Application of Structured Decision Making to Deliver Grassland Bird Conservation throughout the Eastern and Central United States

A case study from the Structured Decision Making Workshop

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(This decision applies to the following Landscape Conservation Cooperatives: Appalachian, Desert, Eastern Tallgrass Prairie, Great Plains, Gulf Coast Prairie, Gulf Coastal Plains and Ozarks, Peninsular Florida, Plains and Prairie Potholes, South Atlantic, and Upper Midwest and Great Lakes. It also encompasses the following Bird Habitat Joint Ventures: *Appalachian Mountains, Atlantic Coast, Central Hardwoods, East Gulf Coastal Plains, Gulf Coast, Lower Mississippi Valley, Northern Great Plains, Oaks and Prairies, Playa Lakes, Prairie Pothole, Rainwater Basin, Rio Grande, and Upper Mississippi River/Great Lakes Region*)

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Decision Problem and Background

A revised program of strategic conservation delivery is needed to successfully conserve and restore grassland bird populations. Grassland birds are among the fastest and most consistently declining birds in North America; 48% are of conservation concern and 55% are showing significant declines (North American Bird Conservation Initiative 2009) (i.e., in some cases, declines exceed 80% (Peterjohn and Sauer 1999)). Many reasons for these declines have been suggested, the most prominent being the loss of perennial grassland habitats – both native and exotic-, which exceeds 90% in many locales (Samson and Knopf 1994, Vickery and Herkert 2001). Given that remaining grassland habitats are increasingly threatened on multiple fronts—by economic incentives for agricultural conversion, potential funding cuts to the U.S. Department of Agriculture's Conservation Reserve Program (CRP) and other state and federal conservation programs, energy development, and other competing land-use objectives—those concerned about grassland bird conservation face many challenges. To prevent further population declines and to ensure the viability of these populations and their associated habitats, it is necessary to consider how to prioritize and leverage limited resources and direct management and conservation efforts at multiple scales in the most strategic way possible.

The Migratory Bird Treaty Act of 1918 declared that all migratory birds and their parts (including eggs, nests, and feathers) are fully protected, and the U.S. Fish and Wildlife Service (USFWS) is the federal agency with trust responsibility for these species. Executive Order 13186 mandates that the USFWS coordinate, develop, and implement bird conservation activities with other Federal agencies. In addition, many state wildlife agencies and non-governmental organizations (NGOs) are charged with protecting and enhancing natural resources in concert with multiple public uses on their respective lands.

To achieve grassland bird conservation goals, commitments of resources for conservation and management decisions are made at several spatial scales (i.e., national, regional, and local levels). At the national level, funding decisions are made annually by elected officials and department leads, and determining conservation status of individual grassland bird species is the responsibility of the USFWS Division of Migratory Birds (with assistance from Partners in Flight and numerous conservation partners). At a more regional level, program managers, tribal leaders and state agency directors make decisions about allocating resources (funding, equipment, and staff time) to conservation activities including local land management, land acquisition, and assessment of bird species' conservation status. At the local level, decisions of when, how, and where to restore grassland habitat through management activities or acquisition are made annually by local land managers representing state and federal agencies, tribes, and non-governmental organizations (although program administrators often make the final decision about land acquisition).

Decisions for grassland bird conservation are also made at different temporal scales; many decisions are made annually, some are irregular, and others are one-time decisions. At the national and regional levels, decisions are typically made on an annual basis. At the local level, management and land acquisition decisions made by land managers are often made on an annual basis, but land acquisition decisions by program administrators can also be a one-time decision. Many of the decisions made at the local level are linked to decisions made at the regional level, and regional decisions are linked to those at the national level. In addition, decisions made at the local level are often linked. For example, conservation delivery on private lands often depends upon the willingness of landowners to participate in conservation programs.

The decision problem addressed in this report relates to where (defined here as east of the Rocky Mountains in the U.S and Canada, in addition to Mexico, Central and South America) and how to conserve and restore grassland bird populations at multiple landscape scales in a way that integrates events on the breeding, migration, and wintering grounds (i.e., across the annual cycle). Management decisions at the international, national, regional and local levels are inherently linked through the life history of grassland birds throughout a given annual cycle, and conservationists therefore are inextricably linked in stewardship responsibility for these species. Unfortunately, decisions for natural resource management are made more difficult by uncertainty. For example, there is ecological uncertainty and multiple competing hypotheses about the response of grassland bird populations to management activities (see below). In addition, there is partial observability in measurements of bird population responses at large and small spatial scales. Partial observability interferes with the distribution of resources, selection and placement of management practices, and the design of monitoring programs to learn about the effectiveness of management on public and private lands. Finally, partial controllability and factors outside conservationists' sphere of influence reduce individual and collective abilities to influence grassland bird populations.

A myriad of monitoring programs and management plans have been developed, but they afford limited opportunity to evaluate the effectiveness of and prioritize future conservation and management actions to achieve grassland bird population objectives. Additionally, grassland bird population objectives are inconsistently apportioned throughout the landscape (e.g., top-down Partners in Flight estimation approach vs. bottom-up approach based on conservation opportunity within the landscape). Recent monitoring of grassland birds on some managed lands indicates that certain management practices are not producing the expected responses from grassland birds in some locations. Competing hypotheses for variation in grassland bird response at the local level include the following:

- Landscape context is a limiting factor (too much cropland, not enough high quality non-fragmented grassland);
- Populations are limited during other phases of the annual cycle (i.e., wintering ground or migratory stopover habitat and forage quality and quantity);
- Not enough time has elapsed since restoration for birds to locate sites and resume nesting, or disturbance from the management activities themselves is limiting bird response;
- The structure of the restored grassland is somehow substandard (too many shrubs, too little litter, etc.) for the target species;
- Current monitoring and research efforts are not accounting for all parameters (i.e., vital rates) influencing population dynamics;
- Grassland bird populations are so small that individuals do not occupy all available breeding habitats; and
- Anthropogenic mortality throughout the annual cycle (e.g., unrestrained cats, renewable energy development, collisions with structures) is exceeding grassland bird productivity.

A structured framework is needed that will allow managers, scientists, and decision makers to integrate management efforts with human dimensions and create partnership opportunities to deliver the most effective conservation actions at local, regional, and national scales. With the long-term success of bird habitat Joint Ventures (JVs) and the recent establishment of the partnership-based Landscape Conservation Cooperatives (LCCs), it is timely to harness the shared interest and energy being directed towards grassland birds (and grassland conservation as a whole) to develop a bird conservation framework that relates to explicit, measurable habitat and population goals within the annual cycle context. This framework should transcend administrative boundaries and allow us to learn faster about where grassland birds are most limited, which actions are most effective in conserving and sustaining grassland bird populations, and where we should implement actions to elicit the greatest bird response.

Decision Structure

Decision structure incorporates objectives, action alternatives, and predictive models at all three landscape scales (local, regional, and national) relevant to integrating grassland bird and habitat management. The decision model represents a coupled, human-natural system. Grassland bird populations are influenced by the amount and configuration of grasslands throughout their annual cycle. The amount and configuration of grasslands in these predominantly agricultural landscapes are largely determined by the decisions of many private landowners. Thus, there is an indirect link among landowner decisions and grassland bird dynamics, which results in uncertainty associated with partial controllability. To evaluate the efficacy of different alternatives, it is necessary to link the effects of alternatives on landowner decision-driven land use change to responses of grassland bird populations using a full annual cycle model. Thus we developed two models, a land-use change model and a spatially-explicit grassland bird model, and the outputs of the land-use model provide the input for the grassland bird model. Taken together, it is possible to evaluate the collective response of landowners to different alternatives using the outputs of the grassland bird model.

The geographic scope and complexity of integrating the different annual cycle events of grassland birds prohibited us from developing all aspects of all possible management decisions. To create a rapid prototype, it was necessary to simplify the decision structure. Therefore, we focused on the fundamental objective of how different types of landowners, as hypothetical decision makers on the landscape, would affect the means objectives linked to providing habitats for grassland birds (Figure 1). The decision makers represent three categories of private landowners: 1) a profit-maximizing producer, 2) conservation-minded small farmer, and 3) a conservationist. We recognized that there are additional decision makers representing various stakeholders and agencies at various landscape scales, and they will be included in future dialogue to further develop the framework. We chose to focus on the grassland objective and the hypothetical decision makers as a means to develop a working decision model in the time available during the week-long workshop.

Objectives

Our fundamental objective was to ***sustain and restore grassland bird populations east of the Rocky Mountains, including Canada, for the breeding, migration and wintering seasons, and Mexico, South and Central America for the migration and wintering seasons.***[17]

> Due to limited resources, an additional objective is to determine which phase in the annual cycle of grassland birds (migration, breeding or wintering) is the "bottleneck" that most limits the growth of the population[18].
>
> Given that the loss of habitat is likely the major driver of decline (and one must first have grassland habitat in order to manage it), an additional objective is simply to sustain and restore as much grassland habitat as necessary.

[17] We recognized that grassland birds occupy other grassland habitat types west of the Rocky Mountains and elsewhere, but we concurred to focus this framework to the geographic areas stated above because these grassland habitat types have more similar properties and ecosystem functions. Furthermore, this framework may be applied to other geographic areas at a later time if appropriate. (And no one from the group represented a stakeholder west of the Rockies)

[18] We also recognized the potential for overlap among species (e.g., one species' breeding area may serve as migratory stopover or wintering habitat for another species).

Furthermore, because the majority of land within the grassland birds' ranges is privately owned, an additional objective is to maximize the likelihood that private landowners choose to provide habitat suitable for grassland birds.

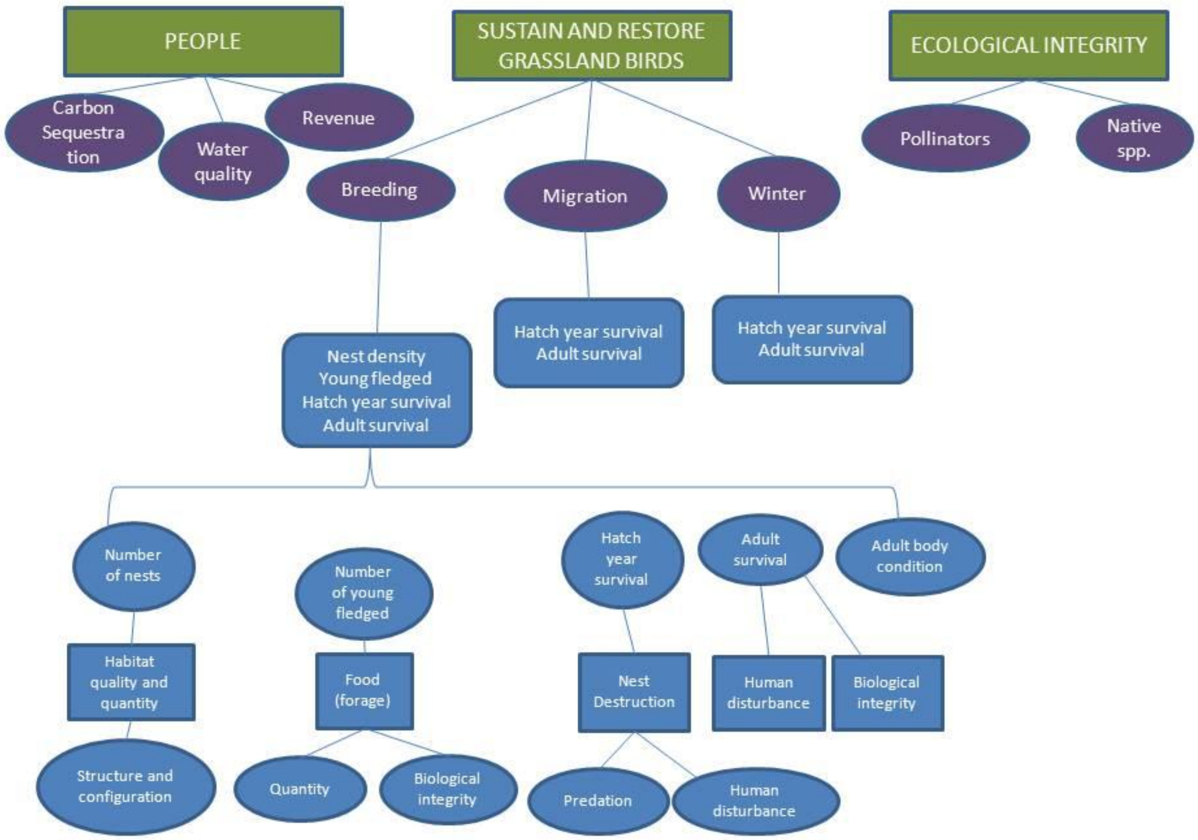

Figure 1. Objectives hierarchy for grassland bird conservation.

Alternatives

We evaluated a series of alternatives (in comparison to the status quo) and modeled the outcomes for grassland birds associated with these various alternatives. The resulting analysis was intended to identify opportunities and to provide insight regarding which strategies are worth further consideration and at which point assumptions would need to be further evaluated and additional data could be incorporated.

Because the majority of land within the ranges of grassland bird species is privately owned, we evaluated national-level alternatives that would likely affect landowner decisions. We grouped these alternatives into nine categories and identified examples of each, as follows:

1. **Conservation Design:** Maximize the use of biological planning to develop decision support tools, including maps and models, to guide management. Identify priority geographic areas for conservation and determine population-based objectives for habitat or other limiting factors based on these tools.

2. **Outreach/Marketing:** Foster the culture of grassland preservation and restoration. For instance, we could get a high profile celebrity figure, such as Oprah Winfrey, to champion grassland habitats. Additional ideas included developing an “Adopt a Prairie” program, collaborating with the America’s Great Outdooors campaign, promoting ecotourism, collaborating with Wildlife Conservation Society to use bison as a means to promote grasslands (akin to Smokey the Bear), and engage and incentivize landowners to collaborate with private entities, such as the NWRS Friends group, cattlemen’s association, and other NGOs to champion policy development.

3. **Regulatory/Enforcement (International):** Improve regulatory and enforcement policies internationally, with an emphasis on Mexico, Central and South America (i.e., ensure that government sanctions are enforced, employ a certification program for Mexico, Central and South America for beef cattle, and raise money for Mexico for the purpose of protection and law enforcement).

4. **Regulatory/Enforcement (US):** Improve regulatory and enforcement policies nationally (i.e., a “no net loss” policy for sod buster regulations).

5. **Public Land Acquisition:** Promote existing grassland habitats in public ownership and new public ownership (i.e., improve integration of wetland restoration and flood mitigation projects with grassland habitat conservation, advocate for increased acquisition of public grasslands, and designate “grassland” National Parks (i.e., as the “American Serengeti”)).

6. **Best Management Practices (BMP):** Use empirical data and adaptive management frameworks to ensure we were promoting and implementing management practices with high likelihoods of success for meeting grassland birds’ life history needs.

7. **Policies (Ecosystem Services):** Provide compensation for landowners maintaining grasslands for the services they provide (i.e., supporting pollinator populations, sequestering carbon, providing recreational hunting opportunities, contributing to high water quality, and protecting view sheds).

8. **Policies (Economic Incentives):** Ensure more robust incentive programs are available to landowners. Actions described under this alternative included: incorporating flexibility to change rental rates in response to changes in commodity prices, allowing for state and regional flexibility in setting rental rates, eliminating the ethanol subsidy, and focusing on creative alternatives to make energy development more grassland friendly (such as cellulosic ethanol production and the Swiss dairy subsidy model).

9. **Status quo** (the No Action Alternative)

Predictive models

An agent-based land cover choice model

We developed a simple agent-based model (ABM) of land cover change. ABMs of land cover change are used to determine how local level decision-making leads to land use and landcover change (Evans and Kelley 2004). In our simple prototype, a landowner chose one of three options for land use: agriculture, grassland, or forest. Our use of an ABM model here was similar to an econometric modeling approach in that we expected a rational decision to be made that maximizes utility for a landowner but differs because there are several types of landowners with different value systems (Manson and Evans 2007). We applied this framework to evaluate how each of nine policies might affect each of three landowner's land cover choices.

Specifically, we modeled the responses of private landowners in the following categories: 1) a profit-maximizing producer, 2) a conservation-minded small farmer, and 3) a conservationist. We assumed that each landowner maximizes their land's utility based on five objectives: grassland birds, biodiversity, carbon sequestration potential, financial value, and water quality. The importance weight of each objective depended on the landowner, and we assumed that the conservationist based decisions on biodiversity and grassland birds over other metrics, the profit-maximizing producer's decisions were dominated by financial value, and the conservation-minded small farmer was a hybrid of these two extremes (Table 1). To determine which land cover choice maximizes the owner-specific utility, we applied the simple multi-attribute rating technique (SMART), first evaluating the utility of each choice with respect to each objective and then determining the overall weighted average utility using the owner-specific objective weights. We recognized that, while each landowner was rational and would choose the land cover that provided the highest utility, we assumed that he/she had imperfect knowledge, so the land cover choice was still probabilistic – this is referred to as "bounded rationality" (van den Bergh et al. 2000). We represented this probability by dividing the utility of each choice by the sum of utilities over all three choices. Since the higher utility of one land cover choice was relative to the other choices, the higher the probability that the landowner would select it. We then used the resulting probabilities to generate landscapes to use as inputs for breeding, migrating and wintering stages of a spatially-explicit, annual cycle model of grassland birds. For our first prototype, alternative landscapes were generated assuming a single landowner type, and we generated landscapes for each landowner type under each policy scenario, yielding 27 owner-policy combinations.

Table 1. Preference weights, on a 0 – 1.0 scale, by each landowner type for each objective. These weights were used to evaluate land cover choices for each landowner.*

Profit-maximizing Producer	Conservation Design	Outreach/ Marketing	Regulatory/ Enforcement (Int'l and US)*	Public Land	BMP	Ecosystem Services	Economic Incentive	Status Quo
Birds	0	0.5	0	0	0	0.05	0	0
Carbon	0	0.7	0.1	0	0	0.1	0.2	0
Water Quality	0	0.7	0.1	0	0	0.1	0.1	0
Revenue	1	1	1	1	1	1	1	1
Biodiversity	0	0.4	0	0	0	0.1	0.05	0

Small Farmer	Conservation Design	Outreach/ Marketing	Regulatory/ Enforcement (Int'l and US)*	Public Land	BMP	Ecosystem Services	Economic Incentive	Status Quo
Birds	0.25	0.7	0.4	0.5	0.7	0.7	0.7	0.5
Carbon	0	0.2	0	0	0.2	0	0	0
Water Quality	0.5	0.3	0.2	0.5	0.5	0.5	0.4	0.2
Revenue	1	1	1	1	1	1	1	1
Biodiversity	0.1	0.8	0.4	0.5	0.7	0.7	0.6	0.5

Conservationist	Conservation Design	Outreach/ Marketing	Regulatory/ Enforcement (Int'l and US)*	Public Land	BMP	Ecosystem Services	Economic Incentive	Status Quo
Birds	1	1	1	1	1	1	1	1
Carbon	0	0.7	0.4	0.4	0.6	0.4	0.4	0.4
Water Quality	0.5	0.7	0.4	0.4	0.7	0.7	0.6	0.4
Revenue	0.8	0.8	0.8	0.8	0.8	0.9	0.9	0.8
Biodiversity	0.7	1	0.9	0.8	0.9	0.9	0.8	0.7

***For this exercise, we only worked with eight policy scenarios. Whereas there were nine overall, we combined the Regulatory/Enforcement Scenario for International and US lands during this intermediate stage.

Grassland bird life-cycle model

We developed a conceptual model of grassland bird life-cycle events (Figure 2) to inform the predictive models. During the duration of the workshop, we focused on developing a predictive model to determine how land-use changes affected birds within a landscape through decisions made by different landowner types (Figure 3). The model incorporated landscape considerations (e.g., area, configuration, edge, etc.)

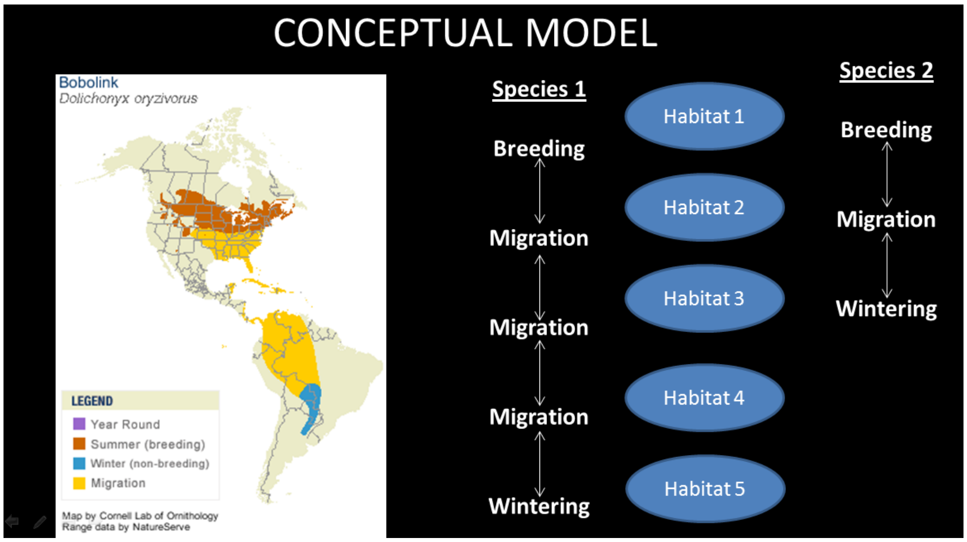

Figure 2. Conceptual model of grassland bird life cycle events.

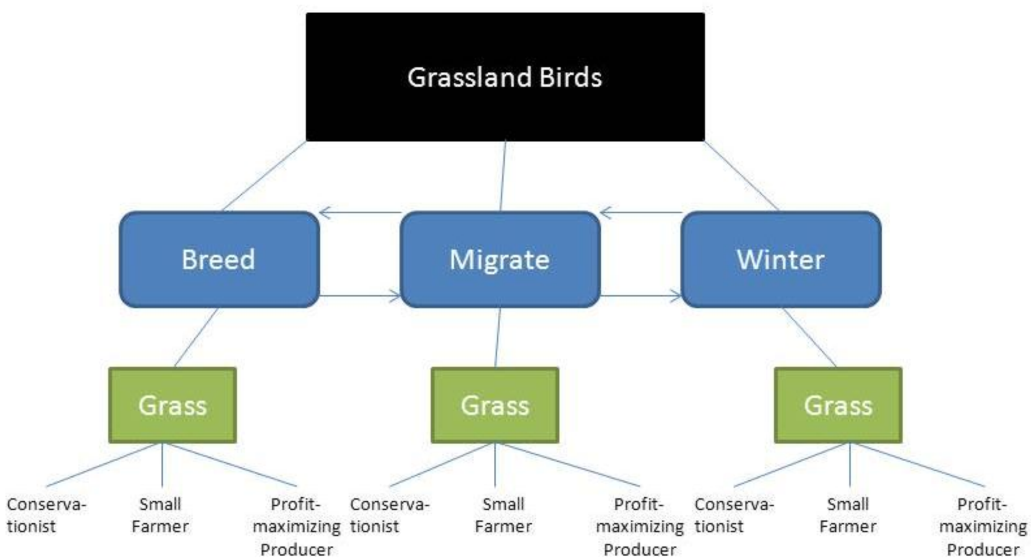

Figure 3. Partial influence diagram for grassland bird conservation.

Using the inputs of the agent-based model, we developed a spatially explicit, annual cycle model for grassland birds. Like many birds, the majority of grassland birds have four phases of their annual cycle that roughly correspond to the four seasons but occur in different locations; a summer breeding season in the north, a wintering period in the south and two migratory periods in the spring and fall where they travel between wintering and breeding areas. Thus, reproduction occurs in one season and location and then the majority of mortality occurs during the other three seasons and is integrated across locations. To reflect this basic biology, we modeled the population of birds in the breeding area just at the start of the breeding season during year t ($N_{t)}$ as:

$$N_t = N_{t-1}(1+R_b)S_f S_w S_s \text{ ,}$$

Where R_b was the reproductive output during the summer breeding season and S_f, $S_{w,}$ and S_s were the survival probabilities during fall migration, over-winter, and spring migration, respectively. We defined the values of each of these steps as a function of a landscape that consists of forest, grassland and agriculture. We extended the model to reflect multiple stopover sites by adding stages to the fall and spring migration. If there were M stopover sites, then the final survivorship estimates for fall and spring migrations were simply the product of survivorship across the M sites, such that:

$$S_f = \prod_{m=1}^{M} S_{f,m}$$
$$S_s = \prod_{m=1}^{M} S_{s,m} \text{ .}$$

Carrying Capacity

It is worth noting that carrying capacity was built directly into a spatially explicit model. The amount of habitat determined the number of birds that could survive and reproduce. Here we assumed that up to 40 birds can persist on each 30 meter pixel in the wintering and stopover sites. The nest density and number of nest sites determined the carrying capacity in the breeding grounds and is defined below.

Reproduction (R_b)

We used our own knowledge of grassland birds to describe how reproduction may change with respect to the composition and configuration of the landscape. One key assumption of the model was that grassland bird density and productivity are higher in larger grasslands than smaller ones (i.e., grassland birds are area sensitive, Ribic et al. 2009), although patterns of area sensitivity can vary regionally (Winter et al. 2006). We assumed that grassland bird nest density and productivity was lower near edges, specifically within 25 m of an edge (Johnson 2001, Renfrew et al. 2005). We also assumed that grassland bird abundance in the patch increases as the landscape around a patch becomes more grass-dominated (Ribic and Sample, 2001; Renfrew and Ribic 2008). Using these base ideas, we developed a raster-based model to calculate the expected number of birds that would fledge from each pixel given the land cover of that particular pixel and the surrounding pixels. We used 30-m pixels, a common resolution of remotely-sensed data. Below we present the details of how this expected number was calculated.

We determined the number of birds fledged by calculating the potential for nests to occur within a pixel, the survivorship rate of an individual from egg to migrating, and the expected density of nests on the pixel. To determine nest potential, we assumed that only grassland pixels can support a nest (smallest, middle pixel in Figure 4). For the prototype, we assumed that predation from woodland-associated predators was the main source of mortality; this ignored the importance of grassland-associated predators (Pietz et al. 2012), but, given time limitations, simplified the modeling. We assumed that these predators were largely influenced by the amount of forest within 30 meters of the nest site. Translated to the raster model, as the number of pixels of forest within a one-pixel radius of the pixel where the nest was located increased, the survivorship of each egg decreased (medium-sized box in Figure 4). To reflect patch size and the effect of the landscape on bird density and subsequent nest density in the raster model, we estimated the density of nests on a pixel by assigning a potential nest density value to each land cover type (Table 2), and then calculated the average density value for all pixels within 300 meters (a 10-pixel radius) of the nest site (largest outline in Figure 4).

Table 2. Nest density in grassland pixel as a function of land cover.

Surrounding pixel type	Nest density in grassland
Agriculture	1
Grassland	0.5
Forest	2

For future model development, we would recommend a larger landscape of perhaps 500 meters or greater. So, as the amount of grassland in the surrounding landscape increases, we expect the density of nests within a pixel to decline and the fledgling rate to increase.

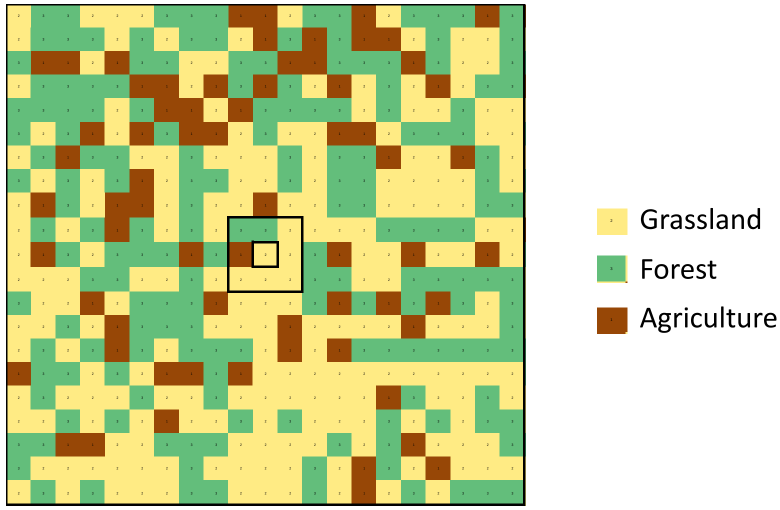

Figure 4. Example landscape for our model analyses.

Survivorship during fall and spring migration (S_f and S_s)

Compared to the breeding and wintering phases, much less is known about migratory stopover habitat use and survivorship phases, so much of our model was based on expert opinion. However, developing a simple modeling framework should provide insights and guide future research in the context of management. As grassland birds reach potential stopover habitat, they first must find a suitable stopover site. We assumed that birds may not find small or isolated high quality grassland sites within larger stands of forest. Once they find a site, they may forage in the surrounding landscape, and their survivorship increases with increasing forage quality of the surrounding landscape. We reflected this basic representation of stopover ecology by dividing stopover survivorship of an individual pixel into two components, occupancy and survivorship. Like reproduction, each component depended on the landscape composition at different scales.

Occupancy, the probability that a pixel is found and selected, was determined by the cover of the individual pixel and by the immediate surroundings. At the pixel scale, we assumed that agriculture and grassland were suitable for a stopover but forest was not. To represent the effect of isolation on occupancy, the occupancy rate of a suitable pixel was determined by the amount of forest within 30 meters (one-pixel radius). As the amount of forest increased, occupancy rates declined.

Survivorship was determined by the forage quality within a one hectare "patch," so we used a three-pixel by three-pixel analysis to evaluate forage quality. Both agriculture and grassland pixels provided forage, but, the higher the proportion of forage within a hectare that was grassland, the higher the survivorship (Figure 5).

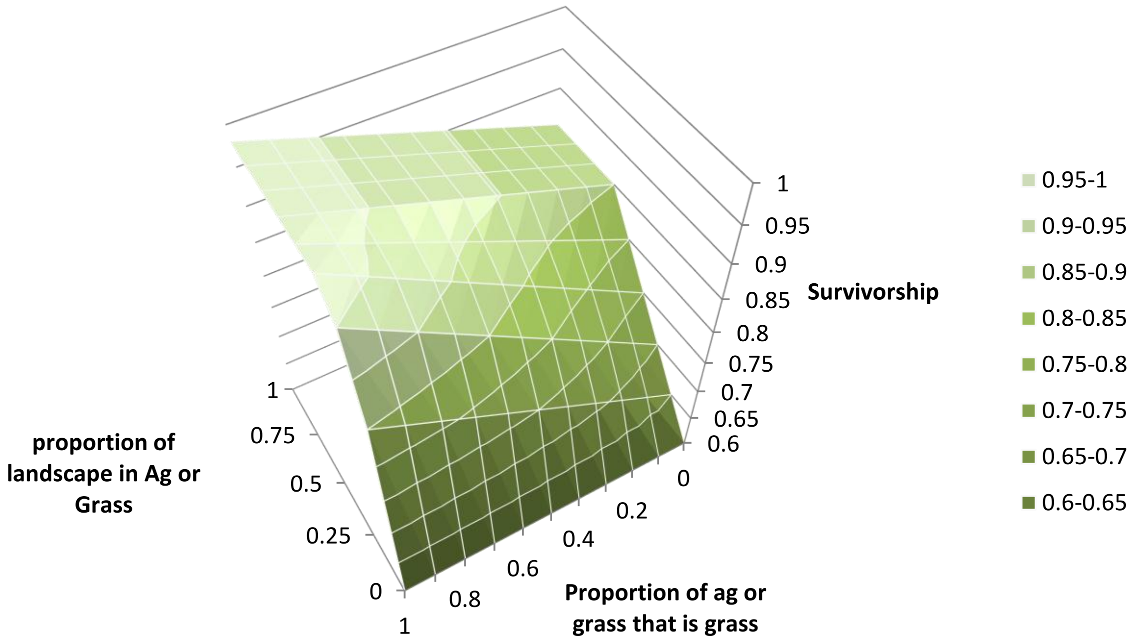

Figure 5. Survivorship increases with increasing amount of grassland in the landscape.

Winter survivorship (S_w)

Here, we represented a grassland bird's interaction with the landscape during winter in a similar way to the migration framework. However, it was simplified in that only the individual pixel-level determined survivorship. We assumed that grassland birds do not use forest sites during the winter and that grassland pixels had higher survivorship than agricultural pixels. We further assumed that the over-winter survivorship rate was simply the average survivorship value of all suitable pixels, such that:

$$S_w = \frac{p_A \omega_A + p_G \omega_G}{p_A + p_G},$$

where p_A and p_G were the proportion of agriculture and grassland in the wintering grounds, respectively, and ω_A and ω_G were winter survivorship rates of birds in agriculture and grassland pixels, respectively.

Decision Analysis

Decision Analysis - Integrating the land cover choice and grassland bird models

To combine the models, we generated five, 1.44 km^2 landscapes that were each filled with 1600, 30-meter pixels. We assigned each pixel as grassland, agriculture or forest with the probability of each choice being determined by the alternative-generated results of the agent-based model. We assigned one landscape to represent the breeding area, three to be migratory stopover areas, and one to be the wintering ground. Once the landscapes were generated, we applied the spatially-explicit model to them.

Using this framework, we evaluated each of the 27 landowner by alternative combinations. We started each bird population with 100 birds and ran the model for 30 years. We calculated the growth rate for each year and used average growth rate across 30 years in our consequences table (Table 3) to evaluate the effectiveness of each potential alternative for grassland birds.

Table 3. Consequence table of the effect of each policy and landowner on the expected growth of grassland bird populations.

Alternatives	Profit-maximizing Producer	Small Farmer	Conservationist
Conservation Design	-0.12	0.03	0.09
Outreach/Marketing	0.06	0.07	0.09
Regulatory/Enforcement - International	-0.11	0.03	0.05
Regulatory/Enforcement - US	-0.06	0.03	0.06
Public Land Acquisition	-0.20	0.04	0.08
Best Management Practices	-0.16	0.07	0.10
Policy - Ecosystem Service	0.03	0.09	0.10
Policy – Economic Incentive	0.05	0.09	0.13
Status Quo	-0.23	0.03	0.07

Uncertainty

Uncertainties in ecology and natural resource management can generally be placed into four categories: 1) structural uncertainty, 2) environmental variation, 3) partial controllability, and 4) partial observability (Williams 1997). We briefly review the ways that uncertainty may influence aspects of grassland bird and habitat conservation. The implications of each type of uncertainty, and more explicit descriptions of important sources of uncertainty, will be explored during model refinement and development of specific monitoring protocols.

Structural Uncertainty:

Structural or biological uncertainty refers to unknown relationships among biological variables or other components of system models. The largest source of biological uncertainty in our prototype is the response of grassland birds to a given level of funding for management actions. This relationship, or "management potential" for a particular site, has not been measured to the best of our knowledge. To measure the effects of this uncertainty, we will require empirical data on funding, management actions, and grassland bird response to parameterize the models. Furthermore, we recognize that there is uncertainty due to multiple competing hypotheses about the impact of surrounding landscapes on grassland bird abundance on specific local sites.

Environmental Variation:
Unpredictable environmental variation will affect both habitat management at the local scale and population distribution at larger landscape scales. Results of planned management treatments will be influenced by unpredicted weather effects (i.e., floods, droughts and abnormal temperature regimes) at the management site. Major weather events during a season may redistribute birds across the larger landscape, thereby confounding predicted results of management actions. Additionally, global climate change will also affect the distribution of grassland birds during the breeding, migration, and wintering periods. Our demographic model does not account for effects of environmental variation on reproduction and survivorship.

Partial Controllability:
Uncertainties around partial controllability are related to situations where we believe a management action can be conducted but circumstances beyond our control result in the inability to perform a specified action as planned. More specifically, since we chose to focus on policies during this workshop, we recognize that we may not have control over people's behavior or the global economic markets.

Information Needs

Workshop participants identified a suite of information needs for different landscape scales.

1. Continental:
    a. Identify focal grassland habitats or geographic areas during migration and wintering periods.
    b. Understand life history needs, vital rates and other demographic information in the migration and wintering grounds.
    c. Quantify stressors for all three annual cycle stages, particularly during migration and wintering periods.

   d. Estimate grassland bird abundance at breeding, migration and wintering sites.
   e. Calculate grassland habitat objectives needed to sustain populations at all landscape scales.

2. Regional:
   a. At each management site, determine management costs, quantity/quality of habitats, and response of target species to management.
   b. Identify priority species and quantity/quality of habitat to meet species needs at specified locations within region.

3. Local:
   a. Understand grassland habitat response to management actions.
   b. Understand grassland bird response to habitat management.
   c. Determine the relative contribution of local level management conservation activities to grassland bird populations within a larger landscape context.
   d. Develop a list of priority grassland bird species at regional and national scales along with identification of habitat surpluses/deficits at key migration and wintering locations throughout the grassland habitats east of the Rocky Mountains, Canada, and South and Central America.
   e. Funding and staffing resources to be provided on an annual basis.
   f. Quantify the type and amount of stressors and/or level of disturbance at individual sites.
   g. Determine the landscape configuration (site juxtaposition) needed to maximize grassland bird abundance on breeding, migration, and wintering areas.

Discussion

We approached the problems associated with grassland bird conservation through an integrated framework that incorporates the relationships between national policies, private landowner decisions, and habitat availability and quality—and ultimately assessed the population implications thereof. Because of time constraints and many uncertainties, this rapid prototype analysis was kept relatively general; many assumptions were made that should be further evaluated. Still, several important insights can be drawn from this effort.

1) **Providing sufficient habitat is vital for maintaining and restoring grassland bird populations.** Ultimately, grassland bird populations depend on the availability of habitat. Policies must seek to protect existing habitat and restore habitat in strategic locations. There are many uncertainties associated with grassland bird declines, but one thing is for certain: their habitat has declined drastically and remains one of the most

threatened ecosystems in the world. This is further compounded by their dependence on habitat for migration and wintering periods. National and regional policies must focus on ensuring that there is sufficient habitat on the ground. Once sufficient habitat of reasonable quality has been assured, then there is great opportunity to leverage resources and focus on strategic implementation (i.e., spatial prioritization of management actions) in order to maximize the benefits being provided.

2) **It is critical to evaluate the full life cycle of grassland birds**. Limiting factors should be considered not only on the breeding grounds but also in relation to the availability and quality of migration and wintering habitat. This framework should be applied on a species by species basis (for focal/indicator species), due to the wide range of natural history and geographic considerations, and then further evaluated as a whole. Spatial-demographic modeling can help to identify bottlenecks and thresholds where habitat protections are disproportionately important. This approach can also help guide the strategic restoration of habitat to maximize the broad-scale population outcomes of various local management actions.

3) **National policies must be designed to influence private landowners' decisions related to providing grassland bird habitat.** Grassland bird species depend on a diverse array of habitat types throughout their annual cycle; different policies will likely impact these habitats (and their population outcomes) in different ways. The effectiveness of individual policies, over the long term, will depend on leveraging various policy and management strategies together. Considering the many threats facing grassland birds and their habitat, particularly in agricultural landscapes, the fundamental need to provide sufficient habitat means that policies will have to influence private landowners' decisions—through an appeal to their value judgments of wildlife habitat and/or by providing competitive economic incentives for wildlife habitat conservation (preferably both).

4) **Policies must be designed in such a way as to be reasonably competitive with other economic forces.** Agricultural programs, such as CRP, are extremely important given the widespread pressures driving habitat conversion. While it is critically important to influence the conservation values of the public and private landowners, it is also necessary to ensure that those who want to provide conservation services can afford to do so. Policies must provide sufficient funds to support the ecosystem services being provided through alternative agricultural and conservation practices that do not provide landowners with the same level of economic returns that would be expected without

subsidization. Programs that emphasize conservation-oriented "working lands" will likely be the most cost-effective and socially acceptable.

5) **Individual and social value systems are extremely important in determining the population outcomes of national and regional policies.** Social science and economics play an important role in understanding these relationships and ultimately determining what the most effective policies will be enacted. Effective marketing and communication strategies are critical for success. Ongoing monitoring and adaptive management will provide the basis for making informed decisions in the future.

6) **A lack of monitoring information should not be an excuse for inaction.** Using a structured framework and integrated modeling approach, we can begin to identify critical information gaps. For example, we clearly need to know more about migration and wintering habitat—but we can also evaluate the sensitivity of the system to different changes and provide informed decisions on where to leverage resources. This approach allows for the identification of bottlenecks and critical thresholds and can further be linked with econometric and agent-based models to evaluate cost-benefit relationships and probabilities of success. Expert-based conceptual models can fill the gaps, critical assumptions can be identified and evaluated, and models (and management strategies) can and should be adapted over time. The status quo is quickly leading us in the wrong direction for most grassland bird species, and many of the threats are increasing. Thus, an informed, proactive and timely strategy is warranted to ensure the survivability of grassland birds; this framework is intended to provide the basis for such an approach.

Our rapid prototype analysis is intended to provide a framework for future, more detailed analyses that can be applied to make better decisions that link policies (at various scales) with management practices on the ground (to ultimately benefit grassland bird populations). Our analysis underscores the importance of landowner ethics and social value systems and their roles in influencing grassland bird habitat at all points in their annual cycles; it also suggests that this is an international problem with no easy solution. Policies that compensate landowners for providing ecosystem services, including grassland bird-friendly practices, proved to be the most successful in retaining grassland bid habitat for all three types of landowners. Leveraging these economic incentives with strategic communication and marketing efforts will likely provide the greatest benefits for grassland birds. The scientific challenge ahead lies in understanding how policies and economics, at various scales, influence landowner decisions and how these decisions ultimately affect grassland bird populations throughout their annual cycles. This framework is a step in that direction.

The workshop format and diverse participants involved allowed us to develop a transparent decision structure for grassland bid conservation. We believe the outcome of the SDM process will foster buy-in from other decision makers and stakeholders who represent various partner agencies and organizations. We also believe that this preliminary framework provides a transparent process that will encourage constructive criticism and suggestions to create a network of partners to work together in developing a unified framework that transcends administrative and disciplinary boundaries and provides sound guidance to all partners engaged in conserving and sustaining grassland bird populations.

In addition to the general discussions above, each team member was asked to summarize how his/her organization could potentially use this framework. This summary is provided in Appendix A.

Recommendations

Workshop participants recognized that the draft framework from this workshop was only a small but productive initial step toward the development of a much larger, integrated conservation framework that will involve numerous partners. Furthermore, we realized that extensive communication with and input from partners and stakeholders must be initiated. We identified the following steps to further develop the framework:

1. Solicit buy-in for an overall framework that will allow managers, scientists, and decision makers to integrate various management efforts with aspects of human dimensions and partnership opportunities for purposes of determining the most effective management decisions at the local, regional, and national scales:
    a) Identify people/groups that can help further develop the framework (e.g., avoid re-inventing wheels)
    b) Identify decision makers at various landscape scales.
    c) Look for and engage other stakeholder groups
2. Identify support and funding needs:
    a) Find resources and hire a full-time grassland bird conservation coordinator.
    b) Integrate support staff.
3. Develop teams around annual cycle events (breeding, migration and wintering) linked by the fundamental objective (sustaining and restoring grassland birds).

4. Maintain and expand a coordinated network for grassland bird conservation (e.g., wintering grounds).
5. Refine the models (e.g., fit into large landscape context).
6. Develop an implementation plan.

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APPENDIX A: Insights on the potential uses of this framework for future grassland bird conservation efforts.

Table 4. Team members determined the spatial scales at which their organizations operate to accomplish their missions.

ROLES OF ORGANIZATIONS	Continental	National	Regional / Landscape	Local
The Nature Conservancy				
USFWS Migratory Birds				
Rocky Mountain Bird Observatory				
National Bobwhite Conservation Initiative				
Bird Habitat Joint Ventures				
State Agencies				
USFWS National Wildlife Refuges				

Table 5. Anticipated uses of the results from our Structured Decision Making Workshop in accomplishing the key steps for Strategic Grassland Bird Conservation.

Partnerships and collaboration	The framework will help us understand the relative importance of our geographic area to supporting certain bird species during specific periods in their lifecycle (especially when we collaborate with stakeholders across a larger geography).
	Structured Decision Making (SDM) represents a proactive approach for achieving RMBO's Mission to conserve birds and their habitats and Vision that native birds are sustained in healthy ecosystems.
	SDM can help integrate the objectives of various stakeholders (conservationists, energy development, government agencies, private landowners, etc.) to ensure a good conservation outcome.
	Working across borders in Mexico or even South America is a very realistic possibility, and having a framework that ties the countries/continents together could really help mobilize conservation work and philanthropy opportunities for the project.

Policy	Potential next steps are to bridge some large gaps, notably for USDA Farm Bill policy, and for conservation on the ground. A potential model might be the USDA sage-grouse initiative, which includes national policy and funding, and on-the-ground participation by game-bird NGOs.
	Identify actions for future policy changes that influence the amount of grassland on the landscape.

Planning	If we can come up with a framework/model that specifies how much and where we need grassland for grassland birds, this could easily be incorporated into our protection strategies across the landscape.
	The framework will help foster discussions and planning for grassland bird management among state agencies in the upper Midwest. These discussions will help assure the most efficient expenditure of effort and resources for grassland bird habitat management in our state and others.
	The report will help validate a state agency's expenditure of resources on grassland bird habitat management efforts.
	A recent strategic planning effort identified the need to better integrate Science, Education, Stewardship and International partnerships to achieve more tangible conservation outcomes.

Education	This framework can help us address the following questions: 1) Which regional and demographic profiles should be educated to provide the best conservation outcome, 2) Which key messages and strategies for different audiences provide the greatest conservation outcome, 3) Where in the wintering grounds in Mexico will Education and Stewardship have the greatest conservation outcome, and 4) Which Education and Stewardship strategies in the wintering grounds in Mexico will have the greatest conservation outcome?

Modeling	Determine how much habitat we need, what quality, and where is very useful to our partnership and allows us to determine the best allocation of financial and human resources.
	Structure predictive models for evaluating objectives and alternative actions for the conservation of breeding, migrating and wintering populations?
	Model where in the landscape that habitat management will have the greatest conservation outcome.
	Identify actions for future policy changes that influence the amount of grassland on the landscape.
	Identify actions for future bird population declines (state dependent decisions).
	As we begin to tie our framework into a broader strategy (i.e., a plan of action), this framework can help us determine what the most strategic and efficient use of limited resources will be, at which point we will try to impact those strategic decision points with tools that help managers, researchers, and policy makers make better decisions.

Monitoring and Research	This process can eventually help us develop a clearly articulated research/monitoring framework to address information needs (full lifecycle models for priority birds) and assumptions from our modeling efforts.
	This can help us determine how to use ongoing and design new monitoring programs to measure the effectiveness of Education and Stewardship strategies.
	This provides the framework to identify critical information gaps (areas of uncertainty that are deemed to be "sensitive" in terms of their overall impact on grassland habitat and/or bird populations) to guide research and monitoring, including analyses of data that we may already have available.
	Additionally, I hope that we can use this framework, incorporating empirical data/models, when possible, to develop a series of (scenario modeling) analyses that are targeted at evaluating bottlenecks, looking for the most robust strategies, and identifying limiting factors. If we can do that in a meaningful and persuasive way, and then write that up as some sort of "plan", then I think this will really start to have an impact.

Delivery	A framework that determines ‘how much’ and ‘where’ helps us focus our partners’ delivery efforts in the right places
	This can help me recommend habitat management actions that are known to have the greatest conservation outcome.
	I would like to use this process to understand how habitat management influences bird survival and how grassland conservation on the wintering grounds contributes to species recovery.
	I would use this framework to help our land managers focus their management activities in the areas with the appropriate amount and configuration of grass. Essentially, we would try to focus on the quality of the grassland on the ground for the birds.
	This framework provides an approach for crafting strategies for achieving bobwhite population and habitat goals identified in the 2011 plan, NBCI 2.0.