CHAPTER

An Emerging Agency-Based Approach to Conserving Populations Through Strategic Habitat Conservation

8

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We describe a framework for strategic habitat conservation (SHC) that enables the efficient maintenance of wildlife populations at objective levels through protection of existing habitat, habitat restoration, and habitat manipulation. The conventional model of habitat conservation by fish and wildlife agencies has for many species, at best, slowed the rate of long-term population decline. This is largely due to insufficient conservation resources compared to ever increasing human pressures on natural systems and to insufficient regulatory authorities. We believe that 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 to aid their recovery; and a limited ability to demonstrate the population effects of our conservation actions. Collectively, these factors contribute to a lack of awareness by the public, elected officials, and representatives of other government agencies, which reduces the credibility and influence of wildlife conservation 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 conservation decisions.

Conversely, the SHC approach is planning intense; requires the integration of planning, conservation delivery, monitoring and research; and benefits from inter-agency collaboration and coordination. The approach is essentially a business model, and the concept of a conservation business model is gaining acceptance (Keen and Qureshi 2006). Successful businesses must articulate their purpose, develop products, identify target markets and marketing strategies, and create feedback loops that ensure product quality and continued viability in a competitive environment (Prahalad and Hamel 1990, Drucker 1994, Keen and Qureshi 2006). These elements are developed into a business strategy that includes communication and marketing tools designed to inspire investor confidence. 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. This may be the greatest failing of the traditional conservation paradigm. Even small budget increases are often accompanied by an implicit expectation that perceptible benefits will result. Failure to produce these perceptible benefits reduces public and policy maker (i.e., investor) confidence. Although the general magnitude of the challenge of conserving populations at objective levels may be intuitive to conservation professionals, most of the public and elected officials are lay people who routinely lack this understanding.

For wildlife conservation agencies to be more successful and increase support by the public, it is imperative that these agencies be more explicit about objectives, strategies, and estimated costs of attaining objectives. Furthermore, we believe that wildlife conservation agencies must more fully adopt the role of stewards and purveyors of the biological foundation for conservation, seeking to influence the actions of other government agencies and inform policy makers and public perceptions. We believe that developing and communicating explicit, science-based habitat conservation strategies are critical to building this support and that the concepts we present in this chapter can help remedy current deficiencies.

The framework we describe places models in a useful context of the larger conservation enterprise. It is based on our personal experiences in attempting to meet the information needs of managers in government wildlife conservation agencies, and it is not a synthesis of the extensive literature on theories of conservation biology. Although many of the concepts we describe are well known within the scientific community, their application is still novel within most conservation agencies. As agencies implement this framework, they will be more efficient, transparent, and accountable and ultimately more credible and effective in informing the actions of policy makers and other agencies. We believe that if scientists understand the state of agency-based strategic conservation, they may recognize their role in facilitating it.

AN OVERVIEW OF SHC

We define SHC as an iterative process of, first, setting explicit objectives for populations and systematically figuring out how to achieve them *most efficiently* using agency resources and by working with partners. Or, more specifically, it is a process of developing and refining a conservation strategy, making

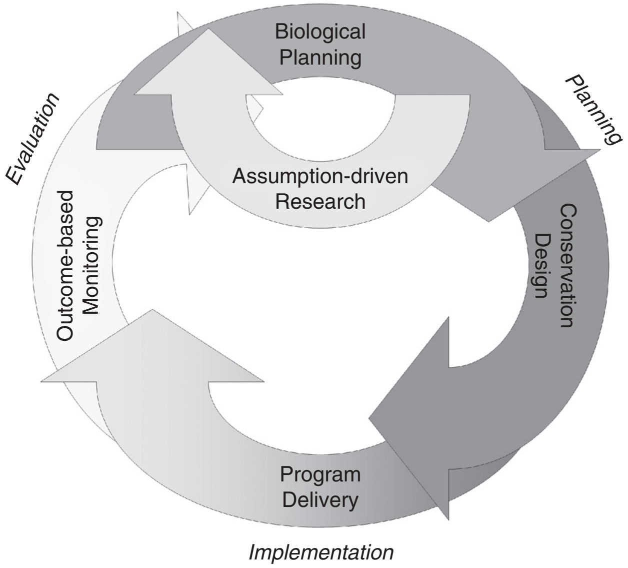

FIG. 8-1

The strategic habitat conservation cycle.

efficient conservation decisions based on that strategy, and using research and monitoring to assess accomplishments and inform future iterations of the conservation strategy (Fig. 8-1). SHC is a form of adaptive resource management (Walters 1986, Walters and Holling 1990, Williams 2003) wherein habitat conservation at multiple spatial scales is the primary form of intervention.

The goal of SHC is to make natural resource conservation agencies more efficient and transparent and, in part, thereby making them more credible and wide-reaching in effect (Johnson et al. 2006). *Conservation efficiency may be thought of as the ratio of population impacts to conservation costs*. Science-based habitat conservation strategies are developed to increase efficiency over random or haphazard conservation delivery. This approach presumes that sites vary in their potential to affect populations in a predictable fashion, and habitat managers are able and willing to prioritize their actions (i.e., operate strategically).

A comprehensive habitat conservation strategy should address the following 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 conservation treatments are available to overcome these limiting factors?

3. Where should we apply these conservation treatments to effect the greatest change in populations at the lowest possible total monetary and nonmonetary costs to conservation agencies and society?
4. How much of a particular type of conservation will be necessary to reach our population objectives (a habitat objective—a minimum estimate, but useful nonetheless for reasons we will describe)?
5. What are the key uncertainties in the answers to questions 1–4 and what assumptions were made in developing the strategy that will guide our research and monitoring activities?

In the case of federal and state fish and wildlife conservation agencies, it is usually most 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 these other functions by applying the same basic concepts.

Efficient conservation requires that agencies strategically apportion their resources at broad scales. This commonly means that agencies must undertake SHC in multiple regions, since the relationship of a species to its habitats is likely to vary among major ecoregions. Strategic habitat conservation will be more efficient when it is applied to ecoregions 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. Conducting SHC within ecologically based regions such as Bird Conservation Regions (U.S. Fish and Wildlife Service 1999; Sauer et al. 2003; Fitzgerald et al., this volume) is a logical way to apply SHC across a state, country, or continent.

SHC TECHNICAL ELEMENTS

We focus on the technical elements of SHC—*biological planning*, *conservation design*, *assumption-driven research*, and *mission-based monitoring* (Fig. 8-1). These elements are not a rigid, linear sequence of events (Fig. 8-2). Biological planning, conservation design, and research and monitoring blend together in an iterative process. However, the process achieves its full value only when all five elements, including conservation delivery (Fig. 8-1), are in place.

Biological Planning

Biological planning is the systematic application of scientific knowledge about species and habitat conservation. It includes articulating measurable population objectives for selected species, considering what may be limiting populations to

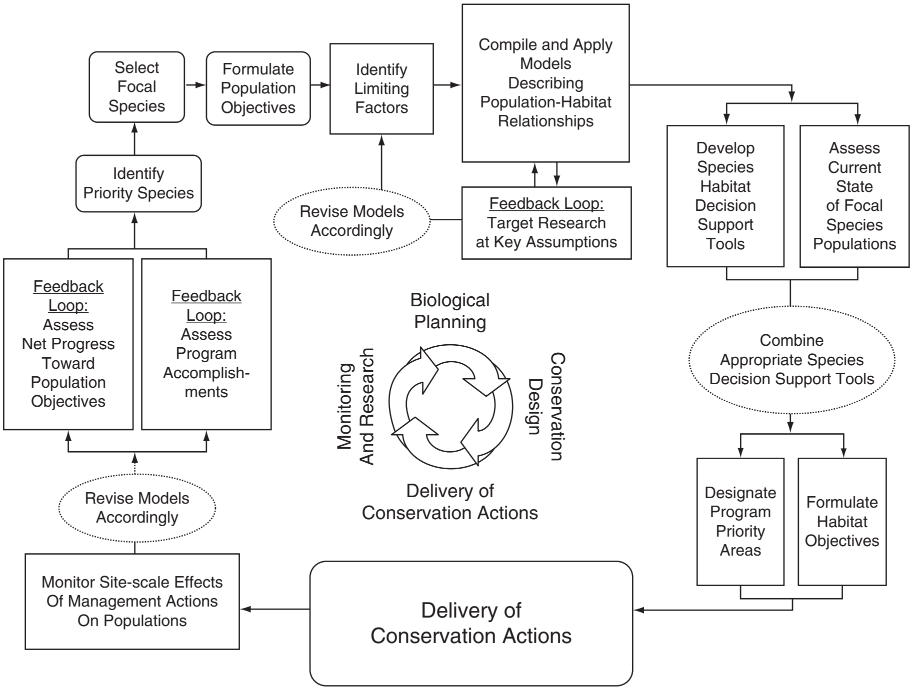

FIG. 8-2

Important elements in the iterative, strategic habitat conservation approach to conservation.

less than objective levels, and compiling models that describe how populations are expected to respond to specific habitat conservation actions.

Select Focal Species.— Strategic habitat conservation is focused on priority species whose populations are at less than desired levels. Ideally, we would model species-habitat relationships and spatial patterns in conservation potential for every priority species. The use of focal species, however, is usually necessary because trying to integrate information about too many species representing key ecological processes can become overwhelming.

Focal species are used as surrogates for the needs of larger guilds of species that use habitats and respond to conservation similarly (Noon et al., this volume); however, focal species may be more sensitive to patch characteristics, landscape context, or habitat conservation (Lambeck 1997, 2002). Other focal species may have unique habitat needs (e.g., some threatened and endangered species) or may be keystone species and therefore important determinants of ecosystem function (Mills 2007). Hagan and Whitman (2006) provided a valuable overview of the use of indicator species. They recommended selecting 5–15 species that are sensible indicators of the ecological communities and processes stakeholders value most. Of course, the assumption that other species and ecological processes will respond as predicted to habitat conservation for focal species must be evaluated (Lambeck 2002).

Lambeck (1997, 2002) and Lindenmayer et al. (2002) suggested that the use of multiple focal species will typically be more satisfactory than the use of a single umbrella species. 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, socioeconomic, programmatic, or political reasons. One useful method for selecting focal species may be to start by assigning species to guilds based on their basic habitat needs and response to conservation. One or more focal species may be selected from each guild (Appendix A).

Because one outcome of SHC is an objective for each general habitat type, it will often be important to also select focal species with large enough population objectives to ensure 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 U.S. Fish and Wildlife Service (USFWS) may be better served by selecting focal species that help us make better decisions about managing our trust resource responsibilities. Likewise, partners may select the focal species that best meet their needs. This does not preclude a continuous dialogue with partners, but agencies with different trust responsibilities plan separately for focal species and *then* integrate the outcomes of the biological planning processes.

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

If an agency *was* simply to conserve habitats, an objective like "restore 5,000 ha of wetlands in the Great Lakes ecoregion of the United States each year" might be adequate. However, an activity-based objective like this does not promote accountability because no explicit relationship has been established between the habitat objective and the mandate to conserve populations. It is 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 explicit predictions for the public or policy makers about the consequences of succeeding or failing to attain the objective.

Strategic habitat conservation is founded on objectives expressed as desired population states, such as "maintain an average annual capacity to produce 1.7 million duck recruits per year in the Great Lakes ecoregion of the United States." These are "mission-based objectives." Efficient attainment of a mission-based objective requires that we know the current state of the system relative to the objective, make informed assumptions about environmental factors that are limiting populations below objective levels, determine where and how conservation can most effectively remediate these limiting factors, and monitor population state relative to the objective. Furthermore, we acknowledge that site and landscape-scale factors interact to affect the population impacts of conservation. Thus, *where* we deliver conservation is an important determinant of *how much* habitat is required to sustain populations at objective levels.

Population objectives may be more useful if they are composed of desired abundance and a performance indicator. For convenience, we will refer to these as P_1 and P_2 subobjectives, respectively. Examples of hypothetical population objectives might be

1. Maintain a population of 1250 moose (*Alces alces*) (P_1) in northwestern Minnesota with a mean annual calf:cow ratio of 0.84 (P_2);
2. Increase king rail (*Rallus elegans*) density 300% (P_1) at marsh bird survey sites and maintain a mean annual nesting success of 60% (P_2) in the southeastern coastal plain ecoregion; or
3. Maintain 25 distinct stream segments (P_1) with stable or increasing (P_2) breeding populations of lake sturgeon (*Acipenser fulvescens*) in Michigan.

In each case, the P_1 subobjective enables us to estimate how much habitat we need to conserve based on model-based abundance estimates, or where information on a species is more limited, predictions of relative habitat suitability, territory size, or average density in suitable habitat. Above minimum viable population sizes, P_1 subobjectives are value-based expressions of how many individuals of a species we want, or, more accurately, that we believe the public wants and will support. Ecoregional-scale P_1 objectives should be stepped down from range-wide objectives when these broad-scale goals exist; doing so links local conservation actions to state, national, or continental strategies and vice versa.

P_2 subobjectives, which are commonly vital rates, describe how we want to affect the population. If we believe that some habitats yield higher productivity or density than others, the P_2 subobjective should help us decide how to configure or treat the habitats we conserve. In practice, it will often be necessary to express P_2 subobjectives as assumptions about the effects of conservation.

Although vital rates are notoriously difficult to estimate, monitoring both P_1 and P_2 subobjectives paints a much clearer picture of how we are influencing focal species populations and ecological function than we would get from monitoring abundance alone because estimating short-term trends from annual abundance data often requires unrealistically intensive monitoring. For some species, P_1 and P_2 subobjectives may be combined, as in the previous Great Lakes duck example, in terms of number of recruits produced, rather than a P_1 subobjective for number of a breeding pairs and a P_2 subobjective for recruitment rate.

Identify Limiting Factors and Appropriate Conservation Treatments.— The purpose of habitat conservation 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, pp. 110–111). One purpose of SHC is to identify areas where these limiting factors can be most efficiently alleviated, i.e., areas where potential population impacts are relatively high, conservation 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 forests 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 we understand the limiting factor, several potential conservation treatments designed to increase recruitment or survival may be considered:

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

Generally, one or two conservation 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 conservation 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 ecoregion 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 SHC is the application of models to spatial data to target specific conservation treatments. Models are simply a means of organizing our science to aid in understanding how a system functions by expressing real relationships in simplified terms (Starfield and Bleloch 1991; Millspaugh et al., this volume).

Whether aware of it or not, almost all managers use models to predict the probable outcomes of applying a particular conservation practice at a particular site. The difference between this intuitive approach to modeling and the more deliberate use of models in SHC is that, in the latter, models are stated in explicit, 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 how confident we should be about our predictions; and
   - **b**. Target critical uncertainties with research to make future predictions more reliable;
3. Models may be used to report accomplishments expressed as estimated population effects.

Model predictions must be expressed in the same terms as population objectives to (1) estimate the amount of habitat conservation necessary to attain population objectives; and (2) to 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 SHC. 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 our hypothetical focal species of forest breeding bird example, we believe that 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* requires that we use models that describe the relationship between the ratio of perimeter:area and recruitment rate (Fig. 8-3). In this example, we see that after the perimeter:area ratio exceeds 0.1 (about 50 ha for a square patch, larger for irregularly shaped patches), further increases in recruitment rate begin to slow down. We have reached the point of diminishing returns. A strategic approach to attaining our objectives, as informed by this model, would indicate that once we have reached a ratio of 0.1, we should move on to a new patch rather than continue to make the same patch bigger and bigger for less and less additional benefit.

The value of a model is measured by the extent to which it adds useful information to the conservation of focal species. Generally speaking, as model

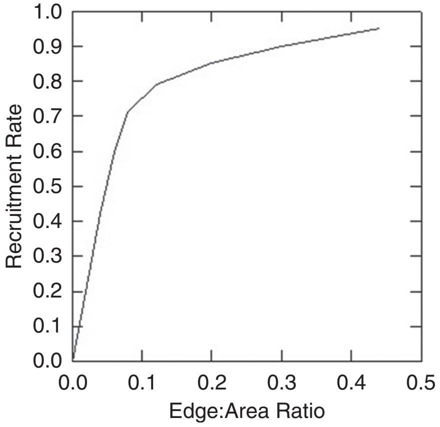

FIG. 8-3

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

complexity goes up, so does the added value for decision making because model predictions move beyond our capacity for intuition. Advances over the past two decades in spatial data management enable depiction of complex multidimensional biological models in two-dimensional (map) form that contribute to a better understanding of how conservation potential varies among landscapes. However, models and the maps derived by applying them to spatial data have inherent uncertainties that should be explicitly acknowledged, but this is rarely the case. Burgman et al. (2005) recommended using multiple competing models in pursuit of robust conservation strategies that are likely to result in tolerable outcomes, despite uncertainties.

Numerous types of models are described in this book. We describe the most basic dichotomy among types of models as data-based (empirical) and experience-based (conceptual) models. Niemuth et al. (this volume) present empirical models for breeding duck access to grasslands, sora (*Porzana carolina*) use of wetlands, and empirical and conceptual models for marbled godwits (*Limosa fedoa*).

Both empirical and conceptual 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. 8-4). 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 conceptual modeling like that for marbled godwits in Niemuth et al. (this volume) is useful for predicting relative apparent habitat suitability, the outcome of estimating abundance using a purely conceptual approach would be less certain. However, if apparent habitat suitability is all we are able to reliably predict, we may still

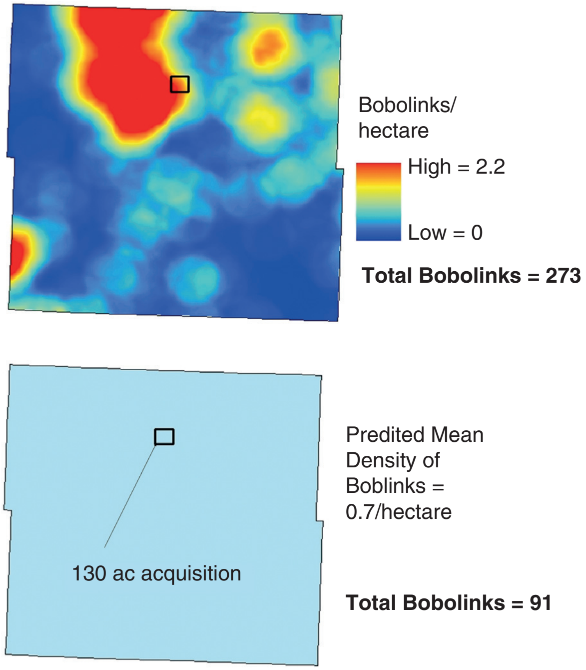

FIG. 8-4

The predicted relative abundance of bobolinks (*Dolichonyx oryzivorus*) in Grant County, Minnesota, assessed for 1 ha pixels (top) and at a county scale (bottom) and a hypothetical 52 ha grassland acquisition. County or large watershed-scale assessments make the unreasonable assumption that the entire area has homogeneous conservation potential.

predict abundance using empirically derived average density estimates from "suitable" versus "unsuitable" or "less suitable" sites.

Estimating the effects of habitat conservation on population vital rates is an ideal that is presently impossible for most species because appropriate data for model development do not exist. However, models could be constructed to estimate probability of occurrence, relative abundance, or habitat suitability for most species although many would have to be experience-based and may contain untested assumptions.

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 we manage habitat. 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, we propose the use of the phrase "spatially explicit models" (SEMs) in lieu of maps to emphasize that developing and applying models relating a species to limiting habitat factors is the essence of SHC.

Assess the Current State of the Ecosystem.— A conservation strategy is a route between the current state of the system and the objective 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 area of habitat.

Develop Species-Specific SEMs.— Spatially explicit models will generally be specific to a focal species and a conservation treatment that affects that species (e.g., targeting a particular conservation 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. Conservation treatments, therefore, include strategic grassland restoration on sandy sites (away from roads) and road signage placed around known or suspected populations. In this situation, an 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. Spatially explicit models 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.

The resolution of SEMs should match or be smaller than the scale at which conservation occurs. Maps of large geographic units like counties or major watersheds may be deceptive because they implicitly include the unreasonable assumption that conservation 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 conservation outcomes). The geographic units assessed using models and portrayed in SEMs should be small parcels that more or less match, or are finer than the typical scale of conservation (i.e., as fine as possible but generally <256 ha) (Fig. 8-4).

Spatially explicit models typically include an assessment of the potential of every part of the ecoregion 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 managers typically only deal with willing landowners, and it is not always possible to limit conservation to the highest priority sites; and a conservation action with a lower predicted biological impact may still be efficient if costs are low enough.

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 conservation. For example, grassland habitat objectives for an ecoregion 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 hectares to be restored and placed in the conservation estate. In theory, if we know the capacity of every hectare to contribute toward our population objective for each focal species, we can simply tally up the smallest area (cost per ha 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 we make up the conservation deficit and attain our population objectives depends on our ability to act strategically by operating at sites with the greatest potential to affect each focal species' populations and reconcile potential management conflicts. Because managers cannot typically work exclusively within the highest priority sites, estimates of the amount of habitat needed to attain our population objectives will likely be underestimates. Nonetheless, explicit habitat objectives based on population-habitat relationships enable us to convey to policy makers and stakeholders the extent of actions required to conserve populations. While some deviation from our strategy is inevitable, close adherence to it by limiting our conservation actions to high-priority sites will help ensure that our habitat objectives, while minimal, come close to providing the anticipated population response. Timely adjustments to habitat objectives can be made based on recent conservation accomplishments, new scientific information, and other influences on habitat due to policy changes and socioeconomic factors.

Designate Priority Areas.— Priority areas can only be delineated in the context of explicit objectives. "Show me the best areas for conservation" is not a satisfactory question on which to base conservation assessment. Because 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 conservation potential to affect species X" and "Show me the set of sites with the greatest aggregate potential to affect species X, Y, and Z" are more appropriate questions.

Multiple species-specific 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 propagate in the overlay process and because not all species that could occur at a site have compatible habitat needs or responses to site scale management (e.g., burning). Before combining SEMs, we need 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.

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 by 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 conservation). Optimization models have been used to select areas for conserving species richness or the occurrence of selected species and to factor in costs associated with acquisition or management (see Flather et al., this volume; Haight and Gobster, this volume), but potentially could be used to select areas to meet population objectives for a group of focal species.

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 conservation have little utility at the pixel, patch, or local scales at which conservation actions actually occur. Instead, conserving biodiversity requires balancing the area and configuration of habitats needed by the full array of species within an ecoregion. 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 conserve and manage tracts such that ecoregional biodiversity is conserved, 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, SHC is founded on being explicit, measurable, and communicable. Unless a measurable and universally acceptable definition of biodiversity can be developed, it cannot 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 conservation potential. Maps of species richness are easy to produce using modern geographic information system techniques. Species richness maps are commonly based on data such as range maps or species occurrence. Abstract goals such as maximizing species richness at patch scales are inappropriate, as 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 more narrowly defined purpose when they are established. 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. We have the following concerns about maps of species richness as they are commonly portrayed:

1. Occurrence data are notoriously subject to errors, particularly errors of omission (e.g., 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; there are normally no benchmarks against which to assess accomplishments;
3. The approach makes limited use of the biological foundation available for many species including factors that are limiting populations and thus
    a. Provides little information about how and where conservation can be effectively used for species recovery, especially using habitat restoration;
    b. Provides no means of estimating conservation effects on populations, which is critical for targeting conservation 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. Conservation compatibility is often not explicitly considered. 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 conservation decisions are routinely implemented. The implicit message is that habitat conservation anywhere within a large 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 SHC. Nevertheless, 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 biological planning and conservation design, 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 conservation 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

Although our knowledge of ecological systems will always be incomplete, agencies must still make conservation decisions using the best information to guide their actions. Models force us to make assumptions about limiting factors and their effects on populations, and this highlights uncertainties in the biological foundation for conservation. The advantages of an iterative process of SHC are two-fold with respect to reconnecting management and science. On one hand, the overall process is a systematic means of applying the existing, albeit incomplete, biological foundation about how species relate to habitats and management at local and landscape-scales. However, science is primarily a means of learning. The scientific method is founded on articulating hypotheses (assumptions in the planning process) and then setting out to try to disprove them (evaluation through research). Without monitoring and research, SHC is not an iterative process by which managers learn and increase their effectiveness.

Assumption-Driven Research.— Not all assumptions made in biological planning are equally important. Two important criteria for evaluating assumptions are (1) how uncertain is the assumption, and (2) to what extent would better information affect conservation 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.

Assumption 1: Soybeans are a preferred habitat for greater prairie chicken broods.

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

Scenario 3**—**Dabibling duck daily nest survival rates have been shown to 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).

Conclusions: Considerable uncertainty and considerable value of better information because millions of dollars are spent annually to protect grassland for upland nesting ducks, 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 benefits to conservation of obtaining better information. Assumption 3 may be restated as at least four competing hypotheses (Fig. 8-5):

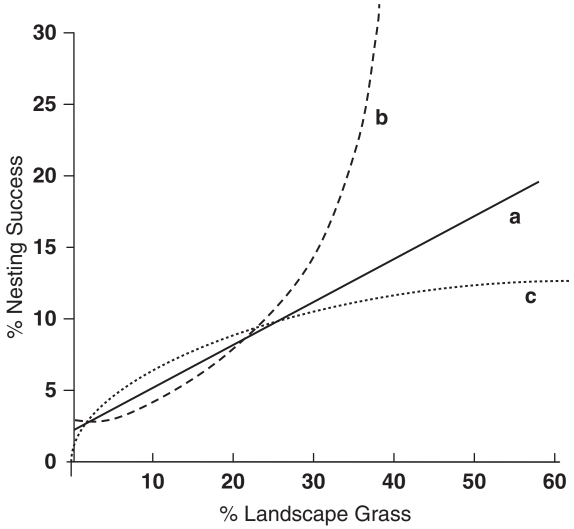

FIG. 8-5

Alternative relationships that describe a general trend of increasing waterfowl nesting success with increasing amounts of grass in a 3.2 km radius landscape. Each implies the need for a different grassland restoration strategy.

H_O: Nesting success and percent grassland are independent;

H_{A1}: Nesting success and percent grassland are positively and linearly related (the current assumption);

H_{A2}: Nesting success and percent grassland are positively related but the relationship is exponential; and

H_{A3}: Nesting success and percent grassland are positively related but the relationship is nonlinear and reaches an asymptote at about 40% grassland in the landscape.

If you are working exclusively within landscapes with <25% grasslands, the value of better information is minimal because all three hypotheses predict similar nesting success. However, the implications of obtaining better information about this relationship when working in landscapes with 25% or more grassland are huge. If the relationship is linear (curve 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 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 25–40% grassland. Above 40% 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 (H_O) cannot 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, we are targeting mission-critical research, not simply indulging our 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 in the iterative SHC framework.

Outcome-Based Monitoring.— Conservation agencies should evaluate their actions based on (1) the effects of specific conservation actions on habitats and individuals; (2) program and agency accomplishments expressed in terms of population impacts; and (3) net progress toward population objectives.

Assessing the Effects of Conservation Actions.— To evaluate whether conservation actions have the predicted consequences, we need to monitor actual outcomes. For example, did the conservation 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 we compare observed and predicted population response at the site scale and refine our models of species-habitat relationships. This means that monitoring programs should be structured around the same ecoregions as biological planning to ensure efficient model updating. It may not be necessary to monitor the outcome of every conservation action, but monitoring outcomes with repeated counts at a valid sample of sites is essential.

Assessing Program and 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 short-term environmental variations. Consequently, except for intensive sampling to assess long-term trends, actual counts of individuals often have little utility for assessing annual accomplishments. Rather than using highly variable counts of individuals, we can use models used to target conservation actions to estimate population impacts of conservation that actually occurred (Fig. 8-6). The sum of the estimated impacts of each individual conservation action is an agency's

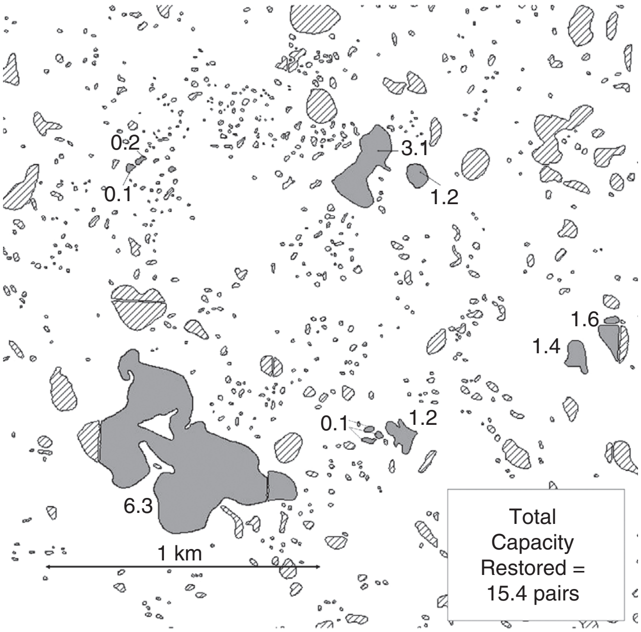

FIG. 8-6

Models, such as regression models, which can predict numbers of breeding ducks (Neimuth et al., this volume) can be used to target habitat conservation practices such as wetland restoration. They can also be used to estimate accomplishments in terms of population impacts. Crosshatched features are drained wetlands, solid features are restored wetlands, and numbers are the predicted increase in capacity to support breeding pairs in a 10 km^2 western Minnesota landscape.

accomplishments in accordance with the science built into the models. In other words, population monitoring at a sample of sites used to assess the effects of conservation actions is used to indirectly assess accomplishments, with model refinement and estimation as the intermediate step. This approach to accomplishment reporting has two important implications:

1. Managers should report their annual accomplishments in terms of predicted aggregate population effects. Overall program and agency accomplishments are the sum of the output of individual managers; and
2. Program and agency accomplishments will be expressed in the same terms as mission-based population objectives.

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 socioeconomic or long-term environmental factors than by agency accomplishments. Just like assessing agency accomplishments, assessing net progress toward population objectives is a model-driven process. Essential field data collection consists of site-scale data on species response to habitat codified in models, as noted previously; and ecoregional, 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. Continued broad-scale surveillance monitoring of populations is still warranted, because if model-based predictions do not match observations of species status or trends, it is likely that an important limiting factor has been overlooked.

CONCLUSIONS

We believe that SHC can make conservation planning

1. More efficient at habitat conservation because of the ability to estimate biological benefits relative to conservation costs;
2. More transparent and defensible because actions are based on a systematic application of the best available science;
3. More strategic in allocating limited research and monitoring funds;
4. More compelling at communicating the magnitude and nature of the conservation challenges and the strategies proposed to address them;
5. More accountable;
6. More wide-reaching in informing agencies and policy makers, contributing to greater leadership in the conservation.

Although from time to time the focus may shift from one element to another, SHC is a continuous iterative process of overlapping elements that occur both sequentially and simultaneously: biological planning, conservation design, conservation delivery, assumption-driven research, and outcome-based monitoring. 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 replanning using better information about how a species responds to its habitat and conservation actions. Furthermore, external forces operate on habitats and populations, and our strategies must acknowledge their effects on the attainment of our objectives. The SHC framework is designed to promote learning about populations and how they respond to habitat. By following the adaptive cycle of planning, doing and evaluating, and replanning described as SHC, we continuously move toward more and more reliable conservation decisions. 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.

SUMMARY

We described a framework for strategic habitat conservation (SHC)—biological planning, conservation design, conservation delivery and monitoring, and research—that enables efficient conservation of wildlife populations. Strategic habitat conservation is gaining greater acceptance among conservation agencies that historically tended to manage habitat opportunistically, often without regard to site and landscape heterogeneity and the magnitude of potential population responses. We described the basic elements of SHC as they are being communicated within and among agencies, including most importantly establishing explicit, outcome-based objectives and the use of models relating populations to limiting habitat factors. Although many of the concepts we described are well known within the scientific community, their application is still novel within most conservation agencies. We believe that as agencies implement this framework, they will be more efficient, transparent, and accountable and ultimately more credible and effective in informing the actions of policy makers and other agencies. We present this chapter with the expectation that if scientists understand the state of agency-based strategic conservation, they may recognize their role in facilitating it.

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APPENDIX 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 (represented by letters) 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 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 five 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.