Planning for Bird Conservation: A Tale of Two Models[1]

Douglas H. Johnson[2] and Maiken Winter[3]

Abstract

Planning for bird conservation has become increasingly reliant on remote sensing, geographical information systems, and, especially, models used to predict the occurrence of bird species as well as their density and demographics. We address the role of such tools by contrasting two models used in bird conservation. One, the Mallard (*Anas platyrhynchos*) productivity model, is very detailed, mechanistic, and based on an enormous body of research. The Mallard model has been extensively used with success to guide management efforts for Mallards and certain other species of ducks. The other model, the concept of Bird Conservation Areas, is simpler, less mechanistic, and less well-grounded in research. This concept proposes that large patches of suitable habitat in a proper landscape will be adequate to maintain populations of birds. The Bird Conservation Area concept recently has been evaluated in the northern tallgrass prairie, where its fundamental assumptions have been found not to hold consistently. We argue that a more comprehensive understanding of the biology of individual species, and how they respond to habitat features, will be essential before we can use remotely sensed information and geographic information system products with confidence.

Key words: *Anas platyrhynchos*, Bird Conservation Area, geographical information system, grassland bird, Mallard, model, remote sensing.

Introduction

Planning for bird conservation is currently in vogue. Although conservation planning has a long history, most plans focused on single species, typically threatened or endangered ones. The North American Waterfowl Management Plan led the way in multispecies planning. That Plan successfully brought together a wide variety of agencies and organizations from three nations, all with disparate missions, but with a common interest in waterfowl and their habitats. Later, Partners in Flight was formed to draw attention to birds that migrate from Canada and the United States to Latin America. It subsequently evolved to include landbirds in general. Other organizations coalesced to focus on waterbirds, shorebirds, and other groups of birds. Because birds from different groups often share the same habitats, conservation efforts to favor one group of birds often provide benefits to species in other groups. Recognition of this fact has led to more comprehensive, all-bird conservation planning under the North American Bird Conservation Initiative.

Central to each organization's efforts is the development of plans intended to achieve certain population or habitat objectives through a variety of mechanisms. The widespread availability of geospatial information about habitats, ownership, and other land features has resulted in GIS (geographic information systems) and remote sensing playing critical roles in the planning process. GIS gives planners ready views of many types of information, and particularly their spatial arrangement. Certain types of information (layers) are known with some exactitude; these include land ownership, locations of roads, long-term climatic patterns, and sites where particular bird species have been recorded. Other types of information derive from remote sensing and require either automated or manual interpretation; included here are land cover, identification of wetlands, and the like. The quality of these information layers is improved if on-the-ground verification of the interpretation is conducted. A third type of information often included in GIS reflects the output of models. For example, the suitability of a site for a particular bird species may be modeled in relation to the habitat type at the site, size of habitat patch, and location of the site relative to the range of the species. Graphical displays of information, especially spatial information, look very "real," lending an air of credibility to the information that may not be warranted.

Our purpose here is to address the role of models and the applicability of GIS and remote sensing in planning for bird conservation. We do that by contrasting two models currently in use, both of which use remotely sensed data and are amenable to GIS. One is the Mallard productivity model (Johnson et al. 1987), which has been widely used in planning for Mallards

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[2]U.S. Geological Survey, Northern Prairie Wildlife Research Center, 8711 37th Street Southeast, Jamestown, ND 58401.
E-mail: Douglas_H_Johnson@usgs.gov
[3]State University of New York, College of Environmental Science and Forestry, Syracuse, NY 13210

on their breeding grounds (Cowardin et al. 1988). The Mallard productivity model is very detailed, mechanistic, and based on an enormous body of research. The other model is the concept of Bird Conservation Areas, which is included in several plans for breeding landbirds (e.g., Fitzgerald et al. 1998). The Bird Conservation Area concept is based on the observation that some bird species respond to the size of a habitat patch and to features of the landscape that surrounds the patch (e.g., Robinson et al. 1995). Unlike the Mallard productivity model, inputs to the Bird Conservation Area model can be derived solely from remotely sensed data. This is certainly an attractive feature for planners concerned about large land areas.

The Mallard Productivity Model

The Mallard model has been widely used, initially to guide research, but later for management applications. For example, it played a prominent role in developing the Mallard Management Plan for the Central Flyway (Cowardin et al. 1988). In that application, biologists evaluated the effects on Mallard recruitment of a variety of management practices, such as nest baskets, delayed cutting of alfalfa, no-till winter wheat, and predator-resistant fencing. Another early application was to compare various treatments for the U.S. Fish and Wildlife Service (Cowardin et al. 1988). Among the practices considered there were purchases of easements on wetlands and retirement of cropland. The model also has been used to evaluate mitigation plans for water development projects. More recently, it formed the basis for comparing management options for the Prairie Pothole Joint Venture, under the North American Waterfowl Management Plan. Lercel et al. (1999) used the Mallard model to estimate the effect of the loss of a mate in late winter on reproduction during the subsequent breeding season. Delta Waterfowl is applying the Mallard model to predict the efficacy of predator removal on Mallard recruitment.

The Mallard model is restricted to the breeding season, which has been demonstrated to be most influential in determining population dynamics of the species (Johnson et al. 1992, Johnson and Owyn 1992, Ankney 1996). The model comprises seven basic components: breeding population size, nest initiation, nest site selection, clutch size, nest success, brood and duckling survival, and survival of the female. Each of these components can be influenced by many variables, but the model incorporates only the most influential variables and those that either can be measured or can be generated internally within the model.

Breeding population size is determined for a prescribed site to which the model will be applied. The numbers of breeding pairs either can be defined by the user or can be determined as a function of the wetlands at the site. Each wetland is assigned an expected number of Mallard pairs, depending on its size and class (Cowardin et al. 1988). Those expected numbers are summed for all the wetlands at the site. Equations to generate these expected numbers were developed from analyses of counts of ducks on thousands of wetlands in the Prairie Pothole Region, and are specific to individual areas within that region. Further, the number of breeding pairs can vary in response to average nest success in the area. This added influence reflects the tendency of female Mallards to return to a breeding area (i.e., home) if they were reproductively successful the previous year (Johnson and Grier 1988, Lokemoen et al. 1990).

Arrival dates of simulated birds at the breeding site follow a random distribution that mimics arriving ducks during a typical year. After arrival, each female proceeds through the simulation on a day-by-day basis until it dies or leaves the site. On each day, a bird that is not already nesting can, with a specified probability, initiate a nest. That probability is a function of the date within the season, declining after mid June and falling to zero in mid July. The probability is higher when there are more wetlands containing water at the site (Krapu et al. 1979, 1983; Cowardin et al. 1985). The probability also is affected by the physical condition (expressed as body weight) of the hen (Cowardin et al. 1985, Eldridge and Krapu 1988), which in turn is a function of the number of eggs she has already laid during the season.

Once a simulated Mallard commences nesting, she selects a nest site from among the possible habitats at the site. The probability that she selects a particular habitat type is modeled as a function of the quality (height and density) of vegetation in that habitat type, multiplied by the proportional availability of that habitat type at the site. Again, because female Mallards are thought to return to habitats in which they were successful earlier, the model allows a heightened probability of selecting a habitat type with high nest success.

A large number of proximate and ultimate variables have been demonstrated to influence clutch size of birds (Godfray et al. 1991). The Mallard model incorporates two variables demonstrated to exert the most influence on clutch size in Mallards: date within season (reviewed by Rohwer 1992) and age of hen (Coulter and Miller 1968, Batt and Prince 1978, Krapu and Doty 1979). Simulated clutch sizes are large (mean about 11 eggs) early in the breeding season and decline linearly thereafter. Clutch sizes for yearling hens are about one egg smaller than for older birds.

The probability that a clutch is successful in hatching (nest success) is one of the two most influential components of population size (Johnson and Owyn 1992). Predation is the most common cause of clutch failure in Mallards and most other waterfowl (Sargeant and Raveling 1992). While we might have modeled nest success as a function of the densities of various predator species, in reality those densities are almost never known and could not be usefully employed in applying the model. What has been determined in many areas of the Prairie Pothole Region are nest success rates in various habitats (e.g., Klett et al. 1988, Shaffer and Newton 1995). So the model can use either these estimates or site- and habitat-specific rates provided by the user.

The other most influential component of population size is brood and duckling survival. When the model was developed, information was not sufficient to model those rates in terms of variables that could be measured, so the probability that one or more members of a brood would fledge (brood survival rate) was set at 0.74, a typical value for the Prairie Pothole Region (Johnson et al. 1987, Sargeant and Raveling 1992). The probability that an individual duckling within a successful brood would survive to fledge (duckling survival rate) was fixed at 0.54. Subsequently, Cox and Johnson (in prep.) were able to use more-recent research findings to enhance the model by making brood and duckling survival rates vary in response to extrinsic variables or to variables simulated within the model. Brood survival rate in the enhanced model depends on hatch date (Krapu et al. 2000), wetland conditions (Krapu et al. 2000), and an index to the abundance of mink (*Mustela vison*), a key predator of Mallard ducklings (Talent et al. 1983). Survival rate is lower for nests hatching later the season; hatch date is generated from the nest initiation date internally within the model. The user can specify wetland conditions and one of three levels of mink abundance-low, medium, or high.

Rates of duckling survival (survival of individual ducklings within a successful brood) in the enhanced model depend on the weight of the bird at hatch (Cox et al. 1998), the abundance of invertebrate foods (Cox et al. 1998), and the occurrence of extreme weather events when birds are young (Cox and Johnson in prep.). The user can indicate whether invertebrates are abundant, about average, or uncommon. The other phenomena are simulated within the model.

Whether or not a female Mallard survives the breeding season is most strongly influenced by predation while she is on the nest. The model assigns a baseline daily mortality rate of 0.001 for days the hen is not nesting or she is nesting and her nest survives. If her nest is destroyed, the probability that she dies during that event is set at 0.06. This combination of rates has been found to yield realistic survival rates for the breeding season (Johnson and Sargeant 1977).

A variety of components in the model have been subjected to testing and evaluation procedures and have fared well (Johnson et al. 1986, Cowardin et al. 1988). In addition, biologists familiar with waterfowl ecology have found simulations made with the model to be consistent with their understanding of waterfowl nesting biology.

Because of interest in using the model in areas beyond that for which it was originally designed, a number of extensions have been made. The United States Fish and Wildlife Service and Minnesota Department of Natural Resources gathered data to modify the model for use in Minnesota (Zicus and Rave 1998). Ducks Unlimited, Canada, has conducted a number of studies to determine how the model applies to the Canadian Parklands and what modifications are necessary.

In sum, the Mallard productivity model illustrates what can be done to develop a tool to guide management of an avian species. It is mechanistic, incorporating known features of species behavior and basic population dynamics. The model is based on a tremendous number of research and management studies and reflects a considerable knowledge of biology. Nonetheless the model still is data-hungry for information on key variables such as nest success rates in available habitats and geographical areas that are being modeled.

The Bird Conservation Area Concept

We next turn to a much simpler, less mechanistic model, encompassed in the notion of a Bird Conservation Area (BCA). The fundamental idea of a BCA is that a large patch of suitable habitat, in a landscape that is not hostile, will maintain viable populations of breeding birds. This idea is based on three tenets: 1) A patch of suitable habitat is necessary. The habitat requirements of many species of grassland birds have been reviewed and summarized recently (Johnson et al. 1998). 2) In small patches of habitat, some species of birds often are absent or occur at low densities (Winter and Faaborg 1999, Johnson and Igl 2001), or they suffer low reproductive rates (Donovan et al. 1995, Porneluzi and Faaborg 1999). 3) Reductions in density and productivity with decreasing patch size (and corresponding increasing proportions of edge habitat) can be ameliorated if the surrounding landscape is favorable (Donovan et al. 1997). Patch size and landscape effects are at least partially mediated through edge effects, for example, lowered density and productivity close to a habitat edge (Faaborg et al. 1993). For grassland birds, woody vegetation is considered a hostile edge because certain grassland species avoid it (Johnson and Temple

1990, O'Leary and Nyberg 2000), and it provides travel lanes for various predators (Winter et al. 2000b) and perch sites for raptors and brood-parasitic Brown-headed Cowbirds (*Molothrus ater*; Chalfoun et al. 2002a, b). BCAs attempt to provide adequate habitat to ensure the long-term survival of bird species nesting at that site by designing reserves based on principles of both patch size and landscape structure.

Although the BCA concept has been proposed for grassland systems, most of the research that describes the patterns underlying BCAs was conducted in forest systems (Donovan et al. 1995). Only a few studies have investigated patch size and landscape effects on grassland birds, and the results of these studies vary widely among regions and years (Johnson and Winter 1999, Johnson 2001, Johnson and Igl 2001). The BCA model for grassland birds thus is based on a set of assumptions, most of which have not yet been tested in the appropriate habitat, or on the appropriate spatial and temporal scales.

The specific numbers for BCAs were suggested for a single grassland-nesting species, the Greater Prairie-Chicken (*Tympanuchus cupido*). The Wisconsin Department of Natural Resources proposed that grassland BCAs would maintain populations of Greater Prairie-Chickens and, under that umbrella species, other grassland-dependent birds, such as Grasshopper Sparrow (*Ammodramus savannarum*), as well (Henderson and Sample 1995). Specifically, in the northern tallgrass prairie region (Fitzgerald et al. 1998), each proposed Bird Conservation Area would consist of an 800-ha core of high-quality grassland embedded in a 4,000-ha buffer. This buffer would include an additional 800 ha of smaller patches of grassland. Partners in Flight suggested that such an area, if managed properly, would be sufficient to support Greater Prairie-Chickens and other grassland birds of concern (Fitzgerald et al. 1998).

Note that this conceptual model is ambiguous as to which species—other than Greater Prairie-Chicken—are likely to be favored by a BCA. Also, the model is without any explicit mechanism. Work on forest-nesting species has elucidated several mechanisms for patch size and landscape effects, such as differences in pairing success (Gibbs and Faaborg 1990, Villard et al. 1993, Bayne and Hobson 2001), differences in distribution of nest predators (Heske et al. 2001) and of brood-parasitic Brown-headed Cowbirds (Porneluzi and Faaborg 1999) and potentially differences in juvenile dispersion (Anders et al. 1997). But much less is known about such mechanisms in grassland species (Johnson 2001). The BCA concept thus is based on only general ideas that large patches and neutral landscapes are better than smaller patches and hostile landscapes, most of which were developed in forested systems. However, mechanisms in grasslands may differ from those described for forest systems due to differences in bird species assemblages and predator communities.

If a BCA would work, we therefore would not necessarily know how or why. Yet, the model is useful in guiding management, *based on the information currently available*. Further, that model may be all that is necessary. If it works, we may not need to know why. If the model fails to work, however, at least for some species or in some situations, then questions about mechanisms become more important.

For four years we have evaluated the BCA concept in the northern tallgrass prairie (Winter et al. 1998, 1999, 2000a, 2001). We examined the influences of patch size, landscape configuration, and their interaction on densities and nest success rates of breeding birds. We attempted to reduce the effect of proximate habitat features by selecting study sites with similar vegetation; most of them were native prairie. Absolute comparability was impossible, of course, so we recorded vegetation measurements to use as covariates during analysis.

Study sites were located in three regions, two in northwestern Minnesota and one in southeastern North Dakota. Within each of those regions we had both small (<40 ha) and large (>250 ha) grassland patches in both neutral (few trees in vicinity) and hostile (many trees in vicinity) landscapes. We compared breeding bird densities at 45 sites; on 30 of those we also gathered nest success information.

As will be shown elsewhere, the predicted patterns have not always materialized (Winter et al. 1998, 1999, 2000a, 2001). The effects of patch size and landscape on both density and nesting success were inconsistent, varying among years, regions, and species. For example, in the first year of study, Savannah Sparrows (*Passerculus sandwichensis*) were more common in plots in neutral landscapes than in hostile landscapes, and Bobolink (*Dolichonyx oryzivorus*) densities were positively associated with both neutral landscapes and large patches. Those patterns did not hold consistently in the subsequent years, however. It thus seems that at this time we cannot safely use patch size or simple landscape data (many versus few trees in the surrounding landscape) to predict grassland bird assemblages and habitat quality. The "black box" approach to planning for grassland bird conservation based on models that lack detailed mechanisms may be inadequate to the task, at least in the northern tallgrass prairie.

Discussion

Typically a model provides certain outputs, based on certain inputs. As an abstraction of a real system, a model incorporates the relevant knowledge we have of that system. Where we lack knowledge, we use assumptions to fill the void. If a model incorporates a lot of knowledge, and is dependent on few critical assumptions, the output from the model is likely to be trustworthy (*fig. 1*). In contrast, a model based on little knowledge and a lot of unsubstantiated assumptions will provide predictions with greater uncertainty and should be used only with caution.

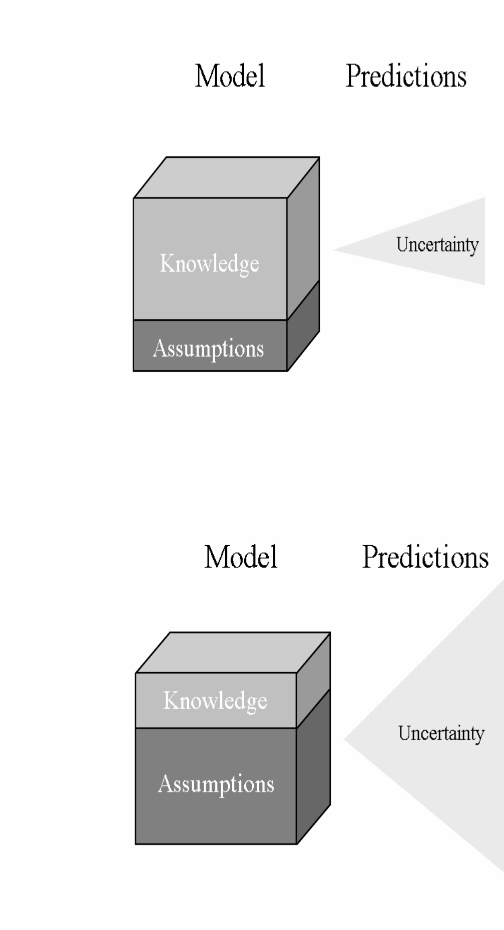

Figure 1— The quality of predictions from models depends on the amount of information incorporated in the model in comparison to the assumptions necessary to fill information voids. Less knowledge results in greater uncertainty in predictions from a model.

Birds respond, either in abundance, survival, or reproductive success, to numerous features of the breeding site. Among these are the geographical location relative to the species' range, gross (macro-) habitat characteristics-such as forest versus grassland, microhabitat features-such as litter cover, food resources for both adults and young, the abundance and composition of the predator community, and weather and other phenomena that act rather capriciously. Of these listed factors, remote sensing is realistically able to identify only the first two, location and gross habitat type. Therefore, any GIS or model based solely on remotely sensed data will be incomplete unless: 1) all the other features are unimportant; 2) long-term or large-scale averages of the other features are available and are adequate for planning purposes; or 3) cues to the other features can be identified and modeled themselves. We have serious doubts that the first option, disregarding the remaining factors, is prudent. The second option may be viable; we do think that modeling based on averages can be useful, but its value is limited. For example, one could base a model for Mallards on long-term average wetland conditions, but in most years on the prairies, wetlands are either markedly drier than average or wetter than average. And Mallard abundance and reproduction differ dramatically under those conditions.

We suggest that the third option holds the most promise. It is important to understand the processes that influence the abundance of birds and their reproductive performance. These processes no doubt will vary to some degree regionally and temporally, as well as among species. Understanding the behavior and ecology of the Mallard, for example, allowed biologists to appreciate when that species can be used as a proxy for other upland-nesting dabbling ducks and when modifications are necessary (Carlson et al. 1993). Further, careful monitoring of certain variables will be necessary to assess the accuracy of model predictions. The success of the Mallard model is in part due to on-the-ground collection of data on wetlands, Mallard abundance, and nest success by habitat. These data are very time- and site-specific, but are essential to the good performance of the model.

As modeling proceeds, we think it important to treat predictions from a model as hypotheses to be evaluated. That was done, for example, by Cowardin et al. (1985), who used the Mallard productivity model to guide their study and provide questions to address; in turn, results from that study were used to modify the model. This thinking is clearly in line with the adaptive resource management notion (Walters 1986). Under that philosophy, managing a system and learning about that system go hand in hand. Knowledge about the system is treated as one of the products of the system, which is managed in part to provide further information so that the system can be better managed in the future. As BCAs are established, they should be adequately monitored to determine how well they are meeting the objectives for which they were created.

Remote sensing, geographical information systems, and models are valuable tools. They can play important roles in conservation planning for birds. But we must not lose sight of the importance of understanding the birds, their behavior, and how they use the habitats and other resources we intend to conserve and manage for their benefit. As Buckland et al. (2000: 6) observed, "It is an unfortunate fact of life that, if two pieces of software are available for a given task, most wildlife managers will select the one that is most impressive visually, irrespective of the relative merits of the methodologies underlying them. The inevitable consequence of this is that there will be an increasing trend toward a videogame mentality." Remote sensing and GIS data may have poor resolution and be error-prone, but they provide visually compelling products. We must be careful not to be seduced by the persuasive power of pixels.

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