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

Paul A. Wood[2], Deanna K. Dawson[3], John R. Sauer[4], and Marcia H. Wilson[5]

Abstract

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

Introduction

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

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

Rancho Sandoval

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

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

[2]Calle 18 #102, Chuburná de Hidalgo, Chuburná, Mérida, Yucatán, México.

[3]USGS Patuxent Wildlife Research Center, 12100 Beech Forest Rd., Laurel, MD 20708.

[4]USGS Patuxent Wildlife Research Center, 11510 American Holly Drive, Laurel, MD 20708. Corresponding author e-mail: deanna_dawson@usgs.gov.

[5]NPS Inventory and Monitoring Program, Mt. Rushmore National Memorial, 13000 Highway 244, Keystone, SD 57751

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

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

Methods

Geographic Information System

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

Alternative Management Scenarios for Rancho Sandoval

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

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

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

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

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

Modeling Bird Distributions on Rancho Sandoval

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

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

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

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

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

Results

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

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

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

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

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

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

Discussion

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

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

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

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

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

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

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

Acknowledgments

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

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