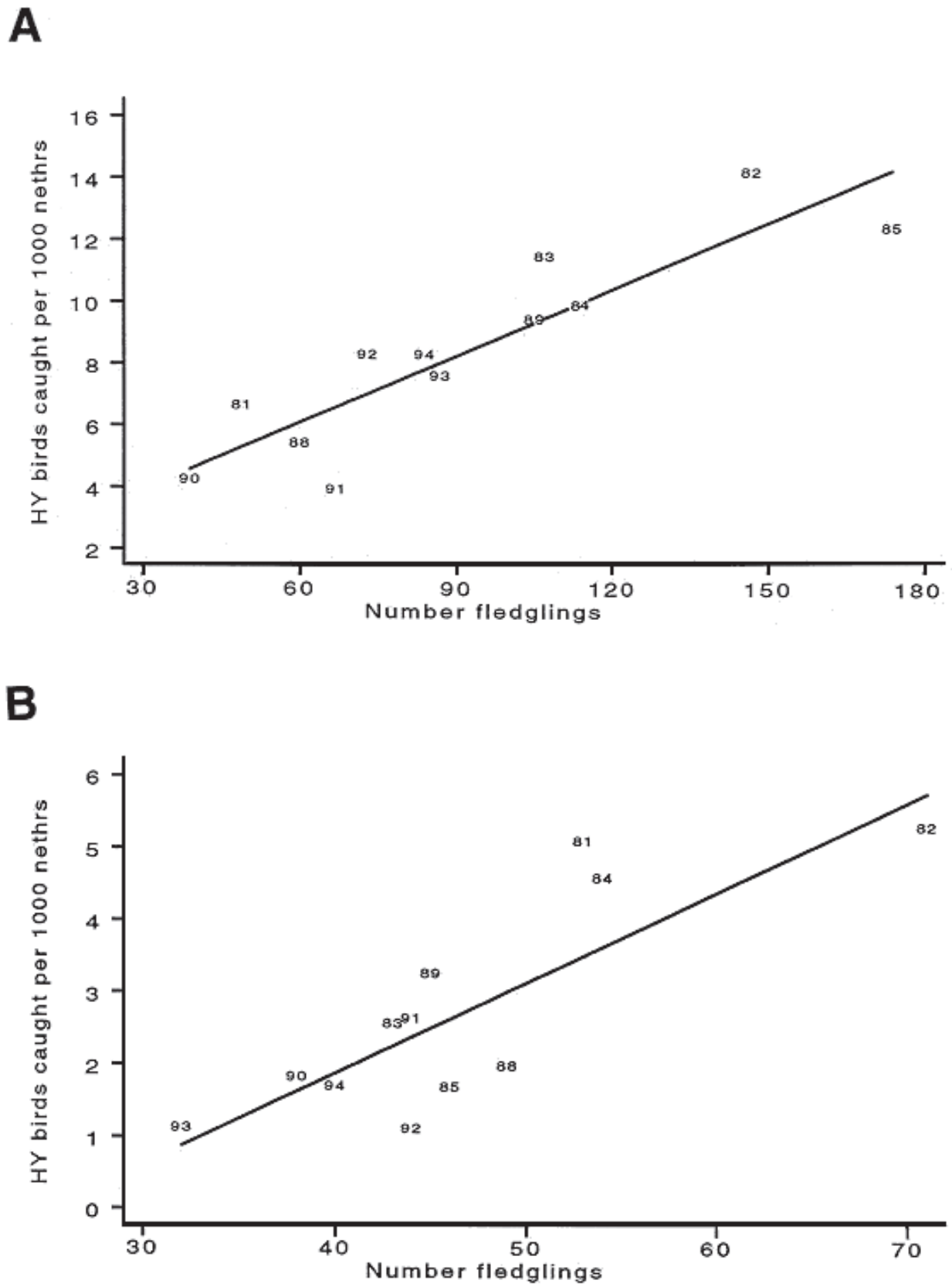

Figure 1—Comparison of local productivity of song sparrows (A) and White-crowned Sparrows (B) in relation to number of total HY caught for each species in each breeding season (whether local or not) per 1,000 net-hours. X-axis for each panel shows number of young that fledged on the study plot (see text). "80" refers to 1980 breeding season, etc. In each figure panel, the solid line is the best least squares fit to the data. Regression statistics are: $R^2 = 0.802$, $P = 0.0001$ (A); $R^2 = 0.673$, $P = 0.0011$ (B).

Table 1—Capture probability of locally fledged young, captured in first summer, and proportion of all Hatching Year (HY) birds caught that were of local origin, in relation to year.

Year	Fledglings N	Percent captured in mist nets[a]	Total HY caught N	Percent of HY that are local
Song Sparrows				
1980	67	31	183	12
1981	49	22	83	13
1982	137	32	188	23
1983	105	15	144	11
1984	103	22	123	19
1985	164	29	157	31
1986	—	—	59	—
1987	12	33	119	3
1988	56	41	66	35
1989	100	27	116	23
1990	39	5	51	4
1991	52	29	43	35
1992	66	30	84	24
1993	69	19	76	17
1994	69	33	89	25

Year	Fledglings N	Percent captured in mist nets[b]	Total HY caught N	Percent of HY that are local
White-crowned Sparrows				
1980	70	36	106	24
1981	53	43	64	36
1982	71	24	70	24
1983	43	19	32	25
1984	54	19	57	18
1985	46	20	21	43
1986	—	—	41	—
1987	20	15	43	7
1988	49	14	24	29
1989	45	22	40	25
1990	38	3	22	5
1991	44	21	29	31
1992	44	14	11	55
1993	32	9	11	27
1994	40	8	18	17

[a]Significant year-to-year variation in capture probability: P = 0.0006 (LRT; excludes 1987 because of low sample size); P = 0.026 (LRT; excludes 1987 and 1990).
[b]Significant year-to-year variation in capture probability: P <0.0001, all years (LRT); P = 0.0006 (LRT, excluding 1990); P = 0.0004 (LRT, excluding 1990 and 1987 because of low sample size).

years, or it may reflect differences in post-fledging survival (i.e., in some years fledglings may have died before they could be caught). Examination of table 1 indicates that 1990 was unusual: For both species, it was the year with the lowest capture proportions. For example, among Song Sparrows, only 5% of fledglings were subsequently caught in mist nets, compared to the median percentage of 28%. Even if 1990 is excluded from the analyses, significant year-to-year variation in capture proportions still was evident among locally fledged Song Sparrows and White-crowned Sparrows (table 1).

Results for Wrentits previously were presented in Nur and Geupel (1993a,b). No relationship existed between the total number of HYs caught (which includes local and nonlocal young) and the number of young known to have fledged from the study plot (see fig. 4B in Nur and Geupel 1993a), but a significant relationship did exist between the number of locally fledged young that subsequently were caught and the total number of young that fledged from the study plot (fig. 2 in Nur and Geupel 1993a). The proximal explanation for this result is that the number of *non-local* Wrentit HYs caught is uncorrelated with productivity as measured on the study plot (Nur and Geupel 1993a). Nur and Geupel (1993a) were unable to distinguish between two competing hypotheses to explain this paradoxical result: (1) productivity outside the plot is not correlated with productivity on the plot, or (2) year-to-year differences in the number of nonlocal HYs caught does not reflect productivity differences, but rather differences in dispersal or capture probability.

Thus, the ability of mist net capture data to index productivity appeared to be good for two species, Song Sparrows and White-crowned Sparrows; for the third species, the results are mixed. In previous studies, Feu and McMeeking (1991) found differences in the ability of mist nets to track

annual variation in productivity among four British passerines. Bart and others (1998) concluded that mist nets could adequately index annual variation in productivity of Kirtland's Warblers (*Dendroica kirtlandii*).

Which Criterion of Productivity to Use—For Song Sparrows, we compared two different mist net based measures of productivity (HY caught per 1000 net hours; HY caught per AHY caught) with two different direct measures of productivity on the study plot (total number of young fledged from the study grid; number of young fledged per breeding pair). HY captures alone were better correlated with total number of fledglings produced on the grid than was the ratio of HY to AHY birds ($r = +0.915$, $P < 0.001$; $r = +0.459$, $P = 0.16$, respectively). In addition, HY capture rates were better correlated with the number of fledglings produced per pair than was the ratio of HY to AHY birds caught, though the difference was slight ($r = +0.674$, $r = +0.669$, respectively).

That the HY/AHY index of productivity did not perform better than the HY-only index may seem surprising. Incorporating information on capture rates of adults, as a means of estimating breeding density, did not improve our ability to estimate, for the study site, productivity per breeding pair. The problem is not, in our view, that AHY captures are unrelated to breeding density. On the contrary, in a separate analysis, we determined that capture rates of AHY Song Sparrows were significantly correlated with breeding density (as determined by observations of color-banded birds; Silkey and others, in press). Rather, the problem may be that the number of AHY birds caught is not a sensitive index of breeding density *in the area that is producing the HY birds* (i.e., the catchment areas for AHY and HY birds likely differ). Furthermore, at the Palomarin study site there were no marked fluctuations in Song Sparrow breeding density during the course of the study (as determined by observations of color-banded territorial birds; e.g., Helzer and Geupel 1996). In the absence of marked fluctuations in breeding density, we recommend the use of HY captures per net hour to index productivity. However, where breeding density fluctuates greatly, the HY/AHY index may prove a better index of productivity than simply using the number of HY captures per net hour. In the latter situation, incorporating a rough measure of breeding density (reflected in AHY captures) may be better than ignoring variation in breeding density.

Breeders and Floaters

Two groups of adults are caught in CEMN: Site-faithful (this includes, but is not limited to, territory-holders, i.e., breeders) and transient individuals. Failure to distinguish between these two groups can lead to serious bias in estimating survival (Peach 1993; Nur and Geupel 1993a). In this study we attempt to distinguish these two groups, first, on the basis of whether individuals held a territory, and second, on the basis of whether individuals were caught once or more than once per breeding season.

The number of breeders (i.e., territory holders) and nonbreeders (i.e., non-territory holders or "floaters") varied among years. In most years, 40% or more of adults caught were non-territory holders (average = 53%). This has important implications. First, when estimating productivity, if one divides HY captures by AHY captures to estimate productivity (see above), the latter is reflecting abundance of the nonbreeding segment of the population as well. Second, the large number of non-territory holders caught in the nets has important implications for survival estimation, because nonbreeders tend to be much more transient than breeders (see below). Furthermore, the percent of adults caught that were floaters varied significantly among years ($LRS = 26.39$, $df = 12$, $P = 0.01$).

That the number of nonbreeders caught in the nets equaled or exceeded the number of breeders caught does not imply that nonbreeders equaled or outnumbered breeders in the population as a whole. The nonbreeders were, for the most part, just "passing through" the study site, whereas breeders stayed put. Thus, over the course of the breeding season there was a high turnover of nonbreeders, but not of breeders. The transience of these nonbreeders is indicated by the fact that few were ever recaptured (in contrast to breeders, see below). Also, most (83%) of these nonbreeders were first caught in the winter or spring of their after-hatching year (i.e., they were neither locally fledged nor caught in the nets in their first year of life). In contrast, 81% of breeders caught in nets had been locally fledged or were caught in nets during their first year of life. Thus, most nonbreeders caught during the breeding season never had been seen before nor ever were seen again. We would expect transients to be an especially large component among captures of migrant species, a result that has been confirmed at the Palomarin Field Station for Swainson's Thrush (*Catharus ustulatus*, Johnson and Geupel 1996) and Wilson's Warbler (*Wilsonia pusilla*, Chase and others 1997).

Our work has revealed that floaters are a large component of adult captures of Wrentits. In fact, Wrentit floaters constitute an even larger fraction of adult captures than is the case in Song Sparrows: $X = 18.9$ floaters caught per year versus $X = 9.1$ breeders caught per year, $n = 10$ years (PRBO unpublished data; see also Nur and Geupel 1993a). As with Song Sparrows, this difference in capture rates may not necessarily reflect the numerical dominance of floaters in this Wrentit population. Rather, the difference in capture rates reflects the fact that breeders show very high site fidelity, whereas floaters are usually very transient. Only breeders within 200 m of the nearest mist net were caught at least once during the breeding season (Nur and Geupel 1993b; Nur and others, in press); those breeding farther away almost never were caught. In contrast, floaters were very transient, and thus over the course of the breeding season a high number "passed through" our study site. Once caught, most Wrentit floaters were never seen again. Only 52 out of 189 floaters (28%) were seen again in the same season, either caught in mist nets or observed and identified by means of their color-bands. In contrast, most breeders were caught repeatedly during the breeding season. Sixty-two percent of breeders were recaught in the same breeding season ($n = 91$), some repeatedly. The highly transient nature of floaters has important implications for estimation of adult survival using CEMN, as discussed below.

In Wrentits, even more so than Song Sparrows, the number of floaters caught each breeding season varied markedly, between 3 and 34. We examined demographic influences on variation in Wrentit floater abundance (Geupel, personal

communication). Using a stepwise multiple regression analysis we found that floater capture rate (floaters caught per 1000 net-hours) in year x varied most strongly in relation to two demographic parameters: (1) breeding density in year x (i.e., the more pairs breeding, the fewer the vacancies and hence the greater the number of floaters), and (2) productivity in year $x - 1$ (i.e., the greater the production of young during the previous year, the more floaters are present the next year). Once productivity in the previous year was controlled for statistically, there was a significant relationship between floater capture rate and breeding density ($P = 0.006$, fig. 2); conversely, after controlling for the effect of breeding density, the effect of productivity was significant ($P = 0.01$; Geupel, personal communication).

Survival Estimation

Analyses of survival and recapture probability (i.e., the probability that a bird that has survived to year x is caught in year x), were conducted using the statistical program SURGE on the Song Sparrow mist net capture data (data from 323 different individuals caught between 1981 and 1994) and the results were compared with detailed observations on individually color-banded Song Sparrows (420 different individuals).

We used SURGE to estimate survival and recapture probability for adult Song Sparrows based on observations of *territory-holding* color-banded birds (i.e., individuals that did not hold territories are not included in this data set). An individual that was actually observed in a given year, but not as a confirmed territory holder, is considered to be "not observed." Thus failure to be "resighted" incorporates failure to hold territory among experienced breeders. Adult survival for color-banded Song Sparrows is shown in table 2A: Males survived better than females (64% versus 56%); mean survival was 60.0%. Resighting probability was high for both sexes (87% to 92%). There was an indication of annual variation in survival, but this was not significant for either sex (table 2B).

Use of Double-Capture Criterion to Distinguish Transients—In most CEMN protocols it would not be possible to distinguish breeders (or territory-holders) from nonbreeders (or floaters). Therefore, we have considered a mist net based criterion for distinguishing transients from site-faithful individuals. That criterion is the following: Individuals caught at least two times during the breeding season (and at least 7 days apart) are presumed to be "resident," the others are presumed transient (similar criteria adopted by Peach and others 1991; Peach 1993; Chase and others 1997). In our analyses, an individual that is "resident" in any one year is assumed to be resident in all years. Indeed there is a significant association between multiple capture and breeding status ($P < 0.0001$, LRS = 44.43, df = 1). There were 79 double-caught Song Sparrow

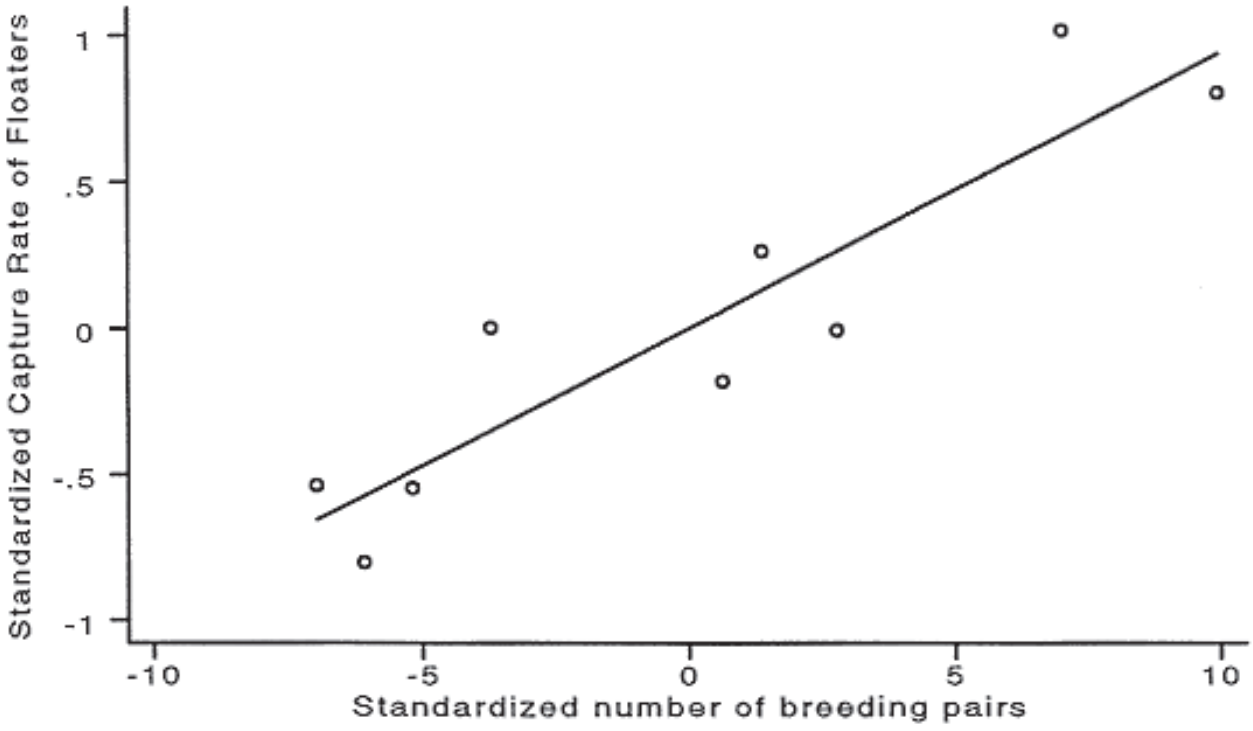

Figure 2—Relationship of Wrentit floater abundance in relation to Wrentit breeding density, after both are statistically controlled for effect of production of Wrentit young during the previous year. The figure, referred to as an "Added Variable Plot" (STATA Corp. 1997), graphically presents the results of a multiple regression analysis (dependent variable is floater capture rate; independent variables are breeding density and productivity the year before) and illustrates the effect of breeding density on floater capture rate. Each data point represents data from one year; the solid line is the best least squares fit to the data. On y-axis is shown floater capture rates (number of floaters caught per 1,000 net-hours, standardized to a mean of zero); on x-axis is shown number of breeding pairs on the study site (standardized to a mean of zero). The effect of breeding density is highly significant, $P = 0.004$, after controlling for the effect of productivity.

Table 2—Song Sparrow adult survival in relation to sex and year.

(A) Survival and resighting probabilities for color-band observations of breeding males and females, from SURGE (N = 420 individuals).

	Survival (+ S.E.)	Resighting (+ S.E.)
Male:	0.644 + 0.021	0.918 + 0.020
Female:	0.556 + 0.026	0.874 + 0.031
	P = 0.008[a]	NS[a]

(B) Year-to-year variation in survival as estimated from color-band observations of breeding males and females (columns 2 and 3; N = 420 individuals) and as estimated from SURGE analyses of mist net capture/recapture data (column 4; N = 323 individuals, both sexes combined). For the latter analysis, adults were classified as single- or multiply caught, and separate recapture probabilities were allowed for each class of adult. Recapture probability did not vary significantly between years (LRT) and was assumed constant with year for all analyses.

	Color-band observations		Mist-net observations
Year	Male[b]	Female[b]	Adults[b]
1981	0.540 + 0.24	0.527 + 0.11	0.500 + 0.22
1982	0.648 + 0.23	0.576 + 0.12	0.274 + 0.13
1983	0.714 + 0.071	0.706 + 0.14	0.728 + 0.18
1984	0.569 + 0.069	0.383 + 0.12	0.410 + 0.12
1985	0.584 + 0.073	0.386 + 0.15	0.915 + 0.17
1986	0.642 + 0.066	0.671 + 0.15	0.530 + 0.15
1987	0.749 + 0.071	0.652 + 0.16	0.519 + 0.16
1988	0.624 + 0.075	0.568 + 0.11	0.608 + 0.19
1989	0.767 + 0.13	0.555 + 0.20	0.512 + 0.18
1990	0.670 + 0.081	0.546 + 0.11	0.608 + 0.20
1991	0.601 + 0.15	0.717 + 0.11	0.576 + 0.24
1992	0.528 + 0.11	0.546 + 0.12	0.442 + 0.34

[a]LRT, df = 1, comparing the two sexes with respect to survival and resighting probabilities.
[b]No significant year-to-year variation (LRT, df = 11, P>0.1) for males or females or adults.

adults, of these 57 (72%) were known breeders. However, most breeders were not double-caught: Among 157 known breeders that were caught at least once during the study period, only 57 (36%) were double caught in at least one breeding season. Thus the double-capture criterion is not very efficient at identifying Song Sparrow breeders. Nonetheless, this criterion appears to provide a good means of obtaining estimates of adult survival that accord well with estimates based on color-band observations (table 3).

Differentiating birds according to the multiple criterion yields estimated survival of 62% for double-caught birds (assuming different recapture probabilities for single-caught and double-caught birds) and 41% for birds that never were multiply caught, a significant difference (P = 0.013, LRT). A pooled estimate of survival for both classes of adults is 56% (assuming different recapture probabilities for the two groups; table 3). The survival estimate for double-caught birds only and the pooled survival estimate for both classes of birds agree closely with estimates from color-band observations. In fact, any discrepancy between the color-band estimate and the estimate for double-caught individuals is due to 1993/1994 data being included for the latter and not for the former; when both data sets cover exactly the same years (1981-1993), the two survival estimates yield nearly identical estimates: 60.0% and 59.9% survival for color-banded and mist net data. Note that double-caught birds are a mixture of mostly known-territory holders (constituting 72% of double-caught birds), with some presumed floaters (the other 28%). Despite differences in breeding status, it appears that both types of double-caught individuals demonstrate relatively high site fidelity between years.

The double capture criterion excludes many individuals who are likely resident, and not transient. An alternative criterion is to carry out analyses on individuals caught in at least two different years. The assumption is that such individuals are site-faithful, not transient (Pradel and others 1997). We conducted an analysis of survival using individuals who were first caught as HYs and then caught at least once as AHY individuals. For the Song Sparrow population there were 110 such individuals. Adult survival of these individuals (from their first capture as AHY individuals, and excluding 1993/94 to make the estimate compatible with analyses of color-banded individuals) was estimated to be 52.8% (S.E. = 4.6%); less than the color-band derived estimate of survival, and less than the double-capture derived estimate. Hence, use of this criterion (survival of individuals caught at least once as a AHY individual and previously caught as a HY individual), rather than the

Table 3—Survival and recapture probability of Song Sparrows. Results of SURGE Analyses on mist-net capture data for adults, 1981-1994, with respect to multiple-capture criterion (caught more than once in at least one year versus never caught more than once in a season).

(A) Separate estimates of survival and recapture for multiply caught and for not multiply caught (N = 79 individuals and N = 244 individuals, respectively).

	Survival		Recapture	
	Probability	S.E.	Probability	S.E.
Multiply caught	0.621[a]	0.044	0.475[b]	0.065
Never multiply caught	0.413[a]	0.066	0.184[b]	0.054

(B) Separate estimates of recapture probability for multiply caught and for not multiply caught; pooled estimate of survival (sample size as in part A).

	Survival		Recapture	
	Probability	S.E.	Probability	S.E.
Multiply caught[c]			0.508	0.064
Pooled estimate (multiply and not multiply caught)	0.564	0.038		
Never multiply caught[c]			0.109	0.025

(C) No differentiation between multiply caught and never multiply caught (N = 323 individuals).

	Survival		Recapture	
	Probability	S.E.	Probability	S.E.
All Adults	0.475	0.038	0.302	0.046

[a]Comparison of multiple versus single capture: LRS = 6.21, df = 1, P = 0.013.
[b]Comparison of multiple versus single capture: LRS = 9.43, df = 1, P = 0.002.
[c]Comparison of multiple versus single capture: LRS = 44.00, df = 1, P < 0.0001.

double-capture criterion, increases sample size—thus improving precision—but decreases accuracy.

Year to Year Variation in Adult Survival—SURGE analyses of color-band observations and mist net capture/recapture data indicated between-year variation in adult survival (table 2). Annual survival estimates using mist net capture data varied by more than two-fold, as did estimates of annual adult survival based on color-band observations (table 2). However, there was no significant correlation between estimates of adult survival in each year obtained from the mist net data and estimates of survival obtained from observations on color-banded individuals (linear regression, $P > 0.2$). This was the case whether the data sets for color-banded individuals included only males, only females, or both sexes pooled. The lack of concordance between year-specific estimates from the two types of data collection calls into question the ability of mist nets to track annual variation in adult survival. However, we must consider the possibility that the color-band observational data are insufficient to accurately estimate survival on a year-by-year basis (as opposed to a long-term average, see above). Marshall and others (this proceedings) discuss whether observations of color-banded individuals can be used to accurately estimate adult survival.

Other Demographic Parameters

Constant-effort mist-netting can be used to investigate a number of other demographic parameters, discussion of which lies outside the scope of this paper. Examples include age structure of adults (where Second Year adults can be distinguished from After Second Year individuals), dispersal (of juveniles and adults), and offspring survival and recruitment (Nur and others 1995). Offspring survival and recruitment is especially important, yet information is sorely lacking (Perrins 1991; Clobert and Lebreton 1991; Sherry and Holmes, this proceedings).

Conclusions and Implications for Avian Monitoring Programs

These results demonstrate that temporal variation in productivity can be estimated well using CEMN. This is not a universal conclusion (Wrentits being a possible exception), but does appear to be well justified for Song Sparrows and White-crowned Sparrows. This study did not address the practice of using CEMN data to assess spatial differences in productivity (e.g., DeSante and others 1993b), which should be the target of a future validation study. Furthermore, we do not recommend that differences in HY capture rates, or comparisons of HY/AHY ratios, be used to assess between-species differences with respect to productivity. For example, Vansteenwegen (in press) compared HY/AHY ratios for 24 species with large sample sizes, as part of a national CEMN program in France. There was a 100-fold difference in this ratio among species! It is unreasonable to maintain that such differences in HY/AHY ratios reflect mainly differences in productivity; as our own data suggest, most of the differences surely reflect different capture probabilities of adults and juveniles.

Mist net capture/recapture data appear to give good estimates (estimates with small bias) of adult survival, provided that transients and non-transients can be distinguished. In the absence of any distinction between these two classes, survival estimates will be substantially biased (by 14 percentage points for Song Sparrows [i.e., 0.62 versus 0.48, table 3]; by 30 percentage points for Wrentits [Nur and Geupel 1993a]). The double-capture criterion (two or more captures in the same breeding season, at least 7 days apart) appears to be a good means to make this distinction, at least for Song Sparrows. The double-capture criterion also produced much improved estimates of Wilson Warbler survival, compared to not distinguishing transients at all (Chase and others 1997). Note that the bias in estimating survival if transients and site-faithful individuals are not distinguished lies not so much in survival differences between the two groups, but arises because recapture probability is poorly estimated (being very different for the two groups of individuals), which results in poor estimates of survival. When recapture probabilities are separately estimated for each group and a combined survival probability is estimated, there is some bias but not that great (0.62 for double-caught individuals only versus 0.56 for the combined survival estimate [table 3], a difference of six percentage points).

We recommend a two-pronged approach: For obtaining estimates of absolute survival, we recommend confining analysis to double-captured individuals (table 3). However, for obtaining an index of year-to-year variation in adult survival, we recommend use of statistical models that incorporate all individuals, with separate recapture probabilities estimated for single-caught and multiply caught individuals, and a pooled estimate of survival probability for each year (as done in table 2). If a study can obtain large sample sizes of double-caught individuals each year, there would be little reason to include single-caught individuals as well. An implication of this approach is that, in establishing a constant-effort mist-netting program, one goal would be to maximize the number of adults *recaught*, not just caught. Running nets often (at minimum, two or more times per 10-day period) would further that goal.

We make the following additional recommendations regarding implementation of monitoring programs on the basis of results from our intensive study of demography of several passerine species:

1. We recommend that calculations of adult survivorship from mist net capture/recapture data always attempt to distinguish transients from non-transients. Transients (mostly floaters) appear to be a large component of adult catches of both year-round resident species and migrant species.

2. More work needs to be done to establish the best means to distinguish transients from non-transients. The double-capture criterion appears to yield valid estimates of survival, but, for some species, may be too restrictive; other criteria should also be investigated.

3. We recommend running mist nets more than once every 10 days. This will increase the number of adults that are double-captured, and recaptured in the following year, thus improving the accuracy and precision of survival estimates. Running nets more often also will increase the sample size of juveniles that are caught, improving our ability to infer

trends in productivity and juvenile survival/recruitment. It is likely that recapture probabilities differ between sites (Peach 1993) and thus adequate sample sizes are required to estimate site-specific parameters. The optimal frequency with which to run mist nets should be the topic of future investigation.

4. While mist nets appear to provide a good means of indexing year-to-year variation in productivity, at least in coastal scrub habitat, more work is needed to evaluate the use of mist net capture data to compare productivity at different sites and in different habitats.

We conclude that there is great value to combining CEMN with intensive observations of color-banded individuals. The use of several techniques in concert, rather than being redundant, provides one with information that could not otherwise be attained. An example of the power of a multi-level, integrated approach is the ability to track abundance of nonbreeders (floaters). Through spot-mapping or point counts we can potentially track the number of breeders, but floaters are an important component of avian demography, yet are hard to observe in the field due to their secretive nature. Mist-netting allowed us to track the total number of adults (whether breeding or not), but by itself could not tell us which were breeders. Putting both together (total adult abundance and breeder abundance) allows inference about nonbreeder abundance. This allowed us to correlate the abundance of nonbreeders with several demographic parameters. The ability of a population to respond to perturbation might well be related to the existence and abundance of nonbreeders (as exemplified by the Northern Spotted Owl *Strix occidentalis caurina*; Verner 1992).

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Estimating Survival of Neotropical-Nearctic Migratory Birds: Are They Dead or Just Dispersed?

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Abstract—The most common method for estimating adult survival in site specific demographic studies of Neotropical-Nearctic migratory bird populations is by measuring the return rate of marked individuals. Return rate historically has been defined as the ratio of resighted birds to the total number banded (i.e., with bands on) the prior year, and has been used as a "minimum number known alive" estimate of survival. Return rates potentially underestimate true survival (the complement of mortality) for two reasons. First, not every bird that returns to the study plot is actually encountered by the field researcher, and second, not every bird that survives to the next breeding season returns to the study plot. We use a branching-tree diagram to illustrate that the essential problem with return rate methodology is that the fate of birds that are not resighted is unknown. It is widely recognized that Cormack-Jolly-Seber based analyses greatly improve "survival" estimates by incorporating the probability of resighting a bird given that it is alive and present on the study plot. However, these estimates will underestimate true survival if birds disperse beyond the range of the resighting effort. Because long-distance dispersal events are an important component of migratory bird ecology, we cannot estimate true survival from return rate data until better information on dispersal distances and probabilities are collected. We discuss several conservation implications of underestimating survival, and suggest terminology that is potentially less confusing.

The decline of some Neotropical-Nearctic migratory landbird populations has prompted a number of demographic studies that examine the possible factors contributing to the declines. Included among the broader issues on which recent studies have focused are source-sink dynamics (e.g., Donovan and others 1995a,b; Brawn and Robinson 1996; Robinson and Morse, this proceedings) and revealing how and where populations are limited (e.g., Martin and Finch 1995; Sherry and Holmes 1996). Similarly, most authors in this section of these proceedings recommend that demographic responses must be investigated if we are to understand the effects of management practices and other perturbations on bird populations. To understand the demography of most populations of Neotropical-Nearctic migrants requires estimates of three parameters: Productivity (defined as the average number of fledglings produced per pair per year), annual survival rate of hatch year (HY) birds, and annual survival rate of adult or after hatch year (AHY) birds. A common approach to a demographic study is to establish one or more study plots and estimate these three parameters simultaneously for a particular local population. However, each of the three parameters needed for these site-specific demographic analyses is difficult to obtain.

Data collection for productivity or fecundity (defined as the average number of female fledglings produced per female per year) estimation is labor intensive, necessitating finding and monitoring nests and following each nest attempt of individually marked adults through the nesting season (Sherry and Holmes, this proceedings). Models now exist that estimate seasonal fecundity based on the sample of nests actually found and monitored without requiring a marked population, provided certain life history parameters are known (Pease and Grzybowski 1995).

The survival rate of HY birds is especially difficult to estimate, because these birds seldom return to their natal site to breed (Greenwood and Harvey 1982). This natal-dispersal will continue to challenge attempts at estimating annual survival for this age class until the ability to monitor between-season movements is improved. As a result, researchers often have employed the largely untested assumption that juvenile survival is half that of adults (e.g., May and Robinson 1985).

Adult survival rate therefore becomes an essential parameter to estimate, and has been estimated using various approaches. The typical approach for local demographic studies is to individually mark birds after capturing them using mist nets. Targeted mist-netting can be used in conjunction with tape recordings and study mounts for the capture of both males and females, while nets can be placed at or on a nest site to capture nesting females that may not respond to tape playbacks. Based on unique color markings, birds are "resighted" rather than physically recaptured during a subsequent breeding season (in contrast, general mist-netting for all species, such as that performed in constant effort mist-netting [DeSante, this proceedings] does not target individual birds for capture and relies upon physical recaptures in a subsequent time period). The ratio of resighted birds to the total number banded the prior year can be used as a "minimum number known alive" estimate

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of survival, historically referred to as the "return rate." However, it is widely recognized that differences in the ability to detect a given bird will vary with researcher effort, resighting technique, and bird behavior, resulting in several biases (Nichols 1986; Lebreton and others 1992; Martin and others 1995). This is one reason why many researchers are analyzing return rate data using extensions of the Cormack-Jolly-Seber (CJS) approach (Cormack 1964; Jolly 1965; Seber 1965) that incorporate the *probability* of resighting a bird (Lebreton and others 1992). The objective of this approach is to arrive at the number of birds that were alive and present on the study plot, but "missed" by the field researcher. If resighting probability is <1, that is, marked birds that are alive and present on the study plot go undetected, return rate will underestimate the true survival rate (Pollock and others 1990; Martin and others 1995).

Field researchers also have recognized that where a particular plot or sampling area is searched for marked birds, the potential exists for birds to disperse from the study area. That is, a marked bird that survives to the next breeding season may not return to the study plot due to between-season breeding dispersal (Greenwood 1980). Numerous between-season, long-distance dispersal events have been recorded (Marshall and others, in review) and many anecdotal observations exist where a color-marked bird is resighted a great distance from the original place of banding. It is unknown how frequently these dispersal events occur, and therefore to what degree this phenomenon will lead to underestimates of true survival. Difficulties posed by nonterritorial birds (floaters) in survival estimation have long been recognized (Nur and others, this proceedings) where birds disperse after initial capture, are not captured again, and are therefore indistinguishable from dead birds. Corrections can sometimes be made by omitting single-caught birds from analyses (Nur and others, this proceedings). A similar situation exists where between-season breeding dispersal results in permanent emigration from the area of a local demographic study. The degree of philopatry exhibited can be affected by a variety of factors, including past reproductive performance at the previous year's breeding site (Robinson and Morse, this proceedings; Marshall and others, in review) and thus attempts at estimating survival become confounded with permanent dispersal.

In this paper, we illustrate that the essential problem with return rate methodology is that the fate of birds which are not resighted is unknown. We discuss the historical use of the term "return rate" and scenarios in which existing terminology is ambiguous and confusing; make suggestions on more consistent terminology; and provide suggestions concerning appropriate parameters to use with different study objectives.

Surviving, Dispersing, and Returning: The Potential Fate of a Color-Marked Bird

Illustrating the possible fates of marked birds, a branching tree diagram (fig. 1) follows a bird through two time periods (years), branching at each point where one of two events could occur. For example, a marked bird could survive (SURVIVED) or die (DIED) during time period t to time period $t + 1$. Similarly, if a bird survives and returns to the study plot, it can be resighted (RESIGHTED) or missed (NOT RESIGHTED). We extend the diagram originally presented by Nur and Clobert (1986) to include the event that a bird could return to the study plot (ON PLOT) or off the study plot (OFF PLOT) the following year.

Examination of figure 1 reveals several important points: (1) there are 13 possible paths or unique event-histories that an individual bird could follow over these two time intervals; (2) of these 13 unique paths, only four separate events are *observable* by the field researcher who either resights (R) the bird or does not resight (NR) the bird in each of the time periods $t + 1$ and $t + 2$; (3) only one of the four observable events, (R-R), is unique in that all of the events that make up that event-history are known; (4) the other three observable events (R-NR, NR-R, and NR-NR) are confounded by the inability of the field researcher to determine whether a bird that is not resighted is dead, alive on the plot but missed, or alive and off the plot; and (5) seven of the 13 unique paths result in the bird *not* being resighted in either time period (NR-NR), but in only *one* of the seven is the bird *actually dead* in both periods.

The associated probability of each event occurring can be assigned to each branch (fig. 1), and a particular event history can be described by its respective cumulative probability. Each observable event, therefore, is the sum of each of the cumulative probabilities that are described by that observable event (table 1). Therefore, we can see that to actually model the true survival rate of the species in question from return rate data, two additional pieces of information are required for which we do not yet have good estimates. The first is the probability of a color-marked bird that was present on the study plot in year t, surviving to year $t + 1$ but not returning to the study plot. This is a recognized (e.g., Lebreton and others 1992; Robinson and others 1995a) but perhaps underappreciated phenomenon in studying migratory passerine bird demography and is likely due to the difficulty in obtaining such estimates. The second and equally difficult piece of information to obtain is the probability that a marked bird that returned to an area *off* plot in year $t + 1$, survives and returns to settle back *on* the study plot in year $t + 2$.

Existing and Suggested Terminology

Although the probability of resighting a bird if it is alive and present on the study area is largely a function of researcher effort, the resighting probability resulting from even the most rigorous of efforts still cannot be assumed to be 1, and will likely vary across species, sexes, habitats, and years (Martin and others 1995). Many capture-recapture software programs exist for modeling "survival" rates and should be used in all cases so that estimates are not biased when capture probability is <1. If sufficient data exist, a fairly complex model with separate parameters for sex, age, habitat, or other independent variables can be supported (e.g., Clobert and others 1988; Lebreton and others 1992).

However, an implicit assumption of these models is that the resulting "survival" estimate includes the complement of

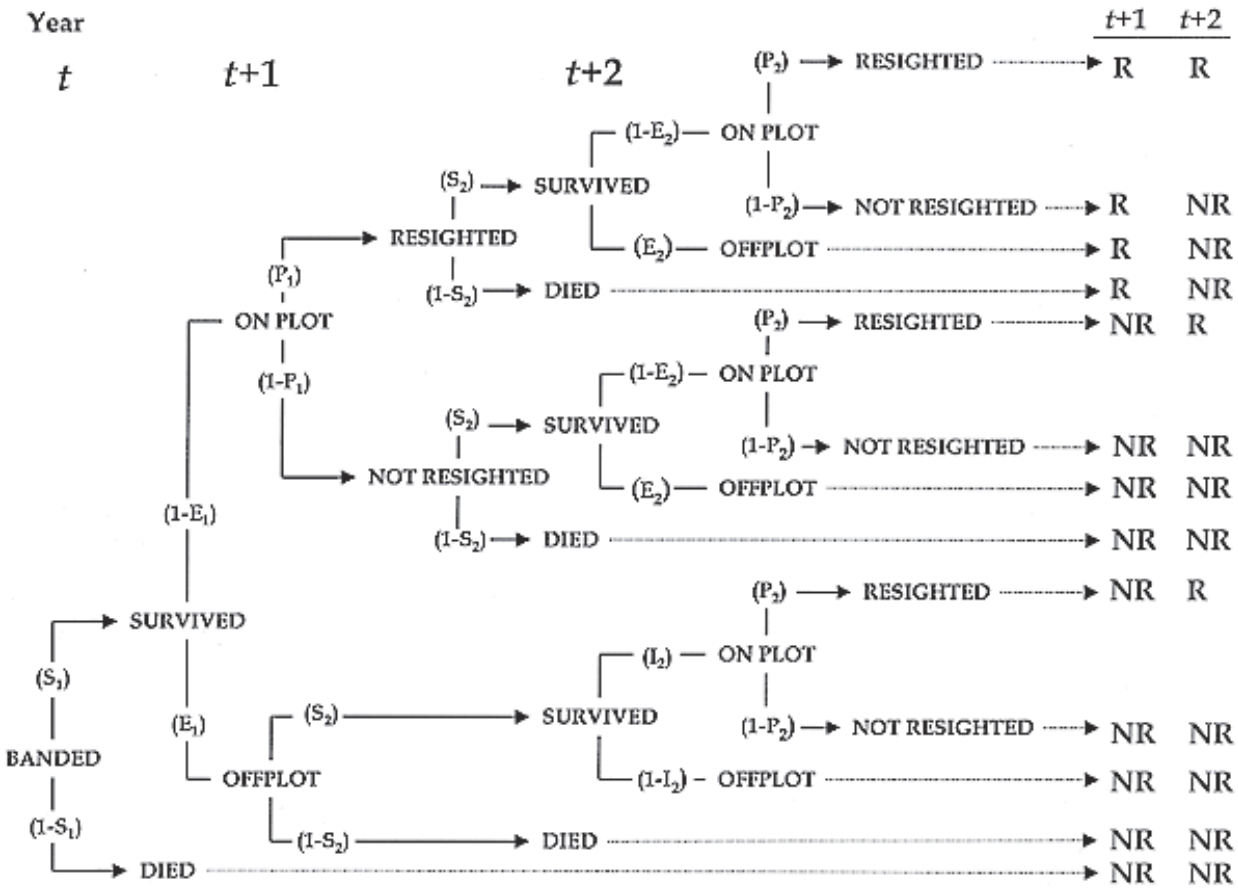

Figure 1—Branching-tree diagram illustrating the potential fate of a marked bird over three time periods. Birds are marked in year *t* and then survive to year *t* + 1 with probability S, emigrate from the study plot with probability 1-E and then, if alive and present on the study plot, are resighted with probability P. The branching continues for a second year, (*t* + 2), generating 13 unique event-histories a marked bird could follow. A marked bird that is off-plot in year *t* + 1 returns to the study plot in the year *t* + 2 with probability I. A field researcher either resights (R) or does not resight (NR) the bird in *t* + 1 and *t* + 2, respectively (the observable events, last column).

Table 1—Summary of each observable event (marked in year *t* and resighted [R] or not resighted [NR] in *t* + 1 and *t* + 2), also expressed as a capture history (1 = resighted, 0 = not resighted), and the number (No.) of unique event-histories that are expressed by each observable event/capture history. The probability associated with a particular capture history is the sum of the cumulative probabilities of the individual event histories (fig. 1) expressed by that capture history.

Observable event			Capture history				
t	*t* + 1	*t* + 2	*t*	*t* + 1	*t* + 2	No.	Cumulative probabilities
Marked	R	R	1	1	1	1	S1(1-E1)(P1)(S2)(1-E2)(P2)
Marked	NR	R	1	0	1	2	S1(1-E1)(1-P1)(S2)(1-E2)(P2) + S1(E1)(S2)(I2)(P2)
Marked	R	NR	1	1	0	3	S1(1-E1)(P1)(S2)(1-E2)(1-P2)+S1(1-E1)(P1)(S2)(E2) + S1 (1-E1)(P1)(1-S2)
Marked	NR	NR	1	0	0	7	S1(1-E1)(1-P1)(S2)(1-E2)(1-P2) + … + S1(E1)(S2)(1-I2) + S1(E1)(1-S2) + (1-S1)

mortality *and* permanent emigration (Lebreton and others 1992). Recognizing that dispersal is an inherent aspect of the ecology of these birds, even "survival" estimates that take into account resighting probability will underestimate true survival if birds disperse beyond the range of the resighting effort. While it is true that "CJS models yield unbiased estimates of survival," it is potentially confusing with regards to site-specific resighting studies, because the estimates are still underestimates of true survival (the complement of actual mortality) if permanent emigration occurs. Even though these estimates are preferable to simple return rates, we cannot estimate true survival from local resighting studies until we can estimate the probability of dispersing "off-plot" and also the probability of settling "back on the plot" in a subsequent year (fig. 1).

We suggest alternate terminology to be used in local demographic studies that should accomplish two tasks. First, the term itself will imply what is actually measured, and second, will modify existing terminology only slightly for clarification.

- *Apparent Return Rate*—Ratio of marked birds that are *resighted* on the study plot in year $t + 1$ to the number banded (i.e., the number that had bands) in year t.
- *Resighting Probability*—Probability of resighting a marked bird given that it is alive and present on the study plot.
- *Return Rate*—Probability model-based estimate of the number of birds that *return* to the *study plot* in year $t + 1$ to the number banded in year t.

What historically has been referred to as Return Rate is now referred to as Apparent Return Rate to imply that this measure reflects only the birds that the field researcher actually encounters. Return Rate should *now* be the result of a model-based estimate that adjusts the Apparent Return Rate by the probability of resighting the marked birds. Here again, we are referring to the rate at which marked birds return *to the study plot*. This term is equivalent to a "CJS estimates of survival," but more clearly implies that we are not estimating true survival, the complement of mortality. To use the term "survival" in the context of local, resighting studies, we must take into account dispersal of marked birds out of and into the study plot (fig. 1).

Implications for Demographic Analyses

True Survival Estimates

Questions involving sex-specific survival, the costs of reproduction, and other aspects of life-history theory require that true survival be estimated. Once the means for separating emigration from mortality are incorporated into sampling designs that measure return rate as a response variable, modeling true survival can be accomplished. Similar model structures already exist for estimating true survival from other sampling designs. These estimates require that a portion of the birds that emigrate from the study plots be captured, resighted, or recovered elsewhere (e.g., Lebreton and North 1993 and references therein). For example, models combining the use of capture-recapture and band recovery data (Burnham 1993) seem promising as more birds are banded nationwide. Multi-state capture-recapture models (Nichols and others 1993), in which capture-recapture/resighting data are collected at a number of isolated breeding sites, also allow estimation of true survival as well as movement rates (e.g., Spendelow and others 1995). The MAPS program (DeSante and others 1995), which uses a constant effort mist-netting approach, is also a means by which true survival estimates can be collected by combining data from a number of trapping locations.

Treatment or Management Effects

If the objective of the study is to compare demographic rates among different treatments, management options, habitats, or other factors, then return rate (modified by capture probability) is a meaningful parameter, because it reflects the multiple ways in which the population may be affected by the factor in question. Hypotheses regarding the effects of a particular treatment still can be tested with meaningful results, as long as it is recognized that the response variable includes both mortality and movements from the study area. One potential problem still exists regarding birds that may temporarily (i.e., for one breeding season) disperse from the study area (fig. 1) in response to a short-term treatment effect. These movements are important to detect, but currently are indistinguishable from birds that were simply "missed" during that year (table 1).

Source-Sink Dynamics

Prompt management decisions often are needed without a complete knowledge of the system, and it may seem that underestimates of true survival are "better" because management recommendations would be more conservative. However, underestimates of survival may result in the misidentification of potential source populations (or at least stable populations) based on the measured reproductive output. Fecundity and/or juvenile survival would have to be greater than what is truly needed to balance an underestimate of adult survival. The problem is twofold, especially when considering that population models are typically female only (May and Robinson 1985) and the potential to disperse from the study is greater for females (Marshall and others, in review). First, birds that are alive, but have dispersed from the study plot, are considered dead in the "survival" component of the equation. Second, these birds are not only alive but *breeding* elsewhere, and their contributions to reproductive success are not included in the fecundity component. Thus we need to either incorporate dispersal from the study plot into the "survival' component, or to add their reproductive contributions to the "fecundity" component. Misidentifying a source population that is sustaining one or several sink populations could have serious conservation implications (Pulliam 1988). Pragmatic conservation recommendations with respect to these sources of uncertainty are discussed in Robinson and Morse (this proceedings) and Sherry and Holmes (this proceedings).

This cautionary note reemphasizes a longstanding recommendation to obtain better information on dispersal probabilities and distances dispersed across species, sex, and age

classes for a better understanding of the population dynamics and conservation needs of long-distance migrant landbirds. Eventually, some of these problems may be solved when radiotelemetry technology allows investigators to closely follow small birds over great distances and long periods of time. Until then, we hope that some of the recommendations made here will help clarify our thinking on this subject.

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The Value of Monitoring Demographic Parameters and Associated Habitat: The BBIRD Program

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Abstract—To simultaneously conserve all species of nongame birds in North America, we need a long-term plan that includes an effective national monitoring program. Effective monitoring programs should provide (1) early warning signals about potential or developing population declines, (2) information on habitat requirements for population maintenance, and (3) information on the potential causes of observed population declines. A program that monitors demographic parameters can potentially meet these 3 criteria. The BBIRD program was established in 1992 as a national avian monitoring program that replicates intensive local studies of avian nesting productivity at sites across North America. After only 4 years, the program has been extremely successful. BBIRD participants have collected data on more than 25,000 nests from 76 BBIRD sites in 28 states, including data on >20 nests for 102 species. Products resulting from BBIRD nesting productivity studies include 24 papers in peer-reviewed journals, 10 technical reports, 5 book chapters, and 11 completed graduate theses/dissertations. The BBIRD program has both a national and local component and serves both a monitoring and research role, and should be instrumental in aiding avian conservation efforts in North America.

One of the ultimate goals of conservation efforts is to maintain regional species diversity by preventing local species extinctions. Preventing local extinctions requires preservation of local habitat features that maintain stable or increasing populations of all indigenous species. This task is challenging in the face of increasing anthropogenic changes to the environment and limited information on the effects of environmental perturbations on populations. Limited financial resources and personnel prevent intensive monitoring of all populations. Consequently, biologists and managers have tried to maintain regional biodiversity by focusing limited resources on conserving species, populations, or habitats at highest risk of declining. This approach is reasonable, but relies on timely identification of populations or habitats at risk. Broad-scale monitoring programs provide one means of identifying populations at high risk of future decline. To be most effective, programs should monitor population parameters that are sensitive to environmental disturbance and that can provide early warning signals indicative of future population decline. Early detection is important because reversing declining population trends can take decades (Green and Hirons 1991).

Monitoring programs also should identify the habitat features associated with healthy populations. Identifying critical requirements for maintenance of each species is necessary to provide managers with specific targets for recovery. This type of detailed data is currently not available for many species of North American birds, but is urgently needed because many populations of migratory birds are declining (Robbins and others 1989b; Askins and others 1990). Population declines are frequently blamed on anthropogenic changes to the environment (e.g., forest fragmentation; Terborgh 1989), which are becoming increasingly common. Ultimately we must preserve the critical habitat requirements of all species, so that in the future we can prevent population declines despite changing land-use patterns. Knowledge of critical habitat features will allow managers to develop local, regional, and national conservation plans with specific recommendations for maintaining healthy populations of coexisting species.

Traditional avian monitoring programs, such as the Breeding Bird Survey (BBS), have focused on estimating trends in species abundance. The BBS has been effective in identifying particular species and specific habitats that have undergone drastic long-term declines (Robbins and others 1989b; but see Bart and others 1995; Thomas and Martin 1996). However, trends in species abundance do not provide information on the potential cause of population declines. To be most effective in conserving species we need to know not only which populations are declining; we also need to know why they are declining so that we can implement appropriate recovery efforts. Indeed, delays in species recovery typically are the result of misidentification of the cause of the decline (Green and Hirons 1991). In summary, an effective national monitoring program would be one that: (1) provides early warning signals about potential or developing population declines, (2) provides information on critical habitat requirements for population maintenance, and (3) provides information on the potential causes of observed population declines. Traditional avian monitoring programs that monitor trends in species abundance do not meet all of these needs (Nichols, this proceedings), and a more effective monitoring program is needed. A national program that includes monitoring of demographic parameters can potentially meet all 3 criteria.

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Detecting Problems Early

Monitoring demographic parameters allows early detection of population problems. Local population size is affected by local demographic parameters, emigration, and immigration. Because immigration rates can vary spatially, monitoring trends in population size alone can not differentiate healthy and unhealthy populations (in a healthy population, local recruitment equals or exceeds annual mortality). Environmental perturbations may negatively affect reproduction or survival, but local population size might still be maintained by immigration from other populations, with the result that local environmental problems may not be reflected in population trends until problems become severe. Alternatively, identifying populations in which local demographic parameters are insufficient to maintain local population size would allow us to identify populations at risk of decline before drastic declines occur.

Identifying Critical Habitat Requirements

Monitoring demographic parameters also provides the opportunity to measure specific habitat features that influence population health. Habitat features that correlate with local demographic parameters are more appropriate targets for management than those that correlate with abundance (Martin 1992a), because immigration contributes to local abundance but is influenced by nonlocal processes. Identifying and managing for habitat features that influence demographic parameters is the best approach for maintaining healthy populations of species.

Identifying Causes of Declines

Finally, monitoring demographic parameters provides information on the causes of population declines. For example, Peregrine Falcon populations were declining in the 1950s due to unknown causes (Hickey 1969). Monitoring reproductive success revealed abnormally low hatching success. Research on the causes of low hatching success ultimately led to the discovery that chemicals in the environment were causing females to produce abnormally thin egg shells (Peakall and others 1975; Peakall 1976). Monitoring population size alone never would have revealed the ultimate cause of Peregrine Falcon population declines. Only through monitoring reproductive success was the cause determined; this knowledge was necessary for effective recovery.

Monitoring demographic parameters meets our 3 criteria for an effective national monitoring program, but which demographic parameters should we monitor? Nesting success and productivity are particularly appropriate because they are relatively easy to estimate (compared to annual survival), provide sensitive barometers of population health, help identify causes of population declines, and allow measurement of specific habitat features associated with local population health. Moreover, variation in reproductive success greatly influences population trends (Temple and Cary 1988; Martin 1993b).

Monitoring avian nesting productivity as a tool to identify and remedy population problems requires a broad geographic scope. This is best accomplished through collaborative partnerships among independent scientists using similar methods. However, bringing scientists across the country together to focus on studies of avian nesting productivity using standardized methods requires an organized effort. The Breeding Biology Research and Monitoring Database (BBIRD) Program was initiated in 1992 to meet this need. BBIRD uses standardized sampling protocols to gather data on nesting success, breeding productivity, and habitat requirements of coexisting nongame birds. BBIRD provides managers with information on habitat requirements and estimates of nesting success and productivity at local, regional, and national scales. BBIRD is a cooperative project with sites across the continent; core sites are located in large forest blocks to minimize the influence of habitat degradation and to provide baseline data on life-history traits within healthy ecosystems. This paper gives a general overview of the BBIRD program, including history, program objectives, methodology, and results produced, and highlights the unique contribution that the program can make toward developing a national conservation plan for nongame birds.

History

BBIRD is organized through the Division of Cooperative Research of the Biological Resources Division of the United States Geological Service, but depends on partnerships with other agencies. Each site is administered by an independent principal investigator to maintain high data quality and facilitate rapid identification, publication, and dissemination of important results from local sites. Data from all sites are merged and maintained in a central repository at the Montana Cooperative Wildlife Research Unit to allow overview analyses of trends and patterns across sites, and to allow individual investigators to query the database to compare their results with other sites.

The BBIRD program was initiated in 1992 with funding from the National Biological Service's Global Change Program for a 4-year feasibility study. Initial funding was for 8 BBIRD sites, and the objectives of the feasibility study were to:

- Develop standardized national sampling protocols for monitoring demographic and associated habitat parameters of nongame birds.
- Determine the feasibility of coordinating a national program for monitoring avian breeding productivity.
- Determine whether sufficient scientific interest and partnerships could be generated to provide additional and continued funding for program expansion.
- Estimate variance in reproductive parameters to determine sample sizes needed to make comparisons across habitats, management treatments, or environmental gradients.
- Develop a national database and computing center to house data and disseminate results.

After 4 years, the BBIRD program has been extremely successful, and has gone beyond the objectives of the feasibility study. We have worked closely with program participants to establish nationally recognized sampling protocols and guidelines (Martin and Geupel 1993b; Martin and

others 1997). The BBIRD Field Protocols (Martin and others 1997) is a 64-page illustrated document with detailed procedures for plot selection, marking plots, finding and monitoring nests, conducting point counts, measuring vegetation, calculating nesting success, and submitting data. BBIRD Field Protocols help others design and implement large-scale manipulative and mensurative experiments to investigate how breeding birds are affected by different treatments. The Field Protocols are requested by approximately 200 managers and researchers annually, and provide a benchmark for approaches to nesting productivity studies. Field Protocols are now available on the BBIRD home page (http://pica.wru.umt.edu/bbird), and users are able to download several word processor-compatible versions.

We have demonstrated the feasibility of a national program for monitoring nesting productivity through rapid growth, participation, and research products. Participants have collected data on more than 25,000 nests from 76 BBIRD sites in 28 states, including data on >20 nests for 102 species (table 1). Substantial data for many species already are available from multiple BBIRD sites, which allows comparisons of nesting productivity across sites (table 1). Most data are from BBIRD sites in eastern hardwood forests; more sites are needed to expand coverage and scope of inference. More than 100 partners have provided funding for one or more BBIRD sites, including federal, state, and local government agencies, universities, nongovernmental conservation organizations, industry, and private foundations. Funding exceeds 2 million dollars annually for all sites combined. An annual meeting is well attended, and offers a unique forum for collaboration and data-sharing. One-half day is devoted to presentation of research results by participants, and 1.5 days are devoted to discussing sampling and analytical issues and suggesting new directions. Annual minutes of the meeting are distributed to all BBIRD participants.

BBIRD studies have been very productive in both research and education. In only 5 years, products resulting from BBIRD nesting productivity studies include 23 papers in peer-reviewed journals, 5 book chapters, 11 technical reports/monographs, and 11 completed graduate theses/dissertations (see BBIRD home page). These published results of data from individual BBIRD studies demonstrate that sample sizes are sufficient to gain valuable research results at each site and to make valuable comparisons among habitats, management treatments, and environmental gradients (e.g. Martin 1993a; Donovan and others 1995b; Robinson and others 1995b; Hejl and Paige 1994; Petit and Petit 2000).

All monitoring programs should address potential biases of the techniques used. We have begun to address one potential bias of estimating nesting productivity from our nest monitoring program. Within a species, individuals may vary in the caution with which they approach their nest. If nests of less-cautious individuals are more likely to be found by both nest searchers and predators, we might underestimate true nesting productivity. By recording a behavioral index based on the caution with which each individual approaches its nest, and comparing nesting success and habitat features between cautious and less-cautious indi-

Table 1—Number of nests currently in the BBIRD database for species in which ≥20 nests were found at ≥ 1 BBIRD site, 1992-1996.

Species	Total no. nests	No. sites with ≥20 nests
Broad-winged Hawk	□21	1
Wild Turkey	□25	□0
Mourning Dove	□140	1
Yellow-billed Cuckoo	114	3
Whip-poor-will	28	0
Ruby-throated Hummingbird	32	0
Northern Flicker	476	3
Yellow-bellied Sapsucker	208	1
Williamson's Sapsucker	252	1
Red-naped Sapsucker	284	4
Red-bellied Woodpecker	32	0
Downy Woodpecker	100	1
Hairy Woodpecker	137	1
Acorn Woodpecker	45	1
Eastern Wood-pewee	51	1
Western Wood-pewee	274	4
Eastern Phoebe	99	1
Eastern Kingbird	33	1
Least Flycatcher	496	3
Acadian Flycatcher	2637	24
Dusky Flycatcher	168	2
Cordilleran Flycatcher	372	1
Willow Flycatcher	40	1
Violet-green Swallow	54	1
Scrub Jay	49	1
Blue Jay	35	0
Stellar's Jay	22	1
Black-billed Magpie	29	1
American Crow	22	0
Carolina Chickadee	43	1
Black-capped Chickadee	146	1
Mountain Chickadee	435	4
Chestnut-backed Chickadee	33	1
Plain Titmouse	41	1
Tufted Titmouse	22	0
Wrentit	82	1
Bushtit	112	1
White-breasted Nuthatch	131	1
Red-breasted Nuthatch	464	4
Pygmy Nuthatch	346	1
Brown Creeper	202	3
House Wren	799	3
Carolina Wren	36	1
Winter Wren	109	1
Ruby-crowned Kinglet	30	1
Blue-gray Gnatcatcher	176	2
Eastern Bluebird	61	1
Western Bluebird	101	2
Wood Thrush	1734	19
Veery	192	3
Swainson's Thrush	53	1
Hermit Thrush	543	3
Bicknell's Thrush	21	0
American Robin	1019	5
Gray Catbird	91	1
Cedar Waxwing	136	2
European Starling	38	1
White-eyed Vireo	87	1
Solitary Vireo	254	4
Red-eyed Vireo	1092	10
Warbling Vireo	455	3

(con.)

Table 1 (Con.)

Species	Total no. nests	No. sites with ≥20 nests
Prothonotary Warbler	23	0
Orange-crowned Warbler	438	1
Virginia's Warbler	239	1
Black-thr. Blue Warbler	84	1
Black-thr. Green Warbler	44	1
Blackpoll Warbler	63	1
MacGillivray's Warbler	113	2
Yellow-rumped Warbler	230	2
Black-and-white Warbler	129	2
Yellow Warbler	1120	2
Kentucky Warbler	158	4
Hooded Warbler	635	10
Worm-eating Warbler	392	6
Pine Warbler	79	1
Prairie Warbler	112	1
Louisiana Waterthrush	33	0
Ovenbird	966	11
Common Yellowthroat	59	1
American Redstart	203	3
Red-faced Warbler	260	1
Yellow-breasted Chat	224	2
Scarlet Tanager	168	2
Western Tanager	235	2
Summer Tanager	39	1
Northern Cardinal	448	3
Rose-breasted Grosbeak	97	1
Black-headed Grosbeak	194	3
Indigo Bunting	520	4
Green-tailed Towhee	340	2
Spotted Towhee	94	1
Eastern Towhee	30	1
Song Sparrow	279	3
Chipping Sparrow	127	2
White-crowned Sparrow	41	1
Lincoln's Sparrow	20	1
Fox Sparrow	39	1
Field Sparrow	88	1
Dark-eyed Junco	639	5
Red-winged Blackbird	44	1
Bullock's Oriole	62	1
American Goldfinch	23	1

viduals, we will be able to evaluate the magnitude of this potential bias.

We have established a national database and computing center at the University of Montana. The computing center includes a work station and networking software, and the data are stored in a relational database. A full-time program manager works with participants to submit their data in proper format, merges incoming data files, and handles data requests.

Program Objectives

After successfully meeting the goals of the 4-year feasibility study, we revised the program objectives based on initial results and national conservation needs. Current BBIRD objectives are to:

- Provide baseline data on nesting productivity of species in minimally disturbed environments.
- Develop models of habitat needs for healthy populations of coexisting species.
- Use models to assess suitability of habitat conditions for sustaining bird diversity under varying land management and disturbance regimes.
- Examine distributional and demographic responses to temporal and spatial climate changes to project long-term responses to global climate change.
- Identify species' breeding habitat requirements.
- Use habitat information to recommend specific management solutions to maximize probability of reversing declining population trends prior to species listing under the Endangered Species Act.

BBIRD Methodology

BBIRD replicates intensive local studies of avian nesting productivity at sites across North America. Nests of all or focal bird species are located and monitored to provide productivity data on coexisting species. BBIRD sites are either funded or volunteer sites. Funded sites follow BBIRD protocols (Martin and others 1997) completely. Volunteer participants use BBIRD protocols to the greatest extent possible. The minimum requirement for participation in the program by volunteers is data on nesting productivity and sources of nesting mortality. However, measurement of vegetation associated with nest sites also is a critical element and is strongly encouraged. Point counts are included whenever possible to provide estimates of local trends in species abundance.

Plot Location and Establishment

Each BBIRD site includes replicate plots, the size and number of which vary depending on local objectives and productivity of the habitat. A sufficient number of nest plots should be established so that field personnel find at least 20 nests per year, in a single treatment/habitat type, of each of the most common local species. In eastern hardwood forest this is typically about eight 35-50 ha plots, while in productive western riparian sites, eight 10-20 ha sites might be sufficient. These are only guidelines. The success with which BBIRD participants find nests varies, because: Species vary in nesting density and the ease with which their nests are located; field workers vary in nest-finding ability; and habitats vary in accessibility and species diversity (Hejl and Holmes, this proceedings). Densely vegetated habitats with low nesting densities may require greater numbers of plots or additional nest searchers. Investigators initiating new BBIRD sites need to ensure that they have enough plots and trained personnel to find suitable numbers of nests to address their local study objectives.

Nest Location and Monitoring

Nest searching and monitoring protocols follow methods outlined in Martin and Geupel (1993b) and Martin and others (1997). Plots are searched for nests every 2 days, and

individual nests checked every 3-4 days. Each BBIRD site typically has 4-10 volunteers, technicians, and graduate students working in the field each summer. Each full-time technician can effectively monitor 2 nest plots, visiting each plot every other day. Some cooperators choose to focus their effort on a few common "focal" species when locating and monitoring nests (Hejl and Holmes, this proceedings). Focusing on focal species allows a cooperator to address a specific question of local interest using a few representative species for which almost all active nests within the study plots can be located and monitored intensively.

Vegetation Measures at Nests and Nonuse Sites

Vegetation sampling methods are currently established for forest and grassland habitats. Forest vegetation sampling is similar to methods described by Martin and Roper (1988) and Martin (1993b) with some modifications (Martin and others 1997). Habitat features are measured within 5- and 11.3-m radius circular vegetation plots centered on each nest and a nonuse site adjacent to each nest. Vegetation is measured at nonuse sites to determine which patch (5 and 11.3-m scale) characteristics influence nest site selection (BBIRD participants decided to discontinue measuring vegetation at nonuse sites at the 1996 annual cooperators' meeting). Shrub and sapling stems are counted by species, and ground cover and litter depth are estimated in the 5-m radius plot. Trees are counted by species, and canopy cover and height are estimated in the 11.3-m radius plot. The number of stems of each tree species is counted for various size classes.

Territory Maps of Nest Plots

Some BBIRD participants create territory maps for each species. Nest searchers visit nest plots every other day throughout the breeding season and hence can effectively make territory maps of each plot. Territory maps provide measures of species abundance, and allow participants to estimate proportion of territories for which nests were found for each species. These data also can be used to estimate pairing success of territorial males.

Point Count Surveys of Nest Plots

Point count surveys are conducted to index spatial and temporal differences in population size. We use 10 minute, 50-m fixed-radius point counts. All birds detected beyond 50 m are also recorded to provide total number detected for each species. BBIRD sites typically include 8-12 point count plots within each nest-search plot. Each point is separated by 200 m and point counts are surveyed 3 times per season.

Vegetation at Point Count Survey Plots

Vegetation is measured at 4 subplots within each 50-m radius point count plot. Each subplot consists of a 5- and 11.3-m radius circle identical to vegetation circles on nest plots.

Results

With this standardized methodology and program design, BBIRD data can provide answers to a variety of important questions that are essential for designing effective conservation efforts. The sampling design of the program allows us to make both between- and within-site comparisons. Consequently, results from the BBIRD program can provide important information for managers at local, regional, and national levels (Johnson, this proceedings; Nichols, this proceedings). Because of the standardized methodology, comparisons across multiple BBIRD sites allow examination of broad landscape-scale conservation questions that previously were impossible to address with scientists working independently at single sites using different methodologies. For example, examining the effect of forest fragmentation on bird populations requires a large number of replicate plots in both fragmented and non-fragmented landscapes distributed across a large geographic region. By incorporating data across sites using similar methods into a meta-analysis (Gurevitch and Hedges 1993; Johnson, this proceedings), BBIRD cooperators can begin to address these large-scale questions. Indeed, comparison across sites has provided the best test of the effects of forest fragmentation on avian nesting productivity (Robinson and others 1995b). Replication of studies in space and time is considered far more important than replication within a study for examining the effect of a management treatment (Hawkins 1986; Johnson, this proceedings). Robinson and others' (1995b) analysis is a good example of the important questions that can be addressed by regional comparisons among a large number of replicate sites.

At a regional scale, BBIRD data can be used to identify potential "source" and "sink" populations (Pulliam 1988) by comparing estimates of nesting success and productivity among sites. Areas or habitats with comparatively high nesting productivity can be targeted for preservation efforts, while areas or habitats with low nesting productivity can be targeted for more active conservation and management efforts to increase regional population health. Identifying and preserving healthy populations and employing proactive management strategies in areas with unhealthy populations are essential steps for making efficient use of limited resources in developing and implementing effective regional conservation plans.

In addition to providing national and regional results, the BBIRD program also has a within-site component. Most monitoring programs (e.g., BBS, MAPS) require pooling data across a wide diversity of sites to provide statistical inference. BBIRD is unique in that individual sites also can provide strong statistical inference to evaluate effects of local management actions. Consequently, the program can address national and local goals simultaneously. Within many sites, investigators can make statistically valid comparisons of differences in demographic parameters across years, species, environmental gradients, habitats, management practices, or treatments (e.g., Cooper and others, this proceedings). Indeed, local experiments to investigate functional relationships between population parameters and environmental

variables are essential for effective management, and this approach is far superior to correlative retrospective analyses (Nichols, this proceedings). These local studies will help us understand the environmental factors influencing variation in breeding success and population health across a species range. Local objectives of individual BBIRD sites include:

- Examining the effects of forest fragmentation on population health by measuring variation in nesting success. Investigators are examining the effect of distance to clearcut edge and the amount of forest cover in the surrounding landscape on the probability of nest predation and parasitism.
- Examining the effects of silvicultural treatments on abundance and nesting productivity of forest bird communities.
- Examining the effects of climate on nesting productivity. Comparisons across years within several sites have demonstrated that clutch size, nesting success, and probability of renesting can vary with climate.
- Examining habitat suitability and population dynamics of selected focal species of local management or conservation concern.
- Examining the habitat factors influencing the probability of nest parasitism by brown-headed cowbirds.

These are just a few examples of the local objectives being addressed by BBIRD studies. This local component to the BBIRD program produces research results that help local and regional managers make decisions that might help mitigate the effects of local land-use practices on avian populations. Thus, partners contributing to a BBIRD site are not only contributing to a national monitoring program, but can also obtain information needed to improve local management efforts.

In summary, the BBIRD program has both a national and local component, and serves both a monitoring and research role in developing short- and long-term management plans. Consequently, the BBIRD program is designed to serve a vital role in aiding avian conservation in North America. As the BBIRD program continues to grow, the wealth of data at both local and national scales undoubtedly will enhance our ability to effectively manage and conserve avian populations in North America.

Using BBIRD Methodology in a Logistically Constrained Study

Sallie J. Hejl
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Abstract—One of the goals of the Breeding Biology Research and Monitoring Database (BBIRD) program is to examine the effects of management and other anthropogenic disturbances on avian breeding productivity. The BBIRD program relies on a network of cooperators using standardized sampling protocols to find and monitor the nests of all species or a subset (focal group) of species in an area. In a study of fragmentation effects on forest birds, we initially used the community-level BBIRD approach, finding and monitoring nests of as many species as we could. From 1992-1994, we found twice as many nests in the second year (152 nests of 27 species) and third year (140 nests of 23 species) as in the first year (65 nests of 15 species), but in most cases, we found insufficient numbers per species to make good inferences. In general, we found more nests of common than of uncommon species, but we could not easily find nests of all of the common species. Cavity nests and enclosed nests generally were easier to find than open-cup nests, but nests of most species took large amounts of time to monitor. Each observer was able to monitor from 10 to 15 nests per day. In 1995, we realized that to get good information on nesting productivity in these habitats, we either had to hire more people to cover more plots, or to focus on fewer species. We decided to focus on two old-growth associates, with a primary emphasis on Winter Wrens (*Troglodytes troglodytes*) and a secondary emphasis on Brown Creepers (*Certhia americana*), resulting in our finding 51 wren and 13 creeper nests. We also colorbanded these species to obtain data on pairing success, probability of renesting, number of broods per season, and return rates. In addition, colorbanding helped us confirm that we had obtained most of the wren nests in each area and were able to minimize a potential bias in nest success studies: that of discovering only easy-to-find nests. We obtained good information on Winter Wrens, and minimal information on Brown Creepers. Our study illustrates that breeding productivity studies are labor intensive and often encounter budgetary and other logistic constraints (e.g., low nest densities and difficult habitat in which to work). In addition, when trying to address landscape-level questions, such as the effects of fragmentation, locating accessible replicate plots of rare habitat can be difficult. Even for the most common species in cedar/hemlock old-growth forests, replicate plots are essential for obtaining sufficient sample sizes of nests to test hypotheses. We agree with current BBIRD recommendations that suggest eight 35-50 ha plots/treatment for areas with low nest density. We found that our habitat required one person/50-ha plot to find most nests of focal species and to monitor those nests. Thus, we would need 16 field assistants for an ideal expanded study comparing nesting success in fragmented and continuous forests, in which we would expect to find about 20 nests per treatment per year for each of five focal species. When limited by constraints such as ours, we suggest that researchers focus on one to five focal species. If focusing on a few species, then colorbanding individual birds to examine additional aspects of population dynamics also may be possible.

Anthropogenic disturbances have significantly altered historical landscapes throughout North America since European settlement (Askins and others 1990; Hejl 1994). These changes have presumably affected the bird species associated with habitats and landscapes that were once previously governed by "natural" presettlement processes (Hejl 1992; Hejl, this proceedings). Birds can be sensitive indicators of environmental changes (Furness and Greenwood 1993) and many forest birds, in particular, have been affected by anthropogenic disturbances (Askins and others 1990; Freemark and others 1995; Hejl and others 1995).

Anthropogenic disturbances continue to occur, and managers who are interested in producing commodities while maintaining healthy populations of birds want to know how specific management actions will affect birds. In the past, most studies on the effects of management actions compared bird distribution and abundances in disturbed and undisturbed areas (Hejl and others 1995; Hejl, this proceedings). From these comparative studies, researchers hoped to find indications of whether and how management actions affect certain bird species. In more detailed studies of bird habitats, based on correlations between bird presence or abundance and habitat features, researchers hoped to find key elements that species require. Both comparative and bird-habitat relationship studies use presence or abundance data as an indication of whether a species is affected by a management action or not. These response variables, however, do not necessarily reflect breeding productivity, and give no indication of whether sampled birds are members of healthy populations (Van Horne 1983) or are located in sink habitats, wherein productivity of a species is insufficient to maintain a viable population without the immigration of new individuals from healthy populations (Pulliam 1988).

According to Martin (1992a), measures of breeding productivity are more appropriate metrics for examining the effects of management actions on bird populations. The Breeding Biology Research and Monitoring Database (BBIRD) program was initiated to encourage studies of breeding productivity using standardized sampling protocols that allow

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geographic and temporal comparisons (Martin and others 1997). One goal of this national monitoring program is to better evaluate the effects of forest management practices on population health for many avian species throughout their ranges.

The BBIRD program includes a network of cooperators using standardized sampling protocols (Martin and others 1997). General BBIRD methodology includes: (1) using randomly located (when possible) replicate plots of the habitats or treatments of interest; (2) conducting point counts to obtain bird distribution information across the plots; (3) finding and monitoring nests of all species or focal species to obtain nesting success information; and (4) sampling vegetation throughout the plots, at survey points, at nest sites, and at nonuse sites. Although not part of the protocol, banding birds for the purpose of survival estimation also is encouraged. In general, BBIRD data document the distribution of birds and nesting success in relation to different habitats and vegetation features.

Nesting success is one of the primary factors influencing population trends in birds. Other important demographic factors include immigration/emigration, pairing success, propensity to renest, number of young fledged per nest, number of broods per season, adult survival, and juvenile survival. BBIRD protocols do not include all of these parameters, although Martin (1992a) suggests estimating them to obtain a more complete picture of the demography of a species in an area or habitat.

We were interested in the effects of fragmentation resulting from clearcutting on bird distribution and productivity in old-growth western redcedar (*Thuja plicata*)/western hemlock (*Tsuga heterophylla*) forests and began using BBIRD monitoring protocols in 1992. We had hoped to find at least 20 nests per treatment (in unlogged and logged forests) as recommended by Hensler and Nichols (1981) and Martin and Geupel (1993a) as a minimally adequate estimate of nesting success using Mayfield estimators (Mayfield 1975). In this paper, we describe our use of community-level BBIRD methodology (trying to find nests of all species) in cedar/hemlock forests and the series of modifications we subsequently made in order to increase our sample sizes of nests, thus increasing our ability to accurately measure effects of the treatment we examined. Our goal is to aid present and future cooperators using BBIRD and related methods in designing and conducting research on breeding bird productivity. We also discuss how colorbanding individual birds complemented our use of BBIRD protocols and will increase our knowledge of the effects of forest fragmentation on specific demographic parameters.

Methods

We had two primary study sites: (1) an area composed of recent clearcuts embedded in a matrix of old-growth forest (the Distillery Bay Timber Sale on the Priest Lake Ranger District, Idaho Panhandle National Forests) and (2) a continuous block of old-growth forest (Teepee Creek and Bottle Lake Research Natural Areas on the Priest Lake Ranger District, Idaho Panhandle National Forests). We had two plots in each of the two locations. Plot size changed from 25 ha in 1992 to 50 ha in 1993, because we realized we needed to search in as large an area as one person could adequately cover.

We followed BBIRD protocols (Martin and others 1997) in these areas for three years (1992-1994): We conducted point counts, searched for nests, and monitored nesting success of all nests located in each area. We had four primary nest searchers each year. We searched for nests in May and June in 1992, May through early July in 1993, May through mid-July in 1994, and mid-April through mid-July in 1995. During 1992, each observer shared two plots with one other observer. After 1992, each person had one plot for which s/he was responsible. Three of the nest searchers conducted point counts one or two times per week, and they searched for nests the other days in 8- to 10-hr days in a five-day workweek. One to three others helped intermittently to search for nests each year. Budget constraints required that observers stop nest-finding in early to mid-July to complete vegetation sampling for nests and nonuse sites. A separate three-person field crew measured the general vegetation throughout the study sites each summer.

In 1994, we attempted to increase the number of nests found per species by focusing on searching for nests of five focal species: Red-naped Sapsucker (scientific names listed in table 1), Chestnut-backed Chickadee, Red-breasted Nuthatch, Brown Creeper, and Winter Wren. We chose these species because we predicted they might be vulnerable to fragmentation and we previously had been successful in finding their nests. We also continued to look for nests of other species but with less effort.

In 1995, we realized that to get good information on productivity in these habitats, we had to increase search effort either by increasing the number of searchers or by focusing on fewer species; we chose the latter. The point count information obtained as part of the BBIRD protocol from 1992-1994 (Hejl and Paige 1994; see table 1 for 1992 point counts) and a literature search on forest fragmentation indicated that Winter Wrens and Brown Creepers were two of the species most likely to be negatively affected by the type of forest fragmentation in our area. Therefore, in 1995, we decided to focus on Winter Wrens and Brown Creepers, emphasizing the wrens. We also monitored any Chestnut-backed Chickadee nests that we found in our searches for wren and creeper nests. In addition, we attempted to band all the Winter Wrens and Brown Creepers in the study areas. In 1996 and 1997, we resighted banded wrens on our plots.

Results

In 1992, we found 65 nests of 15 species (table 1). In 1993, we found 152 nests of 27 species. As expected, we found more total nests in 1993 due to a better understanding of potential nest locations and nesting phenology of each species, larger plot sizes, plot ownership (one person/plot), extending the nest-searching time into July, and an unusually competent field crew. However, we found less than 20 nests per species per treatment even after pooling data from both years.

In 1994, when we focused on searching for nests of five focal species, we found 140 nests of 23 species (table 1). While we found more nests of Winter Wrens, we did not find any more nests of the other focal species, and we still had low

Table 1—Number of nests found for each species by year and area (forests fragmented by clearcuts = Frag and continuous forest = Unfrag) as compared to point count results from 1992 (Hejl and Paige 1994) in cedar/hemlock forests in northern Idaho ("—" indicates not sampled in 1995).

	1992 counts		1992 nests		1993 nests		1994 nests		1992-1994 nests		1995 nests	
Species	**Frag**	**Unfrag**	**Frag**	**Unfrag**	**Frag**	**Unfrag**	**Frag**	**Unfrag**	**Frag**	**Unfrag**	**Frag**	**Unfrag**
American Kestrel (*Falco sparverius*)	0.07	0.00	2	0	0	0	0	0	2	0	—	—
Calliope Hummingbird (*Stellula calliope*)	0.00	0.00	0	0	1	1	0	0	1	1	—	—
Rufous Hummingbird (*Selasphorus rufus*)	0.00	0.03	0	0	4	1	1	1	5	2	—	—
Red-naped Sapsucker (*Sphyrapicus nuchalis*)	0.22	0.08	7	3	10	1	8	2	25	6	—	—
Hairy Woodpecker (*Picoides villosus*)	0.08	0.08	1	1	1	1	1	1	3	3	—	—
Three-toed Woodpecker (*P. tridactylus*)	0.00	0.00	0	0	1	1	2	0	3	1	—	—
Northern Flicker (*Colaptes auratus*)	0.07	0.01	4	0	1	0	2	0	7	0	—	—
Pileated Woodpecker (*Dryocopus pileatus*)	0.07	0.07	0	0	1	0	1	0	2	0	—	—
Dusky Flycatcher (*Empidonax oberholseri*)	0.10	0.07	0	0	1	0	1	0	2	0	—	—
Tree Swallow (*Tachycineta bicolor*)	0.00	0.00	0	0	0	2	0	1	0	3	—	—
Common Raven (*Corvus corax*)	0.13	0.03	0	0	1	0	1	0	2	0	—	—
Chestnut-backed Chickadee (*Parus rufescens*)	0.60	0.51	7	4	6	5	4	7	17	16	3	3
Red-breasted Nuthatch (*Sitta canadensis*)	0.72	0.56	4	4	17	9	16	5	37	18	—	—
Brown Creeper (*Certhia americana*)	0.21	0.57	3	3	6	2	2	5	11	10	4	9
Winter Wren (*Troglodytes troglodytes*)	0.40	0.92	1	2	6	5	8	21	15	28	18	33
Golden-crowned Kinglet (*Regulus satrapa*)	0.38	0.69	1	0	0	3	0	0	1	3	—	—
Mountain Bluebird (*Sialia currucoides*)	0.00	0.00	0	0	4	0	0	0	4	0	—	—
Townsend's Solitaire (*Myadestes townsendi*)	0.19	0.00	1	0	1	0	0	0	2	0	—	—
Swainson's Thrush (*Catharus ustulatus*)	0.36	0.76	2	0	4	4	1	4	7	8	—	—
Hermit Thrush (*C. guttatus*)	0.06	0.10	0	1	1	4	2	3	3	8	—	—
American Robin (*Turdus migratorius*)	0.43	0.01	3	0	7	0	6	0	16	0	—	—
Varied Thrush (*Ixoreus naevius*)	0.36	0.57	0	0	2	0	0	1	2	1	—	—
Yellow-rumped Warbler (*Dendroica coronata*)	0.50	0.22	0	0	2	1	1	0	3	1	—	—
Townsend's Warbler (*D. townsendi*)	0.67	0.43	0	0	0	0	1	0	1	0	—	—
Northern Waterthrush (*Seiurus noveboracensis*)	0.00	0.00	0	0	0	1	0	0	0	1	—	—
MacGillivray's Warbler (*Oporornis tolmiei*)	0.15	0.04	0	0	0	0	1	0	1	0	—	—
Western Tanager (*Piranga ludoviciana*)	0.21	0.06	0	0	2	0	1	0	3	0	—	—
Chipping Sparrow (*Spizella passerina*)	0.25	0.03	2	0	10	1	2	0	14	1	—	—
Dark-eyed Junco (*Junco hyemalis*)	1.22	0.64	7	2	15	5	14	13	36	20	—	—
Evening Grosbeak (*Coccothraustes vespertinus*)	0.00	0.00	0	0	1	0	0	0	1	0	—	—
Total			45	20	105	47	76	64	226	131	25	45

numbers of nests per species in each treatment. Furthermore, even after pooling across all three years, we had greater than or equal to 20 nests per treatment for only one species, the Dark-eyed Junco, not a focal species. After three years of study and as a result of low sample sizes, we had not yet obtained adequate estimates of nesting productivity for the focal species in our habitats, according to the suggestions of Hensler and Nichols (1981).

By concentrating on one species in 1995 and making a special effort to learn the behaviors of this species, we came close to finding enough nests of the difficult but, for our habitat, fairly abundant Winter Wren (18 in fragmented forests and 33 in continuous forests). In addition, in 1995, we successfully banded all male and about half the female Winter Wrens. For the Brown Creepers, our secondarily emphasized species, we were able to find only 13 nests and band a small subset of the individuals.

Banding the birds did take time away from nest finding. However, it helped us to focus our nest searches based on observations of banded adults, and also helped us confirm that we had found most of the wren nests in both areas. We were able to avoid a potential problem in nesting success studies—that of discovering only easy-to-find nests. In addition, from the data obtained from colorbanding individual birds, we will be able to examine density, site tenacity, pairing success, propensity to renest, number of broods per season, adult survival, and territory size and quality, as well as nesting success and number of young fledged per nest for the Winter Wrens in our study. We will not be able to determine juvenile survival, because we chose not to remove nestlings from their delicate nests, partly for fear of influencing predation. We do not have enough data to examine these factors for Brown Creepers.

In general when we used community-level BBIRD methodology, more nests were found of the more common (e.g., greater than 0.20 individuals/point count in an area) than of the uncommon species every year (table 1). Yet, we could not easily find nests of all of the common species. We found only a few nests for some of the common species. Cavity-nests and enclosed nests generally were easier to find than open-cup nests, but nests of most of our species took large amounts of time to monitor. Each observer was able to monitor from 10 to 15 nests per day in our forests. In general, using BBIRD methodology to assess breeding productivity was practical for only some of the most common species in our forests.

Discussion

It is difficult to assess the effects of anthropogenic disturbances on bird populations by using presence/absence or abundance data alone (Martin 1992a). The BBIRD program was established to identify habitat conditions affecting breeding bird productivity, providing a general methodology for researchers and managers (Martin and others 1997). Our study illustrates that breeding productivity studies are relatively intensive and have the potential to encounter certain logistic constraints in the following areas: (1) budget, including how many people one can hire, transport, and house; (2) availability of the habitat of concern, including sufficient number of replicate areas of adequate size, proximity, and accessibility; (3) structural characteristics of the habitat of interest; and (4) characteristics of the birds in the habitat, including the density of the species and the behavior of the birds and hidden nature of the nests.

Many factors contributed to our small sample size of nests: (1) we had few nesting plots (only two per habitat condition); (2) the density of individuals within species was low (i.e., an average of 9 territories per 50-ha plot of continuous forest for Winter Wren, our second-to-most abundant species); (3) it was often very time consuming to move between nests (traveling between nests usually consisted of hiking 100 to 400 m over large logs in rugged terrain) and to monitor nests (a majority of the nests were cavity nests, which can commonly take 0.50 to 1 hr to confirm activity during a visit); (4) the vegetation was structurally complex and had a very high canopy (30-60 m), resulting in difficulty locating and following individuals; (5) the physical conditions were often dark and rainy, hindering nest finding; and (6) many of the species had cryptic behavior and nests. The relative importance of each factor in determining the probability of finding an active nest varies across species. For example, cryptic behavior and nest placement (tree canopy) limited our ability to find nests of abundant species such as Golden-crowned Kinglet and Townsend's Warbler (compare point count results with nest numbers in table 1). Height of four kinglet nests ranged from 11 to 27 m in 27 to 43 m tall trees. Alternatively, many of the species' for which we could find nests fairly easily have relatively large territories (Northern Flicker territories are 16 ha in mature conifer forest [Lawrence 1967]), resulting in few total nests found because only about 100 ha were thoroughly covered in each habitat condition.

When using BBIRD methodology to monitor nests of all coexisting species, those with hard-to-find nests (even fairly common species) are likely to be undersampled. For example, the Winter Wren was one of the most abundant species recorded during point counts in continuous old growth (Hejl and Paige 1994), yet we found relatively few active nests in 1992 (table 1). Winter Wrens are cryptically colored and secretive, and they build multiple, well-concealed nests in a variety of nesting substrates each year. Due to the diversity of nesting locations, it took a relatively long time to develop search images for wren nests. In addition, only some of the nests that are built in a year are used in that particular year (e.g., of 101 wren nests found in 1995, only 51 were active that year). Because we originally were trying to get as much information as we could on as many species as possible, nest searchers would often abandon more difficult searches, such as those for Winter Wren, and focus on other species. By concentrating on Winter Wrens in 1995 and making a special effort to learn the behaviors of this species in previous years, we came close to finding 20 nests of the difficult but fairly abundant Winter Wren in each treatment that year.

Once an individual observer had found many nests, the act of monitoring nests became a bigger time commitment than searching for nests. Nests of most of our species took large amounts of time to monitor. The contents of most cavity nests, many enclosed nests, and high open-cup nests could not be directly observed. As a result, observers used adult behavior around the nest to determine nest activity and fate. For many of our species, nest monitoring required from 30 to 60 min to determine nest stage during each visit. Because of the amount

of time we had to spend monitoring each nest and the distance and difficulty in the terrain among nests, any one observer was able to monitor from 10 to 15 nests in a day in a 50-ha plot. The amount of time it took to monitor nests in these cedar/hemlock forests was not necessarily unusual for conifer forests. In a similar study examining the effects of salvage-logging on cavity-nesters in post-fire coniferous forests, one person could successfully monitor 7 to 12 nests per day (SJH, unpublished data). In addition, in cedar/hemlock forests, we found many ultimately unused nests for four of our five focal species. Each unused nest required as much time to monitor as an active nest (nest fate again being determined from observing adult behavior) and multiple visits were made to each as if it were an active nest until we had clearly determined that it was inactive.

Within our study, we encountered constraints in all of the above-mentioned areas leading to a tradeoff between finding low numbers of nests for many species or focusing on selected species. The main constraints were the low density of the species for which we could find nests, inaccessibility of replicate plots (none within driving distance of our housing in April to mid-May), and our limited budget that determined how many people we could hire, house, and transport. We eventually chose to focus on two species of concern to find an adequate number of nests for those species in each treatment each year. In addition, we decided to measure other components of population health. Even with this focus, it would be preferable to include more sites to increase the number of nests monitored and the applicability of our results beyond our two study areas. More replicates would require more financial resources to hire more people. Ideally, we would have liked to have had six additional study areas (3 of each treatment), with two 50-ha plots in each for a total of 12 more plots, in order to adequately sample from one to five focal species and address the question of whether fragmentation affects these species.

Martin and Geupel (1993a) suggest that each field worker can be in charge of two plots, although they do not consider logistic differences among habitats. Because of the constraints listed above, we found that our habitat required one person/plot to find most nests of the focal species in these old-growth forests and to monitor those nests. One person could monitor nests successfully on 25 ha (one-half plot) in an 8- to 10-hr day. Thus we would need 16 field assistants for our ideal expanded study. In addition, measuring other components of population health by colorbanding individual birds requires at least one and preferably two additional field assistants for each four, widely dispersed, 50-ha plots. To implement a BBIRD study, Martin and others (1997) currently recommend at least four plots/treatment in any habitat and as many as eight plots/treatment in habitats with low nest density. Based on the number of nests found in 1993 and 1994, we agree with Martin and others (1997) that 8 plots/treatment would be a reasonable approach in our low-density habitat. We would then be likely to obtain 20 nests/treatment for most focal species each year.

Cavity- or enclosed-nesters might seem an ideal group to focus on in old-growth coniferous forests. In general, we were fairly successful in finding their nests. Cavity-nesters and some enclosed-nesters, however, are also difficult to study in that one cannot easily look into their nests without special equipment (e.g., nest cameras) or technical climbing equipment and experience. Without this special equipment or experience, the researcher is left to guess nest fate based on observational data, mostly obtained from watching adult activity on the outside of the nest. In addition, when contents cannot be directly determined and these nests are watched from afar, the observer often has to spend from 30 minutes to 1 hr (sometimes greater than 1 hr for Pileated Woodpecker), watching the nest to determine what activity is actually occurring, making it difficult time-wise to monitor many nests, and leaving little time for additional nest searching. Invariably, some nest cards must be thrown out because nest fate is impossible to determine. Finally, because many cavity-nesters have large territories (especially woodpeckers), large areas must be surveyed to find large samples of nests. In spite of the difficulties in studying them, cavity- and enclosed-nesters as a group are critical to study; they are among those species that are most likely to be negatively affected by silvicultural practices, and therefore warrant considerable attention (Hejl and others 1995).

BBIRD is a valuable program for a number of reasons, including the fact that it is the only set of standardized protocols for evaluating reproductive success of landbirds. BBIRD also gives us a useful methodology for evaluating the effects of forest management practices on bird populations. When using BBIRD methods or otherwise measuring nesting success and when limited by constraints such as ours, we suggest emphasizing one to five focal species. In addition, if a researcher is uncertain what species are of concern in the habitat of interest or for which species observers will be able to find an adequate number of nests, then we suggest either: (1) one season of community-level BBIRD; or (2) one season of point counts and minimal nest-finding to determine the species of interest and those for which nests can be found in adequate numbers to test hypotheses. In following years, the researcher will be able to use BBIRD methods to study all species or just focal species. For example, based on point count results from the first year of study, we would concentrate nest-finding efforts on species with greater than 0.20 individuals/count in future years in cedar/hemlock forests. If focusing on a few species, then we suggest colorbanding individuals of one to several of those selected species. Colorbanding can help observers focus searches on hard-to-find nests within a species, potentially resulting in a less biased estimate of nesting success and predation and parasitism rates for that species. Colorbanding also allows one to examine additional parameters related to population health for the selected species.

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Demographic Modeling of Migratory Bird Populations: The Importance of Parameter Estimation Using Marked Individuals

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Abstract—We argue that monitoring of population abundance, or even of general demographic features such as nesting success, is not sufficient to understand what factors cause migratory bird population declines or changes in abundance. Instead, a demographic approach is needed, based on data from marked individuals and coupled with population modeling. The dynamics of a population can be modeled most simply using only one parameter, the population growth rate, which is given by the per capita birth rate minus the per capita death rate. Simple model refinements, including habitat- and season-specific vital rates, can add considerable realism and model utility. Empirical estimation of vital parameters requires monitoring the activities and fates of uniquely marked individuals. With such models and parameter estimates one can (1) assess whether particular populations have sufficient production of offspring (e.g., by habitat) to offset annual mortality; (2) investigate ecological influences on population dynamics, including effects of winter versus summes circumstances, population size, and actual or hypothetical environmental changes; and (3) identify where new empirical data are most critical (e.g., dispersal, age effect. We illustrate these points with emphasis on long-term data on color-banded Black-throated Blue Warblers (*Dendroica caerulescens*) and American Redstarts (*Setophaga ruticilla*) in the Hubbard Brook Experimental Forest, NH, and in Jamaica, and we discuss practical aspects of parameter estimation and demographic modeling for migratory species.

Many populations of birds and other organisms are threatened or endangered now, or will likely become threatened soon, as a result of human-induced global change. Aspects of global change include altered ecosystems, climate, land-use patterns, and species distributions (Terborgh 1989; Wilson 1992; Vitousek 1994; Vitousek and others 1996). Improvements in scientists' ability to document species loss and decline have motivated a variety of programs to monitor the health and status of populations, and to investigate the causes of population changes. The Audubon Christmas Bird Count, for example, arose early in the present century out of the need to monitor populations of colonial wading birds threatened by the plume trade. More recently, the Breeding Bird Survey was initiated to monitor all species of birds detectable along roadside transects throughout North America (Robbins and others 1986). The data so collected are being used to assess the extent and location of diverse population changes throughout the continent (e.g., Robbins and others 1989b; Fleury and Sherry 1995; Sauer and others 1996b), including the declines of many Neotropical-Nearctic migrant songbird species (Hagan and Johnston 1992; Martin and Finch 1995; James and others 1996).

Although much has been deduced or inferred about the nature and scope of population problems using abundance surveys, efforts are under way to identify the specific localities and causes of population declines by studying birth and death processes (demography) and the possible ecological bases for changes in those demographic parameters (Sherry and Holmes 1995, 1996). For example, two North American programs were begun recently to monitor avian demographic parameters at a continental scale: Monitoring Avian Productivity and Survival (MAPS) of the Institute for Bird Populations, and Breeding Biology Research & Monitoring Database (BBIRD) of the Biological Resources Division of the U.S. Geological Survey. Both of these programs are increasing in number of participatory sites, and thus in the size of databases with which to detect regional or temporal patterns. Even with large databases of demographic information, however, pinpointing the ultimate ecological factors causing the population changes or declines observed will be difficult. The problem results from the myriad potential factors that can separately or jointly influence population birth and death rates, including food abundance at different times of year, predators, parasites, direct and indirect effects of climate (Sherry and Holmes 1995), and presence or abundance of various chemicals in the environment. Disentangling the effects of these various factors is difficult without intensive studies designed to address specific ecological factors, and such studies generally require intensive effort focused on one or a few species. Intensive demographic or experimental studies must often be restricted, for practical reasons, to relatively local geographic scales. Neotropical-Nearctic migrants pose a special challenge to understanding present or future population risks because of the diversity of habitats they occupy, their often large geographic ranges, and the different political and geographic regions they typically encounter over an annual cycle.

In this paper we define and describe a demographic approach to the study of migrant bird populations using a series of heuristic mathematical and graphical models. We focus attention on what we have learned already from these models, and what kinds of information and model development are still needed to take full advantage of a demographic

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approach to population studies of migratory birds. We discuss conservation implications of our findings, as well as the advantages and disadvantages of intensive demographic studies in comparison to broader surveys such as BBIRD and MAPS.

A Simple Model of Birth and Death Rates

The very simplest population models project some initial number of individuals into the future based on one parameter—in this case the Malthusian parameter, or population growth rate. In practice the population growth rate per individual is simply the difference between the per capita birth rate and the per capita death rate. Here we turn the problem around by asking what birth rate is needed to offset the annual mortality rate (the complement of annual survival) so that the population does not decline (see also Sherry and Holmes 1995). Asking this question allows us to consider real demographic variables in a context that is immediately valuable to resource managers. We assume first that inputs (number of juveniles entering population) equal outputs (number of losses due to death or emigration), and define NJ = number of juvenile offspring produced annually per pair of sexually reproducing adults; J = the probability that a juvenile offspring survives its first year; NA = the number of adults lost from the population annually per pair of adults; and A = the probability that an adult survives one year. Based on these assumptions and definitions, NJ * J = NA = 2 * (1 - A). Thus, NJ = 2 * (1 - A)/ J. If we assume, further, that juveniles survive about half as well as adults (see references in Sherry and Holmes 1995, p. 102), on average (i.e., J = A / 2), then NJ = 2 * (1 - A) / (A / 2) = 4 * (1-A) / A. This model tells us what range of juvenile production rates is adequate to offset typical annual mortality rates for a migratory bird population (fig. 1). An annual adult survival rate or probability of 0.5 (and juvenile survival of 0.25) necessitates production on average of 4 juveniles per adult for replacement; and adult survival of 0.6 necessitates production of 2.7 juveniles. Any birth rates greater than these threshold values, depending on what the actual death rate is, will at least sustain the population, and greater birth rates will allow a population to grow.

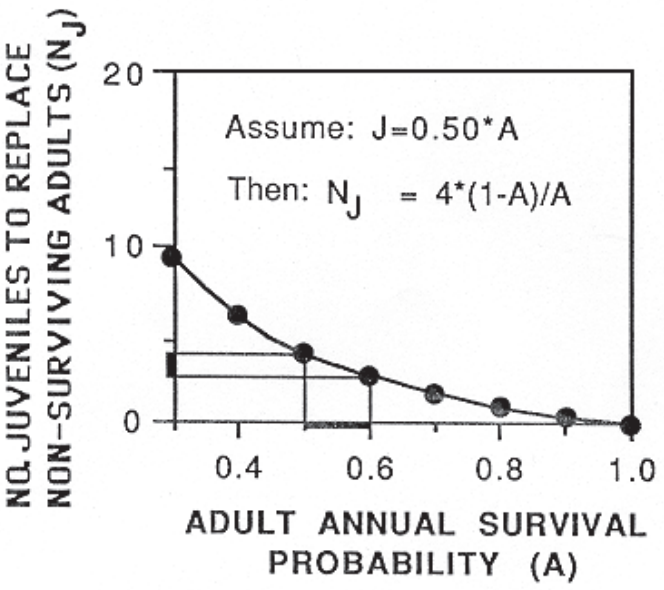

Figure 1—Number of fledglings needed on average to offset annual adult mortality (see text; modified from Sherry and Holmes 1995).

To illustrate the use of this model, demographic studies of individually marked Black-throated Blue Warblers in the Hubbard Brook Experimental Forest, NH, indicate that a pair of adults produces, on average, 3.7 to 5.1 fledglings per summer (table 1). This number of fledglings is sufficient in most years to replace the annual losses due to mortality (probably about 0.5; Holmes 1994 and unpublished data), and thus this population breeding in an old growth, nonfragmented northern hardwoods forest is probably in no imminent danger of decline (Holmes and others 1986, 1996; Holmes and Sherry 1988; Holmes 1994). This model can be modified easily with different parameter estimates or with other species. Other demographic models have focused on genetic and stochastic aspects of populations (e.g., Lande 1988; Lebreton and Clobert 1991; Lebreton and others 1992), and habitat fragmentation effects (e.g., Donovan and others 1995b). The most important point to be made from this simple population model is that accurate demographic parameter estimates are vital for accurate empirical modeling.

Generalization in Space: Source-Sink and Site-Specific Models

The foregoing model assumed that demographic rates are constant, both in space and time. This assumption is probably rarely, if ever, true in real populations. For example, many animals can be found living in habitats in which reproduction is not sufficient to maintain the population, but the population persists because of continuous immigration from other habitats. This notion has led to the development of source-sink models (e.g., Pulliam 1988, 1996; Pulliam and Danielson 1991). A source habitat is one in which reproduction exceeds annual survival; a sink is one in which reproduction is not sufficient to maintain the population.

Table 1—Total seasonal reproductive effort by female Black-throated Blue Warblers, Hubbard Brook Experimental Forest, NH, 1986-1989 (Data from Holmes and others 1992).

	Year			
Parameter:	**1986**	**1987**	**1988**	**1989**
No. females in sample	15	19	14	20
No. eggs laid	95	152	117	113
No. young hatched	83	116	84	92
No. young fledged	69	91	72	74
Proportion of females double-brooding	40.0%	57.9%	71.0%	35.0%
Mean no. fledglings per female ± 1 s.d.	4.6 ± 2.2	4.8 ± 2.0	5.1 ± 3.0	3.7 ± 1.7

Animals tend to move asymmetrically from sources to sinks. Pulliam (1988) used his model to make several nonintuitive deductions highly relevant to conservation: (1) Sink populations can support large populations despite the fact that the entire population would disappear without the source, (2) loss of a small proportion of occupied (but source) habitat can cause extinction, (3) numbers of individuals in a habitat can sometimes be a very misleading indicator of habitat suitability or quality, and (4) in general, managers must be aware of habitat suitability (as reflected in demographic success) to manage populations wisely in complex landscapes with multiple habitat types.

Research on Black-throated Blue Warblers illustrates the idea that demographic success depends on habitat (table 2), and that only some habitats act as sources. In this example, habitats with greater density of shrubs, which are preferred by the species as inferred from relatively high bird density, were found in fact to support greater annual productivity of fledglings (3.6 fledglings on average per female or pair) than habitats with fewer shrubs (2.5 fledglings). Reproductive success in the shrubby habitat was probably sufficient to offset annual mortality, making it a source habitat, whereas the low-shrub-density habitat was probably a sink. Thus, even at a very local scale, habitats can differ in the demographic success of occupants, and careful reproductive studies are necessary to understand population dynamics (see below).

Data on Neotropical-Nearctic migrant populations breeding in Midwestern United States woodlots indicate that reproduction there is often insufficient to maintain the populations, leading to the conclusion that some of these woodlots are habitat sinks maintained by distant source populations (Robinson 1992; Robinson and others 1995b; Donovan and others 1995a,b). In the winter nonbreeding season we have found that survival of birds also can differ among habitats (reviewed by Sherry and Holmes 1996). For example, American Redstarts persist significantly less successfully over the winter in Caribbean dry limestone forest in Jamaica than in other habitats studied, and also lose body mass during the dry season in the dry limestone forest (Sherry and Holmes 1996). Redstarts also experience different ecological conditions by sex in winter, in ways that can influence subsequent survival and even carry over into the reproductive season (Marra and Holberton 1998; Marra and others, in press). Long-distance migratory birds in particular tend to have broad geographic ranges, facilitated by their high mobility, and they often occupy a correspondingly wide range of habitats facilitated by ecological opportunism (Sherry 1990; Sherry and Holmes 1995). We infer that habitats for many, perhaps most, migratory songbirds are heterogeneous, some acting as population sources and others as sinks.

Table 2—Habitat-specific demography of female Black-throated Blue Warblers in Hubbard Brook Experimental Forest, NH, 1990-1992 (from Holmes and others 1996).

	Habitat	
Parameter:	**Low shrub density**	**High shrub density**
Bird density (no./10 ha)	6.6 ±+ 0.4	15.1 ± 1.1
Percent older males	35% (N = 71)	68% (N = 100)
Percent older females	36% (N = 44)	71% (N = 86)
Percent unmated males	12.7% (N = 63)	1.3% (N = 76)
Percent females double-brooding	5.6%	24.6%
Mean no. fledglings produced per female (± 1 S.E.)	2.5 ± 0.3	3.6 ± 0.3

Neotropical-Nearctic migrants tend to compete with members of their own species for mutually preferred habitat, at least during some seasons (Sherry and Holmes 1995, 1996; Rodenhouse and others, in press). When the first individuals arrive in a region to begin a phase of the life cycle, such as breeding or establishment of winter survival territories, individuals tend to settle first in the most preferred habitat, and eventually constrain or force subsequent arrivals to settle in less-preferred habitats. Such constrained habitat selection is often termed despotic or preemptive (Fretwell and Lucas 1970; Pulliam and Danielson 1991). One important consequence of such habitat-settlement dynamics, which are widespread in Neotropical-Nearctic migrants both in summer and winter (Sherry and Holmes 1995, 1996), is that individuals in some habitats experience better demographic success than those in other habitats (e.g., table 2).

Another important consequence of preemptive habitat dynamics is that populations tend to be *regulated*. A regulated population is one that tends to remain within some bounds, i.e., it stays relatively constant because of the tendency for individuals to experience relatively poor demographic success when the population is large versus relatively good success when the population is small. Thus regulation involves demographic success that decreases with population size, or in some cases with population density. Preemptive habitat selection tends to stabilize a population because as the population size increases, and thus as individuals are forced to expand into poorer habitats, the average per-individual demographic success tends to decline (Sherry and Holmes 1995; Rodenhouse and others 1997; fig. 2). Regulation is a special case of limitation, which is the restriction of a population by *any* kind of ecological conditions, regardless of whether the population is regulated.

Rodenhouse and others (1997) generalized this result further to the effect of specific sites or territories on demography (a habitat is a collection of sites with similar demographic success, and often found in similar vegetation structures or types). Rodenhouse and others characterized a mechanism of population regulation which they termed "Site-Dependent Regulation" (SDR), and they parameterized a simulation model with demographic characteristics of Hubbard Brook Black-throated Blue Warblers. This model showed that the SDR mechanism is powerful, potentially widely applicable to animal populations, and operational over a variety of spatial scales—often independently of local population density, but not independently of population size (fig. 3). Rodenhouse and others also conjectured that the suitability of a site is largely extrinsic to characteristics of the organisms rather than intrinsic to the population itself. Intrinsic characteristics include population density and

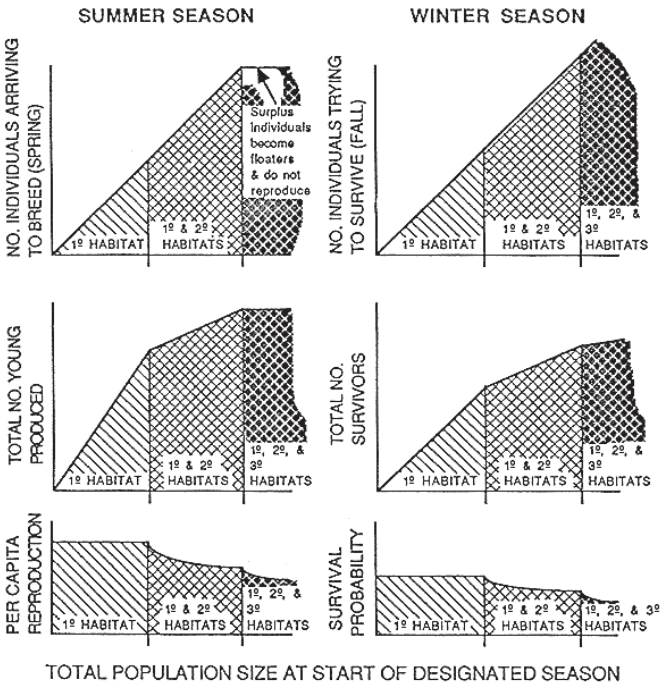

Figure 2—Density-dependent total and per capita productivity in a summer (breeding) season and a winter (nonbreeding) season for organisms occupying multiple-habitat landscape. As a population increases, it expands from occupying just primary to occupying primary plus secondary habitats, and so forth. The total productivity and survival tends to reach an asymptote as suitable habitats become saturated, and per capita fitness declines, indicative of population regulation (from Sherry and Holmes 1995).

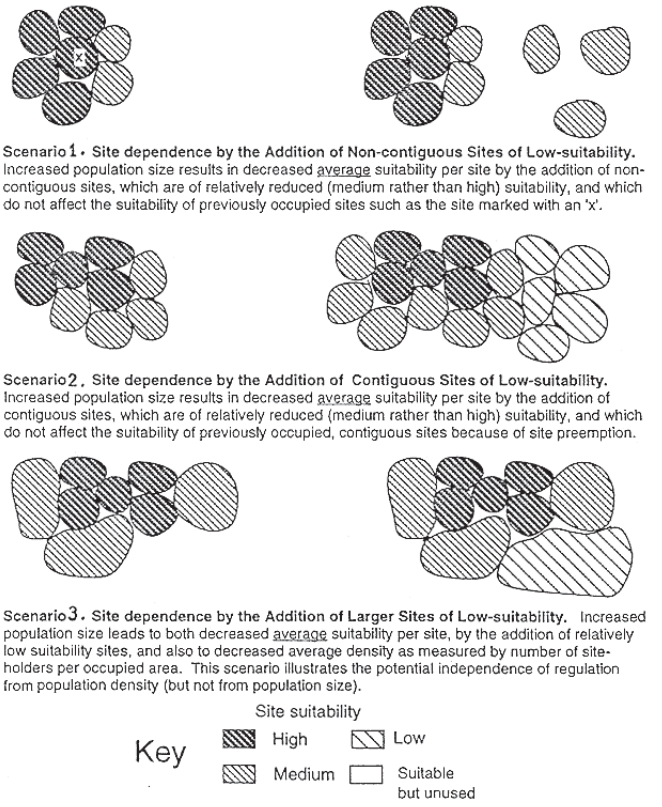

Figure 3—Three scenarios of site-dependent population regulation, in which an increase in population size (number of territories or sites occupied), going from left to right panel, results in decreased average per-capita site suitability as determined by demographic success (from Rodenhouse and others 1997).

proximity to neighbors. Extrinsic characteristics, which could set limits to local abundance, include food resources, predators, and parasites.

The importance of both preemptive habitat selection and of regulation, from the perspective of population management, is that the number of individuals in the population depends on both the quality of the habitat and its quantity, and so populations can be managed in principle by manipulating either the quality or quantity of available habitat (as well as its configuration and connectivity of patches—see Discussion). However, preemptive use of space in many species tends to set an upper limit to local population density, above which boosting the population is very difficult, in which case it will generally be far easier to maintain populations of such animals by maintaining the amount of habitat than by improving its quality. In this context, the task of wildlife management is ultimately to help guarantee a sufficient amount of high quality habitat for the individuals to maintain their own populations via high reproduction and survival (Sherry and Holmes 1993, 1995; Donovan and others 1995b).

Generalization in Time: Seasonal Migration

Another level of complexity in population models is added when organisms migrate between geographic regions. Each region has its own array of habitats (or sources and sinks) in which organisms can reproduce and die, and between which they can disperse. Pulliam (1987) devised a graphical way to study preemptive populations regulated by the interaction of both summer and winter ecological circumstances, and Sherry and Holmes (1995) extended Pulliam's approach to deduce consequences of migratory bird habitat-selection mechanisms. Again, demographic success is assumed to vary by habitat in both seasons, and individuals shuttle between a reproductive season (in North America, for example) that boosts the population through reproduction, and a nonreproductive season (in tropical America, for the bulk of most Neotropical-Nearctic migrant populations) characterized by just mortality (mortality also may occur, of course, during the reproductive season and during migration, as discussed below). The graphical model is constructed from per capita success across a range of habitats within a season, and then by putting effects of multiple seasons together on the same set of axes.

Specifically, the number of individuals in fall is assumed to increase asymptotically with the total population starting the reproductive season in spring (fig. 4A); and, similarly, numbers in spring increase asymptotically as a function of those starting the fall non-breeding period (fig. 4B). Both of these curves are assumed to be asymptotic simply because as the population beginning a season increases, more and

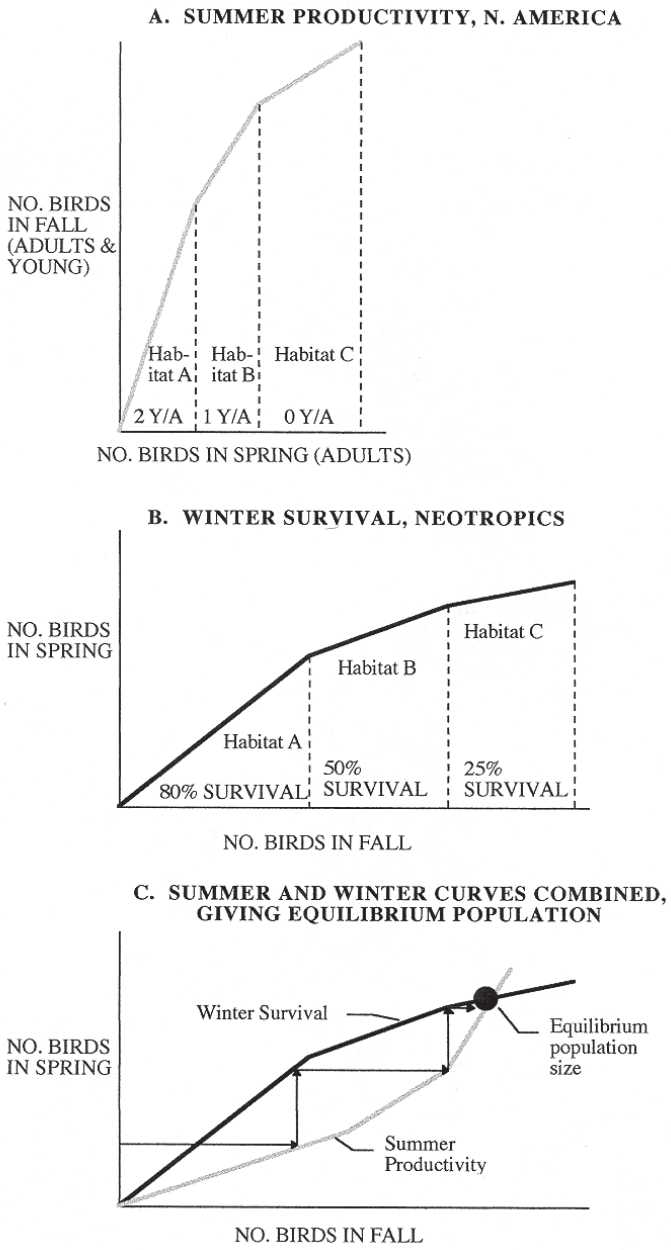

Figure 4—Regulation of migratory population as a result of ecological circumstances in both summer and winter seasons. A. Numbers of individuals in the fall population increases asymptotically as a function of numbers beginning the spring season on breeding grounds, because proportionately more and more individuals are constrained to reproduce in less productive habitats as the population size increases. B. Numbers of individuals in the spring population increases asymptotically as a function of numbers beginning fall (nonbreeding) season on wintering grounds, again because of poorer average demographic success (survival) in larger population. C. A combination of curves from parts A and B onto one set of axes (the axes from part B), and a hypothetical population trajectory, shown by arrows, indicates the tendency of any population to move toward an equilibrium point, indicative of population regulation by a combination of both summer and winter circumstances (see fig. 2 and text; modified from Sherry and Holmes 1995).

more individuals are constrained by despotic behavior to occupy poorer and poorer habitats, resulting in poorer per capita reproductive (or survival) success (as in figs. 2 and 3). One may then combine the curves in figures 4A and 4B on the same set of axes by transposing the axes of figure 4B (fig. 4C). The population size is then determined by starting with an arbitrary initial population size, and rising (or dropping) to the relevant curve in one season, then rotating perpendicularly and moving (increasing in population size) to the other curve in the other season, and so on, alternating between seasons (fig. 4C). The result of this exercise is that any nonzero population eventually will converge on the globally stable equilibrium point at the intersection of the two curves, assuming such an intersection exists. Thus, any population behaving according to this model is regulated, i.e., kept within bounds, and the set point or carrying capacity for the system is determined by *both* the summer and winter demographic circumstances.

We can make several useful deductions from this model. First, because regulation of the population size is determined by both breeding and non-breeding season circumstances, it makes no sense to think of the population as being regulated in either season alone. To the extent that this graphical model captures essential aspects of migratory birds, then by analogy, it makes no sense to say that a population is in general regulated either in summer or in winter. On the other hand, a migratory population is sensitive to limiting conditions in both summer and winter (and other times of year, such as during migration, as considered below), and is thus vulnerable to the worst set of conditions, as a chain is as weak as its weakest link. Specifically, deterioration of habitat either in winter or summer can cause the population to decline to extinction.

Second, the shape of the curves for a particular season depends on both habitat quality and quantity. Habitat quality determines the *slope* of a segment of the curve (e.g., fig. 2) and is identical to the per capita demographic success. Habitat quantity determines the *length* of the segment of the curve having a particular slope. Thus, the number of individuals experiencing a particular per capita demographic success is proportional to the size of a particular habitat, and is given by the length of that segment of the curve (of particular slope) projected perpendicularly onto the axis for the appropriate season. For example, in figure 2, the number of individuals in 1° summer habitat is equal to the length of the abscissa under the habitat labeled 1° habitat. The curves in figure 4 are idealized (smoothed) versions of the curves in figure 2. Thus the overall curve reflects the relative proportions of each potentially occupied habitat type available. Therefore, this heuristic model clarifies how accurate modeling of a real population depends on knowledge about both the habitat-specific demographic rates and the extent of the relevant habitats available to a population.

Third, this model clarifies the fact that population size is determined by alternating (thus additive) effects of different seasons (breeding season, wintering season, migration), each with its own ecological circumstances. The advantage of decomposing annual cycles into components representative of different life-history stages is that this allows one to investigate the separate effects of different seasons, which correspond to different geographic locations in the case of migrants.

Fourth, this graphical approach to seasonal population processes is flexible, and can be modified easily to accommodate a variety of different assumptions and situations. We illustrate this flexibility by incorporating explicitly the effects of mortality during migration, which can be accomplished by decomposing the spring population curve into components attributable to mortality during migrations and during winter, the latter occurring after individuals reach their non-breeding geographic range following the fall migration (i.e., in the Neotropics, in the case of Neotropical-Nearctic migrants). For simplicity we assumed that the mortality rate during migration is independent of the size of the population, and thus is a constant fraction of the population; and that the effects of mortality from fall migration, spring migration, and winter are additive (fig. 5). We also assumed that winter mortality is dependent on population size, which is indicated here by reduced demographic success (winter survival) at larger population sizes occupying increasingly poor habitats.

Discussion and Conclusions

We have presented several heuristic mathematical and graphical models, incorporating increasing levels of complexity, to illustrate how demographic parameters can be used to investigate population regulation and limitation in migratory species and to help identify the particular ecological circumstances that determine their population sizes. In the discussion that follows, we summarize general lessons of the models, indicate the most important weaknesses in our present ability to model migratory bird populations, emphasize the complementary relationship of modeling to population monitoring, and indicate the challenges of obtaining accurate demographic parameter estimates for migratory birds in the field.

Lessons of the Models

In the context of seasonal migrants, these models lead us to deduce that populations are regulated by circumstances in both summer and winter, because the population depends on both high enough birth rates in summer and low enough death rates, primarily outside of summer, for birth rate to exceed death rate, which is necessary for a population to persist. We deduce that deterioration of demographic circumstances (habitats) in either season can cause a population to decline, and thus migratory animals are vulnerable to the weakest ecological link in their annual cycle. These models illustrate how the availability of high-quality habitat (indicated by sufficiently high birth and survival rates) is required for healthy populations, and the models indicate how preservation of a sufficient amount of high-quality habitat in both summer and winter is the single most important conservation need.

We cannot emphasize enough the value of preserving large quantities of high-quality habitat as a conservation tool. In the case of endangered species populations, intensive management efforts are warranted to accomplish this goal. For example, the endangered Kirtland's Warbler (*Dendroica kirtlandii*) requires large areas of young jack pine (*Pinus banksiana*) stands, which regenerate following fires, and the largest remaining stands occur on the sandy soils of

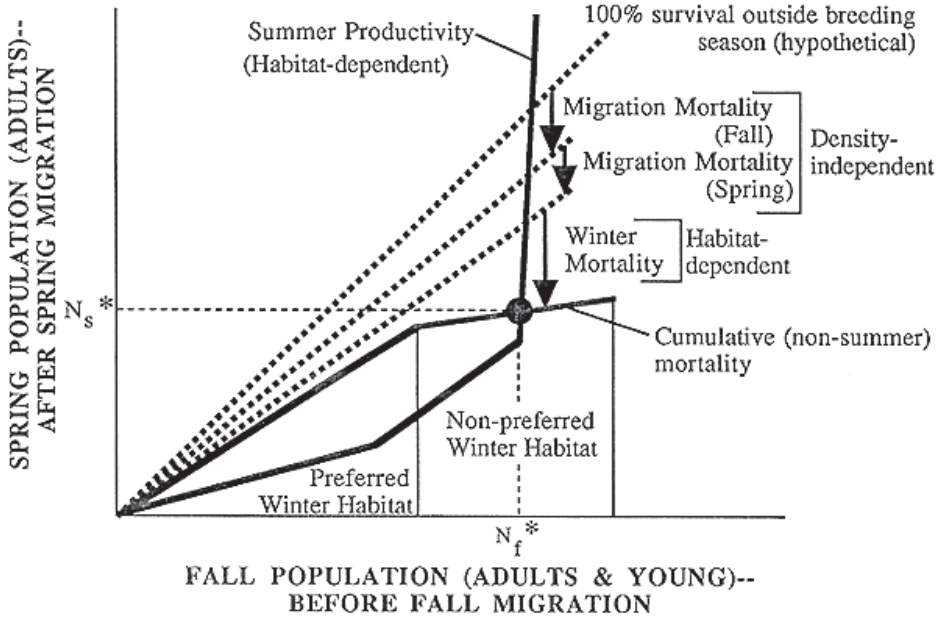

Figure 5—Nonbreeding season mortality components partitioned into density-independent migration components and habitat-dependent (i.e., population size-dependent) winter component, to indicate flexibility of modeling approach introduced in figure 4. Ns* and Nf* are equilibrium spring and fall population sizes, respectively, given by the intersection of the summer productivity and nonbreeding season mortality curves.

Michigan (Mayfield 1993; Sherry and Holmes 1995). Fire is used as a management tool to maintain young jack pine stands, although the most dramatic population increases resulted from out-of-control burns, due to their relatively large size (Mayfield 1993). Similarly, game birds are managed intensively by such measures as increasing ground cover, creating openings within forest, creating second-growth habitats preferred by some game species, and creating conditions favorable to regeneration of food plants. With over a hundred species of Neotropical-Nearctic migrant songbird populations, many of which are declining at present (Terborgh 1989; Finch 1991; Peterjohn and others 1995), prudence would dictate that we manage the quantity of native habitats rather than try to maintain habitat quality intensively for each of the declining species' populations. We suggest that the single best means to protect the future of the diverse migratory birds in the western hemisphere is to preserve large, representative landscapes including each of the distinctive habitat types on which these migrants depend, so as to include sufficient quantities of high-quality habitat for migrant species to persist. The abundance of individual species would need to be monitored, of course, to be sure that such habitat preservation and management was successful.

Migration habitats have been largely ignored in the present review, but figure 5 illustrates how migration habitat quality can influence population abundance. Recent work indicates that not all habitats available to birds during critical stages of migration are equally suitable, and thus the relative abundance of different habitats during migration can influence populations (Moore and others 1995).

An important consequence of thinking about populations using demographic parameters is that it helps link population trends to the ecological conditions causing the trends. For example, birth rates are increased when reproductive success is greatest, and reproduction is influenced in turn by factors such as food abundance, availability of safe nesting sites, predator population sizes, and nest parasite abundance. Similarly, during migration and in winter the biology of survival involves habitats that provide sufficient food throughout the winter period, protection from predators, and havens from disease or other hazardous conditions. The value of knowing these ecological factors is that management efforts can sometimes alter them so as to improve habitat quality.

What We Need to Know to Improve Models

All the models that we have discussed in this paper are heuristic. Thus their value is to inform us about general population processes in migratory animals, rather than how to manage a particular species. To accomplish the latter goal, we would need a more detailed model parameterized for a particular species, and to our knowledge, no such year-round population model exists for any Neotropical-Nearctic migrant bird. Moreover, if models are to be developed that allow prediction of how changing ecological conditions (e.g., land-use patterns, global warming) will affect populations, then the relevant ecological variables must be coupled to demographic parameters within the models. What the foregoing models and discussion can accomplish is to help us focus on the kinds of information needed to structure more useful models.

Because of the importance of habitats, ages, and sexes on demographic rates in general, representative measurements of demographic parameters are needed for each of these strata of data that is important for a particular species (in each of multiple seasons including summer, winter, and spring and fall migrations). Considering habitat, for example, we need some estimate of the relative abundance of the major habitat types used by the population of concern, and we need accurate demographic rates for the population occupying each of those habitat types. This is a daunting task that will require an efficient sampling strategy, and careful attention to statistical treatments of appropriately stratified data. Remote sensing of vegetation and land-use types, coupled with on-the-ground demographic monitoring, almost certainly will be required to accomplish these tasks (e.g., Powell and others 1992). This approach can be applied in principle both locally, e.g., within a national forest or geographic region, and at more global spatial scales.

Survival rate estimates of many long-distance migratory birds are available, but these probably remain highly biased, particularly for females, due to the difficulty of distinguishing those losses of birds that are attributable to disappearance (dispersal) versus actual mortality (Marshall and others, this proceedings; Robinson and Morse, this proceedings). Juvenile survival, i.e., survival from the time a bird hatches until the time it attempts breeding for the first time as a sexually mature adult, is particularly difficult to measure empirically because of the large distances that juveniles often disperse. Thus, few reliable juvenile survival data exist.

Dispersal distances are in general poorly known in birds. Migratory birds are efficient fliers, which permits them to disperse great distances between breeding (or wintering) areas. In populations occupying large geographic areas, knowing how the populations are structured is helpful, e.g., whether subpopulations exist that function largely independently of each other, or whether birds that breed together in summer disperse throughout the winter range (and vice versa—e.g., Chamberlain and others 1997), so that one can effectively treat the population as a single entity. Dispersal distances influence the distances that animals can travel from source habitats to sinks, and thus indicate the potential sources for a particular habitat sink. Dispersal distances also indicate the extent to which habitat configurations (e.g., lack of corridors connecting habitat patches) impede movements, thereby reducing demographic rates by preventing animals from reaching suitable habitats. We recommend that scientists and managers place top priority on developing new methodologies for estimating dispersal rates and distances.

For most species, we lack knowledge about the levels of annual and seasonal variability of demographic parameters. For example, avian nesting (reproductive) success at Hubbard Brook varies annually and seasonally, primarily in relation to mammalian nest predator populations and behavior (Reitsma and others 1990; Sloan and others 1998; Sherry and Holmes 1992; Holmes and others 1992, 1996; TWS and RTH, unpublished data). Similarly, migration-related mortality must

vary annually with changing weather patterns, and anecdotal accounts of mass-mortality of birds during inclement weather are abundant, but we know of no quantitative data on how such mortality affects annual survival rates for any Neotropical-Nearctic migrant bird. Stochastic variation can be incorporated into models of migrant populations (e.g., Rodenhouse and others, in press), but we need better data before such stochasticity improves model accuracy.

To summarize, due to the lack of sufficiently accurate or representative demographic parameter estimates, models remain to be constructed that can project the population size of any Neotropical-Nearctic migrant bird realistically. We also lack the data for most species to incorporate genetic aspects of populations. Sufficient data do exist, however, to construct at least approximate demographic models for a few species, and this should be a major focus of avian population ecologists in the next few years.

Demography and Hypothesis Testing

Intensive demographic data have another important function, besides model development, which is to test hypotheses about the cause(s) of population change. Demographic measurements can indicate, for example, whether a population is locally a source or sink (Pulliam 1996), and can provide the link between population changes and ecological conditions that could be causing the change. Thus demographic data are necessary to follow up on population declines that are of concern to conservationists. In the case of migratory birds, national surveys have identified species whose populations are declining steadily, such as Cerulean Warbler (*Dendroica cerulea*), Wood Thrush (*Hylocichla mustelina*), and Olive-Sided Flycatcher (*Contopus borealis*) (e.g., Peterjohn and others 1995). These species are thus good candidates for more intensive demographic studies. Similarly, population abundance surveys such as the Breeding Bird Survey can identify problem areas ("hot spots for decline" such as the Adirondack Mountains and Blue Ridge Mountains in the eastern U.S.; James and others 1996), where further demographic work would help to focus scientists on the cause of the problem.

Broad-scale, multi-species demographic monitoring programs (e.g., BBIRD, MAPS) already are being conducted within North America and elsewhere. We do not see these programs as a substitute for the kind of intensive demographic studies that we have conducted using Black-throated Blue Warblers and American Redstarts. Instead, different kinds of demographic monitoring are complementary, because they have different strengths and weaknesses. The key advantages of intensive, localized demographic studies is the ability to measure demographic parameters accurately and to link these with specific ecological conditions. For example, BBIRD protocols involve monitoring of nest success, but not necessarily following individually marked animals, which precludes gathering information about annual survival or multiple brooding frequencies, either of which could be key to the maintenance of a particular population. The advantages of programs such as BBIRD and MAPS, compared with intensive single-species monitoring, is the geographic scale and number of species that can be monitored, at least to some extent. Such large-scale monitoring programs also have the statistical power, due to their often large sample sizes, to detect subtle changes in population parameters, but usually not at just one site (Rosenberg and others, this proceedings).

Practical Aspects of Demographic Modeling

The value of obtaining demographic data for migratory birds should be clear from the foregoing discussions. The data can be used in particular to assess the consequences of alternative land management practices. Such practices can include various kinds of agriculture and aquaculture, forestry, landscape management, and other impacts such as suburban and rural residential land-use. For example, Greater Antillean shade-coffee plantations contribute to excellent winter-long persistence of migrants, probably due to abundant food resources late in the dry season (Wunderle and Latta 1998, in review; M. Johnson, unpublished data). In the breeding season as well, human land-use practices and habitat structure demonstrably alter reproductive success of migratory birds (e.g., Robinson and others 1995b; Holmes and others 1996). However, we still lack the kinds of demographic data needed to understand land-use effects, let alone develop management models, for most migrant bird species under most circumstances.

Despite the potential theoretical and practical benefit of population modeling, the empirical estimation of population parameter values is challenging, and thus requires the commitment of time and resources. To illustrate the challenges, Black-throated Blue Warblers breed on 1-2 ha territories spread out patchily throughout northern hardwoods forest (Holmes 1994); finding enough nests and banding sufficient individuals to obtain reliable demographic information requires working in large woodlands (often hundreds of hectares). The fact that this warbler is double-brooded (table 2), i.e., particular females and their mates may fledge two or more successful broods in a season, necessitates capturing and uniquely marking individual birds to obtain the entire season's reproductive productivity per individual bird (Holmes and others 1992). Studies of wintering migrants' demographic success (Holmes and others 1989; Sherry and Holmes 1996) is also time-intensive, because of effort needed to find, capture, and mark individual animals. Survival of redstarts in winter can vary by habitat (Sherry and Holmes 1996), age of bird (R. T. Holmes; T. W. Sherry; T. E. Martin, in preparation), and probably sex (Marra and others 1993), necessitating adequate sample size for each relevant category of individuals, and several biases make data analyses challenging (Marshall and others, this proceedings). Our experience indicates that capturing and marking sufficient animals to accomplish these tasks is most efficient when working with just one or two species, because methods often need to be tailored to particular species (Hejl and Holmes, this proceedings). General methods to capture, mark, and study birds in the field are well known, and training is widely available (Ralph and others 1993). In summary, we need demographic field and modeling studies of migratory birds, and a variety of tools are available to conduct these studies. The field is thus ready to advance rapidly.

Acknowledgments

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Answering Questions in Management and Research Using Large-Scale Manipulative Experiments

Robert J. Cooper
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Leonard A. Brennan

Abstract—An adequate information base regarding management practices for migratory landbirds and other nongame species does not yet exist. Land managers, therefore, must act with inadequate knowledge of the resources they are charged with managing. We believe that part of the solution to this problem rests with the land managers themselves, in that they are in a position to gain new knowledge about this resource by combining research or monitoring with the management activities they currently use or anticipate using. By collaborating with researchers, they can modify some of these manipulations to take the form of well-designed, large-scale experiments. Ideally, such experiments should include features of sound experimental design, such as replication, randomization, and controls. Where such features are compromised, we offer some suggestions on how to modify designs appropriately. They also should include estimation of demographic parameters such as productivity and survival, rather than just assessment of presence/absence. We present four examples from our own work with silviculture in two forest types, prescribed fire, and insect pest management. In each case, a long-term, large-scale, manipulative experiment was developed and funded through collaborative efforts among researchers, managers, and multiple partners. Benefits to managers include timely information directly pertinent to their lands. Benefits to researchers include increased funding opportunities for basic as well as applied research, and the knowledge that their research results are being used. Both groups benefit in that they are able to achieve more together than either could alone.

Land managers (e.g., wildlife managers, foresters, range managers) typically carry out a variety of management practices to promote the resources they oversee. When faced with questions regarding management of their resource, they often resort to what is to them common sense, based on a career-long experience with the resource in question. When faced with questions for which they do not readily have answers, they often rely upon literature and/or expert opinion. A current problem is that an adequate information base does not yet exist regarding management practices for migratory landbirds and many other nongame species. We often simply do not know the effect of a particular management practice on a particular bird species.

Some of the most basic information needed by land managers to effectively manage migratory landbirds involves the effects of typical management practices on migrants. Despite recent advances in the knowledge of management of long-distance migrants, most reviews on the subject have been necessarily general (Finch and Stangel 1993b; Martin and Finch 1995). One of the most common complaints we hear from managers regarding managing their lands for migratory birds is the lack of such information specific to their needs.

We maintain that the power to change this situation rests partially with land managers themselves. Often, important information can be obtained by monitoring, which can be done directly by the land manager if adequate resources and personnel exist, or by collaborating with researchers or volunteers. For example, monitoring conducted in places where different management practices have been applied in the past provides information on effects of those practices. If practices such as timber harvesting, prescribed burning, or pesticide applications are about to be performed, then monitoring efforts aimed at assessing the effects of those practices can constitute manipulative experiments. Attention to attributes of experimental design such as replication, randomization, and controls will help such assessments be more meaningful, and allow extrapolation of results to other areas. Input by experienced researchers, presumably knowledgeable in experimental design, is therefore desirable. By communicating and collaborating with researchers, land managers can make their areas more attractive as research sites. From the researcher's viewpoint, input from managers is just as desirable to ensure that manipulations are done properly and that they reflect realistic management practices. Also, both groups often will be needed to combine scarce resources required to perform the project properly.

The purpose of this paper is to provide suggestions on how such large-scale manipulative experiments can be designed and developed, with some examples of practical application, which come from our own unpublished work, in progress. The lack of sound, large-scale manipulative experiments in the literature at the time of the Cape May workshop reflected the past failure of researchers and land managers to collaborate. We note with optimism that many such experiments are now under way, however, this fact does not diminish

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the pertinence of this paper. It is targeted equally toward managers, researchers, and those interested in monitoring, because without the cooperation and collaboration of all three groups, making the large advances in the knowledge needed to effectively manage Neotropical migratory birds will be difficult.

Experimental Design

If the effect of a particular management practice on migratory landbirds is to be examined, then the investigators should follow rules of good experimental design in their investigation. By experimental design we mean "the logical structure of an experiment" (Fisher 1971). The reader is also directed to Hurlbert (1984), Johnson (this proceedings), and Nichols (this proceedings). In this paper we will largely use the terminology of Hurlbert (1984), who differentiated between a manipulative experiment, in which experimental units (i.e., those units to which treatments are applied) are somehow manipulated by the application, and a mensurative experiment, in which nothing is manipulated, but plots may be established and measured with the objective of comparing experimental units over space or time. We assume in the following that some management practice (e.g., timber harvest, prescribed burning, pesticide application, grazing) is to be (in the case of the manipulative experiment) or has been (for mensurative experiments) applied over a large area (e.g., a management compartment). For example, in the case of a management compartment of several hundred hectares, usually the whole compartment is scheduled to receive a particular treatment at a particular time; nothing is random about the selection of the site or the treatment allocated to it. However, monitoring that site still can be meaningful if another control site is monitored, and if a before-and-after, control and impact (BACI) design is used (Stewart-Oaten and others 1986). Alternatively, and this is the approach we have adopted, if plots can be established within a management compartment or other area, and if the land manager is willing to let various treatments be randomly assigned to the plots, then the study takes on the characteristics of a well-designed manipulative experiment. Below, we briefly discuss some considerations involving the design of large-scale manipulative experiments.

Objective

This may seem obvious, but more than one major investigation has failed because the objectives of the study were not clearly defined. Objectives will dictate the treatments to be applied, the timing of the treatments, what should be measured, and how long the study should last.

What should be measured? Point counts are desirable in that they cover a maximum amount of area with a minimum amount of effort, so that larger numbers of replicates are possible. Also, standardized methodologies have been developed (Ralph and others 1995b; Hamel and others 1996). However, point counts also provide minimal information, and are affected by a number of extrinsic factors. Methodologies should be determined by objectives more than by logistical or financial constraints. We believe that to truly understand the effects of alternative management practices, demographic data (productivity, survival) are required. Much of this section of the Cape May Proceedings is devoted to this proposition.

Controls

By control we mean a treatment that serves as a meaningful comparison to an actual management practice, such that the effects of the practice relative to not performing the action can be assessed. Often, but not always, developing a control involves taking measurements in an area where no management action is taken (see example 2 for a control involving a manipulation). Simply monitoring birds on a single study area before and after a management practice is applied does not provide useful information, because other factors that might influence the birds in question also might have changed over that time. For this reason we believe that, of the features of sound experimental design identified by Hurlbert (1984), controls are the most important.

Randomization

Ideally, treatments (alternative management practices, controls) should be allocated randomly to experimental units. If a particular management compartment, for example, is due to be thinned, but no other compartment is due, then one might divide the compartment designated for treatment in half, thinning a randomly selected portion of the compartment, but leaving the other half as a control. Such a procedure is not always possible, because sometimes a particular treatment must be applied to a particular area. However, if randomization is not used, then the areas studied are not representative of the population from which they were selected, and meaningful extrapolation of results to other areas is not valid. Also, an effort should be made to intersperse treatments, to avoid an unlucky draw in which all replicates of a particular treatment are lumped together in space (Hurlbert 1984).

Replication

If treatments are applied to one experimental unit each, then any differences found may result not from the treatment, but could be attributable to preexisting differences on those sites. In other words, the effect of treatment is confounded with location, and inferences applied to the specific site where the study is being performed are limited.

Because of expense and other considerations, only one set of treatments may be possible at a particular site (i.e., no replication at all). Is a study that compares a number of treatments with no replication worthwhile? While certainly not as desirable as a replicated study, we believe the answer is yes. First, an unreplicated study still can provide the land manager with some insight concerning the potential effects of management practices on birds. Results of unreplicated studies can be thought of as working hypotheses, which the manager can support or refute by further investigations. This approach can be expanded into the area of adaptive resource management (Conroy, this proceedings). Second, if the management practice in question is of interest to one

manager, it probably is of interest to others, and hopefully the study can be, or already is, being replicated elsewhere (perhaps also using a design that is similarly compromised).

Power

Power is defined as the probability of rejecting a false null hypothesis, therefore, having high power in an experiment is desirable. Unfortunately, the only way to increase the power of an experiment while minimizing Type I error is to increase the number of replicates. Because of the relationship between power and sample size, the power of most large-scale manipulative experiments is low. There are several ways to partially overcome the low power inherent in studies with a small number of replicates. First, rather than investigate many different levels of a particular treatment (e.g., silvicultural options), one can reduce the number of treatment levels, and for the same effort, increase the number of replicates per level. Second, standardization of methods among studies with similar objectives can increase power by combining studies from different locations in one analysis (meta-analysis, see Fernandez-Duque and Valeggia 1994). See Cohen (1977) for a more complete treatment of the subject of power.

Manipulation

Sometimes, research aimed at understanding the effects of alternative management practices on birds has involved taking measurements in areas where alternative management practices were applied in the past. This assumes that the different areas were similar to begin with, which probably is not the case. It also ignores the important consideration of randomization. However, short-term effects (≤3 yrs) of alternative management practices are often not the same as long-term effects (say, ≥10 yrs); understanding long-term effects requires a long period of time that we often do not have. Therefore, while mensurative experiments often are not as rigorous or insightful as manipulative experiments, they are sometimes necessary. Furthermore, short-term effects can be misleading. For example, site fidelity can cause migratory birds to occupy breeding territories in habitats severely altered by timber cuts or other management activities that occurred during the previous winter, even though the habitats have become suboptimal. Assessment of both short- and long-term effects are important; therefore, we conclude that mensurative experiments can be valuable. They are not, however, a substitute for good long-term research.

Pretreatment Data

Are pretreatment data necessary in manipulative experiments such as these? Strictly speaking, a treatment effect can be detected on most parameters without pretreatment data if adequate controls are used (e.g., Cooper and others 1990). Pretreatment data are desirable for several reasons, however. First, we have found that a season or two is often required for a project to operate smoothly. Often, we are unsure which species we will monitor for demographic work until we have gained some experience in the study area. Second, estimation of survival necessitates a large number of banded birds, and obtaining adequate sample sizes can take several years. Third, because of low power or no replication, detecting treatment effects is often difficult. An alternative to data analysis involves a largely graphical approach, in which means and standard errors are plotted for each treatment over time (Hurlbert 1984). Pretreatment data are necessary in this type of analysis. Also, a BACI analysis can be employed with this design (Stewart-Oaten and others 1986).

Realism

Researchers tend to want to conduct experiments in an ordered, efficient, elegant fashion. Managers, on the other hand, generally are not as concerned with methodology as they are with results (i.e., which management option produces the desired results). For example, in a study of the effect of different logging practices on avian productivity (see below), it was suggested that different treatments should consist of removing the same total volume of timber on each plot, but the size and number of individual cuts should differ among plots. While this is attractive from a research standpoint, it is not the way that timber is marked and cut in an actual harvest operation on these national wildlife refuges. The objective of harvesting was to promote wildlife habitat. Different prescriptions result in different percentages of standing timber removed. Therefore, the individual trees that were selected for harvest were selected and marked by the refuge silviculturalist using prescriptions typically employed on the refuge. The other approach was simply not realistic, and inferences made from that study design would have had limited application elsewhere.

Plot Size

The size of the study plots will vary with the study and its objectives. We have adopted BBIRD (Breeding Bird Inventory and Research Database) protocols, which call for plots to be at least 20 ha to allow enough area to conduct point counts and to find a sufficient number of nests to make valid inferences (Martin and others 1997).

Collaboration

Research such as that described above requires collaboration and cooperation between researchers and managers. Researchers who attempt large-scale manipulative experiments without close collaboration with the managers on whose land they are working risk conducting a presumably well-designed experiment that has limited application elsewhere; they also risk a certain amount of resentment. Most managers also are willing to share resources such as housing and vehicles if available. On the other hand, most managers are not researchers; they risk conducting a poorly designed experiment if they do not consult with researchers well-versed in experimental design.

Large-scale manipulative experiments with adequate replication are expensive, and may be beyond the means of most

managers. Even on well-funded projects, replication may be minimal. In such cases, collaboration with other land managers and researchers at other locations is helpful. By bringing other resources to bear, a well-designed study can be replicated at another location. If done carefully so that the design and methodology are identical, then different locations can serve as blocks in a randomized design. Even if the different studies are similar only in the questions they pose, they sometimes can be combined in a meta-analysis, which again serves to increase the power of the overall analysis.

Examples

1. Alternative Silvicultural Practices in Bottomland Hardwood Forests—This study was initiated in 1993 by the University of Memphis collaborating with the U.S. Fish and Wildlife Service (USFWS), and was continued in 1997 in a similar collaborative arrangement between the USFWS and the University of Georgia. The study area is the White River National Wildlife Refuge (NWR), one of many federal refuges along the lower Mississippi Alluvial Valley (MAV) originally established for management of migratory waterfowl. Federal refuges also provide some of the largest tracts of unfragmented bottomland hardwood forest remaining in the MAV. Most of the forest on refuges is managed to promote within-stand diversity and the production of hard mast; timber harvest alternatives designed to promote oak regeneration are selective cuts (thinnings) or small (<2 ha) patch cuts.

In 1993, six 50-ha plots were established in the same management compartment (which was due to be harvested in 1995), so that all plots were initially somewhat similar. Three treatment options (thinnings, patch cuts, no cuts) were randomly allocated to two plots each. After two seasons of pre-treatment data collection in 1994-1995, treatments were applied in the late summer-fall of 1995 under the supervision of refuge silviculturalists. Post-treatment data collection occurred in 1996-2000. Measurements taken include point counts, survival, productivity, habitat characteristics, and foraging behavior. Methods generally follow BBIRD protocols.

Since its inception, the project has been funded by a partnership between the University of Memphis (and later the University of Georgia), the USFWS, the U.S. Forest Service (USFS), the Biological Resources Division of the U.S. Geological Survey, and the Arkansas Game and Fish Commission and the Arkansas Chapter of The Nature Conservancy. The refuge staff was present and contributed to every aspect of planning the project, including personnel, equipment, and most importantly housing, which served to defray costs and logistical problems.

Despite the favorable aspects of the design of this experiment, there are still only two replicates of each treatment, providing low power. Therefore, we are collaborating with researchers and managers at Tensas River NWR (D. J. Twedt, unpublished data), who are performing a very similar experiment, also with two replicates of each treatment. For some questions, then, this collaboration will double our number of replicates.

2. Alternative Gypsy Moth Management Practices in the Middle Appalachians—This study was initiated in 1994 by the University of Memphis collaborating with West Virginia University (WVU) and the USFS, and was continued in 1997 with collaboration between the University of Georgia, WVU, and the USFS. The study areas are located in the George Washington National Forest in Virginia and the Monongahela National Forest in West Virginia. The gypsy moth (*Lymantria dispar*), accidentally introduced from Eurasia in 1869, has become the most important insect pest of eastern deciduous forests, annually defoliating millions of hectares. Pesticides are also applied to hundreds of thousands of hectares annually. Although the pesticide most commonly used is the bacterium *Bacillus thuringiensis* (Bt), which affects larval insects only and has no direct effects on vertebrates, it still may affect birds indirectly by eliminating their most important prey, caterpillars. The gypsy moth is expected to eventually invade most of the lower 48 states, and is expected to be most devastating in the southern states, whose forests have a high oak component (oaks are preferred hosts).

Eighteen 200-ha plots were established in 1994, nine in each forest. Within each plot, a 30-ha core plot was established where most of the bird and insect work is being performed. Three treatment options (Bt, no-action [defoliation], and controls) were randomly allocated to the plots to provide six replicates of each treatment option. Unlike many studies, controls are not untreated treatments. Rather, we expect the untreated areas to be defoliated, so they will not serve as controls as defined above. Therefore, six plots will be sprayed with Gypchek, the commercial formulation of the nucleopolyhedrosis virus that affects only the gypsy moth (it is not in widespread production and is available only for experimental purposes). This will assure that the only difference between defoliated sites and controls will be defoliation (neither will have Bt), and that the only difference between Bt-treated sites and controls will be Bt (neither will have defoliation). Pre-treatment data collection occurred in 1995-1996, and pesticide treatments were applied in1997 and 1998. With post-treatment monitoring, the project is scheduled to be a 10-year study. Measurements taken include point counts, territory mapping, survival, productivity, habitat, diet and foraging behavior, and arthropod sampling. Methods again generally follow BBIRD protocols.

This project was funded by a competitively awarded grant to a team headquartered at WVU. The team consists of entomologists, a toxicologist, avian ecologists, and a herpetologist. Plots were located through collaboration with USFS personnel. Spraying was done as part of the gypsy moth eradication programs of the respective national forests, and involved state and federal biologists. Spray volumes and rates reflected normal applications.

3. Alternative Prescribed Burning Practices in Longleaf Pine Forests—In the southeastern coastal plain, applications of prescribed fire for management of northern bobwhite (*Colinus virginianus*) quail in longleaf pine (*Pinus palustris*) forests have been conducted during February and March for more than 70 years (Stoddard 1931). The genesis for this idea came from the understanding that lightning-season ignitions were a natural process of coastal plain

ecosystems. However, elements of controversy (fire burns nests), as well as convenience (February and March are pleasant times to burn, whereas June and July can be miserable), resulted in development of a paradigm of dormant season applications of prescribed fire for many years.

Over time, enlightened managers realized that if prescribed fire was to be used to mimic an ecosystem process, ignitions should be generated during the peak of lightning season (April-August) rather than dormant season (late winter). Although winter months are not outside the temporal range of natural fire occurrence in this region, research and anecdotal observation indicate that applications of lightning season fire are essential for keystone plants like wiregrass (*Aristida stricta*) to flower and set viable seed. The existing literature on comparison of dormant and lightning season fire applications is limited, controversial, and conflicting (Robbins and Myers 1992).

Therefore, an experiment was developed to examine how dormant and lightning season applications of prescribed fire influence the abundance and distribution of vertebrates in longleaf pine forests. In one study, four pairs of 12 ha plots were each established in Apalachicola National Forest in Florida, and the Sandhills region of North Carolina. In each pair, one of the two fire application options was randomly assigned. The plots are imbedded in much larger management units that average 50-100 ha, which is the level of management at which prescribed fire is applied. Here, controls were not used because the "no treatment" option is not a viable management alternative. Therefore, pre- and post-treatment assessments are a central part of the experimental design (Engstrom and others 1996). In this study, bird abundance was estimated by spot mapping. Other work done on these plots and others in ancillary studies include vegetation sampling, arthropod abundance, and quail radiotelemetry. The project is funded through a partnership between the Department of Defense, the North Carolina Wildlife Resources Division, National Fish and Wildlife Foundation, four private foundations, several key donors from the Red Hills Shooting Plantations, the USFS, USFWS, Tall Timbers Research Station, and Mississippi State University (Brennan and others 1996).

4. Longleaf Pine Restoration/Midstory Removal Experiment—Longleaf pine forest once covered nearly 90 million acres of the southeastern coastal plain (Simberloff 1993). Today, less than 1 million ha remain. Much of the remnant longleaf stands are degraded from lack of frequent fire, which causes hardwoods to encroach and invade the midstory of longleaf stands. In many cases, encroachment of hardwood midstory causes keystone species such as red-cockaded woodpecker (*Picoides borealis*), gopher tortoise (*Gopherus polyphemus*), and bobwhite quail to leave or undergo local extinction.

Personnel from Eglin Air Force Base, The Nature Conservancy, the University of Florida, and Tall Timbers Research Station have been collaborating on a comprehensive, large-scale hardwood midstory removal experiment in longleaf pine stands at Eglin. The primary objective of the study is to understand how three methods of hardwood removal (fire, chainsaw, and herbicide) affect soil properties, vegetation, arthropods, and birds. Each treatment area is 100 ha. There are 6 replicates per treatment option (18 total), in addition to 3 untreated stands. Thus, overall, treatments were applied to 1800 ha under various local contracts by the Jackson Guard Natural Resources Division of Eglin. The project features point counts, vegetation and arthropod sampling, and measurements of avian foraging behavior.

Discussion

The benefits of large-scale manipulative experiments involving management questions are clear: Rigorous experimental design, realism, a good blend of management and research, and immediate application of results. Another benefit is that more resources are brought to bear to obtain funding.

How is funding obtained? This sort of research is expensive, and is only likely to be funded extramurally through competitive grants. The need for partnerships is critical, both to make the research stronger and to increase the funding base. Also, with more partners the funding base is more secure. Even if a project is well funded but from a single source, it is in jeopardy of ending if that single source is suddenly gone.

Researchers who have spent their careers conducting basic research might question the wisdom of becoming involved with management questions. We have found that several benefits result from conducting this sort of applied research. First, it is generally easier to obtain funding to do applied research, especially when agencies involved with management are providing some of the funding. Second, basic questions involving the ecology of migratory birds can always be addressed within the framework of the applied study. For example, Bt application can be viewed as an experimental manipulation of prey abundance, providing the basis for interesting questions involving bird/insect interactions and habitat selection theory, among others (e.g., Rodenhouse and Holmes 1992). Third, researchers in conservation biology often wonder if their research is making a difference. We have found that the results of this research are of great interest to managers, and that results are often applied before they find their way into print. Further, if conducted properly, the results of these studies can be applied not only on the study site but elsewhere with similar habitat types. Finally, collaboration among researchers and managers is the essence of Partners in Flight, an ad hoc group whose members, while diverse in interests and backgrounds, all work toward the single goal of conserving populations of Neotropical migratory birds.

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Conservation Insights From Demographic Studies of Migratory Songbirds in the American Midwest

Scott K. Robinson
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Abstract—Recent research on migratory songbirds has focused on monitoring populations and nesting success. These studies have provided many important insights for the North American Bird Conservation Plan. Expanded studies of the demographics of migratory birds (e.g., survival, season-long productivity of marked birds, decision rules governing site fidelity), however, will also be necessary to improve conservation plans. We advocate research directed toward creating a library of demographically well-studied species that will enable us to construct the spatially explicit population models necessary for the North American Conservation Plan. Detailed demographic data will enable us to improve estimates of the source/sink threshold, the vulnerability of species to ecological traps, the effectiveness of various control programs aimed at specific predators and brood parasites, the effects of local management practices on avian population dynamics, the balance of source and sink habitat necessary to maintain populations, and the spatial scale that is most appropriate for conservation planning. Comparable studies of habitat-specific survival during the nonbreeding season will also help us determine the extent to which populations are limited outside of the breeding season.

Recent studies of the population dynamics of migratory songbirds have enormously increased our understanding of both local and large-scale correlates of abundance and nesting success and improved our ability to detect future population changes (e.g., Martin and Finch 1995; Maurer and Villard 1996). In general, abundance, pairing success, and nesting success have been shown to be positively correlated with tract size (reviewed in Faaborg and others 1995). In addition, nesting success has been shown to vary at the landscape scale (e.g., percentage forest cover within a 10-km radius of study sites in the American Midwest: Robinson and others 1995b). Pairing success and nesting success, but not necessarily abundance, have further been shown to vary locally (e.g., with distance from edges: Reviewed in Paton 1994; Faaborg and others 1995).

In many cases, observed gradients in nesting success are steep enough to suggest a mosaic of population sources and sinks (sensu Pulliam 1988) in fragmented landscapes. Productivity in population sinks is insufficient to compensate for adult mortality, whereas population sources produce a surplus of young that are then available to recolonize or "rescue" (Brown and Kodric-Brown 1977) sink habitat. Robinson (1992) and Brawn and Robinson (1996), for example, concluded that nesting success was so low in small agricultural woodlots in Illinois that populations nesting in these woodlots were almost certainly being rescued by immigrants from very distant (>100 km away) sources. Robinson and others (1995b) further suggested that, for forest birds, the American Midwest consists of many small sink populations and only a few large source populations. This hypothesis has been partially corroborated by demographic modeling (Donovan and others 1995a) and by at least one intensive demographic study of a forest songbird, the Wood Thrush (*Hylocichla mustelina*) (Trine 1988). In all of these studies, low nesting success in sink habitat resulted from the combined effects of high rates of nest predation and brood parasitism by Brown-headed Cowbirds (*Molothrus ater*).

Studies such as these have greatly influenced the general approach to the North American Bird Conservation Plan (NABCP). A common-sense application of these results is to protect and enhance large habitat patches that have high nesting success (presumed source populations) and to reduce edges and increase tract size where nesting success is low (presumed population sinks). Any management action that increases levels of nest parasitism or nest predation can be challenged as a potential threat to bird populations.

As we will argue later in this paper, these management recommendations offer an excellent starting point. We will also argue, however, that the long-term success of the NABCP depends upon continued intensive demographic studies of representative species, both on the breeding and wintering grounds. Until we can better estimate key demographic parameters (e.g., survival, annual productivity, number of broods per year), we cannot determine the balance of source and sink habitat necessary to maintain migrant bird populations and reverse population declines. Nor can we determine the consequences of management actions on local population viability. Some species may be relatively unaffected by substantial decreases in local nesting success, whereas others may be vulnerable even to slight increases in rates of nest predation and brood parasitism. Without better demographic data, population models such as those of Pease and Grzybowski (1995) and Donovan and others (1995a) will be difficult to apply.

In this paper, we provide examples of insights drawn from ongoing demographic studies in the American Midwest and explore the implications of these studies for bird conservation

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planning. While we focus on demographic variables associated with the breeding season (survival, decision rules governing site fidelity, season-long nesting success, the consequences of single- versus double-broodedness), we acknowledge that studies of survivorship in nonbreeding habitats may also reveal steep survival gradients, as argued by Rappole (1995). We then advocate and describe a research program aimed at accumulating enough demographic data to model continental and even hemispheric population dynamics of a few representative migratory songbirds such as the Wood Thrush. We conclude by reviewing examples of direct applications of demographic studies to conservation planning.

Juvenile Dispersal and the Population Dynamics of Migratory Birds

Population dynamics of most migratory birds differ markedly from those of more intensively studied year-round resident species (e.g., Parids, cooperative breeders). Migratory bird populations can be limited by events occurring on widely separated breeding and nonbreeding habitats (reviewed in Sherry and Holmes 1995). This difference is widely acknowledged and is the foundation for hemispheric conservation plans for Neotropical migrants. An equally important, but less-appreciated difference is that most, but not all, migratory songbirds disperse far from their natal areas (Weatherhead and Forbes 1994). Because so few juveniles return to their natal sites, local population dynamics and reproductive success can be uncoupled (Brawn and Robinson 1996). Models that link local population collapse with fragmentation-related declines in nesting success (e.g., Urban and Shugart 1986; Temple and Cary 1988; Thompson 1993) may not be applicable to migratory birds, which can maintain locally stable populations over the long term even in habitat patches in which essentially no young are produced (Brawn and Robinson 1996). Such populations can be rescued by dispersing birds; for this reason, migratory birds are usually characterized as having source/sink population dynamics (e.g., Donovan and others 1995a,b). The capacity to recolonize even very poor habitat makes migratory songbirds vulnerable to "ecological traps," which are habitats that attract birds but fail to provide the conditions for successful nesting (Gates and Gysel 1978). The fact that migratory birds can maintain stable populations even in poor habitat (e.g., Brawn and Robinson 1996) makes their abundance and population trends questionable as indicators of site quality (Van Horne 1983), unless nesting success is also measured.

Understanding the population dynamics of migratory birds therefore requires answering the following questions:

1. What is the threshold of nesting productivity and survival that separates population sources and sinks?
2. What determines the "decision rules" adult birds use in making dispersal decisions?
3. Do these decision rules render species more or less vulnerable to ecological traps?
4. What cues are used by dispersing juveniles when selecting breeding sites?
5. Do the decision rules used by juvenile birds make them more or less vulnerable to ecological traps?
6. Is there density-dependent dispersal from source habitat?

The Source/Sink Threshold

The identification of population sources and sinks on the breeding grounds demands data on season-long per-capita productivity and the survival of adult and juvenile birds (Pulliam 1988). The source/sink threshold is the annual productivity per pair necessary to compensate for adult mortality and is defined as

$$\frac{2(1-\mu)}{\mu_0}$$

where μ = adult survival and μ_0 = juvenile survival. A population is likely to produce a surplus of young when it is above this threshold value, and will only be maintained by immigration when it is below it. We can estimate minimal adult survival based on return rates, an approximation that almost certainly underestimates true survival (Martin and others 1995) (see below), and we can measure season-long productivity either directly (e.g., Holmes and others 1992) or indirectly using models (e.g., Pease and Grzybowski 1995, Donovan and others 1995a). Juvenile survival is currently impossible to estimate precisely, and is usually approximated as half of adult survivorship (e.g., Nolan 1978; May and Robinson 1985; Temple and Cary 1988; Holmes and others 1996), although there is little empirical support for this value (Perrins 1991). If the data collected by Anders and others (1997) are representative, however, juvenile mortality during the first few weeks of life may be much higher than usually estimated. Because of these uncertainties associated with survivorship estimates, it is often necessary to calculate a range of source-sink threshold values based on ranges of adult and juvenile survival.

Adult Site Fidelity and Adult Survival

Because at least some adults return to their breeding territories, we can obtain minimal estimates of survivorship based on returns of marked birds. Adult site fidelity, however, is not absolute (Marshall and others , this proceedings). Many intensively studied species use a predictable set of rules when deciding whether or not to return to a site. In general, birds are more likely to return if they have nested successfully both within a season (Robinson 1985; Jackson and others 1989) and between years (Greenwood and Harvey 1982; Robinson 1985; Bollinger and Gavin 1985; Gavin and Bollinger 1989). In some cases, these "decision rules" vary with age and sex (Robinson 1985; Trine 1996). Usually, young birds are less likely to return following reproductive failure in the previous year (Robinson 1985), but in at least one species, the Wood Thrush, older birds are less likely to return following failure (Tine 1996). Decision rules also can vary with sex; usually, males are more likely to return than females. In the Kentucky Warbler (*Oporornis formosus*), females have higher return rates following reproductive

success regardless of age, whereas males take reproductive success into account only following their first year of breeding at the site. Reproductive success has no impact on future dispersal decisions by male Kentucky Warblers following their initial return (S. F. Morse, unpublished data). In some species, however, there are no sex-based differences (Trine 1996).

It may be possible to improve survival estimates of songbirds that follow these predictable rules by identifying the conditions under which individuals are most likely to return, and to use these return rates as survival estimates. In southern Illinois, for example, Wood Thrushes that fledge two broods in their second year in a site return to that site at a rate of over 80% (Tine 1996). In contrast, Kentucky Warblers nesting in the same area never return at rates higher than 60%, even long-term residents that nest successfully (S. F. Morse, unpublished data). Similarly, even the most successful Black-throated Blue Warblers (*Dendroica caerulescens*) return at rates of only <50% (Holmes and others 1992, 1996). Because the most reproductively successful individuals may also be the fittest, return rates of successful birds may overestimate survival rates for all individuals in a population, or at least be less likely to be biased toward underestimating survival. For this reason, experimental manipulations randomly assigning nesting success within several populations may be necessary to control for fitness differences among individuals. Such experiments are under way for at least one Neotropical migrant, the Prothonotary Warbler (*Protonotaria citrea*) (J. P. Hoover, unpublished data). In general, however, the use of probability-based survival models (Martin and others 1995) may be preferable to using return rates for estimating survival.

Because of differences in survival rates (Martin and Li 1992; Peach 1993) the source/sink threshold varies greatly among species. Wood Thrushes, for example, may need to produce only 1.7 young/pair/season, assuming a 70% adult survival rate and a 35% juvenile survival rate (Roth and Johnson 1993). In contrast, for Kentucky Warblers (Morse 1996) and Black-throated Blue Warblers (Holmes and others 1992) to exceed the estimated source/sink threshold, their productivity needs to be in the order of 2.7-4.0 young/year, assuming adult survival rates of 50-60% and juvenile survival rates of 25-30%. Pease and Grzybowski (1995) found that estimates of the source/sink threshold were more sensitive to adult survival than to any other variable.

The Strength of Sources and Sinks

Most studies of the season-long productivity of migratory birds conclude either that populations are sinks (Tine 1998; Thompson and Nolan 1973) or that productivity is at or just slightly above the source/sink threshold (Holmes and others 1992; Nolan 1978). In southern Illinois, Kentucky Warbler productivity even in the "best" habitat (old, interior forest) is at the lower end of the estimated source/sink threshold (Morse 1996; table 1), even though nest predation and parasitism rates are as low as they are anywhere in the Midwest (Robinson and others 1995b). Similarly, Black-throated Blue Warbler productivity is barely above the estimated source/sink threshold even in optimal habitat (presence of a dense shrub layer) in a large, unfragmented eastern forest (Holmes and others 1992, 1996).

The studies cited above strongly suggest that, for many species, sources are weak even under the best local conditions. Clearly, if sources are weak, any factor that increases nest predation and brood parasitism is more likely to push populations below the source/sink threshold, and decrease the pool of potential immigrants for sink habitats. Extensive source habitat may be necessary in order to balance losses in strong sinks, especially if sink habitats act as ecological traps. If sources are typically weak, annual variation in predation rates within source habitat (e.g., for Acadian Flycatchers [*Empidonax virescens*] in southern Illinois: Trine and others 1998; and Wood Thrushes in Missouri: Anders and others 1997) also might be sufficient to create temporal sources and sinks.

If we are systematically underestimating annual survival, then our estimate of the source/sink threshold may be too high (Marshall and others, this proceedings). The high rates of juvenile mortality measured by Anders and others (1997), however, suggest that mortality within the first few weeks of life alone may equal estimates commonly used to approximate juvenile mortality for an entire season. Recent modeling efforts, however, suggest that adult survival may be higher than usually estimated (Martin and others 1995; Chase and others 1997). Given these uncertainties, it seems prudent to assume that we need large areas of source

Table 1—Rates of Brown-headed cowbird brood parasitism, rates of nest predation, and the per-capita production of young in a banded population of Kentucky Warblers breeding in a heterogeneous forested site in the Shawnee National Forest in Union County, IL, from 1994-1995. The data presented here are a subset of those collected from 1992-1996 (Morse 1996). The core forest was relatively mature (70-120 years old) and farther than 1 km from a suitable cowbird feeding area in a nearby agricultural plot. Marginal forest was within 1 km of this plot and consisted of recently disturbed tracts (tree plantations, clearcuts of various ages, and a residential clearing) and a small amount of mature forest. Nest success was calculated using Mayfield's (1975) method.

	"Core" forest	"Marginal" forest
Percent of nests parasitized (N)	13 (80)	50 (86)
Percent of nest predated (exposure days)	57 (890)	82 (780)
Mean host young fledged per female (N)	2.98 (48)	0.92 (52)

habitat to buffer annual variation in productivity, and to compensate for human-induced "black hole" population sinks associated with habitat fragmentation.

Spatial Scale of Sources and Sinks

Robinson and others (1995b) and Donovan and others (1995a) suggested that, for a variety of species, nest predation rates and brood parasitism levels (and thus source/sink dynamics) depend on the distribution of forest cover at the scale of the landscape (operationally defined as the area of core forest within 10 km of the focal patch). Indeed, Wood Thrush nesting success does not depend on forest tract size in the highly fragmented Shawnee National Forest: even in the largest tracts, reproduction is below the estimated source/sink threshold. By contrast, studies of Kentucky Warblers in the same region suggest that reproductive success is linked to both local (within-site) and landscape-level (e.g., tract size) habitat features (Morse and Robinson, in press). For this species, nest predation decreases with forest age, and parasitism levels decrease with increasing distance to a suitable cowbird foraging area. The resulting gradient in reproductive success within this site appears steep enough to produce source/sink dynamics at the scale of the forest tract (Morse 1996; table 1). Black-throated Blue Warblers also show possible source/sink dynamics in relation to stand age (Holmes and others 1996).

Impacts of Nest Predation and Brood Parasitism on Annual Fecundity

Methods for assessing the relative impact of brood parasitism and nest predation on annual fecundity, such as proposed by Pease and Grzybowski (1995), are likewise crucial for modeling the source/sink threshold and for designing effective conservation strategies. Clearly, reducing cowbird populations is easier than controlling the myriad predators that attack nests. Cowbird populations can be controlled locally through trapping (reviewed in Robinson and others 1993, 1995a) or at larger spatial scales by eliminating key cowbird feeding areas. If, however, cowbird parasitism has only a minor impact on annual fecundity as argued by Martin (1992a), then cowbird control may have little net impact on local bird populations.

The impacts of cowbird parasitism and nest predation on annual fecundity depend upon many variables (Pease and Grzybowski 1995). For example, single- versus double-brooded species may respond very differently to nest predation. Even a twofold difference in predation rates near clearcuts had little effect on annual productivity in a single-brooded warbler, the Ovenbird (*Seiurus aurocapillus*), because pairs that lost nests to predators would renest until most were successful at least once (King and others 1996). Prairie Warblers (*Dendroica discolor*) also were able to compensate for very high (>80%) rates of nest predation by frequent and rapid renesting. In contrast, Kentucky Warblers (a facultatively double-brooded bird) produced almost twice as many young in habitats with low (<60%) nest predation levels than in those with high (>60%) levels (Morse 1996; table 1). Without the production of a second brood, Black-throated Blue Warbler populations in presumed source habitat in New Hampshire would have been sinks (Holmes and others 1992).

Brood parasitism interacts in complex ways with nest predation and the number of broods produced (Pease and Grzybowski 1995). Heavily parasitized single-brooded species would suffer substantial losses in seasonal fecundity, because in most of these species, parasitized nests fledge few host young (May and Robinson 1985). Double-brooded species would have more opportunities to escape parasitism, especially if the second nesting attempt occurred in mid to late summer, when cowbirds have ceased breeding. Because at least some host young are produced from parasitized nests, producing two broods would still increase host nesting success, possibly above the source/sink threshold. Because Wood Thrushes are large enough to raise mixed broods, some double-brooded populations are close to the source/sink threshold despite high parasitism levels (100%) and intensity (2-3.5 cowbird eggs per nests) (Trine 1998). Very high nest predation rates also might reduce the impact of parasitism by destroying early season nests that often suffer higher rates of parasitism. Shrubland/edge species may produce most of their young late in the season after cowbirds have finished breeding and dense annual growth of grasses and forbs reduces nest predation rates (S. K. Robinson and S. F. Morse, unpublished data).

These factors together create fertile conditions for the use of population models such as those proposed by Pease and Grzybowski (1995). Such models can detect threshold levels of nest predation and brood parasitism above which populations are likely to be sinks, and could help evaluate the effectiveness of efforts to control cowbirds or nest predators. Once we have better demographic data, these models eventually should enable us to make reasonable estimates of seasonal fecundity where nest predation rates and brood parasitism levels are the only data available.

Determining Vulnerability to Ecological Traps

Three kinds of data are necessary to understand local population dynamics and the vulnerability of a species to ecological traps. First, we need to understand the behavioral decision rules governing site fidelity in adults and, if possible, natal philopatry in juveniles. Second, we need to determine the cues used by juveniles when selecting a breeding site. And third, we need population monitoring data from a wide geographic area and a number of habitats to estimate the extent to which breeding birds saturate suitable habitat. In this section, we discuss each of these research needs.

Decision Rules Governing Adult Site Fidelity

As discussed above, adult birds tend to disperse within a season if their nests are destroyed early in the season (Greenwood and Harvey 1982; Robinson 1985; Jackson and others 1989; Trine 1996) and tend to not return the following

year if they fail to produce young, or, for multiple-brooded species, if they fledge fewer than two broods (Roth and Johnson 1993; Tine 1996; but see Payne and Payne 1993; Hoover and others 1995). Although site fidelity varies with sex and age in some species, all of these studies suggest that adults have a behavioral mechanism enabling them to avoid areas of chronically high nest predation. Viewed in this light, the well-documented area sensitivity of many migratory songbirds (e.g., Robbins and others 1989a) may represent adaptive avoidance of small tracts in which nest predation rates are generally high (reviewed in Faaborg and others 1995). Small woodlots with low nest predation rates can contain high densities of some Neotropical migrants. Roth and Johnson (1993), for example, found high population densities and high adult site fidelity of Wood Thrushes in a small Delaware woodlot in which Wood Thrushes experienced low nest predation rates. The avoidance of small woodlots by ground-nesting warblers in the American Midwest (Blake and Karr 1987; S. K. Robinson, unpublished data) may reflect the abundance of raccoons and resulting high nest predation rates (Brawn and Robinson 1996; E. J. Heske, unpublished data).

Even within sites, decision rules can lead to avoidance of sink habitat. Tine (1996) found that Wood Thrushes abandoned one study site after three years of high nest predation rates. The site was not recolonized for at least 5 years; in contrast, population densities in two nearby areas with lower nest predation rates remained consistently high. In sites with low predation rates, fidelity of young Wood Thrushes was high regardless of their own nesting success, suggesting that their behavioral decisions may have been influenced by the success of their neighbors (Trifle 1996). Holmes and others (1996) found that Black-throated Blue Warblers breeding in optimal habitat were much more likely to return the following summer than those breeding in suboptimal habitat.

Habitat Saturation and Population Sinks

Wood Thrush population densities in southern Illinois are generally low and highly variable from year to year, even in apparently suitable habitat (S. K. Robinson, unpublished data). In contrast, Kentucky Warblers maintain high population densities in all apparently suitable ravine-bottom habitat, and quickly establish high populations in habitat created by activities such as selective logging (Robinson and Robinson, in press). These two species show dramatically different population-level responses to spatial variation in nest predation rates. For the Wood Thrush, ravines with high predation rates can remain unoccupied for years and, within and among ravines, individuals tend to concentrate in areas with low predation rates. Kentucky Warblers, on the other hand, occur at high population densities in suboptimal habitat, even after several years of high predation rates, which suggests a saturated population. Black-throated Blue Warblers similarly show a tendency to occupy optimal habitat first and then "spill over" into suboptimal sink habitats, which have a higher proportion of young birds. Petit and Petit (1996) found a similar tendency for Prothonotary Warblers to occupy habitats with low nest predation rates first.

Black-throated Blue and Prothonotary Warblers therefore conform to Fretwell and Lucas' (1970) models of "ideal despotic" habitat selection, in which optimal habitats are occupied first and suboptimal habitats are occupied only by surplus individuals. When populations are below saturation (e.g., Wood Thrushes in southern Illinois), few individuals are forced to nest in habitats with high predation rates. Some individual Kentucky Warblers, Black-throated Blue Warblers, and Prothonotary Warblers, on the other hand, are forced to nest in areas with high predation rates.

Conservation Implications

The decision rules governing site fidelity appear to be adaptive with respect to nest predation, at least for some species. Sink habitat created by high predation rates may be occupied only if a surplus of individuals is produced in source habitats, in which case sink habitat does not function as an ecological trap. As long as productivity in population sinks exceeds the losses incurred while breeding (as opposed to floating), sink habitat may benefit populations by providing breeding opportunities for birds that might not nest otherwise (Howe and others 1991). Long-term persistence of regional metapopulations therefore depends more on the continued health of source populations than on the extent of sink habitat. A conservation strategy focusing on large, unfragmented tracts can guarantee high regional populations by enhancing the production of surplus individuals available to recolonize even small habitat islands (Brawn and Robinson 1996), an approach advocated in the North American Bird Conservation Plan. Decreases in source habitat caused by fragmentation could cause populations to retreat to remaining source habitat and reduce the number of surplus birds available to recolonize isolated habitat patches. In this situation, the population declines may be analogous to Wilcove and Terborgh's (1984) melting ice cube model of range contraction, because suboptimal, marginal habitats will be abandoned first. Regional populations will continue to decline only with further loss of source populations. As long as source habitat is not reduced, an increase in the amount of sink habitat will cause no further population declines. Adaptive decision rules therefore make populations less vulnerable to population sinks created by high rates of nest predation.

Does Cowbird Parasitism Create Ecological Traps?

Decision rules in response to nest predation and the number of broods fledged suggest a long evolutionary history of responding to predation. For many North American species, however, cowbird parasitism has become a threat only recently, as the Brown-headed Cowbird increased both its geographical range and global population (reviewed in Robinson and others 1995a). This phenomenon is so recent (<50 years in some areas of the West) that many species may not yet have had the opportunity to evolve resistance (evolutionary "lag": Rothstein 1975). Birds of the eastern deciduous forest, in particular, seem to lack any defenses against parasitism. They tend not to eject cowbird eggs or abandon

parasitized nests, nor do they select nest sites that are inaccessible to cowbirds (e.g., cavities). Many prairie and shrubland birds, in contrast, have a variety of defenses against parasitism (reviewed in Robinson and others 1995a), which suggest a long history of coevolutionary interactions with cowbirds (Robinson and others 2000; Rothstein and Robinson 1998).

This lack of defense against cowbird parasitism in forest birds also appears to extend to decision rules governing site fidelity. Wood Thrush populations breeding in fragmented midwestern forests, in which virtually every female is parasitized, return at rates that are as high or higher than those breeding in eastern forests where parasitism rates are low (Roth and Johnson 1994; Hoover and others 1995; Trine 1996). Return rates of Wood Thrushes to two sites in southern Illinois that are likely population sinks (Trifle 1998) averaged 50-80% (Trine 1996). Nest predation rates were low in both of these sites, but cowbird parasitism was so intense (85-95% of nests parasitized, 2-4 cowbird eggs/nest) that annual productivity was well below the estimated source/sink threshold (Tine 1998). Return rates were identical for parasitized and unparasitized female Kentucky Warblers at another site in southern Illinois (S. F. Morse, unpublished data), where parasitism ranged from 15-70%, creating likely population sinks in some areas with low nest predation rates. While predation on Kentucky Warbler nests varied little between mature forest stands within this site, there was a twofold difference in annual productivity due primarily to differences in parasitism rates (17% versus 50%) (Morse 1996). Prothonotary Warblers likewise show no effect of parasitism on site fidelity (J. P. Hoover, unpublished data).

These studies from the American Midwest suggest that many forest hosts lack adaptive responses to brood parasitism. As a result, areas with high cowbird parasitism but low nest predation are likely to qualify as ecological traps. Most of Illinois appears to be an ecological trap for the Wood Thrush; this fact may be causing the regional population declines shown by this species (Peterjohn and others 1995; Roth and others 1996). The ecological trap scenario, however, is probably not responsible for the declines of Wood Thrushes in the Northeast, where cowbird parasitism is much less of a problem, and forest area is increasing (Roth and others 1996).

These results suggest an additional, hidden cost of parasitism which might increase the benefit of efforts to reduce cowbird parasitism. Because cowbird parasitism and nest predation tend to be positively correlated both at a local scale (Temple and Cary 1988; Donovan and others 1995b) and at the landscape/regional scale (Robinson and others 1995b), however, species that avoid areas with high nest predation may also be, on average, avoiding areas of high parasitism.

Cues Used by Juveniles to Select Breeding Sites

In addition to adult site fidelity, the attractiveness of habitat patches to juveniles also will affect local population dynamics. Usually, habitat selection is thought to be based on a "niche gestalt" involving such variables as vegetation structure and food availability (James and others 1984). An additional possibility is that dispersing birds use the presence of conspecifics to evaluate habitat quality (Stamps 1988). "Conspecific attraction" is usually considered to be a problem for avian metapopulations because once a population becomes extinct, the lack of conspecifics might prevent recolonization of the habitat patch in a negative feedback loop (Smith and Peacock 1990; Ray and others 1991). If, however, the lack of conspecifics signals poor habitat, then conspecific attraction could be adaptive. Because adults appear to return to areas in which they have nested successfully, the presence of conspecifics should be a good predictor of habitat quality, especially in habitat patches in which predation rates are predictably low. Failure to recolonize small habitat patches in which the adult population has become extinct may be adaptive for individuals, and may benefit populations as well, if predation rates are chronically high. We do not yet know the extent to which juveniles use the presence of conspecifics when selecting nesting sites. Some species seem to form aggregations within otherwise suitable habitat (e.g., Cerulean Warbler *Dendroica cerulea*: Robbins and others 1992; G. C. Vanderah, unpublished data; Kirtland's Warbler *Dendroica kirtlandii*; Probst 1986), which may result from conspecific attraction. Declining populations may benefit from conspecific attraction, because it helps individuals find mates and would tend to concentrate birds in areas of low nest predation. Experimental studies of conspecific attraction are needed to test this hypothesis.

Winter Decision Rules

Birds often show site fidelity to wintering grounds comparable to that shown by breeding birds (reviewed in Rappole and McDonald 1994; Rappole 1995). We do not yet know the extent to which the decision rules governing site fidelity reflect variables such as food, cover, and condition. Conway and others (1995) and Niven (1996) found few differences in condition or return rates among habitats varying greatly in disturbance. Winker and others (1990), on the other hand, found that return rates of Wood Thrushes varied greatly among habitats. One of the key predictions of Rappole and McDonald's (1994) hypothesis that populations of Neotropical migrants are limited on their wintering grounds was that migrants saturate available winter habitat, which forces many birds into suboptimal habitat, and forces others to live as semi-nomadic floaters. Some of the species that do not saturate their breeding habitat, such as Wood Thrushes in southern Illinois, may be limited by winter rather than breeding-habitat availability. Clearly, we need more winter-season demographic studies of such factors as site fidelity and habitat-specific differences in site fidelity and condition.

Research Recommendations

As we argued at the outset of this paper, the success of the North American Bird Conservation Plan will depend upon improved spatially explicit population models for key species. These models rely on estimates of the source/sink threshold and vulnerability to ecological traps, and are very data intensive, requiring better demographic data than

generally are available for most species (Pease and Grzybowski 1995). For this reason, we advocate research leading toward the creation of a library of demographically well-studied species that can be used for spatially explicit modeling, building on such large-scale projects as MAPS and BBIRD. This research would include intensive studies of color-marked populations on both the breeding and wintering grounds. Ideally, demographic studies would be long term, and conducted in several different parts of the breeding and wintering range. Radio-telemetry of fledglings on the breeding (e.g., Anders and others 1997) and wintering grounds (e.g., Winker and others 1990) will help improve estimates of nonbreeding survival. Such studies also will enable us to use the more powerful versions of Pease and Grzybowski's (1995) models when the only data available are on rates of nest predation and cowbird parasitism.

The species chosen for these studies should reflect both the ease of study and their conservation significance, and should be representative of the major taxonomic groups and nesting guilds. For the eastern deciduous forest, we already have extensive data on Wood Thrushes (reviewed in Roth and others 1996), Kentucky Warblers (S. F. Morse, V. McDonald, unpublished data), Black-throated Blue Warblers (reviewed in Holmes and others 1996), Acadian Flycatcher (D. Whitehead, unpublished data), Prothonotary Warblers (Petit and Petit 1996; J. P. Hoover, unpublished data), and American Redstarts (*Setophaga ruticilla*) (Sherry and Holmes 1992). There also are attempts to work with canopy species such as the Scarlet Tanager (*Piranga olivacea*) (Rosenberg and others 1999) and the Cerulean Warbler (P. Hamel, personal communication). We currently lack good demographic data from Neotropical migrants nesting in spruce woods. Other habitats and geographical areas will require different indicators.

Conservation Applications of Demographic Studies

Here we provide examples of a general conservation plan based on our demographic data from the American Midwest.

1. Conservation efforts should focus first on preserving and enhancing the largest forest (and grassland) tracts within any region. Such tracts are the best candidates for providing population sources for a wide variety of species. These areas may need to be very large if source populations prove to be weak (i.e., they produce only a small per-capita surplus). The reforestation of much of the northeastern United States may provide adequate source habitat for forest birds for this region. In the American Midwest, however, regional populations may depend upon just a few large forest tracts (Robinson and others 1995b; Donovan and others 1995b). For preferred cowbird hosts such as midwestern Wood Thrushes, the size of tracts necessary to provide source habitat may need to be very large, given the 7-km commuting range of cowbirds between feeding and breeding areas (Thompson 1994). Because of consistently heavy parasitism, even tracts of 3,000 ha in southern Illinois are likely population sinks (Trine 1998). For this reason, we advocate focusing on tracts of at least 10,000 ha; in states such as Illinois that lack tracts of this size, maintaining Wood Thrush source populations within the state may entail extensive habitat restoration. Alternatively, a regional conservation plan focusing on source populations outside the state may be the most practical strategy for this species. Virtually all forest species, even those that are not preferred cowbird hosts, will benefit from the preservation, enhancement, and restoration of these "macrosites." Even disturbance-dependent species such as the Indigo Bunting (*Passerina cyanea*) appear to nest more successfully on edges within large forest tracts (Suarez and others 1997).

2. The next priority (after focusing on the largest tracts) for conservation planning should be the largest tracts available within a landscape (or a subregion, such as southern Illinois), even if they are too small to provide source habitat for all species. The source/sink dynamics of less-preferred cowbird hosts such as the Kentucky Warbler may be largely determined by rates of nest predation, and potentially occur on a much smaller scale than that for the Wood Thrush. Although Kentucky Warblers would certainly benefit from extensive forest tracts necessary for the maintenance of Wood Thrush source populations, site management practices within smaller tracts also strongly affect Kentucky Warbler reproductive success, at least in southern Illinois. A management strategy aimed at medium-sized tracts ("mesosites"), which preserves core areas of undisturbed or lightly disturbed forest far (>1 km) from agricultural edges, might increase source habitat for species such as the Kentucky Warbler. Potential population sources exist for Kentucky Warblers in tracts of 900-3,000 ha in the Shawnee National Forest. Within these tracts, nesting productivity could be enhanced further by using uneven-age rather than even-age forestry management, and by eliminating or modifying the management of specific agricultural openings (e.g., feedlots) and recreational areas (e.g., campgrounds with mowed grass) in which cowbirds feed. The "Forest Interior Management Units" management plan for the Shawnee National Forest (USDA Forest Service 1986), which emphasizes uncut "core" areas and uneven-age silviculture within tracts of at least 1,100 acres, should benefit Kentucky Warbler populations. More work needs to be done, however, to determine the source/sink dynamics of other species within these tracts before we can fully assess the value of "mesosites."

3. Relatively small tracts ("microsites") should be the lowest priority for the conservation of breeding forest birds, but they may be extremely important as migratory stopover habitat. In Illinois, small tracts (<200 ha) are characterized by maximal rates of nest predation and cowbird parasitism (Robinson and others 2000; S. K. Robinson, unpublished data). Although some small woodlots undoubtedly contain viable populations of migrant birds (e.g., Roth and Johnson 1993), many are likely to be "black hole" population sinks (e.g., Robinson 1992; Brawn and Robinson 1996). Instead of focusing on breeding birds, management of small tracts should aim toward improving quality of migratory stopover habitat.

4. Within all tracts, ecosystem processes should be carefully monitored and, where possible, restored. It is easy to envision how intensive deer herbivory could destroy source habitat for Black-throated Blue Warblers (Holmes and others 1996) and Kentucky Warblers (McShea and others 1995) by reducing shrub density and ground cover. The loss of tree

species by selective deer browsing also could have a large effect on bird populations of northern forests (Alverson and others 1988; Holmes and Robinson 1981). Altered hydrological cycles in floodplain forests would affect the source/sink dynamics of Prothonotary Warblers (Petit and Petit 1996; J. P. Hoover, unpublished data), by affecting the availability of safe nest sites. We are just beginning to appreciate the extent to which habitat structure and composition affect the population dynamics of migratory birds.

6. Population and Habitat Assessment: Using Volunteers

American Wigeon

6. Section Overview—Population and Habitat Assessment Using Volunteers

Rick Bonney
Greg Butcher

The history of North American ornithology is replete with the contributions of volunteers, and the tradition of volunteer involvement in ornithological field work continues to grow and flourish today. Indeed, much of the information required to develop conservation plans for migratory birds—for example, large-scale surveys of bird populations in varied habitats—is best collected by armies of volunteer field biologists.

This section is intended to illustrate the range and variety of projects in which volunteers can play a major effort. First, Kris Agard describes the Lake Ontario Migratory Songbird Study, conducted over 375 miles of shoreline by The Nature Conservancy and the New York Natural Heritage Program. Agard discusses practices used to recruit, train, and manage volunteers.

In the following paper, Ken Burton and David DeSante describe the behind-the-scenes effort to operate the Monitoring Avian Productivity and Survivorship (MAPS) program, a continentwide, standardized monitoring program that uses mark-recapture data gathered at a network of constant-effort banding stations. An estimated 64% of the effort expended in running MAPS stations is contributed by volunteers. Next, Eric Nelson and Carol Damberg show how volunteer birders were trained to conduct point counts on the Upper Mississippi River National Wildlife Refuge. With only two staff qualified to conduct point counts, volunteers are essential to monitoring birds on this area, the longest national wildlife refuge in the United States.

In the next paper, Linda Siebert shows how the Bureau of Land Management encourages home-grown efforts to recruit volunteers for a variety of educational and conservation efforts in the small town of Moab, Utah. In the final paper, Judi Falk describes a semester-long university course titled "Techniques for Monitoring Songbirds," developed by the Tongass National Forest and the University of Alaska as a training program for volunteers who go on to monitor birds in Juneau or other parts of the United States.

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The Lake Ontario Migratory Songbird Study: A Case Study of the Challenges and Rewards of Using Volunteers in Ornithological Research

Kris Agard West

Abstract—A two-year spring migration research project conducted by The Nature Conservancy and the New York Natural Heritage Program is presented as a model for involving volunteers in basic research. The study area spanned roughly 375 miles of Lake Ontario shoreline. The success of the project depended on more than 200 volunteers to manage information, provide logistical field support, collect data, and provide access to study sites on private land. Practices used to recruit, train, and manage volunteers are presented. Information on successful practices, as assessed by the volunteers, are shared. Volunteer recruitment, training, and administration requires substantial coordination and support. However, the time and financial resources invested in volunteer management are rewarded by the high volume of data collected and the long-term benefits of increased participation in bird conservation by birders and non-birders alike.

The Lake Ontario Migratory Songbird Study was a two-year research effort, encompassing New York's Lake Ontario shoreline, conducted jointly by the Central and Western New York Chapter of The Nature Conservancy (CWNY TNC) and the New York Natural Heritage Program. The goals of the study were to document whether migrant landbirds concentrate in habitat close to Lake Ontario during spring migration. Modeling the study protocol after Mabey and others (1993), volunteers conducted 10-minute point counts twice weekly from mid-April through mid-June in 1993 and 1994 at 239 study sites. The outcomes of the study are currently being used by CWNY TNC and several other groups to conserve important shoreline stopover habitat.

The project was funded through corporate contracts, foundation grants, and gifts from bird clubs. The budget covered project-related expenses for three years including salary for a project coordinator, volunteer training materials and supplies, contract fees for professional services, travel, and field equipment. As a result, volunteers were not asked to contribute financially to the project.

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Project Description

Volunteer Involvement

The project depended on more than 200 volunteers for scientific peer review, mapping services, access to study sites, data collection, logistical field support, and administrative assistance. Scientists from TNC, Natural Heritage Program, Cornell University, SUNY Albany, and SUNY Oswego provided peer review of study protocol. The New York State Department of Environmental Conservation Habitat Inventory Unit donated aerial photo interpretation and mapping services. Public land managers facilitated access to public property by waiving park entry fees and allowing access to restricted areas. Several people provided logistical field support and administrative assistance. More than 150 private landowners provided access to their property for use as study sites. Nearly 80 volunteer bird watchers contributed 726 person-days while conducting 4,826 10-minute point counts. The remainder of this paper will focus on the administrative measures taken to involve private landowners and amateur bird watchers in the study.

Private Landowner Involvement

As a result of a random site selection process, nearly two-thirds of the study sites were located on private property. We identified private landowners through tax records, then asked for permission to establish study sites on their properties. We contacted landowners by mail, and due to tight deadlines, followed up with phone contact. We received permission from about 50% of landowners contacted. Those contacted by phone were more likely to grant permission. The few landowners who explained their refusal cited liability concerns.

We maximized the educational value of private landowner participation by sending landowners background information about migratory bird conservation issues, project status updates, lists of birds observed on their property, and an informational booklet that was completed at the end of the study. The booklet provided information about local bird clubs, lists of recommended bird books, habitat protection options, and habitat management recommendations.

Bird Watcher Involvement

The project coordinator was responsible for recruiting volunteers from local bird clubs, training them in point-count

methods, and supervising all field work. We clearly defined volunteer roles in the project by creating volunteer job descriptions. We then identified people with the skills needed for each role and aggressively recruited them and trained them in methods specific to the project.

Bird Watcher Recruitment

Volunteer recruitment was facilitated by New York's organized bird watching community. The Federation of New York State Bird Clubs provided lists of all bird clubs and their officers. Shoreline area club officers and other people within the bird watching community identified the most skilled bird watchers. The project coordinator aggressively recruited proficient bird watchers through direct mail and personal phone calls.

Volunteer Training

Volunteer training consisted of a bird song identification tape and a one-hour classroom session on point count methodology (Ralph and others 1993). The song identification tape, created by the Cornell Library of Natural Sounds, included songs of 48 bird species commonly found in upstate New York during spring. Copies were provided to all volunteers, allowing them to brush up on their song identification skills before the field season.

Most participants valued the song identification tape as a new way to improve their birding skills. Improvements on our song identification tape would include a good variety of song types for each species. Furthermore, grouping songs by habitat guild would allow observers to use both habitat type and song to identify each species as they do by ear in the field.

The classroom session was a valuable way to discuss point count standards, address all questions, and distribute project materials. To generate a sense of team membership among the volunteers, we provided each volunteer with a clipboard, a TNC baseball hat, a letter of introduction for curious passers-by, a laminated sign to place on their dashboard, detailed written information covering all aspects of their involvement, and the song identification tape. The baseball hat and dashboard sign also provided a way for landowners to identify volunteers on their property from a distance.

Volunteer Administration

The coordinator created the structure of the project by identifying several volunteer roles including field observer, logistical field support crew, and administrative assistants. This allowed the volunteers to step into a pre-defined framework and focus their efforts in areas of most interest to them.

During the field season, the project coordinator focused on providing organizational support and oversight of data collection across the entire study area. This support simplified the tasks of each volunteer. Volunteers were given both written directions and maps to find the study sites. All data forms were provided along with addressed, stamped envelopes for data return to the project coordinator. Cost of gas was reimbursed for all who requested it. On a few occasions, the project coordinator made camping arrangements for volunteers traveling more than 100 miles to study sites.

Flexibility was crucial to the success of the project. Volunteers were allowed to set their own commitment to the project with regard to number of days of participation, maximum travel distance, number of hours per day, and their own role in the project. Data collection was allowed between two hours after sunrise until one hour before sunset to accommodate work schedules. Since most study sites were located off road in rural areas, we did not require volunteer observers to work alone. However, we did require that only one person on a team actually conduct the point count.

Communication between the project coordinator and volunteers throughout the duration of the project also was critical. The project coordinator's home and work phone numbers were provided to all volunteers. Providing the coordinator's home number gave the volunteers a sense that someone was available at any time in the event of an emergency. However, during this two-year study, the coordinator was contacted at home on only a few occasions. As minor problems arose throughout the study, volunteers worked with the project coordinator to identify and implement solutions. The coordinator shared status reports and preliminary results through mailings, newsletter articles, and public presentations, allowing volunteers to see tangible results from their work and to maintain their dedication to the project. Volunteers can never be thanked too often! Recognition and thanks for their contributions were made in all correspondence, during special events, and in published articles.

Data Quality Control

We addressed data quality at several levels including: Study design, volunteer recruitment and training, data review, and statistical analysis. Our study design included rotating observers to different sites to disperse observer bias. As discussed above, to ensure that we recruited competent observers, we focused recruitment on the best bird watchers in our area. Point count training included both written and verbal explanation of methodology and the need for standardized data collection. We assessed song identification skills of each volunteer with the tape. Individuals were encouraged to learn songs that were unfamiliar to them. The project coordinator reviewed all data forms; full accounts of unusual birds were required before they were included in the database. Finally, we analyzed the data for observer bias and removed outliers.

Project Outcomes

Outcomes of the project include: Involvement of the public in bird conservation, action by a conservation organization, and collection of data valuable to the growing field of stopover ecology.

Involving private landowners in this project provided a mechanism to educate them in bird conservation issues. A follow-up survey of landowners indicated that roughly half of them were more interested in songbirds as a result of their participation in the study. The other half indicated that they were already very interested in birds before the study began. Most importantly, about half of the landowners polled intend to improve management of bird habitat on their property.

Their management decisions are important, because most of the Lake Ontario shoreline is privately owned.

The bird watchers who contributed to the study were educated about bird research methods and gained a deeper understanding of bird conservation issues. A subset of them are assisting with long-term bird monitoring projects at several TNC preserves. In addition, CWNY TNC has received increased financial support for conservation projects from both individual bird watchers and bird clubs including Onondaga Audubon Society, Buffalo Ornithological Society, Genesee Ornithological Society, North Country Bird Club, and Genesee Valley Audubon.

The Nature Conservancy has taken several tangible steps to protect important stopover habitats on Lake Ontario ranging from private landowner education, information sharing with public land managers and land use planners, land acquisition, and cooperation with other land trusts and research groups.

We produced an informational booklet targeted to shoreline property owners. The booklet describes the need for habitat protection near the lake's shoreline and provides several options for doing so. The booklet was mailed directly to all volunteer landowners and bird watchers. Additional copies are distributed through Cornell Cooperative Extension offices and Soil and Water Conservation District offices across the shoreline.

The CWNY TNC also has communicated the study's preliminary findings to public land managers and planning entities. Planning departments in two shoreline counties have incorporated the findings into their assessment of important natural resources. We assisted The Town of Mexico, Sea Way Trail, Oswego County Department of Promotion and Tourism, Onondaga Audubon Society, and other partners in organizing a bird festival that attracted more than 1,000 people to the shore of Lake Ontario.

To date, TNC has protected more than 1,000 acres near Lake Ontario, including rare wetlands and the last mile of undeveloped barrier dune on the east end of the lake. We continue to work with public agencies and other land trusts to increase shoreline habitat protection.

Research results from this project will be submitted to a peer reviewed journal. The CWNY TNC is providing assistance to the Braddock Bay Bird Observatory to foster further stopover ecology research and participation in the Migration Monitoring Network. Further, the project's data are being used in state-wide and Great Lakes basin-wide collaborative research programs.

Conclusions

The outcomes of volunteer-based research are tangible and formidable. The success of the Lake Ontario Songbird study depended on (1) clear statement of project objectives; (2) staff support and coordination of volunteer activities; and (3) followup with partners to ensure conservation action.

Acknowledgments

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Volunteers and Training in MAPS

Kenneth M. Burton
David F. DeSante

Abstract—Mist netting and banding are important, well-established tools for researching and monitoring landbird populations; increasingly they are being used in large-scale monitoring efforts. The long-term success of these large-scale efforts depends on the participation of amateur volunteers. Volunteers are critical to the Monitoring Avian Productivity and Survivorship (MAPS) Program. An estimated 64% of the effort expended in running MAPS stations in 1995 was contributed by volunteers involved in all aspects of station operation, and the need for MAPS volunteers is likely to increase because of federal budget cuts. Unfortunately, the number of skilled, well-trained volunteers available to contribute to banding programs is limited. Thus, there exists a pressing need for accessible, affordable training programs in mist-netting and banding. To this end, The Institute for Bird Populations (IBP) offers a large number of internships and has established a nationwide program of low-cost, intensive, bander-training courses. In addition, IBP is facilitating a bander-apprenticeship program whereby trainees are paired one-on-one with qualified trainers. Benefits from these training and apprenticeship programs include: (1) increased participation of the private sector in landbird research and monitoring programs; (2) development of a pool of skilled amateurs and professionals into which agencies can tap for assistance in landbird research and monitoring; and (3) improvements in the accuracy, standardization, and thoroughness of banding data collected in research and monitoring programs. Some suggestions are offered for the development and maintenance of a viable volunteer cadre. The development of an effective North American Bird Conservation Plan must take training needs into consideration.

Mist netting and banding are important, well-established tools for researching and monitoring landbird populations (Baillie 1990; Butcher and others 1993; Nur and Geupel 1993a; Ralph and others 1993). These techniques increasingly are being used in large-scale monitoring efforts such as the Monitoring Avian Productivity and Survivorship (MAPS) Program and Constant Effort Sites (CES) Scheme; various migration-monitoring programs; and winter-season monitoring programs both in temperate latitudes and in the Neotropics (Baillie and others 1986; DeSante 1992b; DeSante and Burton 1995; DeSante and others 1993a; Peach and others 1990; Ralph and Peach, in preparation).

MAPS, like the Breeding Bird Survey, Christmas Bird Count, and Project Tanager, is a continentwide, standardized monitoring program that relies heavily on volunteers for the collection of data. Unlike these programs, however, MAPS entails the capture and handling of live birds and the collection of complex morphometric data. Because the number of skilled banders available to operate monitoring stations is limited, the long-term success of MAPS will depend on its ability to recruit, train, and maintain a viable volunteer base.

This paper demonstrates that volunteers play a critical role in the operation of MAPS stations, and that the need for volunteers in MAPS and other research and monitoring programs is likely to increase in the near future. The paper also outlines the steps being taken to build a viable MAPS volunteer base.

MAPS Volunteers: Role and Need

MAPS is a standardized monitoring program utilizing mark-recapture data gathered at a network of constant-effort banding stations throughout the continental United States and Canada (DeSante and others 1993b). MAPS stations fall into two categories: (1) those operated by IBP using volunteer interns; and (2) independently operated stations.

In 1995, IBP operated 138 out of 391 MAPS stations (35%). Interns contributed approximately 85% of the effort involved; paid IBP biologists contributed the remainder. At the 253 independent stations, volunteers contributed an average of 53% of the effort (based on a sample of 66 stations). Thus, we estimate that volunteers were responsible for 64% of the total effort involved in MAPS data collection in 1995.

Volunteers can be responsible for every aspect of MAPS-station operation, including selecting and preparing mist net sites; opening and closing nets; extracting birds from nets; identifying species (even among difficult groups such as *Empidonax*); banding captured birds; determining age and sex with the aid of appropriate reference materials; accurate scoring of morphometric data such as skull pneumatization, cloacal protuberance, brood patch, fat, molt, feather wear, juvenal plumage, wing chord, and weight; and collecting habitat data. At some independent stations, volunteers are designated to perform a single task such as extracting birds or recording data; this assistance can be particularly helpful on busy days.

The need for volunteers in MAPS and other large-scale research and monitoring programs is likely to increase for two reasons. First, MAPS continues to grow; the number of stations increased from 17 in 1989 to 391 in 1995. Second, federal support of the program, after growing steadily during the early 1990s, is now declining in relation to other sources of funding. During the first two years of MAPS, 1989

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and 1990, slightly more than 10% of MAPS stations relied at least partly on federal money. This figure more than doubled in 1991 and then doubled again in 1992, when the majority (52%) of MAPS stations received some federal funding, owing largely to the involvement of federal agencies in Partners in Flight. From 1993-1995, the number of stations receiving federal support increased more slowly, peaking at 63% in 1995. In 1996 the number declined to 60%.

Bander Training: Objectives and IBP Approaches

The limited pool of qualified banders, combined with the growing number of MAPS stations in the face of reduced federal support, creates a pressing need for accessible and affordable training programs in mist netting and banding. And because the basic data required for MAPS—accurate aging of all birds captured—necessitates the collection of detailed supporting data: Skull pneumatization, breeding condition, molt, and feather wear—we support the establishment of a standardized, continentwide, bander-training program.

Such a program should be designed to achieve the following objectives: (1) increase the number of banders who can capture, identify, band, and release birds without harming them, their mates, or their offspring; (2) improve the skill of banders to increase the quality of data collected; (3) improve the standardization of data-collection and data-recording procedures to make the data more useful for large-scale, long-term monitoring programs; and (4) get existing banders more involved in monitoring programs.

To meet these objectives, IBP has taken a five-pronged approach to bander training.

Internships

Since 1992, IBP has recruited and trained interns to operate federally funded MAPS stations. Interns are recruited through ornithological and environmental job bulletins, university professors and placement offices, and the American Birding Association. Internships begin with intensive, two-week, spring training sessions conducted by experienced MAPS biologists, at a student-teacher ratio of about 6:1. The interns receive additional, intermittent training and supervision throughout their internships. As a result of this internship program, IBP produced about 250 skilled banders from 1992-1997, and six MAPS stations have been established by former interns.

Bander-Training Courses

In 1995, IBP initiated a program of seven-day summer courses at various locations. The courses are open to the general birding community for a modest fee, and are patterned to some extent after our intern-training sessions. Courses are taught by experienced MAPS biologists at a 6:1 student-teacher ratio, and are offered at the height of the breeding season, so that students are exposed to breeding condition, molt, and incompletely pneumatized skulls. We use low-cost facilities such as biological stations and scout camps to keep the courses affordable. Course graduates are encouraged to assist at MAPS stations for the remainder of the field season, and are allowed to attend part of the following year's intern-training session as a "refresher." Approximately 150 people, ranging from birders to professional wildlife biologists, enrolled in our courses from 1995-1997, and course graduates have established a total of nine MAPS stations and assumed operation of three pre-existing stations.

Special DoD/NAS Bander-Training Courses

In fall 1997, IBP and the National Audubon Society (NAS) signed a Memorandum of Understanding whereby NAS is providing information and encouragement to its chapters to take over the operation of existing MAPS stations or establish new stations on DoD military installations, and IBP is providing, through funding received from the DoD Legacy Resources Management Program, free training in mist-netting and banding procedures and MAPS protocol, through special spring and/or summer bander-training courses, to members of Audubon Society chapters and other individuals that agree to take over the operation of existing stations or establish new stations on DoD military installations. Four such courses were scheduled to be offered in 1998 and many more are being scheduled for 1999 and 2000.

"On-Request" Training Sessions

Since 1995, IBP has provided training sessions for agency groups by request. These sessions are similar to the summer courses but vary in length and content depending on the needs, skills, and resources of the group being trained. Also, the sessions are conducted at sites that are selected and prepared in advance by the group. With a large group, most agencies find this training approach to be more flexible and more cost effective than sending individual trainees to the summer classes. As of 1997, four MAPS stations have been established by graduates of these training sessions.

Apprenticeships

IBP is facilitating the establishment of long-term apprenticeships that pair beginning and experienced banders on a 1:1 or 2:1 student-teacher ratio. Each graduate of our summer courses is sent a list of names and addresses of licensed banders in his area, and is encouraged to contact these people to arrange additional tutelage.

Development of Bander-Training Standards and Curricula

In March, 1995, IBP hosted a three-day forum at which 19 banders representing various agencies, educational institutions, and non-profit organizations gathered to discuss recruitment, training, and certification of banders in North America. The primary outcome of this forum was the establishment of the North American Banding Council (NABC), consisting of representatives of major ornithological

societies, banding associations, and other ornithological organizations. NABC is developing training standards, curricula, and materials, and will facilitate the formation of partnerships between sources of new banders and sources of banding expertise.

Skills and Topics Covered in IBP Training Programs

Both our spring and summer training programs cover the following subjects: Overview of avian molt, life histories, and topography; placement and operation of mist nets; extraction of birds from mist nets; proper handling and transport of extracted birds; identification, aging and sexing techniques using plumage, skull pneumatization, external breeding characters, feather molt and wear, and other criteria as appropriate; data scoring and recording following standard MAPS protocol; banding ethics; value of banding and monitoring in bird conservation; and establishment and operation of MAPS stations.

The MAPS Strategy for Involving Volunteers

Based on our six years of using some 250 volunteers to operate MAPS stations, we wish to stress four basic requirements for successfully incorporating volunteers into bird-banding operations. Most of these points are applicable to other volunteer programs as well. While they may seem common sense, too often they are overlooked.

Recruitment

Advertise your operation through as many local channels as possible. Prepare a slide show and present it to your local bird club and chapters of the National Audubon Society, Sierra Club, and The Nature Conservancy. Invite newspaper and television reporters and photographers to feature your operation. Make your operation as appealing as possible, and emphasize the thrill, education, and conservation values of bird banding.

Training

Effective training is key to obtaining accurate, standardized data, and avoiding harm to birds. Training may take either of two basic forms: Long-term, onsite, "apprenticeship" training; or short-term, intensive, "crash-course" training, often followed by a less intensive apprenticeship or internship. Due to varying demands on people's time, both of the two approaches are applicable to volunteers.

Supervision

Supervision of volunteers is essential for maintaining data quality and standardization. Supervision may be constant (i.e., with trainer or supervisor always on site and available in emergencies; this type of supervision is concurrent with training an apprentice), or intermittent (i.e., qualified banders work mostly on their own but with periodic visits by trainers or supervisors). In either case, data should be reviewed and screened for errors before use in any analyses.

Feedback

Few volunteers will stay with a program for long without some reward. By maintaining volunteer enthusiasm and morale, you will improve the quality of your data, and increase the longevity of your operation. Tell and show your volunteers often how valuable they are and how much you appreciate them. Provide perks such as t-shirts and parties. Praise volunteers highly for work well done. At the same time, be sure to point out consistent errors and deficiencies in a constructive manner. Maintaining both data quality and field crews means that volunteer supervisors often must walk a fine line. Invite volunteers to become involved in data analysis and presentation. Show them the results of their work, and let them know how they fit into the larger monitoring or conservation context. Be sure to acknowledge them in any publications resulting from their work, and consider including them as coauthors.

Conclusion

Volunteers play a critical role in the success of the MAPS Program. Without them, the number of stations in the program would be insufficient for large-scale monitoring purposes. IBP's internship, training, and apprenticeship programs are (1) increasing participation of the private sector in landbird research and monitoring efforts; (2) creating a pool of skilled amateurs and professionals into which agencies can tap for assistance in landbird research and monitoring; and (3) improving the standardization, thoroughness, and accuracy of banding data collected in MAPS. An estimated 5% of existing MAPS stations are operated by graduates of our training efforts. An effective North American Bird Conservation Plan must take into consideration the need to recruit, train, and certify volunteers to ensure the continuance of programs such as MAPS.

Successful Use of Volunteer Birders Conducting Point Counts of Migratory Birds on the Upper Mississippi River National Wildlife and Fish Refuge

Eric Nelson
Carol Damberg

Abstract—The Upper Mississippi River National Wildlife and Fish Refuge is the longest wildlife refuge in the lower 48 states, extending approximately 420 km between Wabasha, Minnesota and Rock Island, Illinois, covering 81,000 ha of floodplain forest and backwater wetlands. More than 290 bird species use this north-south corridor. During past decades, standardized refuge inventories have included only waterfowl, bald eagles, and colonial nesting birds. Recently, concern about nongame bird population declines, particularly Neotropical migrants, has inspired managers and researchers to add these birds to wildlife inventories. The refuge uses standardized point counts for determining population trends and habitat associations of these birds during migration and the breeding season. With only two refuge staff qualified to conduct point counts, we enlisted the help of 16 volunteer birders (two off-duty federal employees and 14 local citizens) in 1994 and 1995. All volunteers received training in count methods, and of those tested, each achieved at least a 94% proficiency on songs of 49 locally breeding species. Experience levels range from a couple of years to lifetimes of birding. Volunteers have completed hundreds of counts throughout six habitats on the river corridor. We have 3 years of bird use data by season and habitat. Quality control concerns are reviewed. This core of volunteers strongly supports the inventory and the refuge as a whole. Their reward is public recognition and knowledge that their data are put to good use.

The Upper Mississippi River National Wildlife and Fish Refuge is the longest wildlife refuge in the lower 48 states. Beginning at the confluence of the Chippewa and Mississippi rivers near Wabasha, MN, the Refuge extends 420 km south to Rock Island, Illinois, covering 81,000 ha of floodplain forest, backwater wetlands, and impounded reservoirs. More than 290 bird species use this north-south corridor. During past decades, standardized inventories were conducted only for waterfowl, bald eagles, and colonial nesting migratory birds on the refuge. Recently, concerns about nongame bird population declines (Hagan and Johnston 1992), particularly Neotropical migrants, have inspired managers and researchers to add these birds to wildlife inventories. The refuge now uses standardized point counts for determining population trends and habitat associations of passerine birds during migration and the breeding season. Detection of birds requires expert knowledge of bird identification through visual and sound clues; such expertise is held by few members of the refuge staff. Therefore, we solicit the assistance of volunteers to conduct most of the counts. This paper describes how volunteers conducted point counts during the 1994 and 1995 seasons.

Methods

Migratory bird surveys on the refuge are conducted using point count methodologies adapted from those developed by Ralph and others (1993). These counts involve an observer recording all birds seen or heard within a 25, 50, or 100 meter radius circle for a 10 minute interval, conducted between 0600 and 1000 hrs. during the migration and breeding seasons. Points are located at least 250 meters apart, and usually are within walking distance of access roads.

Such counts are labor intensive and require birding expertise. Thus, to have enough people to conduct sufficient counts over the 1994 and 1995 seasons, we used local contacts and word of mouth to obtain the assistance of 5 volunteer birders in 1994 and 11 in 1995. These volunteers received training from refuge staff in bird identification, count methods, estimation of distances, coding field data sheets, and accessing the survey points. Experience levels for volunteers and staff members range from 2 to more than 35 years of birding.

In 1995, we initiated a bird song identification test to assess the volunteers' birding proficiency. All seven birders who were tested achieved at least a 94% proficiency on songs of 49 locally breeding species that had been detected in studies of the Mississippi River floodplain by Emlen (1986) and Knutson (1995). Each birder was provided a practice tape to review the songs, and then tested using a tape of those species in a different order. The remaining four birders not tested were well known for their years of birding expertise.

Volunteers received data sheets, watches with timers, and hip boots to complete the work. The refuge paid mileage costs to those who used their own vehicles.

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Table 1—Volunteer and staff effort spent in conducting seasonal bird point counts on the Upper Mississippi River National Wildlife and Fish Refuge, 1995.

Observers	Migration counts	Completed breeding season counts	Completed total hours
Volunteers	270	101	300
Refuge staff	100	134	175
Totals	370	235	475

Results

Volunteers completed hundred of counts distributed throughout 6 major habitats on the river corridor in 1994 and 1995. Of all surveys conducted in 1995, volunteers contributed 300 of the 475 hours necessary to complete 605 surveys (table 1).

In 1995, we found that for many species, the mean number of birds detected per point in bottomland forest habitats was comparable to those found in research conducted by Knutson (1995) during the Flood of 1993 and the recovery year of 1994 on the Upper Mississippi River. For other species our numbers were higher than in 1993 and 1994, and perhaps reflect population and habitat recovery in the monitoring area. This concept remains speculative, pending further analyses.

We encountered problems of volunteers submitting incomplete data sheets (missing data) and conducting bird surveys outside the designated survey periods. Approximately 10% to 15% of the data sheets were incomplete, lacking a point count number, habitat code, or having an incomplete bird name abbreviation. These problems were resolved through individual contacts from our office. We also had to deal with observer confusion regarding the definitions of "fly-overs" and "fly-throughs." Program coordinators had to reiterate many of the definitions and protocols used in the surveys. We kept in contact with the volunteers via telephone regarding incomplete data or access problems, and via letters and memos to provide encouragement, thank volunteers for submitting data sheets, and to remind them of upcoming count periods.

After the 1994 survey season, we held a volunteer recognition evening program. Volunteers received refreshments, refuge T-shirts, data summaries of the point counts that each observer completed, and a refuge-wide summary table. In addition, discussion took place about which birds were seen or not seen, access problems, suggestions for making the survey more efficient, and the importance of the refuge for migrating and breeding birds.

Discussion

An important concern about having volunteers (and staff) conduct this type of work is maintaining quality control. This is particularly true during the early years of establishing a corps of qualified observers who can participate in point count surveys for many years. Early quality control will eliminate "bad habits" or tendencies of birders to bias their counts by extending the count area or time period, or selecting "hot spots" for birding. These concerns are applicable to both the seasoned and neophyte birder. Once consistent locations and timing are established, birder comfort levels stabilize, to the benefit of count reliability.

A successful program includes providing volunteers with complete instructions and lots of follow-up, a time-consuming process. Quality assurance will be strengthened through testing participants for hearing abilities, knowledge of bird songs, and speed of detection. Field practice and orientation also are important. Public recognition and mementos for volunteer work are also vital to ensuring continued involvement.

Volunteers have been participating in various bird monitoring projects throughout the world for many years. Our experience on the refuge reinforces the value of including volunteers in monitoring birds at both the local level and on a larger scale such as the Mississippi River corridor.

Focusing Close to Home: Building Volunteer Efforts in a Small Town

Linda Seibert

Abstract—Natural resource managers in the West often work out of small towns. The areas they manage are vast, and human resources are scarce. While the American Bird Association and other national organizations are excellent at recruiting volunteers to help with bird monitoring and research projects, enticing volunteers to small towns and remote areas can be a frustrating experience. While agencies should continue to recruit volunteers through national groups, they also should encourage homegrown efforts. Local people may actually be the most productive volunteers. Bird clubs are obvious sources for candidates, but commercial outfitters such as river guides and outdoor schools should not be overlooked.

Natural resource managers in the western United States often work out of small isolated towns. The areas they manage can be vast, and human resources are usually scarce. An example is the town of Moab, Utah, which includes offices of the Bureau of Land Management (BLM), National Park Service (NPS), and the U.S. Forest Service (USFS), but only 5,000 people. Utah's only urban area is 200 miles away. Breeding Bird Survey (BBS) coverage is light in such a remote area, and other types of avian distribution data also are spotty. While the effective use of volunteers can help to fill the void for surveys and management of birds and their habitat, finding volunteers in remote areas can be a frustrating experience.

Wildlife biologists in the Moab District were interested in developing a volunteer program for bird work. We initially believed that we could not locate sufficient volunteers within our own small towns, so we tried to develop a program focused around national recruiting with the American Birding Association (ABA) and several local outdoor education schools. We had only limited success with these efforts, however. Then we began to realize that we had been ignoring many talented volunteers right in our local area.

National and Regional Recruiting Efforts

Bureau of Land Mangement offices in Utah have tried to tie in with national and regional recruiting efforts. For example, many of us have advertised projects with the ABA. The Moab District also has worked with two outdoor education schools in our area—Canyonlands Field Institute (CFI) and Four Corners School of Outdoor Education (Four Corners)—to advertise bird watching trips that would focus on bird inventories. Southeast Utah is a tourism hot spot, and ecotourism is extremely popular, so asking people to come bird watching in combination with a river or backpack trip seemed like a natural sell. Disappointingly it wasn't, with a few exceptions.

For example, every year Four Corners offers a wildlife-related trip, generally tied to a desirable river, for which they recruit an expert guide and advertise nationally. Their most successful offering, a trip called "In Pursuit of the Peregrine," has gathered useful data on Peregrine Falcons (*Falco peregrinus*), with many new eyries documented in remote areas in southeastern Utah. These sightings have added to Utah's statewide database and have allowed us to support the present proposal for delisting the species. However, during some years this trip has not drawn enough interest to be conducted. During one year BLM and Four Corners worked together to offer a "Neotropical migrant" inventory on the San Juan River. Only one person signed up. A similar trip was advertised with CFI, and also was unsuccessful.

As another example, Utah BLM's Richfield District advertised through ABA for someone to conduct point counts in riparian areas that are subject to special management. They found two excellent birders, both Utah residents. One of them, a college professor, used the opportunity to take his family on weekend camping trips. Meanwhile our district attempted to advertise through ABA several times with no response. Our failure may well have been caused by poor marketing or poorly thought out projects.

Local Successes

Initially we were disappointed with our inability, or only limited success, in recruiting volunteers. Then we began to realize that a great deal of useful birding was going on in our immediate area, and almost no recruiting had been needed to accomplish it. For example, although our town has no chapter of the National Audubon Society (NAS), a nucleus of enthusiastic birders do come together for Christmas Bird Counts (CBCs).

Another focal point for bird enthusiasts is Canyonlands Raptor Center, a rehabilitation program run by a married couple named John and Marilyn Bicking. Their efforts, along with other local birders, proved to be far more significant than those that we purposely had tried to recruit.

The Bickings moved to Moab from New Jersey in 1984. There Marilyn had worked in a rehabilitation center, and she felt a need for one in southeast Utah. In the past 11 years, they have cared for 1,450 hundred raptors, including 125 eagles. In addition, they are very involved in raptor habitat

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management issues. They have taken an interest in the known Utah Bald Eagle population, consisting of three active nests in the southeast part of the state. They have promoted and assisted with banding and genetic studies, and participated in the development of interagency management plans.

Two of the nests are along popular rafting areas, where several years ago my agency proposed to build a new boat ramp in a location close to one of the nests. The Bickings were concerned about the location, and were instrumental in getting it changed when they rallied commercial and private boaters to petition BLM to find a different location.

The Bickings also have used their own funds to hire a man named Nelson Boschen to monitor eagle nests and to search for new ones. A self-taught naturalist, Nelson puts in many more hours than those for which he is paid, as he ensures that bald eagle chicks successfully fledge. He also has added greatly to our knowledge base by making detailed observations of eagle foraging and feeding activities, by conducting a BBS on the Colorado River, and by organizing the CBC for the Moab area.

As another example, Gail Lea, a school librarian, devotes her summers to birding. She also has added greatly to bird distribution data in southeastern Utah. She monitors several peregrine eyries in the Moab area; assists the NPS by conducting several BBSs and by monitoring raptor nests; she has helped BLM with avian inventories on public land; and she now organizes the CBC.

Reaching and Organizing the Right People

Even a small town can produce an abundance of volunteers and volunteer projects. The first problem is finding the people; the second is using them effectively, focusing their energy on the most important needs. Several things should be kept in mind.

First, have your strategies in place. In Utah we have had interagency work groups for priority species such as Peregrine Falcon, Mexican Spotted Owl, and Bald Eagle. We hold regular meetings with discussions on research, inventory and monitoring, and management issues. Non-agency biologists and non-professionals always are invited to these meetings. They are excited to be part of the process, and are more likely to offer their help. This is how the Bickings became involved financially with our bald eagle monitoring, and how Gail Lea took responsibility for monitoring peregrine eyries. Of course, the same tactics should be used with state Partners in Flight meetings. Then regional and state plans can be used to direct volunteers toward appropriate inventory, monitoring, and project needs.

Second, seek out opportunities for ties with the ecotourism and environmental education communities. We are fortunate to have several schools in southeast Utah that specialize in ecotourism. Although such groups don't exist everywhere, many possibilities exist with college classes taking field trips, tour companies who may want to diversify, and established groups such as Hawkwatch.

Third, solicit input from local birders and other citizens when making management decisions that affect avian habitats. This process can make local people feel a sense of ownership that will encourage more participation in the long run. But be prepared to hear opinions that you may not welcome. You cannot use this tactic unless you are honestly going to listen, because people will be very disappointed if they feel their input was ignored, and trust will be lost.

Finally, remember to work with national and regional groups such as ABA or NAS. They are well-established organizations with recruiting mechanisms in place.

A Semester of Birds

Judi Falk Rice

Abstract—Increasing numbers of people have "A Passion For Birds" and are interested in volunteering to assist with songbird monitoring and research. Often these people may not know local birds or be trained in the sciences. To address the need to provide local volunteers with adequate training, I developed a semester-long university course titled "Techniques for Monitoring Songbirds." The course is a partnership between the Juneau Ranger District, Tongass National Forest, and University of Alaska Southeast. The university offers the 3-credit biology course each spring and provides administrative support and classroom facilities. The U.S. Forest Service provides instructors, materials, and applied field opportunities. Course objectives are to teach identification of local birds by sight and sound and to describe and practice monitoring techniques, including mist netting, banding, and point counts. Over 60 people have participated in the course since 1993. Twenty or more are currently involved in bird monitoring projects in Juneau or in other parts of the United States. Monitoring techniques such as point counts that require excellent visual and auditory identification skills are difficult to teach in one semester. Several seasons of field work are necessary in addition to the course. Less time generally is required to train people to assist with banding activities such as recording banding information. It is important to help volunteers identify their strengths and provide them a task at which they can succeed. The investment of time spent training volunteers is worthwhile because of the benefits achieved by encouraging community involvement and stewardship.

Juneau is a lovely southeast Alaska community of about 30,000. The city is unique in that access is limited to boat or plane. As a result, we have a "captive" audience or community from which to draw volunteers! Juneau is Alaska's capital, and legislators from throughout the state gather from January through May. It is also the home of the regional office for the Alaska Region of the U.S. Forest Service (USFS). Many other federal agencies, including the National Marine Fisheries Service and the U.S. Fish and Wildlife Service (USFWS) also have offices in Juneau. The Alaska Department of Fish and Game, the Department of Conservation, the Department of Natural Resources, and other state agencies also reside there. As a result, the city is home to many people who are in some way involved and interested in natural resource issues. Many agency individuals eventually retire in Juneau, and they can be a wonderful source of volunteer assistance, as long as the volunteer projects are interesting, meaningful, and fun.

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Judi Falk Rice, Backcountry Sports, Atlin BC, Canada.

The Alaska Region of the U.S. Forest Service includes the Chugach and the Tongass National Forests. The Tongass is a temperate rainforest composed primarily of Sitka spruce, western hemlock, and in the south, western yellow cedar. The Tongass seems to draw national attention with many important resource issues discussed frequently on national news. The Juneau Ranger District is not only the largest of 11 districts on the Tongass, encompassing over 3.5 million acres of the 17 million acres national forest, but is also the largest of all districts in the forest system. Primary resource activities on the Juneau Ranger District include timber and minerals management, and increasingly, recreation issues associated with rapidly increasing tourism. Often and unfortunately, activities such as monitoring migratory landbirds do not reach the top of the priority list. We depend increasingly on the volunteers who are instrumental in keeping these types of monitoring activities going.

The University of Alaska Southeast (UAS) was established first as a community college in 1956 and became a university in 1972. UAS has an enrollment of 611 full-time and 1,312 part-time students. The high part-time enrollment reflects community interest in continuing education. The biology program has 33 full-time students, and 2 full-time and 1 part-time biology faculty. It is part of the School of Liberal Arts, Sciences, and Education. Administrators are becoming increasingly interested in offering biology students applied learning opportunities, similar to the requirements of student teachers or interns in the school's education program. In that program, graduates must have completed a semester working in the school system with a master teacher.

Methods

In 1993, as the Juneau Ranger District became more involved in Partners in Flight (PIF) activities through participation in Boreal PIF, I approached UAS about teaching a spring semester course entitled "Techniques for Monitoring Birds." UAS would provide marketing through its class bulletin, credit incentive, registration and other administrative support, classroom, and vans for field trips.

I have taught the 200-level, 3-credit biology course for 3 years with an enrollment of 15 students in 1993, 22 students in 1994, and 28 students in 1995. We meet for 2 hours one night a week, January through mid-May. The goals of the course are (1) to increase the awareness of and appreciation for birds in the Juneau area, (2) to increase awareness of and interest in monitoring techniques used by the USFS and other PIF organizations, and (3) to develop a cadre of well-trained and enthusiastic volunteers to assist with bird-related field work. In addition to songbird monitoring, we also train people to assist with surveys of Northern Goshawks (*Accipiter gentilis*), forest owls, and Marbled Murrelets (*Brachyramphus marmoratus*).

Objectives for course participants are (1) to identify 60 local birds by sight and sound, (2) to develop an understanding of the ecology of more than 60 local birds, and (3) to develop an understanding of the techniques used by the USFS and other PIF organizations to monitor birds.

To help students learn visual and auditory identification, we use field guides, slides, videos, cassette tapes, and CDs. The Cornell Laboratory of Ornithology (CLO) and VIREO provide wonderful selections of slides of the birds of North America, from which we select those species we are most likely to encounter in southeast Alaska. We use pre-recorded tapes and CDs, and we also contracted the Cornell Library of Natural Sounds to create a tape with 60 species recorded in the order they would be discussed in class. A copy of this tape is given to each student at the beginning of the semester. CLO has also compiled a CD that includes the songs and calls of most Alaska birds. Development of this CD was made possible by an interagency effort between the Alaska Department of Fish and Game, the USFS, the USFWS, and other Boreal PIF organizations. This CD is extremely useful, allowing selection of a specific track with an individual species recorded on it. Random song and call testing, an important training technique used in the class, was simplified when this CD became available. The CLO has been instrumental in providing training materials of excellent quality, and responsive in addressing training needs with the development of new products.

Frequent testing, although stressful for students, leads to the best learning of song and visual identification. Short, cumulative tests are given at least every other week. This encourages students to keep up with their learning of new songs, and to review those species covered earlier in the semester. Students often depend on the idiosyncrasies of their training tape (for example, water running in the background for the American Dipper) rather than characteristics of the species song. Therefore, recordings that students have not previously heard and recordings from the field with background noise and songs of multiple species are used in addition to tests including segments from students' tapes.

Visual identification ability also is tested. Slides used to portray and discuss a species in class are available for study purposes at the university library at all times. Students also are encouraged to study field guides during winter, and to spend as much time as possible in the field, particularly when migrants begin returning in the spring. Visual testing is accomplished with slides used in class, and additionally, with pictures that students have not previously seen. Students are encouraged to concentrate on field marks to help them identify species in a variety of environmental conditions. In addition, because many migrants return by mid-May, students are tested in the field later in the semester.

Lectures, assigned readings, and field observation are the primary tools used to develop an understanding of the ecology of 60 local birds. Students are responsible for writing a journal describing at least 2 hours of field observation each week. Review of student journals offers instructors an opportunity to recommend species-specific readings that enable students to better interpret behaviors and habitat-use patterns.

Lectures, assigned readings, and field exercises designed to teach monitoring techniques are the tools we use to develop an understanding of the techniques used by the USFS and other PIF organizations to monitor birds. In-classroom activities provide the background on the need for monitoring and research, and the development of techniques that address different questions and hypotheses. Field activities provide time for repetitive practice of techniques including mist netting and banding, conducting point counts, inventorying for forest owls and raptors, and conducting Christmas Bird Counts, Project FeederWatch counts, Breeding Bird Surveys, area searches, and a variety of other inventory and monitoring activities. In addition, scientists conducting local research participate as guest speakers.

Conclusions

Identifying birds by sight and sound, and developing the skills necessary to conduct Breeding Bird Surveys and point counts, may take several years for beginning birders. It therefore makes sense to train your "local experts" to help you accomplish these types of monitoring projects initially. These local experts are ideally individuals already familiar with song and visual identification who require training and practice oriented toward monitoring techniques. Pair the people who are beginning birders with the local experts to provide additional field training to the beginners.

Slides, audio tapes, videos, field practice, and frequent quizzing or testing are all extremely beneficial, particularly to beginning birders.

Many of the skills useful in assisting with a Monitoring Avian Productivity Station (MAPS) can be learned relatively quickly depending upon the individual. Hanging nets and recording data are the skills learned most easily. Both activities, however, require a patience and precision not necessarily present in all people. Removing birds from nets, banding, and determining age and sex characteristics require considerably more skill and practice.

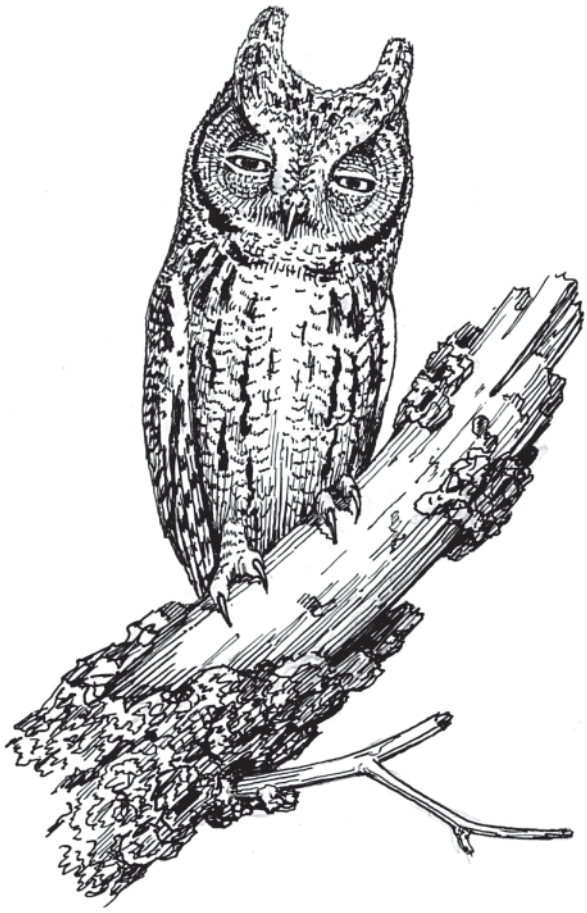
Be perceptive regarding the talents and limitations of volunteers. Openly discuss their strengths and limitations with them. Give them a job at which they can succeed.

We have been extremely fortunate in reaching our goal of developing an enthusiastic and committed group of volunteers in Juneau. Of the 65 people who have participated in the course since 1993, about 10 local people participate regularly in various activities, primarily with MAPS stations. Approximately 90% of students taking the class are not "traditional" students. They are older than the typical 18- to 22-year-old student. Many have lived in southeast Alaska for long periods of time. About 50% are resource professionals or students who seek to expand their knowledge. The remaining 50% are local people with careers outside the natural resource professions who have a great interest in birds. Several elementary and middle school teachers have participated in the class. Juneau has a healthy tourism industry that includes tour businesses that cater to cruise ship visitors and outdoor adventure companies offering 3-day to 2-week kayak, raft, and canoeing trips. Guides who work for both types of companies have taken the

Techniques for Monitoring Birds course. Approximately 8 students who have taken the course have gone on to be involved in bird monitoring and/or research projects in Alaska and in the western United States. Other graduates have gone on to supervise operation of MAPS stations for the Juneau Ranger District (and to co-teach the course), and to initiate Marbled Murrelet surveys that contribute to recent assessments for the revision of the Tongass Land Management Plan. These are just a few of our success stories.

A large commitment of time and resources is required to teach the skills necessary for volunteers to accomplish quality monitoring. Investing your time in community members who will be around and interested over longer periods of time seems to offer the greatest returns and be most rewarding. Training volunteers is well worth the effort!

7. Developing Support: Education, Outreach, and Community Development



Eastern Screech-Owl

7. Section Overview—Developing Support: Education, Outreach, and Community Development

Rick Bonney
Ron Rohrbaugh

The success of North American bird conservation plans will be completely dependent upon their implementation. No matter how good the local and regional plans may be, if they aren't used, they cannot succeed. But to get the plans to be used, a massive effort in outreach and education will be necessary.

The audience for implementation is huge. Land managers must be convinced that the plans are carefully developed and will result in on-the-ground bird conservation. Development agencies must be convinced that the plans will create a stronger, not weaker, economy. And the public must support bird conservation, either through an appreciation of birds, or because of a realization that conserving bird populations ultimately will result in conservation of biodiversity in general.

Developing support for plan implementation is therefore a vast undertaking. In fact, the job is probably harder than writing the plans. The four papers in this section provide a start toward thinking about what must be done.

The first paper, "A Bird in the Hand is Best" by Katy Duffy, offers some ideas for getting the public excited about birds. The goals of her article are: (1) To inspire readers to share their love and concern for birds; and (2) To convince readers that involving the public in birds through interpretive programs will advance migratory bird conservation. "An awareness of birds provides a doorway into the natural world, a door that all of us have walked through," she writes." Let's help others through that door. It will enhance the quality of their lives. It will build a constituency for migratory birds. We protect only what we know and love. To spread our concern and love for birds, try a bird in the hand!"

Another way to reach people is through the classroom, where they are essentially a captive audience. However, this approach requires developing materials that teachers will want to integrate into their already overcrowded schedules. The second paper, "One Bird-Two Habitats: A Model Process for Developing an Education Program on Neotropical Migratory Birds," by Susan C. Gilchrist and Darrel F. Covell, addresses this issue. It describes the process by which a three- to six-week, interdisciplinary environmental education unit for 6-8th grade classes was developed that addresses the need for Neotropical migratory bird conservation. Both the contents of the curriculum and the process of its development reflect a model marriage between research and education. The program was begun to educate people about an important issue identified by researchers, uses background information and activities based on research, and was piloted and evaluated for its effectiveness through research.

However, in addition to educating the public and developing widespread interest in birds, people who determine how land will be used must be convinced of the value of bird conservation. This is the focus of the other two papers in this section.

In "Economics of Open Space Conservation," Paul Kerlinger explains that to date, strategies used to protect habitat have relied primarily on biological arguments such as protection of biodiversity, wetlands, watersheds, and endangered and threatened species, as well as aesthetic arguments relating to preservation of beautiful scenery. Unfortunately, many people are unmoved by these types of arguments. An emerging strategy for protecting habitat and wildlife is the use of economic information. This paper describes the economic value of open space to communities, and explains how this value is greater than commonly believed.

In the final paper, "The Great Texas Coastal Birding Trail: A Tool for Avitourism," Madge Lindsay shows how the state of Texas has used the economic impact of birdwatching to conserve habitat. Recognizing the economic importance of avitourism, and knowing that the Texas Gulf Coast is a major destination for many birdwatchers and avitourists, the Texas Parks and Wildlife Department (TPWD), Texas Department of Transportation(TXDOT), other government agencies, communities, and tourism industry leaders are assisting the development of Texas Gulf Coast avitourism. Their goal is to promote sustainable economic development while conserving habitat for Texas birds. Projects currently under development, including the Great Texas Coastal Birding Trail, are designed to bring a portion of the $238 billion spent on ecotourism each year, worldwide, into Texas coastal communities. Through conservation management, nature tourism development, and marketing, coastal communities can gain economically while protecting some of the habitat necessary to sustain the rich array of birds found in Texas. Such an approach obviously could be used in other areas.

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A Bird in the Hand Is Best

Katy Duffy

Abstract—For a North American Bird Conservation Plan to succeed, the general public must support protection of migratory birds. Many of these birds are exquisite gems, delightful bundles of energy that flit constantly and often are found in dense foliage, high up in trees. Most people never have seen these birds. How can the average person be expected to care about birds that he or she cannot find? This is where a bird in the hand comes in. Show people a bird up close and they cannot help but be captivated. Common responses include "Wow! I didn't know they were so small, so colorful, so beautiful, so soft…" This paper discusses ways to have a bird in the hand, ways to have a bird almost in the hand, and ways of packaging a bird in the hand.

A Bird Almost in the Hand

Ways to have a bird almost in the hand include watching birds at feeders; watching birds in a place where birds fly close (e.g., hummingbirds at feeders at The Nature Conservancy's Ramsey Canyon Preserve in Arizona); using a spotting scope focused on stationary birds; and looking at slides/videos of closeup views of birds.

The typical response to closeup shots of birds is "oooh! aaaah!" While this is not personal or experiential, slides and videos work very well for general audiences, large audiences, and nature clubs in the winter when most migratory birds are far away. Program presenters can easily include an explanation of the problems facing migratory birds and can give the audience positive things to do, such as supporting habitat preservation or planting native vegetation.

A Real Bird in the Hand

Programs incorporating mounts, study skins, and bird parts provide an opportunity to see birds close up, and in some cases, to handle the birds. While mounted birds and study skins usually cannot be touched, bird wings, tails, and feet can be passed around. Many people love to touch feathers; those who have never touched often are surprised at what various feathers feel like. Mounts and study skins that cannot be passed around still can be admired at a closer distance than would be possible in the field.

One way to have a *live* bird in the hand is to use injured birds that have been rehabilitated. Birds that cannot be released are a wonderful educational tool for adult and school groups. These birds allow close inspection as well as a chance to educate the public about human impacts on bird populations and individuals. Most rehabbers do not use passerines as display birds, so this technique works best for raptors.

There are several ways to have live, healthy, wild birds in the hand. For passerines, banding demonstrations are held at Monitoring Avian Productivity and Survival (MAPS) stations and other projects. Raptor banding demonstrations, offered each weekend during September and October at Cape May, New Jersey, attract large audiences. I have banded owls during migration at Cape May each fall since 1980 and have had success with owl demonstrations. I bring an owl captured for banding at night to a location where people can see it without interrupting the banding project. Lucky observers get to release a Saw-whet Owl by perching the owl on their upturned hand, letting go with the other hand, and waiting for the owl to fly when it is ready. Based on positive feedback, banding demonstrations leave lasting impressions.

Songbirds in the hand are as captivating as raptors. Visitors to songbird banding projects get to gorge themselves on close views of tiny but colorful birds. Some visitors stay to apprentice and eventually become skilled assistants or banders themselves.

Researchers sometimes think it would be difficult to conduct field studies with observers or unskilled assistants hanging around and getting in the way. What could be a better way to recruit and train new researchers! Allowing newcomers to witness and eventually assist in ongoing projects, including banding and bird surveys, may engender lifelong interest. Nationwide bird surveys (e.g., Breeding Bird Survey) involve so-called amateurs, the people whose day job does not relate to birds, but these people frequently are the real experts. The Cornell Laboratory of Ornithology has recognized the value of training volunteers and so has developed a citizen-science bird monitoring program.

A myriad of bird-centered activities exist. Here are some that have been received well by the public.

I have conducted the International Migratory Bird Day-North American Migration Count for several years as a ranger-led activity, enlisting the participation of the public. The results have been overwhelmingly positive. Although weather in Wyoming in early May makes counting birds a challenge, the participants, including those new to enjoying birds as well as skilled birders, enjoy group efforts at birding with a purpose.

I have taken the same approach with elementary school children. For several springs, I have had kids in grades 1-4 conduct bird surveys following an indoor training session involving slides, study skins, and mounts. Having kids work in teams to conduct bird surveys keeps them occupied and learning. A measure of competitiveness helps, too. Kids also

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Katy Duffy, Grand Teton National Park, Moose, WY 83012.

enjoy banding demonstrations. Working with kids means accepting a level of chaos. Strict discipline could leave a negative impression; the idea is for kids to go away thinking that birds are fun!

Taking a group on a walk through areas likely to harbor a variety and abundance of birds allows people to experience birds and can be almost like having a bird in the hand. In addition to identifying birds, leaders have the opportunity to talk about conservation concerns, especially the plight of migratory birds.

For those new to enjoying birds, an organized bird walk might be intimidating and too fast-paced. For this reason, special programs for beginners often are developed. For example, I have presented a program each week during summer called "An Introduction to the Joy of Birds." Five to ten people participate in each 2-hour program. We cover some of the basics: Looking for field marks, how to use a field guide and binoculars, how habitat meets birds' requirements, and an overview of the nesting cycle and migration.

These are just a few of the interpretive activities that can be used to involve the public and arouse their concern for migratory birds. Programs on related topics can include reference to migratory birds and their conservation: A naturalist at Grand Teton National Park incorporates an explanation of Neotropical migratory birds and their conservation into her evening slide program on birds. Another naturalist ends a slide program on raptors by emphasizing the dependence of bird-eating raptors on migratory passerines. Migratory birds can even be interjected into programs on topics that are seemingly unrelated: A naturalist at Grand Teton ends her tour of an Indian Arts Museum with a connection to Neotropical migratory birds and indigenous peoples of Mexico and Central America.

For any of these activities, organization is the key to an effective program. A themes-goals-objectives approach is standard fare for interpreters. This technique works very well for those new to interpretation and is quite straightforward. First develop a theme, a sentence that states the idea behind the program. For instance, the theme of this article is: A bird in the hand is one of the most effective ways to reach the public and instill an appreciation of birds.

Next, determine your goals, that is, why you are doing the program. For instance, the goals of this article are: (1) To inspire readers to share their love and concern for birds; and (2) To convince readers that involving the public in birds through interpretive programs will advance migratory bird conservation.

Finally, determine your objectives, measures of what you expect your audience to learn or do as a result of the activity. My objectives here are: (1) Most readers will present at least one new bird-related activity for the public in the next year; and (2) most readers will demonstrate a commitment to bird conservation by encouraging an interest in birds in the people they encounter in their daily lives at least three times each month.

Articulating the theme, goals, and objectives for a program makes organizing it much easier. Anything that does not develop the theme, or contribute to achievement of the goals or objectives, does not belong. Prepare an outline that develops the theme in an understandable manner. Do not be shy about stating and restating the theme or goals. Participants should not have to guess what points you are trying to make. This method of organization makes formal programs effective, and can be readily adapted to spontaneous activities such as banding demonstrations.

Organization, practice, and polish will help to refine the program, but genuine enthusiasm will be the magic ingredient. There is no substitute: Enthusiasm combined with knowledge is incredibly effective. An ideal presenter combines a sincere commitment to protecting birds and an authentic concern for people with a strong knowledge base.

Be available for questions after the program—even months and years after. Help solve mystery bird questions. Share bird song tapes. Research complex questions about bird ecology. Even if you never give an actual presentation, you can influence the people that you encounter so they, too, appreciate birds. Practice on your non-birding friends. Reaching the public one by one may be very energy-intensive, but the results will be worthwhile.

Each year, millions of people visit national, state, county, and regional parks; they form a somewhat captive audience that can be reached via non-personal approaches, too. Show canned videos and slide programs in park visitor centers and nature centers to enlighten general audiences about the fascination and plight of migratory birds. Bird checklists and bird-finding guides have wide distribution and can include information on the status of migratory birds in each area. For example, the Grand Teton bird-finding guide, which is distributed to about 2,000 birders each year, includes information on Partners in Flight. National park newspapers also can be vehicles for informing park visitors about Partners in Flight and the problems faced by migratory birds; about 250,000 copies of the summer Grand Teton park newspaper are printed each year, and these have contained information on Partners in Flight for the past several years. Such venues, even though they are non-personal, have the capacity to reach great numbers of people and hopefully affect their outlook and concern for migratory bird conservation.

To achieve public acceptance of the Bird Conservation Plan, we first need to enlarge the size of the migratory bird constituency. To do so, let's get more people hooked on birds by sharing our passion for them. Once people are concerned about birds, the Conservation Plan will have a more positive reception.

An awareness of birds provides a doorway into the natural world, a door that all of us have walked through, much to our delight. Let's help others through that door. It will enhance the quality of their lives. It will build a constituency for migratory birds.

We protect only what we know and love. To spread our concern and love for birds, try a bird in the hand!

Recommended Reading

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William J. Interpreting for park visitors. 1986. Philadelphia. Eastern Acorn Press.
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Shively, Carol. 1995. Get provoked: Applying Tilden's Principles. Legacy (National Association for Interpretation) 6(4): 6-10.
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One Bird—Two Habitats: A Model Process for Developing an Education Program on Neotropical Migratory Birds

Susan C. Gilchrist
Darrel F. Covell

Abstract—"One Bird—Two Habitats" is a 3-6 week, interdisciplinary environmental education unit for 6-8th grade classes, which addresses the need for Neotropical migratory bird conservation. The curriculum contains 22 activities, a videotape, maps, posters, and a wealth of background information. The major theme of the unit, interconnectedness, emphasizes the connections among people, birds, and forests in the Americas. Both the contents of the curriculum and the process of its development reflect a model marriage between research and education. The program was begun to educate people about an important issue identified by researchers, uses background information and activities based on research, and was piloted and evaluated for its effectiveness through research. The curriculum is available only through participation in workshops. It is personalized for Wisconsin students, including state-specific background information on forests, the selection of one "ambassador" bird, and a focus on our sister state in Latin America. Other states that wish to use the curriculum must adapt and disseminate it in a coordinated manner to ensure that background information is accurate, that balanced messages are conveyed, and that the value of the unit is maintained. The success of this program demonstrates that education and research can be complementary tools. We recommend that the Bird Conservation Plan include an educational component.

To successfully implement a conservation plan, biologists and educators must work hand-in-hand. This paper summarizes the development, evaluation, and implementation of "One Bird—Two Habitats," a middle-school environmental education program that bridges the gap between research and education. The program was developed under the auspices of the Wisconsin Department of Natural Resources, and has been disseminated in partnership with the Cooperative Extension Service at the University of Wisconsin-Madison. Both the development process and the completed curriculum are models that other states can adapt and use.

When the "One Bird—Two Habitats" program was first conceived in 1991, researchers already had identified a conservation problem: Some populations of Neotropical migratory birds were declining. In its "Neotropical Migratory Bird Conservation Program," Partners in Flight identified the need to educate the public about the effects of large-scale, international ecosystem changes and their impact on Neotropical migratory birds.

Just as casual observation confirmed what researchers perceived as bird population declines, it also confirmed the need for education about the issue. In general, people seemed familiar with common backyard or feeder birds, but many did not seem to know that some birds migrate internationally. If people were unaware that some bird species depend on habitat in different countries, they probably did not understand that large-scale changes to the land in one place affect migratory birds in both places.

Staff at the Wisconsin Department of Natural Resources already were concerned about declining migratory bird populations when the director of Wisconsin-Nicaragua Partners suggested developing a videotape on the issue. Wisconsin-Nicaragua Partners is the state chapter of the National Association of the Partners of the Americas, and the issue of Neotropical migratory bird conservation fit the agency's mission of building connections between sister states in North and Latin America. One phone call multiplied into many, and the result was much more than a videotape. For more information, contact: Partners of the Americas, 1424 K Street, NW, Suite 700, Washington, DC 20005; telephone: (202-628-3300).

Development Process

The theme of the curriculum is "interconnectedness," and it applies to the process of development, the contents of the curriculum, and the education methods used to convey the messages.

The program was developed through much networking. Grants from the National Association of the Partners of the Americas through Wisconsin-Nicaragua Partners, the University of Wisconsin-Madison's Center for Biology Education, and the USDA Forest Service supported development of the program through the Department of Natural Resources. Later, grants from the Wisconsin Environmental Education Board through the Wisconsin Society for Ornithology and from the U.S. Fish and Wildlife Service (USFWS) supported the initial dissemination effort.

Many people contributed to the curriculum in other ways, too. Beginning with a writers' workshop in 1992, experts in forest management, ornithology, Latin American culture, and education contributed to the activities

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and background information. Along with researchers and teachers, middle-school students assisted in creating and reviewing the videotape. During the development stages of the program, we sent the curriculum to approximately 90 reviewers.

It is not only the tremendous networking and broad-based support, but also the adherence to the research-education-research cycle, that defines the process of developing "One Bird—Two Habitats" as an exemplary model to follow. While the initial ideas for the curriculum and its contents were based on research about birds and an identified need for education, the program's framework grew from education research. We learned from the experience of other environmental education programs such as Project WILD and Project Learning Tree. We learned about current education trends and incorporated them into the curriculum. We also included activities to teach about avian research, and to explain how we learned the things we know. We conducted a formative evaluation of the program, so that research was part of the method of developing the program, too. In the end, we revised the curriculum based on the evaluation of the pilot as well as the feedback from reviewers. Ideally this research-education-research cycle should continue with an evaluation of the effectiveness of the program after it has been in use for several years. The effectiveness should be measured both as it affects teachers and students, and as it influences conservation efforts, and impacts the birds in trouble.

The Curriculum

In the belief that some students learn better through interactive, hands-on, or participatory activities, we expanded the initial idea of a videotape into creation of a whole curriculum including not only the video, but also 22 activities, a wealth of background information, maps, and posters. The curriculum emphasizes science and social studies, but is also interdisciplinary, including activities using math, art, language arts, Spanish, and physical education skills. While some of the activities are borrowed from other projects, the combined focus on birds, forests, and people is unique.

The issue of declining migratory bird populations is complex. To clarify the issue, we boiled it down and narrowed our focus, first by selecting middle school (6th-8th grades) as our target audience. We selected this audience over high school because the older grades mean compartmentalization, reduced flexibility in schedules and curriculum content, and potential problems incorporating an interdisciplinary unit into single subjects. Also, some educators suggested that the middle-school level showed more of a need for environmental education materials and programs, and we knew that Projects WILD and Learning Tree experienced more success in the elementary level than in high schools (Fleming 1983; Zosel 1989). We also considered the advantages of striving for "vertical articulation," so that the same students would be less likely to experience the same few activities year after year. Because of the WILD and Learning Tree experiences and the complexity of the issue, we decided to create an interwoven unit, rather than a loose collection of activities.

To weave such a unit, we needed to further "boil down" or focus on our subject. In just one unit, we could not adequately represent all the ecosystems important to migratory birds. We decided to focus the curriculum on forest habitat, so that we could include specific forest background information without overwhelming teachers.

The curriculum emphasizes the point that environmental issues are global: That birds, people, and forests are interconnected, and that human actions in the U.S. affect people in Latin America, and vice versa. To personalize this large concept, we focused on the connection with our sister state, Nicaragua. In one activity, "Cultural Exchange," Wisconsin students send pictures and letters to a school in Nicaragua.

To further personalize the issue, we identified one species as our "Ambassador Bird." We selected the Ovenbird (*Seirus atricapillus*) because it is an interior forest bird, it is common in Wisconsin yet not popularly known, and Breeding Bird Survey trends since 1996 show significant population declines in the Central U.S. Other states may wish to choose their own ambassador birds.

The activities in "One Bird—Two Habitats" address key concepts related to forest ecology, bird ecology, interconnectedness, management options, scientific inquiry, and conservation. Within these concept areas, the curriculum treats topics such as the intrinsic value of birds, biodiversity, the mysteries of migration and navigation, forest fragmentation, cowbird parasitism, bird banding and other research techniques, carrying capacity, and forest management. The dependence of both birds and humans on forests is a recurring theme. The messages are multifaceted because conservation of migratory forest birds and their habitats is a controversial and complex issue.

To package our messages about migratory bird conservation in a way that would both appeal to and be useful to teachers, we incorporated current trends in education. In keeping with the current trend in middle schools, "One Bird—Two Habitats" is an interdisciplinary unit addressing an issue. We also incorporated cooperative learning into many of the activities. This educational method supports the theme of interconnectedness. The basic elements of cooperative learning are: Positive interdependence (sharing goals, resources, roles, and rewards), individual accountability, group processing, social skills, and face-to-face interaction (Johnson and others 1990, 1991). To help teachers use the curriculum within the structure of the education system, we incorporated suggestions for alternative assessment into the activities. We designed two specific activities to function as assessment tools, and added an appendix on alternative assessment techniques.

Pilot Evaluation

Although the initial idea for "One Bird—Two Habitats" came from Partners of the Americas, it was the Bureau of Research (now renamed Integrated Science Services) in the Wisconsin Department of Natural Resources that took on the project. The research base was an important element in selling the idea to the Bureau, and the incorporation of research into the development process was vital.

In March 1993, 22 sixth, seventh, and eighth grade teachers attended a day-long workshop to launch the pilot. Not only did more teachers participate in the pilot than the four we initially had recruited, but many of them spent more time on the program than the three weeks we had requested. Rather

than drop activities, many of the teachers expanded their time commitment to 4-6 weeks. We considered this expanded commitment a strong vote of confidence in the program.

Our research design included qualitative and quantitative methods. Researchers conducted 98 classroom observations and 250 student interviews. A random selection of 430 (215 pre- and 215 post-unit) student tests were statistically analyzed. Twenty-two teachers completed questionnaires and attended focus groups following the pilot. A simulated "Town Meeting" from the curriculum was used to help ascertain whether core concepts were being conveyed.

We found the curriculum and workshop worthwhile. Teachers and students generally liked the activities. Students especially liked active, participatory kinds of activities and going outside. Although we had considered creating a curriculum specifically for use outside, feedback from the teachers validated our decision to make this a program that could be used in any middle-school setting, with or without access to a forest. All 22 teachers completing the questionnaire said that they would teach the unit again.

As with other programs, lack of time was probably the main obstacle (Gilchrist 1999; Zosel 1989). We changed the curriculum description to reflect the time commitment more accurately, added "Key Points" to help focus the learning efficiently, honored the request for a "List of Materials by Activity," and continued to provide workshops to expedite teacher preparation. Unable to create more time in a school's curriculum plan or a teacher's day, we took what measures we could to diminish the time barrier and further the success of the program.

The incorporation of current education trends was successful, with a few modifications. Some teachers were anxious about using cooperative learning beforehand, but they liked the method in the end. Although specific cooperative learning techniques were not always evident, students liked working in cooperative groups. Sometimes the cooperative group process required more time than teachers had available, so we reduced the amount of cooperative learning in the unit. As a response to teachers who had difficulty assessing student performance in participatory activities, we added an appendix on alternative assessment.

Students particularly liked the cultural exchange with Nicaraguan classes, although responses from Nicaragua were rare. Problems with the activity are largely due to differences in transportation and communication systems, economic and political conditions, language, and culture. We remain committed to the connection with Nicaragua, and expect that connecting with a Latin American sister state will be easier for others than it has been for Wisconsin.

Learning took place at all three grade levels, with significantly more at the sixth grade than the eighth. Researcher observations, teacher feedback, and statistical analysis of student tests all confirmed the age appropriateness of the activities. In a paired t-test of student test scores, improvements from pre- to post-unit tests were highly significant. Teachers reported student learning and increased interest in birds. The unit successfully introduced the Ovenbird, placed Nicaragua on the map, demonstrated that environmental issues are global, introduced research methods used to study birds, and conveyed the messages that human changes in land use affect birds and that people in both Latin and North America depend on forest products.

Although the curriculum emphasizes environmental awareness more than direct student action, activities in this unit can be coupled with action projects. In one school, students found out about plans to bulldoze a forest to build a parking lot. On their own, they approached the principal and discussed the needs of birds dependent on that forest habitat. The principal listened, conducted an environmental assessment, and decided not to bulldoze the woods.

We have used the evaluation results to revise the curriculum, to support dissemination through workshops, and to market the program both in Wisconsin and to other states. Unless major changes are made, states adopting the program need not conduct a formative evaluation of this magnitude.

Program Dissemination

"One Bird—Two Habitats" is more than a curriculum; it's a whole program. Feedback from the pilot teachers, staff observations, experience of other environmental education programs, and concern for balanced representation of a complex issue led us to disseminate the curriculum through teacher workshops rather than the mail.

Teacher workshops are designed to prepare teachers to use the curriculum with their students. The first, presented by the Department of Natural Resources, took place in March, 1994. Responsibility for dissemination to Wisconsin educators shifted to the University of Wisconsin-Madison Cooperative Extension Service, through the Department of Wildlife Ecology. A series of six teacher workshops distributed the curriculum around the state in 1994-1995.

People who have attended a teacher workshop may then attend a Facilitator Training, which prepares them to conduct teacher workshops on their own. The Department of Natural Resources and the University of Wisconsin cooperated to produce the first Wisconsin Facilitator Training in June, 1995.

People outside the state have been requesting the curriculum. But, personalized for Wisconsin, it requires adaptation for use in other places. To facilitate national dissemination, we designed coordinator workshops to prepare people from outside Wisconsin to adapt and disseminate the program in their own state or region. With support from the USFWS, we held Coordinator workshops in Virginia, Illinois, Maine, and Minnesota. The curriculum has already been adapted into programs in other states such as Illinois, Pennsylvania, Maryland, Iowa, and Minnesota. A need for workshops in the western and southeastern region remains.

Economics of Open Space Conservation

Paul Kerlinger

Abstract—Recent and current research is addressing the question of the true economic value of open space, and thus public perceptions are changing. Usually unconsidered aspects such as property tax stability, ecotourism, and maintenance of nearby property values are now part of the larger picture of open space value. Both developers and conservationists need to understand the wider scope of community development, including the economic arguments, or otherwise face the continued disappearance of open spaces.

The protection and continued survival of Neotropical migratory birds depends on the amount and quality of habitat that remains available to them. To date, strategies used to protect habitat have relied primarily on biological arguments such as protection of biodiversity, wetlands, watersheds, and endangered and threatened species, as well as aesthetic arguments relating to preservation of beautiful scenery. Unfortunately, many people are unmoved by these types of arguments. For habitat protection to be successful, new strategies are needed to convince people who cannot be swayed by biological or aesthetic arguments. In the 1990s this group includes those involved with the conservative "revolution" that is now attacking open space conservation.

An emerging strategy for protecting habitat and wildlife is the use of economic information and arguments. This paper describes the economic value of open space to communities, and explains how this value is greater than commonly believed. The paper is meant to serve as a primer, and is applicable primarily to suburban and rural areas, where many open-space conservation battles are being fought. Although I have not provided a detailed "how to" for the reader, it should be obvious how economic arguments can be integrated into open-space conservation strategies.

The Economic Value of Open Space

The value of undeveloped land differs depending on the viewer. To environmentalists and conservationists, economic value may not come to mind. To a real estate developer or a builder, land is a commodity that represents an investment, a salary, profits, tax benefits and liabilities, and future earnings. To a town planner, open land may represent a park, a school, a parking lot, houses, a factory, a farm, or tax rateables. Therefore, many factors must be considered to determine the true, long-term value of a piece of land. A few of those considerations are presented below. The importance of each is contextual; none are absolutes, because they depend on geographic location, current land use practices, economic character of the area, the physical and biological attributes of the land, and the political climate.

Property Tax Stability

Open-space conservation often contributes to controlling taxes. Why? Soaring property taxes usually can be attributed to poor planning or to unplanned development of open space within communities. Ironically, tax reform and tax rebellion groups have rarely seized the fact that building houses costs a community more than these homes generate in property tax revenues (called rateables). Fifty years ago, taxes generated from housing developments helped to finance roads, public schools, police departments, fire departments, and other community-driven expenses. As the cost of these services rises, property taxes rarely cover them, especially in townships that have grown rapidly (American Farmland Trust 1986). Services often cost 125 to 150% of taxes generated, forcing township governments to raise taxes and to seek federal subsidies (loans, grants.) Despite these facts, real estate developers and builders still manage to convince township officials that the houses they build will generate tax revenues that benefit the community. In communities with a master plan that concentrates housing and business development near existing services and that stipulates conservation of open space, taxes do not increase, or they do not increase as rapidly as in townships that do not plan. In sum, thoughtful master plans not only insure open space for parks and conservation, they also limit development that is costly to a community.

Ecotourism

Some of the most important areas for migrating birds and other wildlife offer marvelous economic opportunities because they attract large numbers of nature lovers or ecotourists, who spend billions of dollars annually to watch and enjoy wildlife.

More than a dozen recent studies of birding ecotourism and birding economics have demonstrated that wildlife refuges, parks, sanctuaries, preserves, and other forms of open space attract millions of tourists and their dollars each year (Wiedner and Kerlinger 1990; Kerlinger and Wiedner 1991; Kerlinger 1993; Eubanks and others 1993; Kerlinger and Brett 1995). These dollars represent important revenues to rural and suburban communities. From the business and community side, ecotourism is a good form of economic development because it requires little investment in infrastructure. Funds that are required are routine

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business investments by the private sector, which provides accommodations, places to eat, services, and products to purchase. The community provides an attraction, which costs it very little.

The suitability of an area for ecotourism is determined largely by the presence of natural attractions. For example, beautiful scenery and rock formations draw people to parks in the Rocky Mountains and the desert southwest. For birding ecotourism, migratory bird stopover sites, high biodiversity, and endangered or threatened species all serve as attractions. In the past decade, ecotourism has experienced faster growth than any other form of tourism. For ecotourism to be a sustainable form of economic endeavor, the natural resources on which this industry depends must be protected. Thus, ecotourism is a sustainable form of economic endeavor as long as the resource is protected.

Maintenance of Property Values

One benefit of open space protection is maintenance of property values. Frequently, property values near refuges and preserves are higher than those of properties surrounded by houses. Properties near open space are desirable because they offer beauty, seclusion, and high resale value. The National Association of Home Builders estimates that parks and recreation areas can increase the value of nearby building sites by 15-20%. Therefore, these sites are prime targets for builders and realtors. Announcement of a new national wildlife refuge usually results in increased land prices within and around the new refuge boundaries. Property taxes of adjacent lots and homes also increase, generating more revenue for a community without costing that community in services. These facts provide a sound basis for clustering homes and businesses to preserve open space.

Groundwater Recharge and Pollution Protection

As development eats open space away, the integrity of existing water resources is threatened. In many suburban and most rural settings, household water is supplied by a single family well that taps an underground aquifer. Also, many houses have private septic systems, consisting of a concrete holding tank for solid waste, and an associated system of pipes (a leach field) buried several inches under the soil. Water passing into the leach field is supposedly clean, and either evaporates or percolates into the soil. In ideal situations, septic tanks are pumped regularly and do not leak, and leach fields emit relatively clean water. In reality, septic systems do overflow, or they fail to cleanse the water before returning it to the ground. Therefore, increased housing in rural or suburban settings often pollutes ground water, so that clean water must be piped from nearby towns and villages, and homes must be linked to city sewage. This engineering, whether for new construction or for retrofitting existing neighborhoods, is costly to taxpayers and rate payers (sewage and water). Rate increases then persuade homeowners to conserve water. This "conservation" measure can be construed as a decline in the quality of life.

In coastal areas, increased housing that relies on wells—either single home wells or city wells—often results in salt water intrusion. That is, when a large quantity of water is pumped from an aquifer, nearby salt water can migrate into the aquifer and then into the wells. Then, new wells or new, desalinized water systems must be developed; both approaches are expensive.

The ultimate cost of "fixing" all these problems rests on the backs of taxpayers. The developers and township officials responsible for poor planning simply pass along the costly mistake of unplanned development. Taxpayers complain, but too late.

Open space can thus prevent both costly infrastructural construction and the service costs associated with water and sewage problems. Natural habitats act as giant sponges, allowing rainwater to percolate into the ground without being polluted, and to recharge aquifers with clean water. The result: taxpayer savings.

Trash Removal and Landfill Costs

A rarely considered cost of developing open space is the creation and maintenance of landfills. With more trash accumulating from more houses, the demand for landfill space increases. Then, fees for disposing trash at landfills ("tipping fees") can increase from a few dollars to hundreds of dollars per ton. Landfill operators raise these fees to create disincentives; they have limited space, and too much trash can require trash-burning facilities, trucking trash to distant landfills, or even building new landfills, all at taxpayer cost.

Also, rural and suburban homes situated far from the center of trash-removal activity are expensive to service. And, the property value of houses near landfills is lower than that of houses far away. The lower values result in lower property taxes for the township. If land is left undeveloped, community taxpayers can avoid many of the social, economic, and environmental problems associated with landfills and trash removal.

Discussion

Developers often state that conservationists do not understand the economic imperatives of community development. In truth, not many developers understand (or are willing to understand) the long-term impacts of various forms of development on the economic stability of a community. They also do not understand that development of open space is often more costly than conserving it. The information provided in this paper can help to combat the myth that habitat conservation is an economic albatross around a community's neck.

Economic arguments can be important, powerful tools for protecting habitat and the birds that live within. When used properly, economic arguments make sense and are difficult to refute. Unfortunately, few conservationists have the expertise needed to delve into economic issues. In addition, some conservationists are philosophically opposed to economic arguments, believing that such arguments should not be used or will not work. Whatever the reason, if economic

arguments are not added to the arsenal of tools used for open-space conservation, we will continue to watch those spaces disappear.

At the same time, economic arguments should not be perceived as a panacea or as the only tool for conservation. Instead, they should be incorporated into comprehensive strategies that also emphasize aesthetics, quality of life, biodiversity, endangered and threatened species, and ecosystem protection. The effectiveness of economic arguments for conservation usually will depend on the economic importance of the land. Such determinations are not easy, although recent and current research projects are addressing questions related to the true value of open space. The addition of such information is quickly changing public perception of the economic value of open space. As this perception changes, protecting lands that enhance our economy and our quality of life will become easier.

The Great Texas Coastal Birding Trail: A Tool for Avitourism

Madge Lindsay

Abstract—When completed, the Great Texas Coastal Birding Trail will cover more than 500 miles, link users and stakeholders, and provide an economic source for dozens of businesses. The Texas Parks and Wildlife Department began the trail in 1993 by marking the trail and by using highway turnoffs, viewing blinds, and observation stations. The project has expanded into trail products and events, a newsletter, and computer link-ups. The trail is a successful and excellent example of avitourism—a part of the growing worldwide ecotourism movement.

Birdwatching is a popular form of outdoor recreation, and avitourism—overnight travel to experience birds in a natural setting—is an important part of the worldwide growth in ecotourism. Recognizing these facts, and knowing that the Texas Gulf Coast is a major destination for many birdwatchers and avitourists, the Texas Parks and Wildlife Department (TPWD), Texas Department of Transportation (TXDOT), other government agencies, communities, and tourism industry leaders are assisting the development of Texas Gulf Coast avitourism. Their goal is to promote sustainable economic development while conserving habitat for Texas birds. Projects currently under development, including the Great Texas Coastal Birding Trail, are designed to bring a portion of the $238 billion spent on ecotourism each year, worldwide, into Texas coastal communities. Through conservation management, nature tourism development, and marketing, coastal communities can gain economically while protecting some of the habitat necessary to sustain the rich array of birds found in Texas.

Tourism Economics and Recreational Trends

Annual expenditures shown by the United States tourism industry amount to $417 billion, providing $58 billion in federal, state, and local tax revenues. The U.S. tourism industry is the second largest employer in America, providing 14.3 million jobs and $110 billion in travel-generated payroll (Eubanks and others 1995).

In a 1992 report by the World Tourism Organization, ecotourism is shown to be the fastest growing segment of the world travel industry, with growth averaging 30% each year since 1987. Global sales totaled $238 billion (WTO 1992). A U.S. Fish and Wildlife Service survey showed that in 1991, 35.6 million people fished and 14.1 million hunted, while 76.1 million people 16 years or older enjoyed nonconsumptive wildlife recreation, spending $59 billion observing, feeding, or photographing wildlife. Thirty million took trips for the primary purpose of enjoying wildlife, spending $22.2 billion on trip-related costs including food, lodging, and transportation (USFWS 1993). The National Trust for Historic Preservation found that travelers who journey to experience cultural, historical, and natural history sites spend an average of $62 per day more than the average traveler (National Trust for Historic Preservation 1994). A Roper Starch Worldwide survey for the Recreation Roundtable, which interviewed 1,993 adults in person from April 16-23, 1994, revealed that 14% of Americans involved in recreation were birdwatchers, more than the number who golf or go motorboating.

According to the Texas Department of Commerce, in 1994 tourism was the third largest industry in Texas. Collecting $24.5 billion from direct travel expenditures, the state ranked 4th in the nation, with $21.5 billion derived from domestic travelers, and $3.0 billion from international travelers. This represented a 5.3 per cent increase from 1993. Texas travel expenditures generated 435,000 jobs in 1994, representing 5.6% of the total state nonagricultural employment, up from 3.8% in 1993 (Eubanks and others 1995).

Recent studies at the Aransas National Wildlife Refuge showed that 75,000 people visit annually to view wildlife, to fish, and to hunt. At Santa Ana National Wildlife Refuge, 99,000 of the 167,808 visitors in 1994 were bird watchers. Avitourists interviewed in a survey there were middle-aged (70% in their fifties and sixties); well-educated (76.9% had attended some college); and wealthy (49.5% had family incomes in excess of $50,000 per year). A majority did not fish (63 percent) or hunt (89.1 percent). They spent $14.4 million in the local communities: $6.16 million on lodging, $2.18 million on meals, $0.44 million on fuel, and $5.64 million on other purchases. The average visitor contributed between $88 and $145 to the local economy (Eubanks and others 1995).

The Texas Coastal Advantage

A 1991 survey showed that since 1988, more members of the American Birding Association have pursued their hobby in Texas than in any other state (Wauer 1991). Four of the top 12 birding destinations in North America are in Texas: Two on the Texas Gulf Coast (High Island and Central Coast), one in South Texas adjacent to the Gulf Coast (Lower Rio Grande Valley), and one in the Trans Pecos (Big Bend National Park) (Kerlinger and Weidner 1994).

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Birdwatchers travel to Texas because the state has documented 596 bird species, one of the largest numbers in the U.S. The Texas Coast alone has more birds than most other states, with more than 400 species possible during the year. This bird richness results from the diverse habitats found in Texas, from the woodlands and prairies on the Upper Coast, to the South Texas thorn shrub and Rio Grande riparian forests on the Lower Coast. Indeed, Texas and the Texas Gulf Coast are known worldwide for their excellent birding experiences.

The Great Texas Coastal Birding Trail: Linking Users and Stakeholders

In 1993, TPWD began the Great Texas Coastal Birding Trail, a sustainable development project designed to capitalize on the potential for Texas to attract birdwatchers. The trail unifies existing and potential birding sites into a cohesive and marketable unit. When completed, the more than 500 mile highway trail network will link the users (birdwatchers) with the stakeholders (private landowners and community business interests). Ranches, lodging establishments, restaurants, and other providers of goods and services will become part of an organized network that will serve and market to traveling birdwatchers. With increased attention from the economic side, wildlife (or bird) habitat will be considered part of the economic base for communities along the trail—a new concept for many coastal community leaders.

The $1.5 million dollar project, with Phase I funding through the TXDOT Intermodal Transportation Efficiency Act of 1991, is sponsored by the TPWD. Sites on the trail are marked with a universal logo sign (Black Skimmer) and corresponding numbers that identify the site on a trail map. Some sites have received enhancements, such as highway turn-outs, boardwalks, viewing blinds, observation stations, and hummingbird gardens. A trail map distributed by TXDOT and TPWD are available for purchase.

Proceeds from ongoing marketing will be used for maintaining the trail. In addition to a trail guide, marketing will include a trail-sponsors program, trail products and events, a quarterly newsletter, computer link-ups, and a quality trail-experience. Marketing and trail maintenance are coordinated by TPWD through communities and siteholders.

The trail project, which has completed its first phase on the Central Texas Coast, has been extremely popular with communities and birdwatchers alike. More than 95 sites are included on the Central Coast section. Three private ranches have been listed, and 13 site holders have provided many in-kind habitat and site enhancements. On September 8, 1994, Roger Tory Peterson helped with dedication ceremonies in which the first trail sign was unveiled at the Connie Hagar Cottage Sanctuary in Rockport, Texas.

Funding to complete the Trail has been obtained from TXDOT. TPWD is encouraging coastal communities, landowners, and industries on the Upper and Lower Coasts to get involved in this valuable endeavor. The Upper Coast opened in the spring of 1999, and the Lower Coast opened in the fall. The Upper Coast houses 30 sites with more than 100 sites planned for the Lower Coast.

When completed, the Great Texas Coastal Birding Trail will provide a model for other areas interested in avitourism. TPWD and all site holders plan to provide a quality experience for trail users with good habitat, birding enhancements, conservation management, ongoing monitoring, and marketing. The Trail has generated a great deal of excitement and attention from both users and communities. Trail planners and participants eagerly await its completion, and hope that it will deliver both conservation and economic development.

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Blackpoll Warbler

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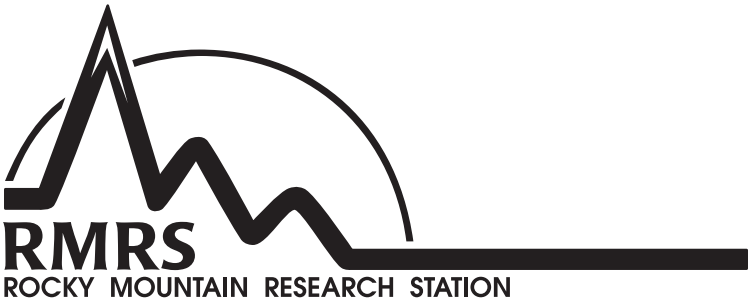

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