U.S. Fish & Wildlife Service

Strategic Habitat Conservation Handbook

A Guide to Implementing the Technical Elements of Strategic Habitat Conservation (Version 1.0)

Report from the National Technical Assistance Team
February 11, 2008

Foreward

This document is based on three presumptions. The first is that we do yet not fully understand all aspects of applying the SHC framework, but that this understanding will grow in proportion to the number of people applying it to make conservation decisions.

The second is that no single office is likely to apply all elements of the SHC framework. Even a dedicated team of conservation planners and researchers that can perform the technical elements of SHC will not deliver conservation programs. Implementation of the full framework will require a Service-wide commitment that will benefit from an integration of program offices providing different but complimentary functions rather than our current program-centric model. Under SHC, the functional roles of the vast majority of Service and USGS staff will not change dramatically, however, how and where staff direct their efforts may change. We will all be asked and empowered to think critically about what we do and why in the broad context of helping the Service fulfill its mission.

Lastly, the functional changes within the Service and USGS demanded under SHC are urgent. The challenge of conserving fish and wildlife populations vastly exceeds the resources we can reasonably expect to have in the future. The future of conservation hinges on a landscape approach, and our success in this area will rise and fall with how well we integrate our efforts with our Federal, State and NGO partners. Thus, it is vital that we engage them in a dialog about SHC and about how we each apply our resources and authorities to conserve landscapes capable of sustaining all fish and wildlife species.

Although the urgency is real, building capacity for SHC will be an organizational evolution, not an overnight change. Institutionalizing the SHC framework is a marathon and this document is intended to chart the course and set a purposeful and competitive pace.

Introduction

This guide describes the framework for strategic habitat conservation (SHC) enabling the efficient conservation of wildlife populations through habitat management, which is defined as protection of existing habitat, and habitat restoration or manipulation. It supplements the description of the SHC framework in the final report of the National Ecological Assessment Team (NEAT), accepted by the Service Directorate and USGS Executive Leadership Team in,2006. This guide provides details on applying the technical elements of SHC; biological planning, conservation design, outcome-based monitoring and assumption-driven research. There are two primary audiences: 1) technical staff who will be performing these elements and need to understand how they should be developed and implemented; and 2) Senior Staff, Program Managers and Project Leaders who need to be able to distinguish conservation planning tools based on the SHC framework from those founded on a different approach.

The purpose of SHC is to help us be more efficient at conserving wildlife populations through habitat management, which we define as protection of existing habitat, and habitat restoration or manipulation.

The essence of SHC is setting explicit objectives for populations and then figuring out how to attain these objectives most efficiently using our own resources and by working with partners. Although the focus of SHC is on species that are limited by habitat, and for which a habitat management solution exists, strategic is operative word in the phrase. Implementing the full SHC framework will make the Service more efficient, transparent, and accountable; and ultimately more credible and effective in informing the actions of policy makers and other agencies. While the focus of SHC is obviously on the conservation of populations limited by habitat, the two most fundamental features of SHC are:

The basic tenets of SHC described in this document also are applicable to species that are limited by non-habitat factors (e.g., pesticide contamination) and to Service programs that, while they may not directly involve habitat management, seek to be more efficient. These scenarios might best be simply called strategic conservation.

1) establishing explicit, measurable objectives and

2) using models relating populations to limiting factors to target management and assess its impacts.

Both are applicable to other functions of the Service, e.g., regulating take and developinglaw enforcement strategies.

Background

The conventional model of habitat conservation by fish and wildlife agencies has for many species, at best, slowed the rate of population decline. This is largely due to insufficient management resources compared to ever increasing human pressures on natural systems and to insufficient regulatory authorities. Both are primarily due to three factors: lack of explicit and socially-accepted conservation objectives; lack of clear compelling conservation strategies that describe why populations have declined and what may be done toward their recovery; and a limited ability to demonstrate the population effects of our management actions. Collectively, these factors contribute to a lack of awareness by the public, elected officials, and representatives of other government agencies that reduces the credibility and influence of wildlife management agencies.

The traditional approach to conservation in many areas can be characterized as an agency operating with limited awareness of the goals and the potentially beneficial or adverse activities of other agencies working in the same landscapes. Planning is often viewed as onerous and the plans themselves as static documents with limited value. Research and monitoring may be perceived to be expensive luxuries with little relevance to making management decisions.

Conversely, the approach recommended in this report is predicated on inter-agency collaboration and coordination. It is planning intense and requires the integration of planning, management, monitoring and research. Although not discussed here in detail, the concept of a conservation business model is gaining acceptance (Keen and Oureshi 2006). Successful businesses must articulate their purpose, develop products, identify target markets and marketing strategies, and create feedback loops that insure product quality and continued viability in a competitive environment (Prahalad and Hamel 1990, Drucker 1994, Keen and Qureshi 2006). These concepts have been developed in a series of communication and marketing tools designed to inspire investor confidence. It is convenient to refer to this collection of tools as a business plan. A conservation strategy serves the same purposes.

The idea of inspiring investor confidence may initially sound like an odd concept for government agencies; however, the competition for public funding may be as intense as competition in the marketplace. Inspiring investor confidence requires that agencies demonstrate their ability to efficiently achieve results. Even small budget increases carry an implicit expectation that perceptible benefits will result. Failure to produce these perceptible benefits reduces investor confidence. Although the general magnitude of the challenge of conserving populations at objective levels may be intuitive to conservation professionals, as lay people, the public and elected officials often lack this perspective. To be successful, it is imperative that wildlife management agencies be explicit about objectives, strategies and estimated costs of attaining objectives in order to build increased support by the public. Furthermore, wildlife management agencies must fully adopt the role of stewards and purveyors of the biological foundation for conservation, seeking to inform and influence the actions of other government agencies and policy makers. Developing and communicating explicit, science-based conservation strategies are critical to building this support and that the concepts presented in this report can help remedy current deficiencies. The framework places the use of models in a useful context of the larger conservation enterprise. It is based on the authors' personal experiences in attempting to meet the information needs of managers in government wildlife management agencies, and it is not a synthesis of the extensive literature on theories of conservation biology.

An Overview of Strategic Habitat Conservation

SHC is simply a specific form of adaptive resource management (Walters 1986, Walters and Holling 1990, Williams 2003) wherein habitat management is the primary form of intervention. Strategic habitat conservation (SHC) is defined as an iterative process of developing and refining a conservation strategy, making efficient management decisions, and using research and monitoring to assess accomplishments and inform future iterations of the conservation strategy (Fig. 1)

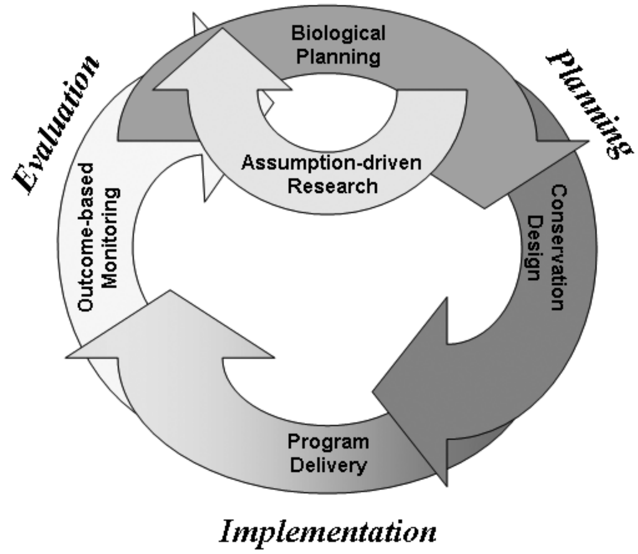


Figure 1. The Basic Strategic Habitat Conservation (SHC) cycle.

The goal of SHC is to make natural resource management agencies more efficient and transparent, thereby making them more credible and wide-reaching in effect (Johnson et al., at press). *Conservation efficiency may be thought of as the ratio of population impacts to management costs.*

A science-based conservation strategy must address five basic questions:

1. Why have long-term average populations declined?

2. What do we want to achieve and how can we achieve it?

    a. What are our objectives for populations?

    b. What factors are acutely limiting populations below objective levels?

    c. What management treatments are available to overcome these limiting factors?

3. Where should we apply these management treatments to effect the greatest change in populations at the lowest possible total monetary and non-monetary costs to management agencies and societies?

4. How much of a particular type of management will be necessary to reach our population objectives (a habitat objective – a minimum estimate, but useful nonetheless).

5. What are the key uncertainties in the answers to questions 1-4 and what assumptions were made in developing the strategy? These will guide our research and monitoring activities.

In the case of federal and state fish and wildlife management agencies it is appropriate to ask and answer these questions in terms of populations; however, these basic questions are equally applicable to other ecosystem functions.

Other agencies and organizations with different mandates may focus on the other functions by applying the same basic concepts. This guide discusses a framework for SHC for the conservation of populations limited by loss or deterioration of habitat.

Efficient conservation requires that agencies strategically apportion their resources at broad scales. This commonly means that agencies must undertake SHC in multiple regions. SHC will be more efficient when it is implemented in geographic regions (i.e., eco-regions) for which species of concern, population-habitat relationships, including limiting factors, and possible future threats to habitats, are relatively homogeneous. This enables the use of strategies tailored to a particular part of a species' range and to a particular season of the year, if necessary, and it also enables more reliable inferences from research and monitoring. Using the SHC framework within ecologically-based regions such as Bird Conservation Regions (U.S. Fish and Wildlife Service 1999, Sauer et al. 2003) is a logical way to organize strategic conservation across a country or continent.

SHC TECHNICAL ELEMENTS

The SHC framework consists of an iterative cycle of five mutually supporting elements that exist in two broad realms –

1. A technical realm consisting of biological planning, conservation design, assumption-driven research, and mission-based monitoring, and

2. A management realm consisting of the suite of management and administrative functions that comprise conservation delivery (Fig. 1). This guide will focus on the technical realm of SHC. The framework described in this report is not proposed as a rigid, linear sequence of events (Fig. 2). Distinctions between biological planning, conservation design, conservation delivery and research and monitoring are somewhat artificial, with each element blending into the others in an iterative process. However, the process achieves its full value when all five elements are in place.

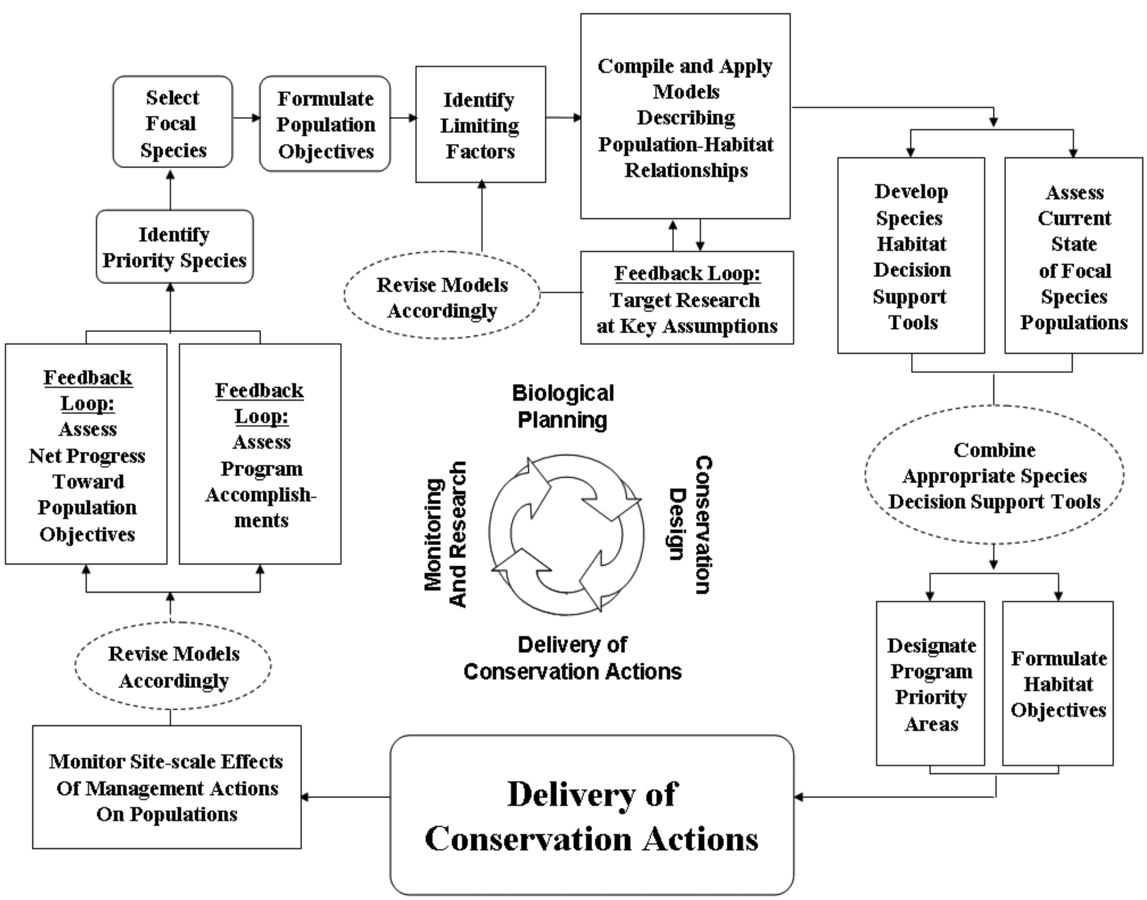


Figure 2. A schematic including many of the important elements in the iterative SHC approach to conservation.

Biological Planning
Biological planning is the systematic application of scientific knowledge about species and habitat management. This means that we articulate measurable population objectives for selected species, consider what may be limiting populations to less than objective levels, and compile models that describe how populations are expected to respond to habitat management.

Select Focal Species
The list of priority species for an eco-region provides a starting point to select a smaller subset of focal species to use in the SHC framework. Ideally species-habitat relationships and spatial patterns in management potential for every priority species would be modeled; however, the use of focal species is usually a necessary planning and design "shortcut." Moreover, trying to integrate information about too many species representing key ecological processes can become overwhelming.

Focal species are used to represent the needs of larger guilds of species that use habitats and respond to management similarly; however, focal species may be more sensitive to patch characteristics, landscape context, or habitat management (Lambeck 1997, 2002). Other focal species may have unique habitat needs (e.g., some T&E species) or may be keystone species and therefore important determinants of ecosystem function (Mills 2007). Hagan and Whitman (2006) provide a valuable overview of the use of indicator species. They recommend selecting 5-15 species that are sensible indicators of the ecological communities stakeholders value most. Of course, the assumption that other species and ecological processes will respond as predicted to habitat protection, restoration, and management must be evaluated (Lambeck 2002).

The use of multiple focal species will typically be satisfactory than the use of a single umbrella species (Lambeck 1997, 2002, Lindenmeyer et al. 2002). There is no single prescription for selecting focal species or the number of focal species (Hagan and Whitman 2006, Mills 2007). Focal species may be selected for biological, socio-economic, programmatic, or political reasons. One useful method for selecting focal species may be to assign species to guilds based on their basic habitat needs and response to management. One or more focal species may be selected from each guild (Example A). Because one outcome of implementing the SHC framework is an objective for each general habitat type, it will often be important to also select focal species with large enough population objectives to insure adequate habitat to meet public demand for these species. Often these will be high profile game species that are actually less limited in their habitat use than some other species. The Service should select focal species that help biologists and managers make better decisions about managing trust resource responsibilities. Likewise, partners should select the focal species that best meet their management needs. This does not preclude continuous dialog with partners, however, each partner should plan separately for their own trust focal species and then integrate the outcomes of the biological planning exercises.

Example A — Forested ecosystems may be characterized by stand composition and age structure. In this simple example, we describe stand composition as deciduous, coniferous, or mixed, and stand age as young or old. Species occur in one or more of these forest community types. We may start by constructing a matrix of forest types by age and assigning species to guilds.

	Forest Type		
Stand Age	**Deciduous**	**Coniferous**	**Mixed**
Young	**A,B,E,H,K,M,N**	**A,C,F,G**	**A,B,D,L,K**
Old	**A,B,I,J**	**A,C,F,G**	**A,B,D,Q,R**

Note that species A is a habitat generalist that uses all of our forest habitats making it unsuitable as a focal species unless there are other compelling reasons to use it in the planning process. Note also that the species composition is the same in young and old age stands of conifers. Consequently, we will combine the two age classes in the planning process. Species C, F, and G require coniferous forest, but F is the most sensitive to patch size and landscape context.

Species E and H occur only in young deciduous stands; however, H is an interior forest breeding species requiring large block habitats while E is area independent. We will use H as a focal species because its habitat needs are more restrictive. Similarly, species I and J require mature deciduous forests, but I is believed to be highly sensitive to disturbance along roads and trails, which J is not.

Lastly, species L occurs only in young mixed forests, and Q only in old-age mixed stands. Furthermore, species L is a popular hunted species with a high population objective. This factor alone recommends it as a focal species because it requires large amounts of habitat to attain population goals.

Thus, through the selection of focal species, planning for the conservation of 16 priority species has been consolidated into the development and application of models for 5 species: F, H, I, L and Q. Of course continued monitoring is necessary to ensure that populations of other species in the same guilds are responding as predicted. If not, they must be brought more directly into the conservation planning process.

Set Population Objectives

Efficient conservation strategies can be developed only after unambiguous mission-based objectives are established. Unlike some past approaches to conservation which tended to view activities like wetland restoration or reforestation as objectives, the "Biological Planning" element of the SHC framework requires explicit objectives for populations because most agencies are charged with the conservation of populations – not habitat.

If The Service mandate was simply to conserve habitats then an objective like "Restore wetlands in the Great Lakes eco-region of the US" might be adequate. However, an activity–based objective like this does not promote accountability because no explicit relationship has been established between habitat accomplishments and the mandate to conserve populations. This is an example of an objective without a clear ending point and without benchmarks for success, i.e., the objective is to do more wetland restoration each year. Of significant concern, a habitat objective without a clearly articulated set of predicted population outcomes provides no justification for increased resources for conservation, because there are no tangible predicted consequences to populations or the public of success or failure.

"Biological Planning" is founded on objectives expressed as desired population states, such as:

> *"Maintain an average annual capacity to produce 1.7 million duck recruits/year in the Great Lakes eco-region of the US."*

This is considered a "mission-based objective." Efficient attainment of a mission-based objective requires knowing the current state of the system relative to the objective, making informed assumptions about environmental factors that are limiting populations below objective levels, and determining where and how management can most effectively remediate these limiting factors. Furthermore, site and landscape-scale factors interact to affect the population impacts of management. Thus, where management is delivered is an important determinant of how much habitat is required to sustain populations at objective levels. These are the basic elements of a conservation strategy and efficient conservation delivery.

Population objectives may be more useful if they are comprised of desired abundance and a performance indicator. For convenience, these are referred to as P1 and P2 sub-objectives, respectively. Examples of hypothetical population objectives might be:

1. Maintain a population of 1,250 moose (Alces alces) (P1) in northwestern Minnesota with a mean annual calf:cow ratio of 0.84 (P2);

2. Increase king rail (Rallus elegans) density 300% (P1) at marsh bird survey sites and maintain a mean annual nesting success of 60% (P2) in the southeastern coastal plain; or 3. Maintain 25 distinct stream segments (P1) with stable or increasing (P2) breeding populations of lake sturgeon (Acipenser fulvescens) in Michigan.

In each case, the P1 sub-objective enables estimation of how much habitat to maintain based on limited knowledge of relative habitat suitability, territory size, population viability, and probability of occupancy or average density in suitable habitat. Above minimum viable population sizes, P1 sub-objectives are value-based expressions of how many individuals of a species wanted, or, more accurately, that the public wants and will support. Eco-regional-scale P1 objectives should be stepped down from range-wide objectives when these broad-scale goals exist; doing so links local conservation actions to national or continental strategies and vice versa.

P2 sub-objectives, which are commonly vital rates, describe the desired affect on the population. If some habitats yield higher productivity or density than others, the P2 sub-objective should help in determining how to configure or manage those habitats. In practice, it will often be necessary to express P2 sub-objectives as assumptions about the effects of management.

Although vital rates are difficult to estimate, monitoring both P1 and P2 sub-objectives paints a much clearer picture of how management actions influence focal species populations and ecological function. Because estimating short-term trends from annual abundance data often requires unattainably intensive monitoring. For some species, P1 and P2 sub-objectives may be combined, as in the Great Lakes duck example above, in terms of number of recruits produced, rather than a P1 sub-objective for number of a breeding pairs and a P2 sub-objective for recruitment rate.

Identify Limiting Factors and Appropriate Management Treatments
The purpose of habitat management is to relieve the constraints limiting factors impose on population size.

> *"The presence and success of an organism or group of organisms depends upon a complex of conditions. Any condition which approaches or exceeds the limits of tolerance is said to be a limiting condition or a limiting factor…first and primary attention should be given to factors that are operationally significant to the organism at some time during its life cycle" (Odum 1971).*

One purpose of Biological Planning is to identify areas where these limiting factors can be most efficiently alleviated, i.e., areas where:

- potential population impacts are relatively high;
- management costs are relatively low; and
- tactics are socially acceptable.

Limiting factors are often related to the appropriate area, type, quality, or configuration of habitat necessary to sustain a population at objective levels. For example, consider a hypothetical example in which low reproductive success in small forest blocks limits populations of a species of interior forest breeding bird. There are not enough large patches to sustain the population at objective levels of abundance. Individuals that settle in small patches fail to recruit young into the population, so the population must be maintained by birds that are able to settle in large patches. Once the limiting factor is understood, several potential management treatments designed to increase recruitment or survival may be considered:

1. Use reforestation to create more large patches
2. Focus on increasing non-breeding survival
3. Use nest predator and nest parasite control in small patches
4. Raise birds in a hatchery and release them into the wild

Generally, one or two management treatments will be most practical and compatible with our goals for the ecosystem and the other species that inhabit it. In this case, managers would likely choose reforestation as the preferred management treatment – coalescing small patches where recruitment is low into larger patches where recruitment is higher. If survival remains the same and reproductive success increases in response to increasing patch size, the population will grow toward objective levels. Hence, a primary purpose of the conservation strategy for the guild of interior forest breeding birds in this eco-region would be strategic targeting of reforestation to most efficiently increase the number or area of large patches.

Develop and Apply Models
Developing an efficient conservation strategy requires that we understand the relationship between populations and limiting factors. A defining feature of Biological Planning is the application of models to spatial data to target specific management treatments that can remediate the limiting factor. Models are simply a means of organizing science to aid in understanding how a system functions by expressing real relationships in simplified terms (Starfield and Bleloch 1991).

> *A defining feature of Biological Planning is the application of models to spatial data to target specific management treatments.*

Whether they are aware of it or not, almost all managers are intuitively using models to predict the probable outcomes of applying a particular management practice in a particular site in its landscape context. The difference between an intuitive approach to modeling and a more deliberate use of models in Biological Planning is that, in the latter, models are stated in explicit and measurable terms. The advantages of explicitly stating and systematically applying models are that:

1. Models and the products of applying them are useful for communicating the scientific foundation for actions, decisions, and recommendations, thereby yielding greater transparency and credibility;

2. The process of explicitly stating a model enables critical evaluation of uncertainties and assumptions and thus: a. Determine confidence in the predictions; and b. Target critical information needs to make future predictions more reliable.

3. Explicit models may be used to report accomplishments expressed as estimated population effects.

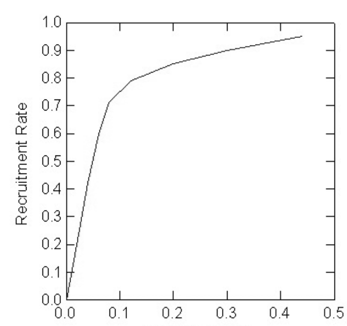


Figure 3. A hypothetical relationship between interior forest breeding recruitment rate and the ratio of forest patch edge:area

Although it is tempting to focus on using models to make maps of conservation priority areas, these other benefits of using models are often just as important.

For the hypothetical focal forest breeding bird species example, it is really the ratio of patch edge:area that limits recruitment rate – as patches become larger and blockier, recruitment rate goes up. Thus answering the questions of where and how much habitat must be conserved requires the use of models that describe the relationship between the ratio of perimeter:area and recruitment rate (Fig. 3). In this example, it can be seen that after the perimeter:area ratio exceeds 0.1, further increases in recruitment rate begin to slow down. The point of diminishing returns is reached. A strategic approach to attaining the objectives, as informed by this model, would indicate that once a ratio of 0.1 has been reached, moving on to a new patch rather than continuing to make the same patch bigger and bigger for less and less additional benefit is the preferred strategy.

The value of a model is measured by the extent to which it adds useful information to the management of focal species. Generally speaking, as model complexity goes up, so does the added value for decision making because model predictions move beyond our capacity for intuition. Advances over the last two decades in spatial data management enable depiction of complex multi-dimensional biological models in two-dimensional map form that contribute to a better understanding of how management potential varies among landscapes. However, models and the maps derived by applying them to spatial data have inherent uncertainties.

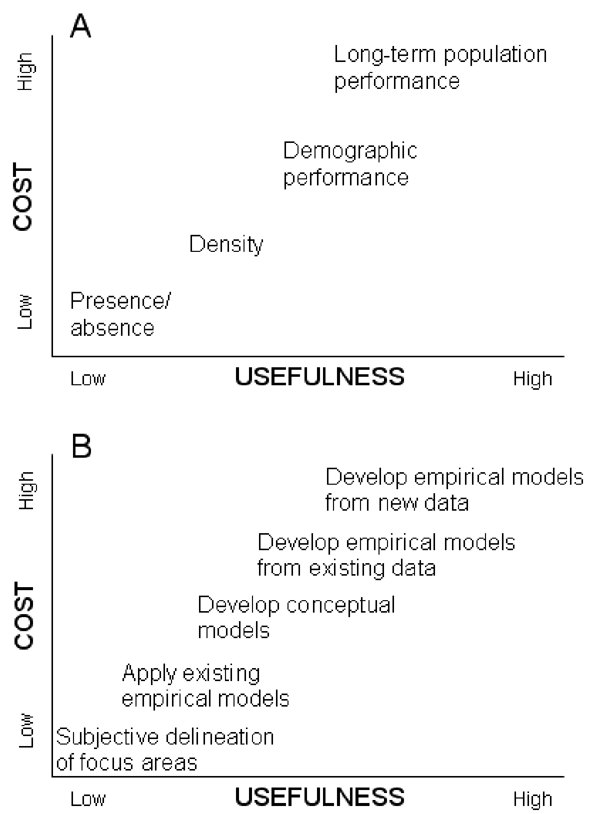


Figure 4. General relationships between usefulness and cost for (A) models predicting various types of biological responses and (B) methods of developing models.

Numerous types of models are described in the literature. This guide describes the most basic dichotomy among types of models as data-based (empirical) and experience-based (conceptual) models. Niemuth et al. (at press) present empirical models for breeding duck access to grasslands, sora (Porzana carolina) use of wetlands, and empirical and experience-based models for marbled godwits (Limosa fedoa) (Examples B, C and D).

Both empirical and experienced-based models may be used to predict factors (in increasing sophistication) such as probability of occurrence or apparent habitat suitability, abundance or density, and demographic rates such as productivity or survival (Fig. 4). Each may be estimated in relative or absolute terms. Generally, models tend to be more data-driven and less experience-based as the sophistication of their predictions increases. For example, although modeling like that for marbled godwits in Example B is useful for predicting relative apparent habitat suitability, the outcome of estimating abundance using a purely experienced-based approach would be less certain. However, if apparent habitat suitability is all that can be reliably predicted, abundance may still be predicted by using empirically-derived average density estimates from "suitable" versus "unsuitable" or "less suitable" sites.

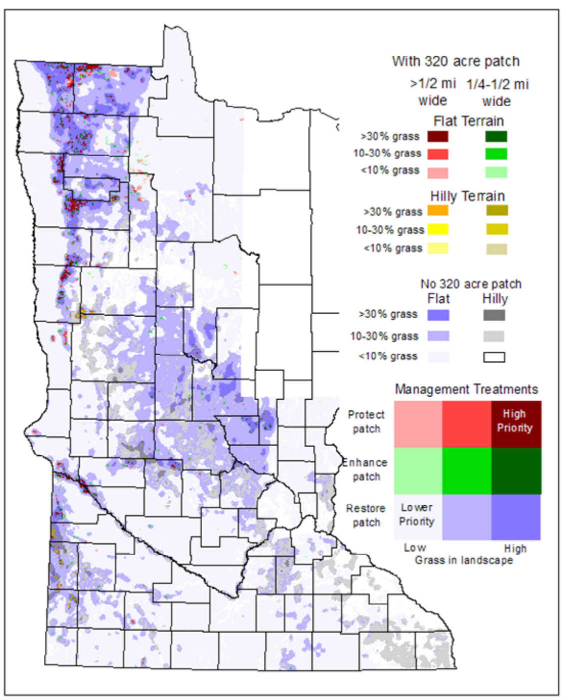
Estimating the effects of habitat management on population vital rates is an ideal that is presently impossible for most species because appropriate data for model development do not exist. However, estimating probability of occurrence or even relative abundance is possible for nearly every species although these models may contain numerous initially untested assumptions.

In Biological Planning, model predictions must be expressed in the same terms as population objectives to (1) estimate the amount of habitat management necessary to attain population objectives; and (2) facilitate estimates of project, program or agency accomplishments and net progress toward population objectives. The implications are that the information available to create models will affect the form of model predictions, which in turn affect the expression of population objectives. Thus, data collection, model development and population objectives are iterative within the overall cycle of the SHC framework.

Example B — In the absence of useful empirical data, experienced-based models can provide guidance for conservation efforts. To identify important breeding sites for marbled godwits in Minnesota, the USFWS Region 3 Habitat and Population Evaluation Team (HAPET) met with marbled godwit (Limosa fedoa) experts from state and federal agencies in Minnesota. By leading the group on a tour of habitats ranging from suitable to unsuitable, essential elements of breeding godwit landscapes were identified. The HAPET formalized these concepts into rules, and applied the rules to elevation, NWI, and classified landcover data. The resulting model identified areas most likely to support breeding godwits and areas with varying potential for habitat restoration (Fig. A). Although the model is experience (versus data) based, independent surveys and ancillary data correlate well with the model output as shown by the yellow circles in Figure B which represent actual godwit observations in northwest Minnesota.

Parameters for marbled godwit conceptual model in Minnesota.

Grassland patch	≥130 ha: ≥ 400 m wide – required
	≥ 800 m wide – higher suitability
Wetlands	≥ 1.6 ha of temporary or saturated wetlands per 130 ha patch
Trees	>100 m between patch and trees
Percent grass (3.2 km radius)	10-30% – required
	>30% – higher suitability
Topography (535 m radius)	≥4% average slope – poor
	≤3% average slope – higher suitability



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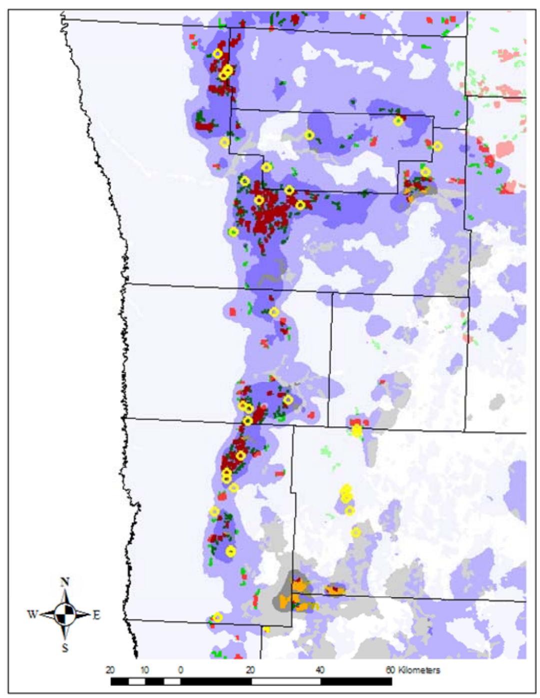
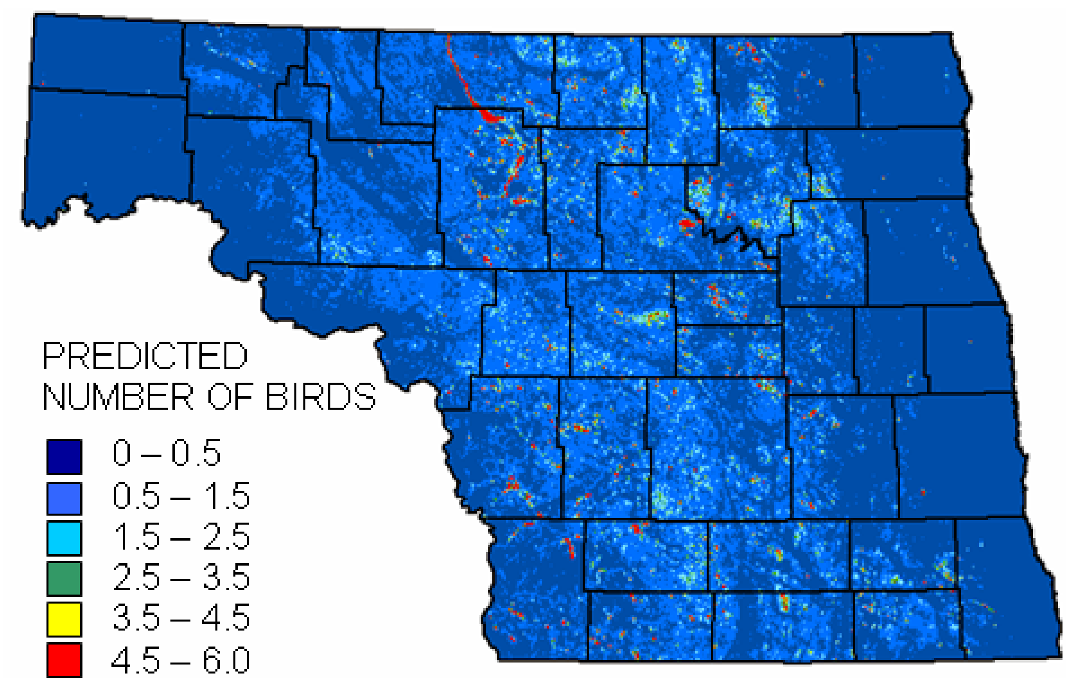


B

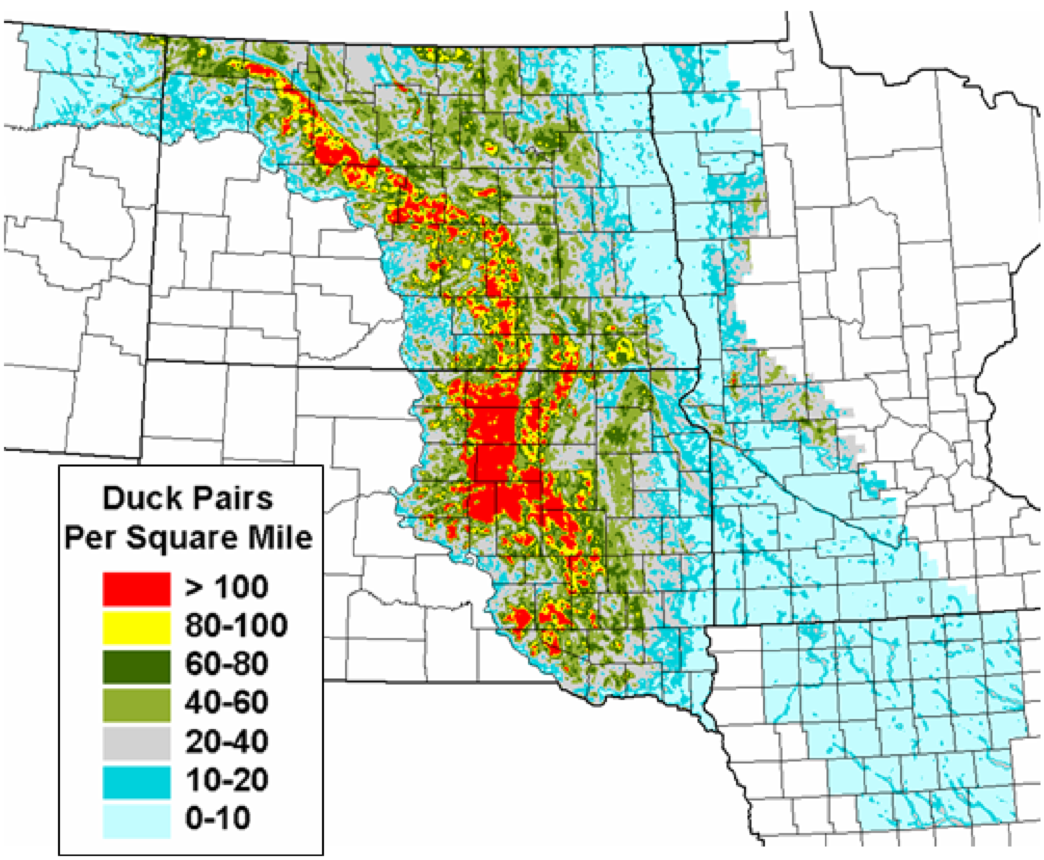
Example C — In some cases, past monitoring has yielded data sets that can be used to construct empirical models. It is important to understand the limitations of the data and thus the limitations of the models developed from them. Circa 1995 data for 27 BBS routes within the Prairie Pothole Region (PPR) of North Dakota were obtained from the USGS, Patuxent Wildlife Research Center and used to evaluate landscape suitability for a variety of land and water birds. Each BBS route contained 50 stops, or survey points, 0.5 mi apart. Stop locations were digitized using GIS. Because many bird species are influenced by the landscape beyond the area included by traditional bird survey methods (e.g. point-count circles), habitat was "sampled" habitat from spatial wetland and land cover data within 400, 800, and 1200-m radii. Poisson regression was used to model the number of soras (Porzana carolina) detected at BBS stops as a function of landscape variables.

In addition to being influenced by observer ability, time of day, and location, the number of soras detected at each stop was positively associated with amount of water in wetland basins, area of temporary, seasonal, and semipermanent wetlands, area of undisturbed grass, number of wetland basins and variety of water regimes in the surrounding landscape. An SEM was created showing predicted number of soras (Porzana carolina) by applying the Poisson regression to spatial data on land cover and wetlands.

Predicted number of soras per 12.5-acre cells covering the PPR of eastern North Dakota.



Example D — Conducting new research or monitoring to build models may be justified if the future value of these models is great enough to justify the cost and time required to collect data. Because of the importance of waterfowl as a trust management concern in the Prairie Pothole Region, the Service launched an annual survey of ducks and wetlands to better understand the effects of management. Waterfowl were sampled on 626 4-mi2 plots that were selected in a stratified random manner. Approximately 4,435 wetland basins were randomly selected within these plots and visited twice each year. Duck pairs and wetland conditions were recorded during each count. Numbers of duck pairs were related to wetland size, type and location throughout the PPR using linear regression in Montana and the Dakotas (Reynolds et al. 2006) and Poisson regression in Minnesota and Iowa (R. R. Johnson, unpublished data). These models were applied to spatial data for approximately 3.3 million wetland basins in the U.S. Prairie Pothole Joint Venture (PPJV). Pairs/wetland was summed for 40-ac cells, and these estimates were totaled for an area corresponding to the size of breeding hen home ranges. The result was an SEM that showed the number of hens that could access a patch of grass, predator exclosure, nesting island, etc. anywhere in the PPJV. This SEM (referred to as the "Thunderstorm Map") shows the relative potential of grassland conservation efforts to affect breeding duck populations (Reynolds et al. 2006, and R. R. Johnson, unpublished data).



Conservation Design

Conservation Design is predicated on the belief that the potential to affect populations varies in space in response to site characteristics and landscape context. If not, it matters little where habitat is conserved. The development of maps predicting patterns in the ecosystem is the outstanding feature of Conservation Design. Maps that are not based on the systematic application of science can be misleading and may impede conservation success. Maps used in SHC are the product of applying empirical or experience-based models to spatial data. Hence the phrase "spatially-explicit models" (SEM) in lieu of maps is used to emphasize that developing and applying models relating a species to limiting habitat factors is the essence of the SHC framework.

Assess the current state of the ecosystem

A conservation strategy is a route between the current state of the system and the objective state (desired future state). Models used to create SEMs also may be used to estimate the current state of the system. The current state of the system must be expressed in the same units as population objectives. The objective state minus the current state represents a conservation deficit to be made up as efficiently as possible. Note that the deficit is expressed in terms of populations, not acres of habitat.

Develop species-specific spatially-explicit models (SEMs)

SEMs will generally be specific to a focal species and a management treatment that affects that species, e.g., targeting a particular management treatment like reforestation or wetland protection to address factors limiting populations below objective levels. For example, the ornate box turtle (Terrapene ornata) is listed as threatened or endangered in a number of Midwestern states. Population declines are primarily attributable to the loss of sandy-soil grasslands and road-related mortality within remnant populations. Management treatments, therefore, include (1) strategic grassland restoration on sandy sites (away from roads) and (2) road signage placed around known or suspected populations. In this example, a SEM for ornate box turtles may be based on a simple empirical or experience-based model with only two variables – land cover and soil type. SEMs derived from these models may be combined with data on the distribution of roads to identify areas with existing or potential turtle populations for population surveys, potential population restoration sites, and sites to erect road signage.

SEMs typically include an assessment of the potential of every part of the eco-region to impact a population or set of populations. This means that geographic units with high, moderate and even low potential to affect populations are included. This is important because 1) managers typically deal with willing landowners and it is not always possible to limit management to the highest priority sites; and 2) a management action with a lower predicted biological impact may still be efficient if management costs are low enough.

The resolution of SEMs should match or be smaller than the scale at which management occurs. Maps of large geographic units like counties or major watersheds may be deceptive because they implicitly include the unreasonable assumption that management anywhere within the county or watershed will yield the same outcomes, i.e., they are simply too coarse to reflect site and landscape effects on potential management outcomes. The geographic units assessed using models and portrayed in SEMs should be small parcels that match, or are finer than the typical scale of management (i.e., as fine as possible but generally <640 acres) (Fig. 5).

Formulate habitat objectives

Habitat objectives are developed for habitat types, not species. The size of an objective for a particular habitat type depends on the diversity of species that depend on it, their population objectives, and on their range of responses to management. For example, grassland habitat objectives for an eco-region will be smaller if every priority species prefers idled grasslands, than if some prefer idled and some disturbed habitat, because the potential for aggregate population impacts is greater for each acre.

Habitat objectives may be expressed for the total area of habitat in public and private, protected and unsecured status, or they may be defined more specifically, such as the number of acres to be restored and placed in the conservation estate. In theory, if the capacity of every acre to contribute toward the population objective for each focal species is known, then it is reasonable simply tally up the smallest area (cost/acre being equal) that overcomes the aggregate conservation deficit. Of course, this is an absolute minimum estimate of the amount of habitat that will actually be required to achieve population objectives since it is almost never possible to work exclusively in the areas with the greatest potential to affect populations. Since potential to affect populations varies in response to site characteristics and landscape context, the relative efficiency with which the conservation deficit is made up, and population objectives are attained, depends on the managers' ability to act strategically by operating at sites with the greatest potential to affect each focal species' populations and reconcile potential management conflicts. Because work can not typically be done exclusively within the highest priority sites, estimates of the amount of habitat needed to attain the population objectives will likely be underestimates. Nonetheless, explicit habitat objectives based on population-habitat relationships enable conveyance to policy makers and stakeholders the extent of actions required to conserve populations. While some deviation from the strategy is inevitable, close adherence to it by limiting conservation actions to priority landscapes will help ensure that the habitat objectives, while minimal, come close to providing the anticipated population response. Timely adjustments to habitat objectives can be made based on recent management accomplishments, new scientific information, and other influences on habitat due to policy changes and socio-economic factors.

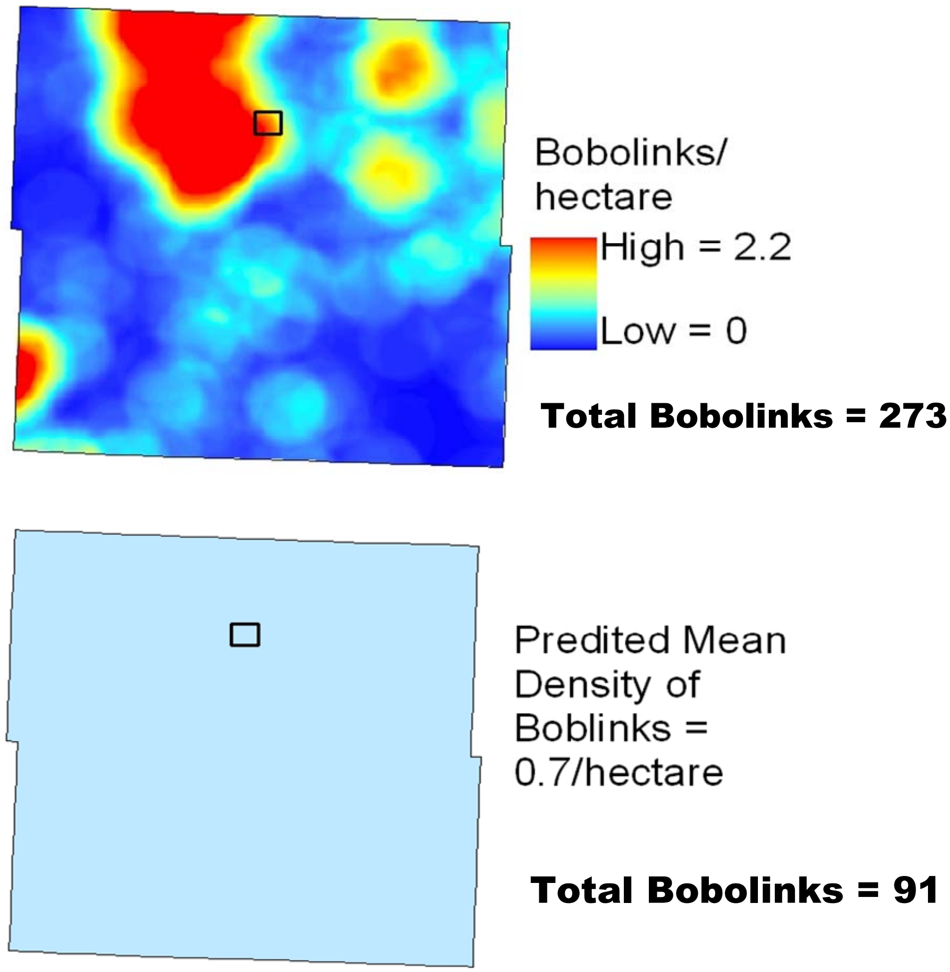


Figure 5. Grassland bird conservation potential.

Designate priority areas — Priority areas can only be delineated in the context of explicit objectives or goals. "Show me the best areas for conservation" is not a satisfactory request on which to base conservation assessment. Since no site is likely to actually have high value for every species, some interpretation of relative priority is necessary. "Show me the set of sites with the greatest management potential to affect species X" is a much more appropriate request. Even more likely is the request: "Show me the set of sites with the greatest aggregate potential to affect species X, Y, and Z." Moreover, different partners will often be most interested in benefiting different combinations of species. Thus, while it may be possible to designate a single set of priority areas for a specific program, it is seldom practical for conservation partnerships. This is why developing a portfolio of focal species x treatment SEMs is important. Once created, SEMs can be rapidly combined to match the unique priorities of programs, agencies and partners (i.e., a portfolio of SEMs provides a rapid response capability to inform management), and may enable scientifically-informed conflict resolution for species that respond differently to management.

Multiple species x treatment SEMs may be integrated to assess the relative potential of each unit of the landscape to yield aggregate population benefits consistent with unique program, agency and partner priorities. Caution must be used in combining SEMs because prediction errors compound in the overlay process and because not all species that could occur at a site have compatible habitat or management needs. Before combining SEMs, it is necessary to (1) know what species or environmental benefits a program emphasizes the most; (2) know what treatments can be employed under a program; and (3) thoughtfully integrate SEMs based on management compatibility.

Biodiversity and Species Richness Maps
Although no single standard definition exists for biodiversity, it is commonly interpreted as the "totality of genes, species, and ecosystems of a region". Thus, concepts of biodiversity management have little utility at the pixel, patch or management project scales at which SHC occurs. Instead, conserving biodiversity requires balancing the area

and configuration of habitats needed by the full array of species within an eco-region. Biodiversity indices are often implicitly emphasized over species-based approaches to strategic conservation (Simberloff 1998). However, rather than a one-size-fits-all approach to program delivery, the appropriate approach is to manage tracts such that eco-regional biodiversity is conserved. This can be achieved with each agency contributing to biodiversity conservation consistent with its specific conservation mandate and priorities.

Contributing to the conservation of biodiversity is undeniably a high priority; however, strategic habitat conservation is founded on being explicit, measurable, and communicable. Unless a measurable and universally acceptable definition of biodiversity can be developed, it can not be described in a mission-based objective. Because explicit definitions of biodiversity are elusive (Wilson 1997), other measures like species richness are often equated to biodiversity management potential. Maps of species richness are commonly produced using modern GIS techniques. Species richness maps are based on data such as range maps or species occurrence. Abstract goals such as maximizing species richness at patch scales is inappropriate, because implementing plans that emphasize high local diversity can reduce overall (gamma) diversity (Noss 1987) and are of little use for programs that typically have a species or guild focus. Maps of species richness are likely to identify ecotones, mountains and river corridors as priority areas because they have greater habitat diversity although they are often poor habitat for many priority species. The following are concerns about using maps to portray of species richness:

1. Occurrence data are subject to errors omission, where no one has looked for a species. This is particularly true for uncommon, candidate or listed species;

2. The approach is not founded on explicit objectives or predictions of population response – the process is not dependent on models and there normally are no benchmarks to compare accomplishments;

3. The approach makes limited use of the biological foundation available for many species including factors that are limiting populations, and thus it:

a. provides little information about how and where management can be effectively used for species recovery, especially using habitat restoration;

b. provides no means of estimating management effects on populations which is critical for targeting management and for estimating accomplishments; and

c. provides no foundation for assumption-driven research;

4. Habitat heterogeneity is often the most important factor in determining species richness. Number of species and habitat heterogeneity are often poor predictors of the importance of a site for conservation.

5. Management compatibility is often not explicitly accounted for. For example, both American woodcock (Scolopax minor) and cerulean warbler (Dendroica cerulea) may be assigned to mixed deciduous forest tracts although the two species respond very differently to stand age and common forest management practices.

6. Estimates of species richness are scale-dependent and common scales of assessment (e.g., large hexagons, hydrologic units, or counties) are much larger than the scale at which management decisions are routinely made. The implicit message is that habitat management anywhere within the geographic unit will provide equal benefits to the full array of species. This assumption is usually unwarranted. Inferences resulting from assessment at fine scales (e.g., 30-m pixels, 16-ha parcels) can be generalized to larger geographic units, but coarse scale assessments cannot be broken down to make fine-scale inferences.

For these reasons, maps of species richness within hydrologic units or counties are not useful tools for strategic habitat conservation. Maps of species richness are often compelling, as is the misperception that they are surrogate predictions of biodiversity. As such, they can inadvertently impede more sophisticated approaches to conservation assessment, based on a critical assessment of trust responsibilities, program authorities and priorities, population objectives, limiting factors, management compatibility and spatial scales. Although single-species planning and management seem to be falling out of favor in the scientific literature, developing a portfolio of species-specific assessment products enables a rapid response to requests to designate priority areas tailored to a program's unique authorities and priorities, including species priorities.

Evaluation

A basic principle of SHC is that our understanding of ecological systems is never perfect. Models force the biologist or manager to make assumptions about limiting factors and their effects on populations. The advantages of an iterative process of the SHC framework are two-fold with respect to science. On one hand, the overall process is a systematic means of expressing what is believed about how populations relate to their habitats and management at local and landscape-scales. However, science is primarily a means of learning. The scientific method is founded on articulating assumptions in the planning process and then evaluating the assumptions through monitoring and research. Without monitoring and research, strategic habitat conservation is not an iterative process by which managers learn and increase their effectiveness. Assumption-driven research and outcome-based monitoring must be carried out to evaluate:

1. Assumptions made about limiting factors in population-habitat models and SEMs;
2. Effects of management on habitat and individuals;
3. Program and agency impacts on population; and
4. Net progress toward population objectives.

Assumption-driven Research — Although knowledge of highly complex ecological systems will always be incomplete, agencies must make management decisions using the best information to guide their actions. By systematically applying the biological foundation in the SHC framework, uncertainties in the biological foundation for management are highlighted. In the absence of perfect knowledge, it is necessary to make assumptions which are essentially testable hypotheses about uncertainties. However, not all assumptions are equally important. Consider each assumption in light of two factors: (1) how uncertain it is; and (2) to what extent better information would affect future management decisions. Assumptions that are both tenuous and high impact are priorities for research. For example:

Scenario 1 – Research shows that soybean fields are used extensively by greater prairie chicken (Tympanuchus cupido) broods, even in the presence of adjacent native grasslands. Soybeans are superabundant at this time in the vicinity of grasslands used by prairie chickens, but soybean distribution varies annually.

Assumption1 : Soybeans are a suitable habitat for greater prairie chicken broods.

Conclusion 1: Limited uncertainty with little decision making value of better information because of high but annually variable soybean abundance driven by market forces.

Scenario 2 – Ornate box turtles are known to burrow extensively in sandy soils but surveys are limited. There are presently no plans for box turtle releases or reintroductions.

Assumption 2: Ornate box turtles have a relative density at sites with sandy loam soils that is 200% greater than their density at sites with clay soils.

Conclusions 2: Considerable uncertainty, but little value of additional information unless long-range management plans suggest releases or reintroductions will be necessary to sustain populations.

Scenario 3 – Dabbling duck daily nest survival rates have been shown to co-vary with percent grass (+) and cropland (-) in the landscape (Greenwood et al. 1995, Reynolds et al 2001). Unfortunately, the relationship is highly variable and its exact nature has been difficult to ascertain.

Assumption 3: Waterfowl nesting success increases linearly with the percent grass within a 2-mi radius of a nest site (Reynolds et al. 2001).

Conclusion 3: Considerable uncertainty and considerable value of better information because millions of dollars are spent annually to protect grassland for wildlife and millions more are spent to restore grasslands through programs like the Conservation Reserve Program.

Among the three hypothetical assumptions, Assumption 3 is the highest priority for research because of its degree of uncertainty and the potential to increase management efficiency of obtaining better information. Assumption 3 may be restated as at least four competing hypotheses (Fig. 6):

HO: Nesting success and percent grassland are independent
HA1: Nesting success and percent grassland are positively and linearly related (the current assumption)
HA2: Nesting success and percent grassland are positively related but the relationship is exponential
HA3: Nesting success and percent grassland are positively related but the relationship is non-linear and reaches an asymptote at about 20% grassland in the landscape.

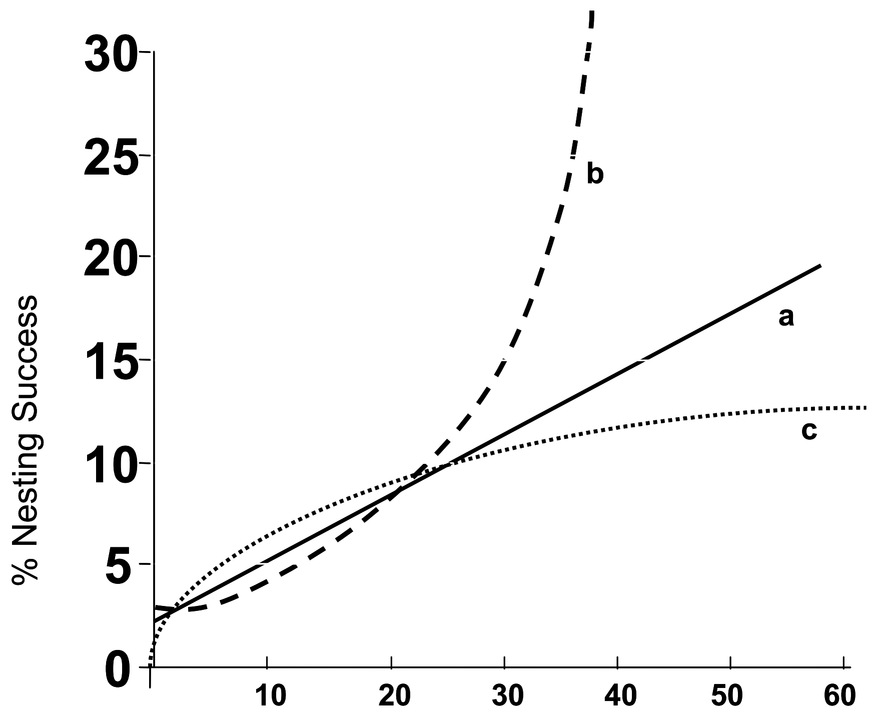


Figure 6. Alternative relationships that describe a general trend of increasing waterfowl nesting success.

If you are working exclusively within landscapes with <20% grasslands the value of better information is minimal because all three models predict similar nesting success. However, the implications of obtaining better information about this relationship when working in landscapes with 20% or more grassland are huge. If the relationship is linear (line a), restoration of grass in any location will yield the same incremental increase in nesting success. If curve b more accurately describes the relationship, an agency should invest all of its grassland protection and restoration resources in a few sites until the entire landscape is grassland or nest success approaches 100%, whichever comes first. If curve c is the best fit, an agency should add grass to locations within landscapes with 20-35% grassland. Above 35% the curve reaches an asymptote and we should move on to other areas because additional grassland restoration will have less and less effect on increasing nesting success. If the null hypothesis (HO) can not be disproved, grassland protection and restoration would not seem to be a very effective treatment for increasing nesting success.

When research priorities are established as an outcome of biological planning, mission-critical research is targeted, not simple indulgence of intellectual curiosity. Thus model-based biological planning helps an agency articulate its research priorities. Moreover, model-based biological planning is the means by which research results find their way into conservation decisions.

Outcome-based Monitoring
An agency needs to make three types of inferences about its resource management actions:

1. The effects of a particular type of management action on habitat and individuals;
2. Program and agency accomplishments expressed in terms of population impacts; and
3. Net progress toward population objectives.

Assessing the Effects of Management — To evaluate whether management actions are having the predicted consequences it is necessary to monitor actual outcomes. This consists of answering two basic questions: did the management action yield the expected habitat response; and, did the change in habitat evoke the expected species response? Answers to the first question enable managers to adjust their tactics to more consistently achieve desired habitat conditions. The second question is the means whereby models of species-habitat relationships are refined. This means that monitoring programs should be structured around the same eco-regions as biological planning to insure efficient model updating. It may not be necessary to monitor the outcome of every management action, but monitoring outcomes at a subset of management sites is essential.

Assessing Agency Accomplishments — Populations vary in space and time in response to a variety of short-term, uncontrollable environmental and anthropogenic factors. Population status and trend estimates tend to have high variances because of limited sample sizes and cyclic or short-term environmental variations. Consequently, except for assessing long-term trends, actual counts of individuals often have little utility for assessing accomplishments. Rather than using highly variable, periodic counts of individuals, models used to target management can be used to estimate population impacts of management that actually occurred (Fig. 7). The sum of the estimated impacts of each management action is an agency's accomplishments. In other words, population monitoring is used to indirectly assess accomplishments, with model refinement and estimation as the intermediate step. This approach to accomplishment reporting has two practical implications:

1. Program accomplishments would be expressed in the same terms as population objectives, as well as acres and dollars; and
2. Managers should report their annual accomplishments in terms of predicted aggregate population effects. Overall agency accomplishments are the sum of the output of individual managers.

Assessing Net Progress Toward Population Objectives — Net progress toward population objectives is a function of habitat gains versus losses, both of which may be driven more by socio-economic or long-term environmental factors than by agency accomplishments. Similar to assessing agency accomplishments, assessing net progress toward population objectives is a model-driven process. Essential field data collection consists of (1) site-scale data on species response to habitat codified in models, as noted above; and (2) eco-regional, national, or continental data on habitat abundance, distribution, and quality (e.g., from regularly updated land cover data). Most broad-scale (national or continental) population monitoring has not compiled data on habitats, with little effort to systematically monitor population responses to habitat at site-scales.

Although continued broad-scale monitoring of populations is generally warranted, interpreting annual changes in population status at any scale benefits from the simultaneous collection of habitat covariates at site and landscape scales upon which population estimates can be conditioned.

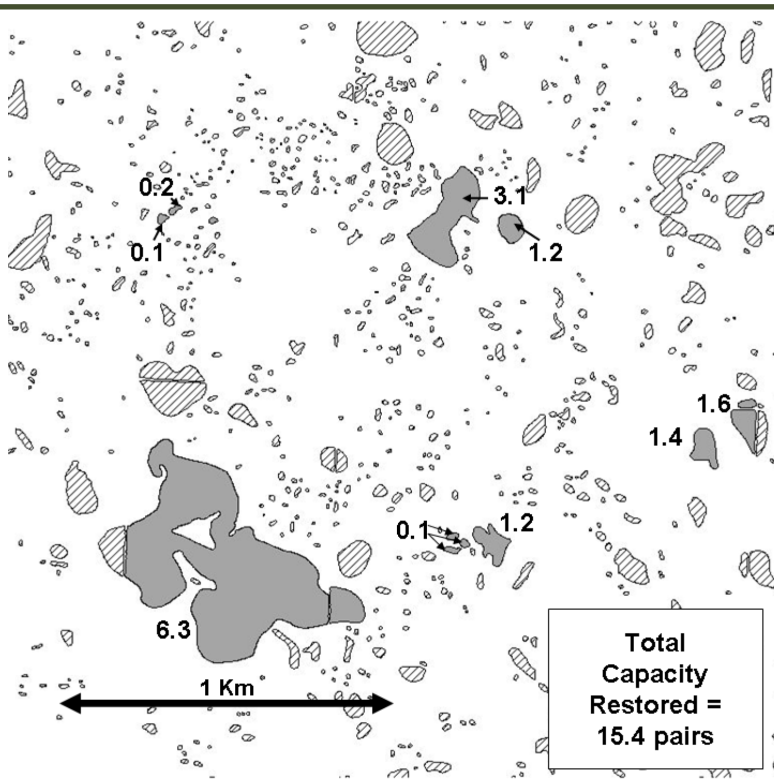


Figure 7. Habitat management in a 10 km2 western Minnesota landscape – cross-hatched = drained wetlands; solid = restored wetlands.

Summary

Implementation of the SHC framework can make an agency that is mandated to conserve populations be more:

1. Efficient at habitat management – a function of being able to estimate biological benefits relative to management costs;
2. Transparent and defensible because its actions are based on a systematic application of the best available science;
3. Strategic in allocating its limited research and monitoring funds;
4. Compelling at communicating the magnitude and nature of the conservation challenges and the strategies proposed to address them;
5. Accountable; and
6. Wide-reaching in informing other agencies and policy makers contributing to greater leadership in the conservation of trust species.

Although from time to time the focus may shift from one element to another, the SHC framework is a continuous iterative process of overlapping elements that occur both sequentially and simultaneously:

1. Biological Planning – Assembling the biological foundation for conserving trust species – including identification of priority species and a subset of focal species; designation of population objectives; and compilation of models that describe expected focal species-habitat relationships;
2. Conservation Design – Applying models to spatial data that culminates in the designation of priority management areas and coarse estimates of the amount of habitat that will be needed to attain a suite of population objectives;
3. Conservation Delivery – Implementing management actions with the goal of efficiently affecting populations;
4. Assumption-driven Research – Evaluating and refining biological planning assumptions; and
5. Outcome-based Monitoring – Assessing the effects of management on habitats and individuals to make inferences at multiple scales that have a bearing on our future management decisions.

Conservation strategies are dynamic suites of objectives, tactics and tools that change as new factors or information influence the system. The very act of doing assumption-driven research and monitoring implies a commitment to continuous refining plans using better information about how a species responds to its habitat and to management actions. Furthermore, external forces operating on habitats, populations and the proposed strategies must acknowledge their effects on the attainment of the objectives.

The SHC framework is designed to promote learning about populations and how they respond to habitat from the process of habitat management. By following the cycle of planning, doing and evaluating described in the SHC framework, the movement toward more reliable management decisions is continuous. The elements of conservation strategies – objectives, tactics, spatially-explicit models of priority areas, monitoring programs, etc. – are all subject to change as new information becomes available or new forces operate on the system. To paraphrase a cliché that is particularly relevant to SHC, “the only thing that’s constant is change.”

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