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CONSERVATION DESIGN: WHERE DO WE GO FROM HERE?

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Abstract. Conservation design entails 1) characterization and assessment of a landscape's capacity to support wildlife, 2) predictive modeling and mapping of species population response to this landscape, 3) assessment of conservation opportunities given those predicted patterns in occurrence and abundance, 4) strategic enhancement of landscapes to achieve conservation goals, and then 5) subsequent monitoring and evaluation to ensure that the conservation actions that follow from this process truly lead to gains for wildlife and wildlands. Conservation design should recognize the dynamical nature of populations and the landscapes they inhabit. It should also balance needs of individual priority species against those of species aggregates. Ideally, aspects of this process should generate recommendations for management which recognize future trends in landscape conditions. Each of these endeavors is influenced by issues associated with scale: temporal, spatial, and thematic. The future of conservation design will likely include shifts from static, pattern-based models of species-habitat response to dynamical projections of process-based models, with commensurate recognition of the uncertainty that accompanies those projections.

Key Words: dynamic models of species distribution, multi-species prioritization, optimal conservation design, strategic habitat conservation.

CONSERVACIÓN DE DISEÑO: ¿A DÓNDE VAMOS DESDE AQUÍ?

Resumen. Conservación de diseño implica 1) la caracterización y evaluación de un paisaje de la capacidad de apoyo a la vida silvestre, 2) el modelado predictivo y la cartografía de especies de la población respuesta a este paisaje, 3) la evaluación de oportunidades de conservación dadas las predichas en modelos de presencia y abundancia, 4) la mejora de los paisajes estratégicos para alcanzar las metas de conservación y, a continuación, 5) seguimiento y evaluación posterior para asegurar que la acciones de conservación que se derivan de este proceso verdaderamente conducir a beneficios para la vida silvestre y áreas silvestres. Diseño de conservación deberían reconocer la naturaleza dinámica de las poblaciones y los paisajes que habitan. También debe equilibrar las necesidades individuales de las especies prioritarias contra los agregados de las especies. Idealmente, los aspectos de este proceso de generar recomendaciones para la gestión de reconocer que las tendencias futuras en las condiciones del paisaje. Cada uno de estos esfuerzos se ve influido por cuestiones relacionadas con la escala: temporales, espaciales y temáticos. El futuro de la conservación de diseño es probable que incluyen cambios de estática, patrón de modelos basados en el hábitat de las especies-la respuesta a las proyecciones del proceso dinámico basado en modelos, en consonancia con el reconocimiento de la incertidumbre que acompaña a esas proyecciones.

INTRODUCTION

Conservation design is a process for enhancing a landscape's capacity to sustain healthy populations of birds. It is the spatial articulation of optimal conservation action. There are various incarnations of conservation design. Partners in Flight, for instance, subscribes to the Five Elements Process (Will et al. 2005), which consists of 1) landscape characterization and assessment, 2) bird population response modeling, 3) conservation opportunities assessment, 4) optimal landscape design, and 5) monitoring and evaluation.

The U.S. Fish and Wildlife Service adopted a new business model titled Strategic Habitat

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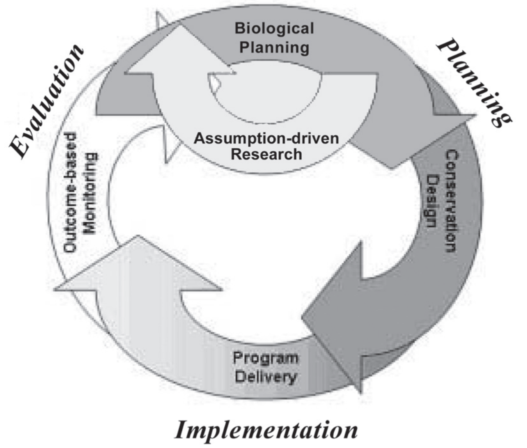

FIGURE 1. Strategic Habitat Conservation as envisioned by the U.S. Fish and Wildlife Service and the U.S. Geological Survey (National Ecological Assessment Team 2006).

Conservation (National Ecological Assessment Team 2006), of which conservation design is one element (Fig. 1). In both the Partners in Flight and Fish and Wildlife Service processes, conservation of regional populations of wildlife is seen as being aided by the development of species-habitat decision support tools such as models and maps. The formulation of habitat objectives, identification of priority areas over multiple spatial scales, and strategic enhancement of landscapes to meet conservation goals are also defining elements of conservation design.

The major bird conservation initiatives involved in conserving regional populations of birds are the North American Waterfowl Management Plan (2004), Partners in Flight (Rich et al. 2004), the United States Shorebird Conservation Plan (Brown et al. 2001), the North American Waterbird Conservation Plan (Kushlan et al. 2002), and various upland game bird initiatives, including the Northern Bobwhite Conservation Initiative (Dimmick et al. 2002), the Woodcock Management Plan (Kelley et al. 2008), and the North American Grouse Partnership (Vodehnal and Haufler 2007). Much of this conservation is directed at the scale of joint ventures or bird conservation regions (Fig. 2). These initiatives usually coordinate the effort of several state governmental agencies, federal entities such as the U.S. Fish and Wildlife Service, U.S. Geological Survey, National Park Service, USDA Forest Service, and USDA National Resource Conservation Service, academic partners, as well as non-governmental organizations such as American Bird Conservancy, Audubon, Ducks Unlimited, The Nature Conservancy, Point Reyes Bird Observatory, and Wildlife Management Institute, among others.

Elements needed to accomplish regional conservation initiatives include identification of the biological foundation upon which species are organized over a region (Scott et al. 2002, Fitzgerald et al. 2008). This usually involves modeling bird-habitat associations to determine the quantity, quality, and spatial distribution of habitat necessary for meeting population goals (Root 2003, Angelstam et al. 2004, Will et al. 2005). Implicit in this process is the desire to optimize habitat targets for all species of interest, which may constrain the ability of conservation deliverers to simultaneously meet population goals for each species.

For instance, maximization of conservation for the benefit of grassland birds may limit a region's ability to meet forest bird population targets; similarly, maximizing early successional forest species may come at the detriment to late successional or climax forest species. Nevertheless, establishment of this biological foundation allows a more efficient and effective delivery of conservation effort in the face of limited funding. Further, the identification of spatially explicit population objectives linked to limiting factors provides initial guidance for how delivery must proceed to be effective. Lastly, establishment of this biological foundation allows for prioritization of actions to meet goals and the evaluation of progress towards those goals.

In February 2008, at McAllen, Texas, Partners in Flight convened ornithologists, conservation planners and practitioners, and federal and state land management personnel from across the western hemisphere to discuss the state of avian conservation (Bogart 2008). Included in the agenda was one session on conservation design (Table 1). We, as the organizers, envisioned this session as a follow-up to the popular conservation design symposium held in St. Louis, Missouri, in April 2006 (Bogart 2006).

THEMES FROM MCALLEN

There were a number of recurring themes from this conservation design session in McAllen, including challenges wrought by 1) changing populations and landscapes and 2) multi-species prioritization and optimization of effort to specific locations in the landscape.

Conservation design, to be most effective, should at least attempt to accommodate the dynamical nature of landscapes and populations (Larson et al. 2004, Niemuth et al. 2008a,b). To this point in time, much regional modeling and mapping is based upon static assessments

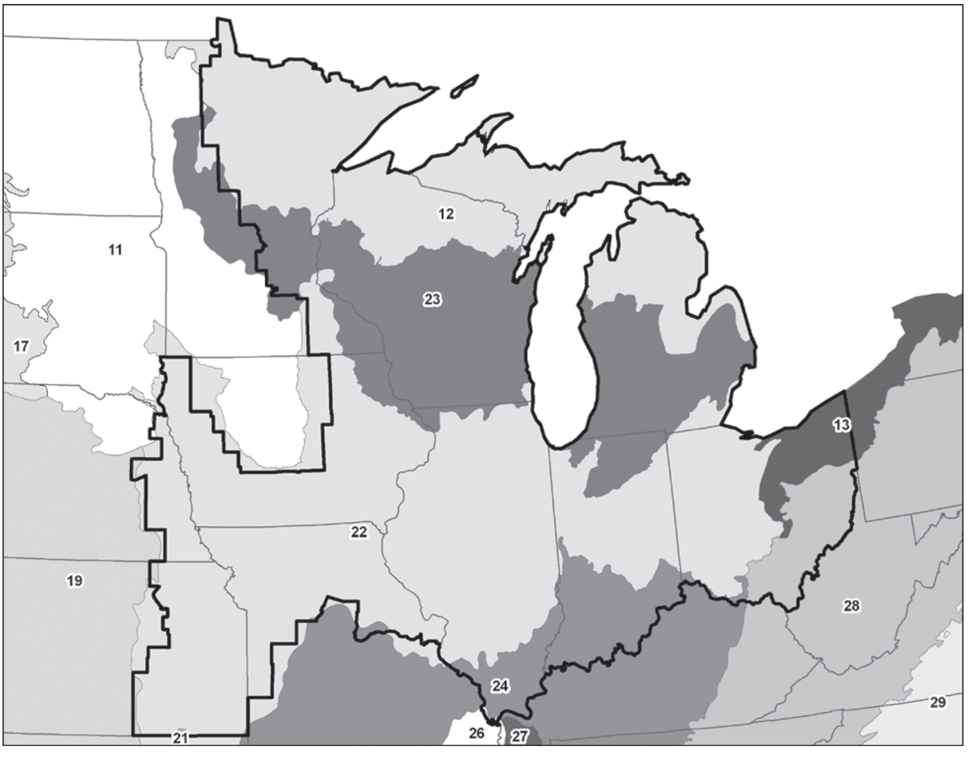

FIGURE 2. Multiple jurisdictional and planning units characterize bird conservation. Boundaries of the Upper Mississippi River and Great Lakes Joint Venture (JV) region (bold line) and associated U.S. Bird Conservation Regions (BCRs) from the North American Bird Conservation Initiative are an example. The JV largely consists of BCRs 22 (Eastern Tallgrass Prairie), 23 (Prairie Hardwood Transition), and the U.S. portion of 12 (Boreal Hardwood Transition). Portions of BCR 24 (Central Hardwoods) and 13 (Lower Great Lakes / St. Lawrence Plain) also are within the JV boundary. The portion of the JV associated with BCR 28 (Appalachian Mountains) was ceded to the nascent Appalachian Joint Venture in 2008.

of land cover as through, for instance, the National Land Cover Datasets from 1992 and 2001 (Vogelmann et al. 2001, Thogmartin et al. 2004a). Unfortunately, these regional maps most often do not acknowledge the cycling of vegetative communities through seral stages (Larson et al. 2004), changes in land ownership patterns resulting in changes to land management practices (Pearson et al. 1999), catastrophic environmental events (e.g., hurricanes and floods) (Knopf and Sedgwick 1987), urban sprawl (Allen and Lu 2003), or climate change (Titus and Richman 2001, Matthews et al. 2004). While it is admittedly much more difficult to look forward than back, Tirpak et al. (Table 1) used data from the Forest Inventory Analysis to assess changes in multiple indices of habitat suitability across two Bird Conservation Regions from 1992 to 2001. Rempel (Table 1) employed models of forest successional dynamics to predict future populations of birds. This ability to model past and potential future trajectories of habitat can help planners to investigate socioeconomic and other factors driving large-scale changes in habitat and to develop strategies for mitigating negative influences on habitat quality in the future.

Niemuth et al. (Table 1) described conservation design issues from a Prairie Pothole Region perspective, emphasizing the importance of accommodating wide annual variability in both waterfowl populations and their habitat (Fig. 3). Their past work (Niemuth and Solberg 2003, Niemuth et al. 2008a) demonstrated the great spatial and temporal variability in bird abundance associated with water level fluctuations. These authors also demonstrated the consequences of a loss of Conservation Reserve Program (CRP) lands on bird conservation, as is occurring with the corn-to-ethanol boom (U.S. Department of Agriculture 2007); they noted some counties in the Dakotas would lose the vast majority of their value to bird conservation should they lose their complement of CRP

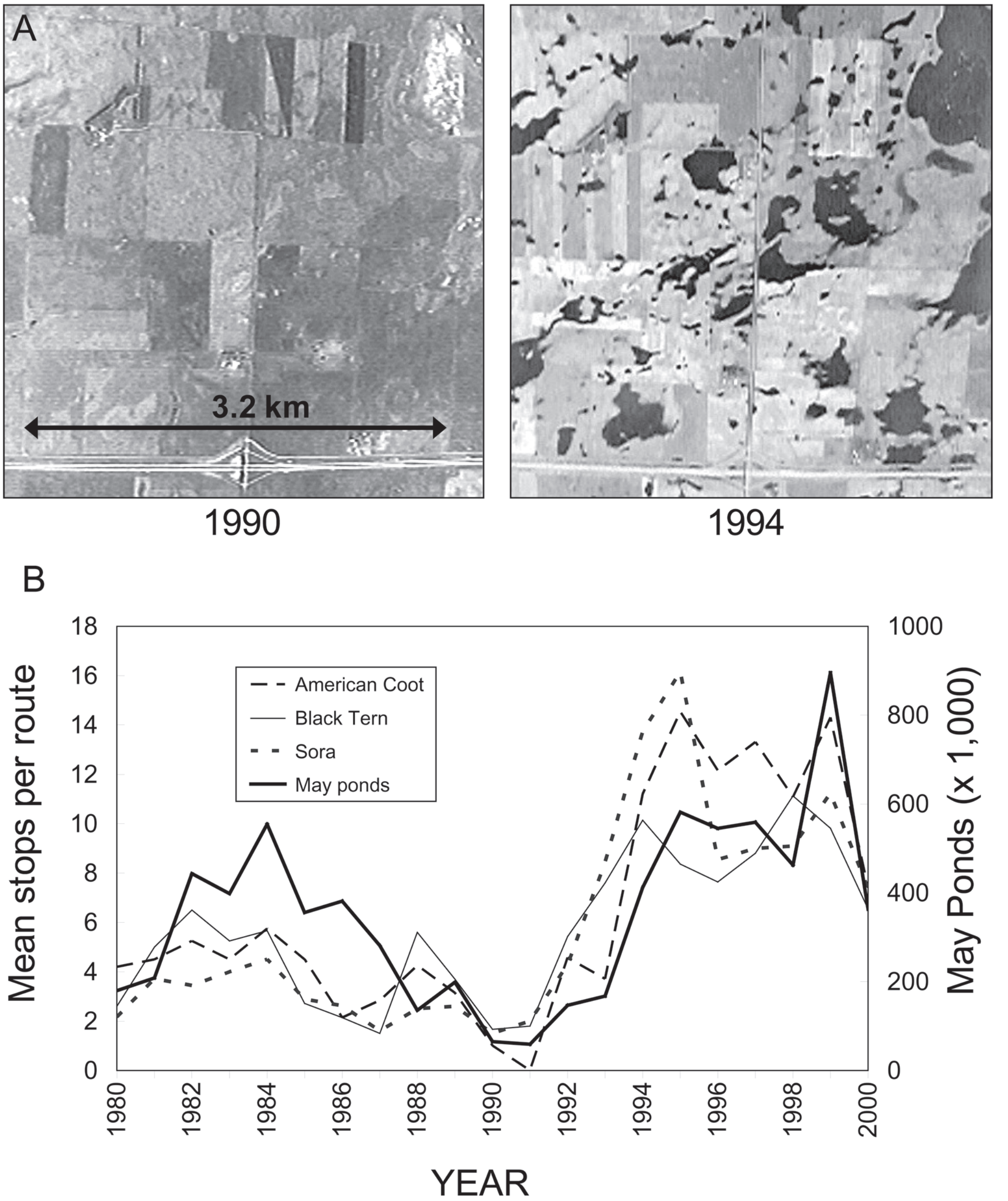

FIGURE 3. Bird populations and their habitat may demonstrate great annual variability as is evidenced in this example from Niemuth et al. (2008a) for the Prairie Pothole Region. The top panel (A) are aerial photographs of four-square mile plot 182 for 1990 (a dry year) and 1994 (a moist year), where the darker colors represent wetter habitat (e.g., ponds, moist soil plots). The lower panel (B) describes waterbird populations as a function of May pond numbers between 1980 and 2000.

TABLE 1. AUTHORS AND TOPICS PRESENTED IN THE SYMPOSIUM CONSERVATION DESIGN: LINKING MODELS TO MANAGEMENT AT THE 4TH INTERNATIONAL PARTNERS IN FLIGHT CONFERENCE HELD IN MCALLEN, TEXAS, FEBRUARY 2008.

Author(s)	Topic
Jane A. Fitzgerald	Introduction to Conservation Design Session
Neal D. Niemuth, Michael E. Estey, and Ronald E. Reynolds	Using Spatial Models to Guide and Assess Conservation of Grassland and Wetland Birds in the Prairie Pothole Joint Venture
John M. Tirpak, Todd D. Jones-Farrand, Jane A. Fitzgerald, Frank R. Thompson, III, Dan J. Twedt, and Bill W. Uihlein, III	Bird Habitat Conservation through Science, Technology, and Partnerships
Rob Rempel	Developing a Focal Species Bioassay for Assessment of Songbird Conservation Design Strategies
C. Ashton Drew, Jaime Collazo, J. Stanton, and Alexa McKerrow	Conserving King Rail in the Roanoke-Tar-Neuse-Cape-Fear Ecosystem: Using Bayesian Belief Models to Guide Research and Management Efforts
L. Wes Burger, Jr., and Rick Hamrick	Stepping Down the Goals of the Northern Bobwhite Conservation Initiative: Focusing Effort Where Suitability Intersects Opportunity
Daniel Casey and Susannah Casey	Informing Land Management and CRP Program Delivery in the Intermountain West
Wayne E. Thogmartin	Conservation Opportunities Assessment for Rare Birds in the Upper Midwestern United States
James B. Grand, K.J. Kleiner, and Allison Vogt	A Decision Support Tool to Guide the Conservation of Open Pine Habitats in the East Gulf Coastal Plain

(Niemuth et al. 2007; Fig. 5). They also emphasized the need for well-designed surveys to better determine abundance and vital rates for model building and validation.

Rempel (Table 1) additionally noted the need to use as few model parameters as possible to enhance the ability to apply models across large landscapes different from those where the initial data are collected (Randin et al. 2006, McAlpine et al. 2008, Rhodes et al. 2008).

The ability of modelers to deliver decision support to planners where empirical data are lacking is improving (Thogmartin et al. 2006). Drew et al. (Table 1) presented a novel approach incorporating initial beliefs constructed from literature review and expert opinion that can then be tested and updated as empirical data are collected. Their iterative approach is designed to both guide and take advantage of the assumptions-based research and outcome-based monitoring mandated by Strategic Habitat Conservation to gradually adapt models to local conditions. The habitat suitability models of Tirpak et al. (Table 1) were derived from data from published literature, but are able to incorporate expert opinion as well (Fitzgerald et al. 2008, Tirpak et al. 2009).

Conservation for individual species can lead to management prescriptions that are contradictory to the successful management of other species (Block et al. 1995, Simberloff 1998). Thus, multispecies prioritization and optimization have become an important aspect to conservation design (Williams et al. 2004, Moilanen et al. 2005, Nicholson and Possingham 2006, Regan et al. 2008).

A number of symposium participants addressed the question, where do we focus our conservation effort? Burger and Hamrick (Table 1) suggested this dilemma comes down, very simply, to the intersection of our programmatic opportunities, habitat suitability, and land use opportunities. Thogmartin (this volume) suggested that this intersection largely occurs, at least in the upper midwestern United States and probably in many other areas in North America, in a private lands context.

Niemuth et al. (Table 1) provided maps of the distribution and abundance of multiple taxa and suggested that conservation that can positively affect multiple species in the same geography be directed to areas where habitat suitability and opportunity overlap. However, they cautioned that, depending on species, targeting areas of overlap may easily result in directing conservation action to coincident, but mediocre, places for multiple species rather than the separate best locations for priority species. Thogmartin et al. (2006a) echoed this suggestion, finding that at a regional scale grassland birds did not demonstrate great overlap in their patterns of predicted abundance, and therefore directing conservation action to areas of high diversity may not capture specific locations in a region important to individual species. Therefore, benefits for non-targeted species associated with habitats identified as important to focal species may be serendipitous rather than the result of targeting.

An element that each author addressed was the issue of scale (Morrison 2002), primarily spatial but also temporal. Burger and Hamrick (Table 1) resolved their conservation implications and management recommendations for Northern Bobwhite (*Colinus virginianus*) over multiple scales, from Mississippi watersheds, counties, townships, and farms. Both Niemuth et al. (Table 1) and Drew et al. (Table 1) resolved their models and maps to be coincident with the resolution of their primary land cover maps, each of which maintained a resolution of 30 m × 30 m. Niemuth et al. (Table 1) reminded us that our spatial models are only as good as the underlying habitat maps upon which they are based; poor thematic resolution, misclassification error, and bias in classification are challenges to mapping at a highly resolved spatial scale (also see Thogmartin et al. 2004a). Therefore it is essential that model validation consider both map error (inadequate data to locate current habitat) and ecological error (false assumptions regarding species-habitat associations). The most useful resolution is that which is no finer than is necessary for the objective. A resolution that is finer than the data allow may lead conservation practitioners to inferences which the data frankly do not support.

CURRENT CHALLENGES OF CONSERVATION DESIGN

Currently, conservation design largely involves assigning conservation priority to lands, landscapes, and ownerships based upon model-based relative assessments of their current and, in some cases, future ability to support populations of priority bird species. Conservation design efforts to date are typically based on current (or outdated) land cover data and the patterns identified among the mapped landscape features. This approach can identify potentially suitable habitat and allow selection from among available habitat units based on conservation principles of connectivity, patch size, redundancy, and representativeness. These efforts are multifarious in their number, form, and specific purpose (e.g., the Habitat Suitability Index models of Tirpak et al. (2009, Table 1), the GIS-linked databases of Casey et al. (Table 1), Bayesian belief networks of Drew et al. (Table 1), and various statistical approaches as employed by Niemuth et al. (Table 1), Thogmartin (Table 1), Grand (Table 1), and Burger et al. (Table 1)) and each modeling approach has their various benefits and drawbacks (Segurado and Araujo 2004, Fitzgerald et al. 2008). Because of delays in developing models informing our conservation design, as well as delays in the various data informing these models themselves, our conservation priorities are often a snapshot of (past) opportunities.

Whether these conservation opportunities persist by the time the modeling and mapping has been completed is usually unknown. What has driven patterns of current habitat suitability are past and present socio-economic forces; most approaches to conservation design in use now do not predict or account for potential spatial and temporal loss and/or shifts in habitat availability because of changes in climate or socio-economic impacts on landuse, for example, nor how to evaluate how populations will respond to these stressors. Prioritizing lands for conservation action based on old or current land cover does not account for the future quality of patches. Future quality may be influenced by climate change, succession, spread of exotic species, development pressures, and feasibility of different management actions. While modeling future conditions is challenging (e.g., such models cannot be easily validated if accounting for long-term trends) there are simple ways that conservation design could account for future quality.

One simple way is to assign each habitat unit a predicted direction of change, either positive or negative. For example, in their marsh bird habitat model, Drew et al. (Table 1) assigned an expectation for declining quality to marshes nearer urban areas based on limited ability to perform preferred management actions (burning), heightened development pressures, and accelerated spread of invasive species. Marsh habitats near shorelines were also assigned a negative expectation because of combined effects of sea-level rise and accelerated erosion with the loss of submerged aquatic vegetation. However, positive future values were placed on marshes with high management potential, and on forested habitat fringing marshes (expected to gradually convert to marsh habitat as sea-level rises). In this manner, two habitat units which might appear to offer equal contribution towards population goals based on current data could be assessed to have quite different future potential. While this approach cannot be as detailed as spatially explicit modeling of climate change impacts or long-term future viability based on demographic data and population responses to changing habitat, it offers a quick index to allow potential future conditions to guide decisions based on static maps of current habitat.

Current approaches typically map variation in occurrence or relative abundance, but few address other factors affecting population viability over time primarily because of a lack of data on vital rates (Root 2002). Similarly, actual population sizes of birds are hard to estimate with any confidence because detection probabilities are lacking in most count data, although this is improving (Royle 2005). Evaluating the level of confidence users can have in these products is crucial but often not discussed (Araújo and Guisan 2006, Murray et al. 2008); similarly, many assumptions, if and when stated, are often not evaluated (Whitaker et al. 2005).

Although the philosophy of conservation design as part of an overall bird conservation paradigm is promoted by the North American Bird Conservation Initiative and the bird initiatives, advances are being made primarily in research institutions associated with government agencies, academia, and to a lesser extent nongovernmental organizations. Initiatives and Joint Ventures need to reach beyond their inner circle to keep pace with innovation and integrate the expertise of scientists with their ongoing conservation planning efforts.

THE FUTURE OF CONSERVATION DESIGN: OPPORTUNITIES AND CHALLENGES

The U.S. Fish and Wildlife Service is adopting, as its way of conducting business, a science-based, adaptive approach to conservation design (National Ecological Assessment Team 2006). An important consideration in the implementation of this philosophy is an explicit recognition that landscapes and the species occurring therein are ever-changing, such that conservation design can never be a one-time activity. The primary drivers of environmental change over the 21st century are associated, in order of expected global magnitude, with changes in land use, climate, nitrogen deposition, biotic exchange, and atmospheric CO2 (Sala et al. 2000, May 2005).

The U.S. Census bureau, for instance, projects a near doubling in the United States population from approximately 275 million people at the start of the 21st century to ~570 million by its conclusion (low and high year 2100 estimates of 437 million and 854 million, respectively) (Hollman et al. 2000). This two-fold increase in human abundance will lead to immense land use changes (Vitousek et al. 1997). Coupled with expected changes in the biota from a changing climate (Walther et al. 2002, Thomas et al. 2004), the spread of invasives (Mack et al. 2000), and the continued risk of toxicological contamination (Nriagu and Pacyna 1988), the challenge to natural resource agencies is clear. Strategic conservation design offers a promising step in addressing these potentially overwhelming threats.

Given the nature of the threats facing wildlife and wildland conservation, the future of conservation design will require moving beyond the static application of models for mapping patterns in species distribution and abundance and on to the incorporation of future scenarios in changing environmental conditions (Oberhauser and Peterson 2003, Larson et al. 2004, Guisan and Thuiller 2005, Bolliger et al. 2007). This recognition of conservation in the face of dynamic conditions emphasizes dealing with and often resolving uncertainties associated with models and maps deriving from the conservation design process. An important source of uncertainty faced by biogeographers is the future spatial distribution of humanity (a knowledge uncertainty) and whether conservation of habitat should occur in the face of this expected human expansion or whether it is best to forego effort in these contested areas for areas that will require less effort at mitigation (a values uncertainty).

Conservation design often ascribes species to habitat using correlative methods (e.g., regression) (Guisan and Thuiller 2005, Fitzgerald et al. 2008). However, a correlative framework for characterizing patterns in species occurrence and abundance fails to identify the causative mechanisms leading to those patterns (Eberhardt 1970, Romesburg 1977). Environmental variables cannot, by themselves, increase or decrease occurrence and abundance: births, deaths, and dispersal can. Therefore, correlational models may not be useful in the face of altered future conditions, especially when species and systems occur outside of their observed range of variation (Lawler et al. 2006, Thuiller et al. 2008). Thogmartin et al. (2004b), for instance, suggested a strong association of Cerulean Warbler (*Dendroica cerulea*) to wooded wetland forest in the upper midwestern United States, however, this effect was undoubtedly correlative as the same phenomenon was not observed in the core of the species range, the Appalachian Mountains, where wooded wetland is rare (Thogmartin, unpublished data). The strong association of Cerulean Warbler to wooded wetlands was likely a function of the extent of forest in the landscape—some of the most extensive tracts of forest in the prairie-hardwood transition are wooded riparian bottoms.

To avoid these potentially spurious and often misleading inferences, models of ecological process rather than pattern are a useful direction for conservation design (Starfield 1990, 1997, Guisan and Thuiller 2005). These process models are becoming increasingly common in understanding migratory stopover and overwintering survival, for instance (Atkinson et al. 2007, Beese et al. 2007). The utility of these process models to conservation design will increase as they become spatially explicit, allowing for the optimization of resources between areas that differ in their functional utility to a species' population dynamics.

Conservation design in the face of dynamical systems implies conservation in the face of uncertainty. Uncertainty, in the form of models and maps, arises when several plausible hypotheses exist to explain system dynamics. As a result, these hypotheses imply different optimal conservation strategies (Runge and Johnson 2002, Hauser et al. 2007). Ostensibly in the conservation design process, over time, new data are used to assess and reassess the plausibility of each hypothesis and update model weights (i.e., an iterative updating of models and maps). This iterative process of updating models and maps as new data become available will necessitate a move in the practice of conservation design away from the domain of scientists and academicians and into the hands of quantitatively savvy practitioners. The success of conservation design as a means of bringing efficiency and accountability to conservation action will hinge on the success of this transition.

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