Measuring the Results of Wildlife Conservation Activities

The H. John Heinz III Center For
Science, Economics and the Environment

The Heinz Center

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Table of Contents

Executive Summary

This report has been written to provide state wildlife agencies and their partners in the United States with a suite of tools and approaches that can be used to develop performance measures for the new State Wildlife Action Plans. The recommendations in this report draw from existing bodies of knowledge and practice, including ecosystem monitoring and programmatic evaluation. The tools and approaches contained in this report are broadly applicable to other areas of wildlife management and natural resource conservation.

Key findings and recommendations

1) Evaluating the performance of wildlife conservation activities described in the State Wildlife Action Plans will require evaluation and monitoring activities at multiple levels (field, program, and statewide) and geographic scales. Techniques and approaches for monitoring will likely differ across scales and levels, as will the specific monitoring targets and the types of data that are collected. The approaches that are actually implemented should be driven by the information needs of wildlife managers, key decision-makers, and the interested public.

2) There is an emerging consensus among experts and in the literature on the steps that should be taken to develop performance measures for wildlife management activities. These steps include, in order:

- Identify conservation targets (species, ecosystems, geographic areas, or vegetative communities);
- Develop a conceptual model that relates conservation targets to stressors or threats, as well as conservation activities;
- Use the model to select potential indicators of target status and conservation effectiveness;
- Develop a monitoring program to measure and track indicators;
- Implement conservation activities, measuring indicators to track progress; and
- Use information from the indicator measurements to modify activities and adjust the conceptual models.

3) Simple conceptual models such as "logic models," "causal chains," or "results chains" can be useful tools for wildlife managers. These models enable managers to clearly articulate their understanding of how management actions will lead to desired conservation outcomes, and may also help suggest intermediate or "proxy" indicators for projects where the full environmental benefits might not be detected for years or even decades.

4) Monitoring and assessment at the state or regional level are probably most tractable using "coarse filter" measures (i.e., landscape-scale habitat metrics), especially if resources for monitoring and evaluation are limited (as is currently the case with many State Wildlife Action Plans).

Each State Wildlife Action Plan describes key "habitats" for wildlife in a particular state or territory. In many cases these "habitats" correspond to vegetative communities, ecoregions, or other geographic areas that can be mapped using tools such as Geographic Information Systems (GIS) software and remotely sensed imagery. At a minimum, states should monitor the extent of these areas on a regular basis, and track the amount of key "habitat" that is currently in some form of conservation management. Other landscape-scale metrics such as degree of fragmentation and habitat patch size may also be useful for monitoring wildlife habitats at a state level.

5) "Fine filter" (i.e., species-level) measures are easily understood by the public and decision-makers. However, outside of certain popular groups such as game species and breeding birds, very few wildlife species in the U. S. are monitored with sufficient frequency or rigor to provide reliable estimates of population status and trends over time. It will require significant new resources to design and implement new monitoring programs, especially for rare or uncommon species. Given these resource limitations, we suggest that states carefully select a small subset of species for in-depth monitoring, and work with existing monitoring programs (e.g., Breeding Bird Survey, federal programs for endangered species) whenever possible.

We suggest using a simple pie chart, which we call the "species trend chart" to summarize the direction of population trends for multiple species of conservation interest within a particular state. The pie chart reports the percentage of species in a particular state that are declining, stable, increasing, extinct/extirpated, or with population trend unknown. Similar charts can be used to present the percentage of key "habitats" that are in different management categories (conservation management, other public lands, developable private land, and lost) and to present trends in the extent of these "habitats" (increasing, stable, declining, or lost).

IMPORTANT POINTS TO REMEMBER

- Monitoring programs for wildlife and ecosystems can be costly and complex, but need not be.
- Simple metrics are available that show progress towards addressing the key goals (habitat and species conservation) of the State Wildlife Action Plans.
- It's better to monitor a few things well than many things poorly.
- It may be more feasible to monitor changes in vegetation or ecosystem extent over time, using remote sensing imagery, than to monitor population trends across numerous species.
- Individual wildlife species often have broad popular appeal but it may be difficult to obtain reliable estimates of population size and other important demographic or population parameters.
- There is nothing wrong with selecting monitoring targets for a State Wildlife Action Plan that are well known or for which monitoring programs already exist.
- Once a conservation target has been selected, simple models ("system models" or "logic models") can be helpful in selecting appropriate management indicators.
- Simple models can also help to identify priority conservation actions, by showing how these activities would affect a conservation target (species or ecosystem).
- Consult with federal agencies, other state agencies, and academia in designing a new monitoring strategy. Most likely, monitoring protocols and even monitoring data are already available from other sources.

Chapter 1: Introduction

State and federal wildlife agencies in the United States spend millions of dollars every year on projects that are intended to benefit wildlife species and their habitats. How do we know whether or not these conservation measures are working? This deceptively simple question has been the subject of considerable discussion and debate in recent years. Standard measures of success such as the number of acres protected or the number of acres restored have been roundly criticized, due to the fact that these measures cannot always be clearly linked to changes in wildlife populations. Yet many wildlife agencies lack the funding and personnel needed to develop sophisticated new monitoring programs that could actually track the effects of specific conservation actions on individual wildlife populations. New approaches for monitoring and evaluation are clearly needed. Fortunately, many new tools and techniques have been developed in recent years that can help wildlife managers determine whether or not their activities have been effective. This report reviews current practices and procedures for developing performance measures for wildlife management activities, with a particular focus on activities related to the direct conservation of wildlife species and their habitats.

Context

Our intent in collecting and publishing this information has been to assist the states and territories of the United States in developing performance measures for the new Comprehensive Wildlife Conservation Strategies (also known as State Wildlife Action Plans). In the United States, ownership and title to wildlife are vested in the individual states, and thus many of the most important activities related to wildlife management and biodiversity conservation take place at the state government level. Each state and most U.S. territories have established a wildlife agency for the express purpose of managing and conserving wildlife within the state's boundaries. These agencies have traditionally focused on managing sport fish and game species, although endangered species have also become an important part of the wildlife management portfolio in individual states over the past 30 years. In addition, many states have developed active "non-game" or "natural heritage" programs that seek to conserve and manage a broad diversity of wildlife species.

In 2000, the U.S. Congress directed each state and territory to develop a strategic document that describes methods and approaches for conserving a broad range of biological diversity within the state boundaries. These documents, known as Comprehensive Wildlife Conservation Strategies or State Wildlife Action Plans, were developed by a coalition of state agency staff in partnership with wildlife experts from academia, non-profit organizations, and industry. The 56 plans (one for each state and territory, and the District of Columbia) were reviewed and approved by the U.S. Fish and Wildlife Service in 2006. The intent in developing these documents was to characterize the wildlife species of conservation need within a state, identify key habitats for these species, identify threats to species and habitats, and outline strategies for ameliorating the threats and conserving the species and habitats. In authorizing the preparation of these plans, Congress required each state to include eight common elements:

1. Information on the distribution and abundance of species of wildlife, including low and declining populations as the state fish and wildlife agency deems appropriate, that are indicative of the diversity and health of the state's wildlife; and,
2. Descriptions of extent and condition of habitats and community types essential to conservation of species identified in (1); and,
3. Descriptions of problems which may adversely affect species identified in (1) or their habitats, and priority research and survey efforts needed to identify factors which may assist in restoration and improved conservation of these species and habitats; and,
4. Descriptions of conservation actions proposed to conserve the identified species and habitats and priorities for implementing such actions; and,
5. Proposed plans for monitoring species identified in (1) and their habitats, for monitoring the effectiveness of the conservation actions proposed in (4), and for adapting these conservation actions to respond appropriately to new information or changing conditions; and,
6. Descriptions of procedures to review the plan at intervals not to exceed ten years; and,
7. Plans for coordinating the development, implementation, review, and revision of the plan with federal, state, and local agencies and Indian tribes that manage significant land and water areas within the state or administer programs that significantly affect the conservation of identified species and habitats.
8. Broad public participation is an essential element of developing and implementing these plans, the projects that are carried out while these plans are developed, and the species in greatest need of conservation.

Congress also directed that the plans must identify and be focused on the species in greatest need of conservation, yet address the full array of wildlife and wildlife-related issues (Association of Fish and Wildlife Agencies 2006).

Broader Implications

Although this report is specifically intended to address the monitoring and performance measurement issues associated with the State Wildlife Action Plans, we recognize that much of the information gathered here may also be of more general interest to wildlife managers and other natural resource professionals. We offer this report to the broader natural resource management community, in the hopes that it may benefit managers who are dealing with complex, real-world management situations where optimal strategies for measuring wildlife populations and habitats are not feasible. We would also encourage the broader community of natural resource managers to consult the State Wildlife Action Plans and review the implementation priorities contained in these documents. Other natural resource managers can also play a key role in collecting information that will help to effectively implement the recommendations contained in the State Wildlife Action Plans.

In preparing this report, we acknowledge that the subject of performance measurement has been a topic of considerable interest and discussion among wildlife professionals for some time. Even the most cursory review of the wildlife management literature shows that there are already numerous journal articles, manuals, and books that have been published on this subject, many of which are aimed specifically at wildlife and natural resource managers (e.g., Holling 1978; Walters 1986; Margoluis and Salafsky 1998; Groves 2003). Given the wealth of information that is already available, we frankly wondered whether this project would have anything new to contribute to the ongoing discussion.

Early conversations with wildlife managers suggested that there was still room for such a contribution. In January 2007, staff from The Heinz Center met with a group of wildlife managers who were struggling to develop and implement performance measurement schemes for wildlife conservation programs at state and regional levels. Many of these managers were familiar with techniques and approaches that are commonly used to monitor individual wildlife species; however, this formal training was insufficient to address the particular set of challenges that these managers were confronting, including:

- An expectation that there will be demonstrable "results" from wildlife conservation activities, and, more specifically, results that can be measured on an annual basis;
- A lack of existing monitoring programs and data on status and trends for many wildlife species and biological communities that are of conservation interest;
- Insufficient resources to develop new monitoring programs for more than a handful of species; and
- An interest from funding agencies in seeing funds dedicated to "on the ground" projects that restore or protect key habitat areas, rather than to existing or new monitoring programs.

These challenges understandably constrain the ability of wildlife managers to track their own activities and performance, as well as their ability to report on their accomplishments to legislators and funders.

Given this context, we decided to focus this report not on "what to measure," but on the question of "how to develop measures" under the specific conditions of these resource constraints. The report therefore differs from much of the monitoring literature in that there are very few descriptions of specific monitoring protocols. There already is a substantial body of primary and secondary literature that describes best available practices for measuring or monitoring wildlife populations, habitats, and ecosystems. Many of the practitioners and managers with whom we spoke are quite familiar with this information. A real challenge is that there are a very large number of environmental attributes that could potentially be measured in a rigorous monitoring and evaluation program. Given that resources for monitoring and evaluation are usually quite limited, only a few targeted resources can be measured well enough to provide data with sufficient confidence and accuracy to inform management decisions. This means that managers must choose a few key "indicators" or environmental attributes to measure, and must choose them with great care.

In the chapters that follow, we discuss a variety of methods and tools that may be helpful to practitioners who are under pressure to develop performance measures, but who also are operating under severe resource constraints. The basic steps for developing and selecting monitoring targets are described here, and specific examples are provided of environmental indicators or attributes that could be monitored at local, state, or regional scales. We hope that these presentations will serve as useful tools for wildlife managers working at a variety of scales and levels.

Why Measure?

We live in a performance-driven society, where individuals, businesses, governments, and social service organizations are all routinely subjected to performance assessment and evaluation. The practice of managing wildlife is certainly not exempt from this broader trend. Indeed, state and federal legislators, government agencies, and private funders are increasingly asking wildlife professionals to explain how – or whether – their management activities have led to demonstrable, measurable improvements in ecosystems or animal populations.

As any wildlife manager knows, answering even the most basic questions about the results of management activities can be surprisingly difficult (Walters 1986; The Wildlife Society 2002). Most management activities are not designed as controlled experiments to establish rigorously cause-and-effect relationships between management actions and wildlife responses. Without an experimental design, a manager is confronted with seemingly endless confounding factors that make it hard to say for certain whether observed changes in wildlife populations are the result of any particular management action. One of the most problematic of these factors is the time lag that often occurs between management activities and wildlife population responses. The time lag makes it difficult to measure results on annual or quarterly time scales, as is often required by agency reporting programs. To further complicate matters, existing monitoring programs for rare species or game species are seldom set up to provide data at frequencies or spatial scales that would be necessary for measuring the performance of specific management actions.

Wildlife managers are not the first group of professionals to encounter these kinds of challenges. Similar problems are shared by practitioners in the social service, business, and health care sectors (Fazey et al. 2004; Pullin and Knight 2001; Stem et al. 2005; Trochim 2006). These fields share certain commonalities with wildlife management – the complexities of the populations with which they work; a desire to commit resources toward "actions" rather than toward monitoring programs and evaluations; the difficulty of linking small-scale actions to the desired "big picture" results; and the challenge of rigorously evaluating project and program outcomes on very limited monitoring budgets.

In response to these common problems, a new science of programmatic evaluation has developed in recent years (Fazey et al. 2004; Kleiman et al. 2000; Salafsky et al. 2002; Stem et al. 2005; Trochim 2006). This science uses simple tools and simple models to select "indicators" that can be measured in efforts to track the progress of an organization's activities.

The focus of evaluation science is on improving the ability of an organization or agency to do its work: as defined by the American Evaluation Association, "Evaluation involves assessing the strengths and weaknesses of programs, policies, personnel, products, and organizations to improve their effectiveness" (http://www.eval.org/aboutus/organization/aboutus.asp). In the context of biodiversity conservation, evaluation science offers a structure and a framework measuring results and accomplishments, as well as for sharing successful strategies.

This report has been written to help wildlife managers become more conversant in this new science and its methods. There are good reasons for adopting an evaluative perspective: managers can use evaluation techniques to document and demonstrate their successes, and to understand and learn from projects that do not succeed. In addition, managers who pre-emptively adopt evaluation procedures will be well positioned to answer questions from their agencies or organizations, funders, and the general public about the effectiveness of their conservation work.

Adopting an evaluation perspective means that wildlife professionals may need to think in new ways about conservation activities: clearly defining the logical steps between activities and big-picture goals, linking each of these steps to potential indicators and metrics, and selecting a small suite of metrics (from among the many that are possible for each project) that most effectively and efficiently measure accomplishments. Another important element of this new thinking involves a careful consideration of the existing programs that monitor wildlife populations. Some data from these programs are useful or relevant to performance measurement, while other data are not. Although monitoring has long been recognized as an important aspect of wildlife management, many of the existing monitoring programs have not been set up in a way that will enable managers to test whether their activities are related to changes observed in wildlife populations.

A question that has come up repeatedly in our conversations with wildlife managers is whether or not the recent focus on evaluation is simply a fad, or whether it is going to become an established aspect of doing business. While it is hard to predict the future, there are a number of signs that suggest that evaluation and performance measurement requirements are here to stay. The Government Performance and Results Act of 1993 (GPRA) requires all federal agencies to track their performance and to report their progress towards achieving meaningful goals. This requirement applies to all of the federal agencies that work closely with state wildlife managers. The Program Assessment and Rating Tool (also known as PART), originally developed as part of the implementation of GPRA, is being applied by the White House Office of Management and Budget to all federal programs dealing with wildlife, including programs under the U.S. Fish and Wildlife Service, NOAA National Marine Fisheries Service, U.S. Forest Service, U.S. Natural Resources Conservation Service, U.S. Bureau of Land Management, and the National Park Service. Many state legislatures have also passed similar accountability legislation that requires regular progress reports from state agencies, including those responsible for wildlife management. And in the private sector, many foundations and other private funders are implementing their own evaluation protocols, which require groups that receive funding to track their accomplishments.

Wildlife managers who are interested in implementing some form of monitoring and evaluation protocol can now choose from a wide array of potential tools and systems (Stem et al. 2005). A program similarity across many of these systems is a coherent set of steps and practices that need to be followed in developing performance measures. Chapter 3 of this report provides a detailed explanation of these steps, drawing on much of the existing literature and the collective experiences of wildlife managers. Chapter 4 provides additional information on modeling tools such as logic frameworks or logic models that can be helpful in selecting management indicators and metrics. Specific, worked examples of logic models and associated management indicators are provided for a variety of common wildlife management techniques.

While it is good to be able to measure the effectiveness of individual conservation actions, it is also important for managers to be able to relate the outcomes of their small-scale actions to broader environmental trends that are being observed in the greater region. Conservation partners and donors may care about the outcomes from individual projects – whether there are more savannah sparrows at a site, for example, but they also care about whether we are contributing to broader societal goals such as "saving biodiversity" and "preventing species extinction." Chapter 7 of this report examines challenges and opportunities associated with linking project- and program-specific metrics to some of the available national environmental indicators, such as those contained in The Heinz Center's *State of the Nation's Ecosystems* report (The Heinz Center 2002) or the U. S. Environmental Protection Agency's *Report on the Environment* (U. S. Environmental Protection Agency 2003).

In summary, evaluation and performance measurement are valuable tools for wildlife managers. They provide frameworks and structures for telling scientifically credible stories about the anticipated outcomes of conservation actions. They help identify strategies that work, and can also suggest possible improvements to strategies that do not quite work as planned. Wildlife managers know intuitively that they have done good work for wildlife and been good stewards of the resources that society has dedicated to wildlife conservation. Evaluation and performance measurement can help managers make clear and logical arguments that this is indeed the case.

Chapter 2: Key Concepts and Frequently Asked Questions

Experts in performance measurement and program evaluation have developed a specific vocabulary for use in the practice of evaluation. We have attempted to provide definitions for many of these terms that reflect their current usage (as based on standard reference texts, such as Holling 1978; Walters 1986 or Margoluis and Salafsky 1998, as well as our conversations with evaluation practitioners). As with any technical vocabulary, many of these terms already have other meanings in other scientific or colloquial settings.

Targets are aspects of the environment that are the focus of a conservation project or program. The State Wildlife Action Plans specifically identify two categories or classes of targets: individual wildlife species (Species of Greatest Conservation Need) and habitats or areas that are of importance to wildlife in a particular state or territory.

Factors are aspects of the environment or human activities that have the potential to affect a target either positively or negatively. Negative factors are also known as **threats.**

Conservation Activities are actions that directly affect a conservation target, or that are intended to provide support or key information needed before action can be taken. The Conservation Measures Partnership and the International Union for the Conservation of Nature (IUCN) have recently developed a reasonably comprehensive taxonomy of conservation activities. This taxonomy includes many of the activities described in the State Wildlife Action Plans, but excludes other categories of activities that are also listed in the State Plans. Since many of these "other" activities (such as basic scientific research, species surveys, and site inventories) are featured prominently in the plans, and since these other activities are clearly of interest to state and federal wildlife conservation agencies, we would propose the following simplified taxonomy of conservation activities.

Supporting Activities

- **Generating Public Awareness and Support –** These activities attempt to inform other members of society about the importance and values of wildlife conservation, or attempt to generate the resources necessary to conduct conservation work.
- **Developing the Scientific Basis for Management** – These activities generate basic information and scientific data needed to develop management plans for species and habitats, and to understand the likely implications of management activities. Such activities include surveys and inventories, as well as basic scientific research.
- **Data Management –** These activities develop systems that provide input of data from surveys and monitoring programs, allowing managers to track the status of populations, species, and ecosystems over time.
- **Planning –** This refers to development of plans to protect, conserve, restore, or manage species, ecological communities, or areas of conservation interest.

Direct Conservation Activities

As noted above, the Conservation Measures Partnership and the IUCN have developed a comprehensive taxonomy of conservation activities. Examples of direct conservation activities that are commonly found in the State Wildlife Action Plans include:

- **Habitat Protection** through fee title acquisition or conservation easement.
- **Habitat Restoration,** which encompasses a wide range of activities from tree plantings to dam removals.
- **Habitat Management,** which includes ongoing efforts to maintain areas such as state nature preserves in a particular ecological condition.
- **Invasive Species Control** or eradication, which is often combined with habitat restoration.
- **Increased Regulatory Protection** for select at-risk species.
- **Direct species conservation activities** are mentioned in some plans for select species (e.g,. federally listed species for which captive rearing or reintroduction programs are already underway).

Monitoring, Evaluation, and Adaptive Management activities provide information about the status of species and/or habitats, and about the effectiveness of management activities.

- **Monitoring –** Repeated measurement of an environmental variable, either at regular intervals, or before and after an intervention.
- **Evaluation –** A study specifically designed to determine whether a particular management intervention achieved the desired effect.
- **Adaptive Management –** A cyclical or iterative process of management, which relies on information from monitoring programs and project evaluations to shape further management decisions.

Inputs are resources necessary in order to do a project. Some common inputs for conservation projects include staff time, funding, materials and supplies, and in-kind contributions.

Scale refers to the geographic extent and time horizon of conservation activities and their impacts. Wildlife conservation activities are typically designed to have benefits at a particular geographic scale: a riparian buffer planting will reduce the water temperature in the adjacent stretch of stream; a dam removal will open a particular sub-watershed to fish passage; a forest conservation project will preserve a certain number of acres of forest; and so forth. The scale at which effects can be measured may be different from the scale at which work is actually done; for example, a dam removal project may involve work only at the site of the dam, yet the effects of the removal could potentially be observed throughout the entire watershed (for example, through increased sediment loadings below the former dam site, increased fish passage above the former dam site).

In designing a monitoring and evaluation program, it is critically important to have an understanding of the scale at which the effects of conservation activities could reasonably be detected. Two different types of scale are particularly important: time or temporal scale, and geography or area. Observations at different temporal or geographic scales may be necessary to detect the full effects or results of a particular project or program. Even for small-scale conservation actions with anticipated small-scale effects, long-term monitoring may be necessary to detect the full effects of the activity.

Monitoring and Evaluation are terms often used as synonyms. In the field of programmatic evaluation, these two terms have acquired slightly different meanings: **monitoring** refers to repeated measurement of an environmental variable, either at regular intervals or before and after an intervention; while **evaluation** attempts to determine whether or not a management activity achieved the desired result. There is of course some overlap between these activities: for example, pre- and post-project monitoring may be an important component of an evaluation of a particular project.

These two terms are also closely related to the concepts of "status assessment" and "effectiveness measurement," which were introduced by Stem et al. (2005) and which are increasingly being used by groups such as The Nature Conservancy in their monitoring and evaluation work. As used here, "monitoring" is similar to "status assessment," except that a status assessment could be conducted on a one-time basis, whereas a monitoring program would need to include multiple measurements. "Evaluation" as used here and "effectiveness measurement" are also related, although evaluation covers the entire process of making a judgment about the effectiveness of a project, not just the measurement of a particular indicator or metric.

Indicators are aspects of the environment that are measured as part of a monitoring or evaluation effort. Indicators summarize or provide insights into more complex ecological processes, providing managers with the information they need to determine whether or not a project is having its desired effect.

Metrics are the specific way by which an indicator is measured. For example, an indicator for a prairie restoration project could be the number of grassland birds using the site. A specific metric for this indicator would be the number of calling male grasshopper sparrows detected during line transect surveys in early spring.

Results are the accomplishments or changes that can be directly attributed to a project or program. The White House Office of Management and Budget (OMB) distinguishes two different types of results – **outputs** and **outcomes.**

Outputs are short-term results, often quantitative, which can be measured at the completion of a project or activity. Outputs also are commonly used in short-term reporting (for example, reporting back to a foundation or a government agency at the completion of a grant).
Examples of outputs include:

- Number of people attending an outreach event
- Number of trees planted
- Number of fingerlings stocked
- New publication printed

Outcomes are results that are directly related to the goals and objectives (the purpose) of a project or activity. Outcomes should relate to the reason *why* you are doing a particular project.

Examples of outcomes include:

- Behavioral change among persons attending outreach event
- Nutrients absorbed by riparian buffer planting
- Fish population large enough to support recreational angling
- Use of new publication in public policy debate

Although outcomes are often described as being big-picture, large-scale, or long-term results, it is important to note that some outcomes may be detectable at smaller scales and over shorter time periods (often referred to as **intermediate outcomes**, especially if they are intermediate steps along the way to a larger, big-picture outcome).

Frequently Asked Questions

In recent conversations with wildlife managers in state and federal agencies, as well as with other wildlife professionals, there seem to be recurring questions about evaluation and performance measurement.

Why should we care about evaluation?

Project and program evaluations are increasingly being required by state and federal wildlife agencies, as well as organizations such as the National Fish and Wildlife Foundation that provide funding and resources for wildlife conservation. The people who provide money for wildlife management want to know whether the work that is being done is effective. Evaluation science gives managers the tools to demonstrate the effectiveness of their work in a scientifically rigorous manner.

Is this just a "flash in the pan" or is evaluation here to stay?

As resources become scarcer and problems become bigger, there is an increased need for managers to be able to prove that their projects and programs are actually having the desired effects. Evaluation is already common practice in the business world, and is increasingly being required by state and federal laws and regulations. As the process of evaluation becomes institutionalized, the chances that it will simply fade away decrease. While the exact form and format of these evaluations may change with time, the process of evaluating and reporting on the effectiveness and results of programs will likely continue.

I don't have enough money to implement a new/expanded/ better monitoring program. What can I do?

Nobody expects that states will be able to effectively monitor all of their Species of Greatest Conservation Need, given the limited resources currently available for State Wildlife Action Plan implementation. We recommend working with existing monitoring programs such as the Breeding Bird Survey in your area to obtain what data you can. Satellite or other remote sensing imagery may help you monitor changes in land cover, including some vegetation types of conservation interest.

You may also find it helpful from a strategic perspective to document how you could use additional resources that would enable you to more effectively monitor species, their habitats, and the results of your management actions.

I have way too many things – species, rare vegetation types, natural areas – to manage and not enough time, staff, or resources. How can I possibly show that I have done a good job?

Since you cannot do everything, we suggest a two-part approach to monitoring and evaluation. Given resource constraints, you are likely only going to be implementing a small set of conservation actions. We recommend following the steps in Chapter 3 to develop a performance measurement strategy that is specifically tailored to the particular types and scale of actions that you will actually be implementing. This will enable you to determine whether or not your actions are having the desired effect.

Second, we also recommend that you implement a statewide tracking or monitoring program that focuses on a few targets – species or vegetation types – that represent broader biodiversity values in your state. You may find it helpful to refer to ecological concepts, such as "indicator species," "umbrella species," or "keystone species" in selecting these targets. Use existing monitoring data (Breeding Bird Survey, Christmas Bird Count, endangered species monitoring, remote sensing imagery, etc.) when you can, in order to cut down on costs.

What about the time lag between my actions and the time at which effects will be seen?

There is often a time lag between when management activities are conducted and when the full effects of those activities are seen in wildlife populations. At the same time, it is often possible to identify intermediate outcomes, measurable over a shorter period of time, that can help indicate whether the management activities are likely to be effective. For example, in a riparian forest planting project, one would not see the

full benefits of the planted trees to forest interior birds for decades, but data on tree survivorship would provide some indication as to whether the overall reforestation effort was likely to be successful or not.

Can I pick things to monitor or measure so that I look good?

Yes, it is possible to try to "game" the system by picking indicators and metrics that will paint a positive or overly optimistic picture. Such an approach may be self-defeating in the long run, however, because it is possible to imagine scenarios in which such a strategy ultimately backfires. For example, if an agency consistently reports that its wildlife species are doing fine and all is well, then it is perfectly reasonable for legislators and administrators to ask why they should be investing scarce resources in wildlife conservation activities (as opposed to other urgent societal needs). And if particular wildlife species continue to decline to the point where state or federal Endangered Species Act protections are triggered, and in the meantime the state wildlife agency has consistently painted a rosy picture of the status of wildlife and the success of its management activities, legislators and administrators can legitimately question the agency's competence at managing resources and monitoring its effectiveness.

We suggest that a more honest approach will require managers to select targets where realistic progress is possible using the resources that are available. Then managers can implement a scientifically sound monitoring system that will allow them to measure progress towards achieving goals on those targets.

What Comes Next?

The next chapter describes the basic sequence of steps that must be followed in order to develop a monitoring program. Following that chapter, we discuss conceptual models, indicator selection, and sample indicators for reporting progress on wildlife conservation at a state-wide level. We then discuss ways to link state-level indicators to environmental indicators that are currently being used at national levels. Next comes a discussion of data sources, data management, and reporting, with links to the broader literature on these topics. We then move on to a discussion of the concept of adaptive management, and conclude with a worked example showing how the state of Nevada is developing a monitoring program for the Nevada Wildlife Action Plan.

Chapter 3: Steps for Identifying Performance Measures

One of the major findings of this study is that there is a straightforward sequence of steps that need to be taken in order to develop performance measures for conservation activities. These steps are described in differing levels of detail by various authors who have written books and articles on the subject of performance measurement (e.g., Holling 1978; Walters 1986; Margoluis and Salafsky 1998; Noon 2003). This chapter and those that follow describe how these steps can be applied to the specific context of the State Wildlife Action Plans.

Each of the State Wildlife Action Plans already includes information that can be used to develop monitoring strategies for specific targets – individual species, suites of species, or vegetation or ecosystem types. What is needed, in many cases, is to translate the information contained in the sections of the state plans into detailed monitoring and evaluation strategies for specific conservation targets. Elements of the State Wildlife Action Plans that are relevant to this discussion include: lists of species and habitats, descriptions of threats, other factors that could influence species or their habitats, descriptions of conservation actions, and descriptions of monitoring and evaluation strategies.

The Steps

The sequence of steps needed to develop a monitoring and evaluation program is as follows:

- Identify a conservation target (species, vegetative communities, ecoregion, natural area, etc.);
- Develop a conceptual model that shows how stressors or threats, as well as conservation activities, affect the target;
- Use the model to select potential indicators of target status and conservation effectiveness;
- Develop a monitoring program to measure and track indicators;
- Implement conservation activities, measuring indicators to track progress; and
- Use information from the indicator measurements to modify activities and adjust the conceptual models (= Adaptive Management).

1) Identify Conservation Targets

Given the breadth of the State Wildlife Action Plans and the relatively modest resources available for implementation and monitoring, states may find it helpful at first to focus their monitoring and implementation activities on a few target species or vegetative communities where conservation success can be easily defined and measured.

Some criteria that may be helpful in selecting targets for priority implementation include:

- The target is well defined (taxonomy of species clearly resolved, vegetative or ecological communities are well defined).
- For individual species, the basic biology, life history, and habitat requirements are reasonably well understood, geographic distribution within the state is fairly well known, and scientifically sound monitoring protocols are available.
- For vegetation cover types or ecological communities, maps are available that show their extent and distributions in the state.
- Limiting factors or factors causing the decline of species or loss of habitat/vegetation type are well understood.
- Actions needed to reverse or stabilize decline of species and ecological communities are well understood.

2) Develop a Conceptual Model for Each Target

For each target, we recommend building a simple conceptual model that describes how major environmental or anthropogenic factors could influence the target, either positively or negatively. Conceptual models take many forms, from sophisticated computerized quantitative models, to simpler spreadsheet models, to the very simple box-and-arrow diagrams (Walters 1986; Margoluis and Salafsky 1998).

Because state wildlife managers are often dealing with complex or poorly known ecological systems, we recommend starting with very simple models, representations of the world that use boxes and arrows to show cause-and-effect relationships. The next chapter will describe the construction and refinement of these models in more detail, including a general model describing the steps and processes by which the State Wildlife Action Plans were developed and are being implemented.

Chapter 10 also provides illustrations of actual conceptual models that were developed by the Nevada Department of Wildlife and its partners as part of the development of a performance measurement system for the Nevada Wildlife Action Plan.

3) Use the Model to Select Indicators

Models are important tools for selecting management indicators. A properly designed quantitative model can help managers identify key variables and process rates that should be monitored. Quantitative modeling can also be helpful in selecting threshold levels for important environmental variables; these thresholds can help managers determine when to take particular management actions. Simpler models can also help suggest key indicators of management activities, including intermediate or "proxy" measures. We will discuss methods for using simple models to select management indicators in the next chapter.

One approach that has been used by state wildlife agencies is to use species as management indicators for ecosystems of conservation interest. Two of the examples included in this report, from Oregon and Nevada, describe processes that state wildlife agencies have used for selecting species as management indicators.

4) Develop a Monitoring Program to Track and Measure Indicators

Once indicators have been selected, the next step is to design a monitoring program that tracks these indicators and provides managers with the information that they need in order to know whether their conservation actions are having the desired effect. Development of a monitoring program does not necessarily mean the collection of new data; as will be seen in several of our case studies, it is often possible to obtain data on species and habitat types of interest from existing state, federal, academic, and private monitoring programs.

In some cases it will be necessary to develop new monitoring programs to track species or ecological communities that are poorly known. Although the development of new monitoring programs is beyond the scope of this report, Chapter 9 provides information that will be useful to state wildlife managers who are interested in developing new programs. We recommend consulting with species or ecosystem experts, as well as persons familiar with the design of monitoring programs, in establishing any new data collection efforts.

5) Implement Conservation Activities and the Monitoring Program

The actual implementation of conservation activities and the collection of monitoring data are outside the scope of this report. Many other books and manuals (including Margoluis and Salafsky (1998), Groves (2003) and Williams, Szaro, and Shapiro (2007)) are already available that describe how to implement conservation activities and initiate the monitoring of conservation programs.

6) Use Information from the Monitoring Program to Modify Conservation Activities and Adjust Conceptual Models

As the monitoring program progresses and data are collected, managers will want to schedule regular reviews of these data and assess whether or not their activities are actually leading toward the desired effect on the conservation target. These reviews allow managers to learn from the effects of previous management decisions: what works well, what works less well, what does not work at all. In many cases, managers will be reviewing information from intermediate or "proxy" indicators that do not measure conservation outcomes directly, but rather measure intermediate steps towards an overall conservation goal.

Information from monitoring programs should also be used to adjust the conceptual model that has been developed for a particular conservation target. This is easiest to see in cases where a project is clearly failing to meet its conservation objectives. Suppose a project is failing, and a careful review by managers indicates that a new stressor has been added to the system which completely overwhelms the positive conservation activities that have already been implemented (think off-road vehicles entering a newly-planted prairie restoration, or an upstream development which dumps new sources of stormwater run-off into a restored stream reach). The conceptual model for this conservation target would need to be adjusted to incorporate the new stressor, and the suite of possible conservation activities would need to be adjusted accordingly to deal with the new stressor more effectively.

Even when a project seems to be on track, revising a conceptual model is a good idea when evidence from the monitoring program or new scientific research suggests that there are significant flaws or gaps in the existing model. Poor models can easily lead to poor decision-making at some point in the future. Reviewing and revising models is an important part of an ongoing monitoring and evaluation program.

This process of learning what works (and what does not) from monitoring programs and adjusting conceptual models and management activities accordingly is known as **adaptive management.** More information about adaptive management is available in Chapter 9, and in standard references such as Holling (1978), Walters (1986), and Williams, Szaro, and Shapiro (2007).

Chapter 4: Conceptual Models

In the previous chapter, we outlined a sequence of six steps that state wildlife agencies and others can follow in developing a monitoring or performance measurement program. During the process of developing the State Wildlife Action Plans, the individual state wildlife agencies have already completed Step 1 (Identify Conservation Targets). In this chapter, we continue the process of developing performance measures for the State Wildlife Action Plans by creating a series of conceptual models (Step 2 in the sequence of steps outlined in Chapter 3). Our first model describes the overall process by which the State Wildlife Action Plans were created and outlines in broad general terms the types of activities that will be needed in order for the state wildlife agencies and their partners to accomplish their conservation goals for wildlife and habitats. We also introduce the concept of a "system model" and show a simple, generalized model that shows the relationship between conservation targets, direct and indirect threats and stressors, and conservation actions for the State Wildlife Action Plans.

In the second section of this chapter, we introduce a very simple type of linear conceptual model (known in the technical literature by a variety of names, including logic model, logic chain, or results chain), which can be used by managers to develop intermediate or proxy indicators as well as outcome measures (Step 4 in the sequence for developing performance measures outlined in Chapter 3).

The third section of this chapter describes simple methods for testing and refining logic models. Our conversations with wildlife managers and evaluation professionals led us to the conclusion that these very simple models require careful testing and refinement before they can be used with confidence in wildlife monitoring programs.

In our final section, we review a variety of other methods for identifying performance measures that have been described in the conservation literature. Some of these methods may be appropriate for particular management situations. For example, if you are managing a deer population for trophy hunting, you already know one of the key indicators at the start of the process (the number of trophy deer harvested). There are techniques from the adaptive management literature that enable managers to build conceptual models around these "known indicators." These models may suggest other process rates or states that could be measured as part of a comprehensive monitoring program. Other methods included in this section focus on identifying measures of goals, objectives, or threats.

A Conceptual Model for State Wildlife Action Plans

The 56 State Wildlife Action Plans represent a significant achievement for biodiversity conservation in the United States. For the first time, each U. S. state and territory possesses a single strategic document that lists priority species and ecological communities for conservation, outlines major threats to biodiversity, and describes key actions that need to be taken to counteract those threats and conserve biodiversity.

As important as this accomplishment is, it would be a mistake to view the plan documents as ends in themselves. Rather, these documents can be viewed as a tangible product from a much more extensive process that has involved numerous staff within the state wildlife agencies, as well as diverse groups of stakeholders from each U. S. state and territory. This process is still underway; at the time of this writing, it is just now moving from a planning phase into a more active implementation phase, with the hope that additional resources will ultimately become available to implement the full suite of activities described in the plan documents. For lack of a better term, we use the expression "State Wildlife Action Plan process" to describe this larger effort that includes plan implementation as well as plan development.

In our conversations with state wildlife agency staff, it has become clear that the State Wildlife Action Plan process relies on a set of underlying assumptions about the process by which change happens in human society and ecological environments that is similar to other multi-stakeholder conservation efforts, such as endangered species recovery teams and watershed coalitions. This set of assumptions or "theory of change" describes the sequence of events that lead from a program, project, or organization's strategies and activities to actual changes in society or the environment (Weiss 1972; Fulbright-Anderson, Kubisch, and Connell 1998; Davidson 2005). "Theories of change" can be expressed using simple box-and-arrow diagrams that show causal relationships between inputs, activities, outputs, and outcomes (Margoluis and Salafsky 1998). In the section that follows, we develop this theory and outline the relationship between its major components using a simple box-and-arrow model.

Basic Elements of the Model

We will use a simple model to show how the development of the State Wildlife Action Plans could lead to actual benefits for wildlife and habitat.

Inputs

The initial inputs into the process of developing the State Wildlife Action Plans can be described using several broad general categories.

- **Personnel –** State agency staff who directly facilitated or assisted in the development of State Wildlife Action Plans.
- **Consultants –** Paid non-staff who facilitated aspects of plan development.
- **Partners –** External organizations, other state government agencies, federal agencies, local governments, and academic experts who provide support in some way for the development or implementation of a State Wildlife Action Plan.
- **In-kind support –** Contributions of staff time, data, and other resources from partners in the planning process.
- **Data –** Basic data on status and trends of wildlife species, usually obtained from a state's Natural Heritage Program or equivalent.
- **Funding –** Initial funding for plan development was provided by the U. S. Fish and Wildlife Service, with additional resources provided by state governments and some private funders (e.g., Doris Duke Charitable Foundation, National Fish and Wildlife Foundation).

Each of these inputs lends itself naturally to certain forms of measurement:

- **Personnel, Consultants, and Partners** can be measured in terms of the Number of staff and hours dedicated to plan development.
- **In-kind Support and Funding** can be measured by the dollar amount of funding and equivalent value of in-kind support.

First Activity: Develop Plan

The process of actually developing the State Wildlife Action Plans took many forms across the individual states, reflecting the amount of data available, the overall conservation approach adopted by each state, and the number of conservation targets (species and ecological communities) that were selected. Some states coordinated planning activities in-house, while other states hired outside consultants to facilitate the process. The role of outside partners varied from state to state – many states convened meetings of working groups focused on taxa and/or ecosystem types of conservation interest, and nearly every state relied on a diverse group of partners to provide outside guidance and review of their plan documents.

There is a logical performance measure for this stage of the process: whether or not the plan is developed and approved by the U.S. Fish and Wildlife Service. This particular performance measure has now been met by every state.

Second Activity: Develop Implementation Partnerships

As part of the plan development process, each state developed a network of partner organizations (known in many states as a "Teaming With Wildlife Coalition") whose staff and members could advise the state on technical aspects of the plan and provide additional resources such as data and staff time that were not directly available within the state wildlife agency.

These coalitions or partnerships have an even more important role to play in actually implementing the State Wildlife Action Plans. Each plan contains a very broad suite of potential actions, and state agencies simply do not have the staff, resources, contacts, legal authority, or flexibility to implement all of these activities in-house. Thus, the coalitions or teams of partners are absolutely essential to implement the full suite of activities that are described in the plans.

Some of the possible performance measures here include the number of partner organizations, the amount of terrestrial or aquatic habitat managed by these organizations, and the membership of these organizations.

Third and Subsequent Activities: States and Partners Take Action

With the completion of the plans, the state agencies and their partners are actively exploring ways to implement the specific actions described in the plans. Given the breadth of the plans, the types of implementation activities are diverse, applying many of the tools and approaches from the sciences of wildlife management and biodiversity conservation. Many of these activities have been described in a classification recently published by the International Union for the Conservation of Nature and the Conservation Measures Partnership (IUCN-CMP 2006). These activities may operate directly on the land, waters, or wildlife species, or indirectly by attempting to influence intermediate factors (including threats). Some of the most frequently mentioned actions in the plans include:

- **Land/Water Protection** – activities that directly protect terrestrial or aquatic habitat, either through direct acquisition, purchase or donation of conservation easements, or proclamation.
- **Land/Water Management** (particularly Habitat Restoration and Invasive Species Management) – activities that attempt to enhance or maintain important attributes of terrestrial or aquatic areas that provide habitat for key wildlife species.
- **Capacity Building** – activities that are designed to enhance the conservation activities of community organizations and other partners. Such organizations may manage wildlife and habitats directly, or may conduct their own education or awareness campaigns aimed at other segments of the state's population.
- **Education and Awareness** – activities intended to educate and inform members of the public, partner organizations, and other interested parties about wildlife and habitat conservation opportunities.
- **Legislation and Regulation** – activities that extend legal or regulatory protection to wildlife species or habitats.

Much of the rest of this report describes methods for measuring the effects of these activities on wildlife species and habitats.

Implementing the full range of activities described in the State Wildlife Action Plans will require additional inputs of funding, staff time, and in-kind donations of goods and services from partner organizations and Congress. Appropriate measures for these additional inputs include the amount of funds, staff time, and other resources that become available to support the activities associated with implementation of the State Wildlife Action Plan.

Results: Improved Habitats, Wildlife Populations

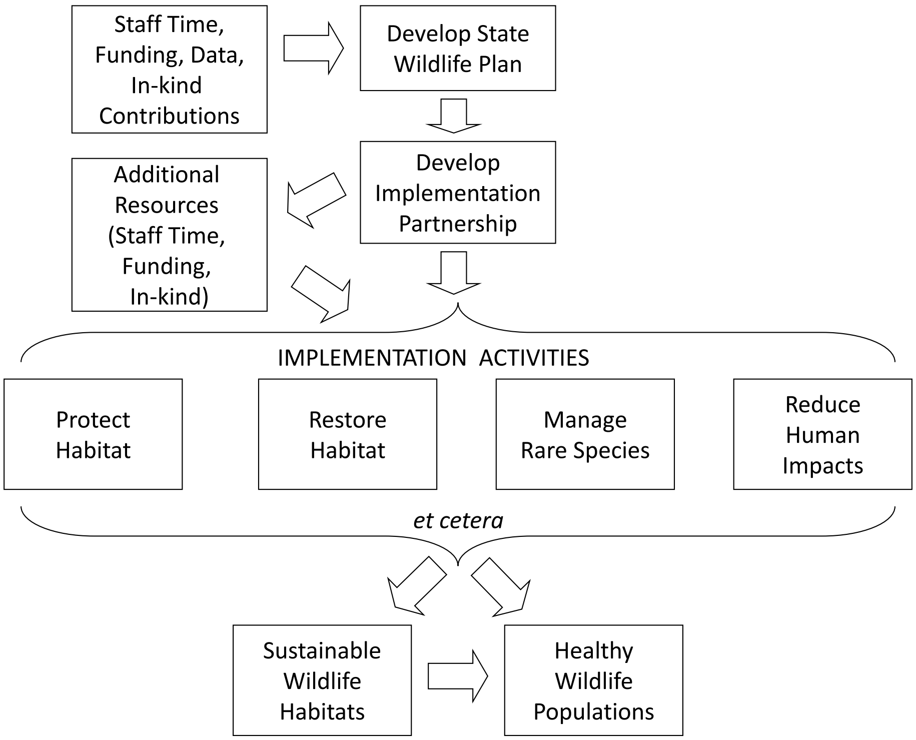
Individual activities described in the plans are designed to improve, conserve, or enhance existing wildlife habitats, and thereby improve or protect the existing status of wildlife populations. The ultimate outcome measures for these plans therefore relate to wildlife populations and ecological communities.

The wildlife management community has developed numerous measures for assessing the status or trends of wildlife species and ecosystems. We will examine many of these measures in subsequent chapters.

Putting It Together: The Path to Implementation

We can summarize the sequence of events that we have described above using a simple diagram (Figure 4.1). Boxes in this diagram represent inputs, activities, and results. Arrows show the logical or causal connections between the boxes. This diagram shows the major steps in the "State Wildlife Action Plan process," as well as the types of inputs and participation that are needed in order to fully implement the plans.

FIGURE 4.1 Conceptual model showing the relationship between inputs, plan and partnership development, conservation activities, and conservation outcomes for the State Wildlife Action Plans.

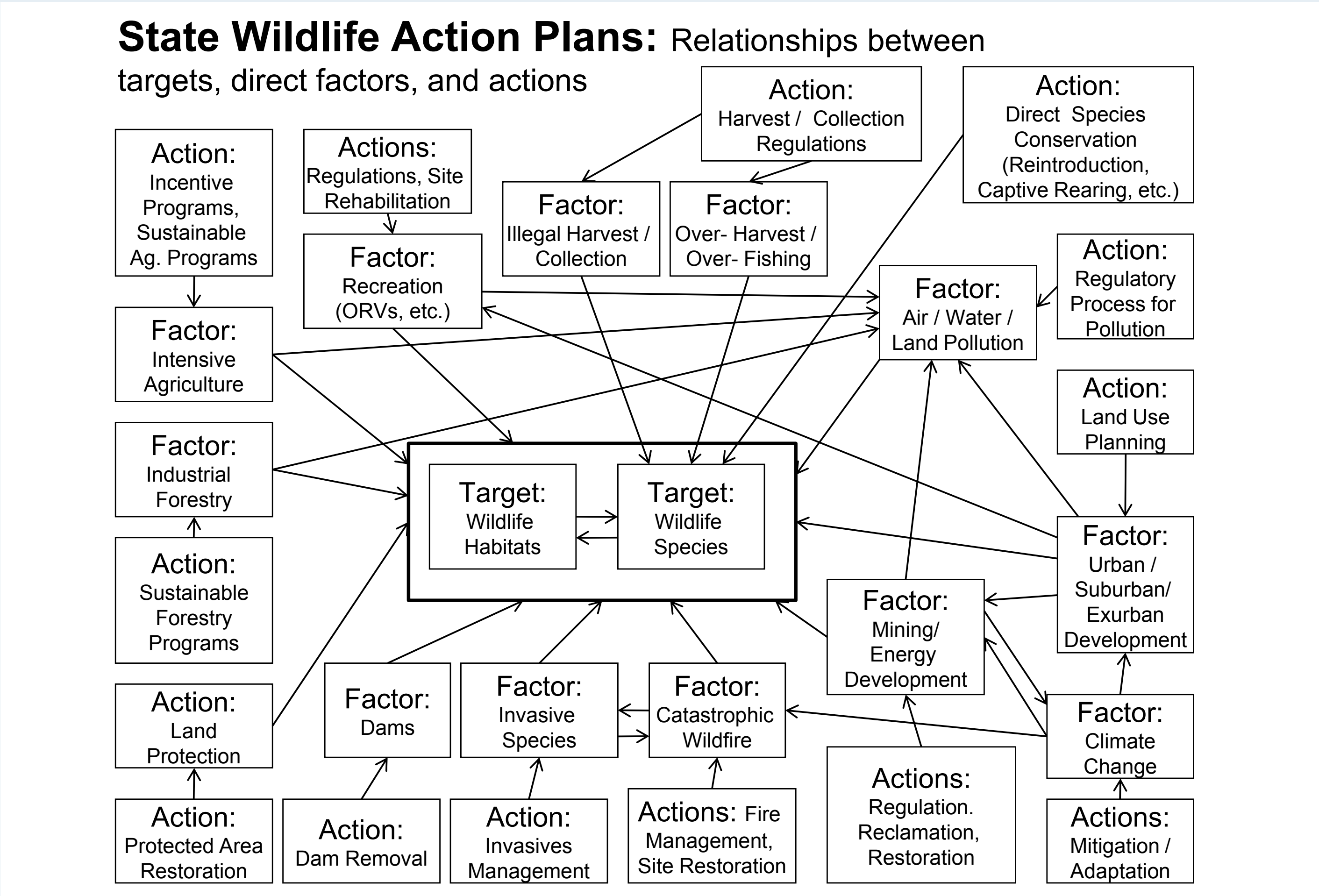


The diagram in Figure 4.1 also serves to illustrate another important point: additional resources (especially funding) are needed in order to implement the ambitious agenda outlined in the State Wildlife Action Plans.

Figure 4.1 is a very simple example of what is known as a **System Model**. These types of models illustrate the relationships between conservation targets and conservation actions, as well as threats, stressors or other factors that affect the targets. Although this particular model does not explicitly include specific system stressors, many of the activities in the state wildlife action plans are focused on ameliorating stressors such as encroachment, invasive species, pollution, off-road vehicle activity, illegal harvesting, and so forth.

More complex system models can be developed which depict the inter-relationships between a conservation target (either a species or ecosystem), direct and indirect stressors that affect the target, and conservation actions that affect the threats, stressors, or targets. These models can help managers develop an understanding of the relative importance of particular activities and the suite of actions that are needed in order to reduce the effects of stressors. Figure 4.2 shows an example of a generalized system model that includes the two targets of the State Wildlife Action Plans (wildlife species and habitats) as well as a number of factors and conservation actions which are commonly mentioned in the individual State Wildlife Action Plans. This model is by no means comprehensive, but it does illustrate what a more complex systems model for a State Wildlife Action Plan might look like. We return to the subject of system models in Chapter 10 where we describe how to construct these models and give illustrations of three systems models which were developed specifically for the Nevada Wildlife Action Plan.

FIGURE 4.2 A generalized system model for State Wildlife Action Plans, showing the plans' conservation targets (wildlife species and habitats), as well as common threats and conservation actions which have identified as priorities across many State Wildlife Action Plans. Note that some actions and factors affect both wildlife species and habitats, whereas other actions and factors only affect species directly.



Logic Models and Other Simple Tools for Identifying Management Indicators

The conceptual model that we have just developed provides a broad and general outline of the steps by which State Wildlife Action Plans will lead to conservation of fish and wildlife populations and habitats. However, there are significant gaps and omissions in this model. Even though we have identified a series of activities that are intended to benefit wildlife species and their habitats, it remains to be shown how exactly these activities will lead to measurable improvements in wildlife populations and habitats. To make these detailed linkages clear, we need to develop more explicit models that show the exact sequence of steps between a particular conservation activity and its intended result.

This section introduces a simple tool, known as a "logic model," that can help make these connections. Logic models (also known as logic chains, causal chains, or results chains) are commonly used in the public health, philanthropic, and social service sectors as part of performance measurement and evaluation systems. These simple models show the anticipated causal links between activities, short-term outputs, intermediate outcomes, and long-term outcomes.

Logic models are simple linear box-and-arrow diagrams, and thus are among the simplest types of conceptual models. Such models can be helpful in situations where quantitative models are not available or are difficult to develop. Unlike strictly quantitative approaches, logic models can combine both quantitative and qualitative results (outputs, outcomes) in a single integrated model. They can also be used to combine different types of outcomes (social, educational, economic, environmental, or human health).

The first logic model was developed by the U.S. Agency for International Development in the 1970s to help the agency's grantees explain how their proposed activities would lead to desired effects. Logic models have since become popular in the performance management and evaluation literature (e.g., Burt et al. 1997; CDC Evaluation Working Group 1999; IUCN no date; Margoluis and Salafsky 1998; USAID 2000). Various versions of logic models or causal chains have been implemented by major foundations such as the National Fish and Wildlife Foundation and the W. K. Kellogg Foundation (see, for example, W. K. Kellogg Foundation 1998).

By segmenting an activity and its consequences into a series of steps, a logic model can also help identify short-term and intermediate indicators of management success. One of the most significant challenges for wildlife managers is that desirable outcomes may take years or even decades to detect, whereas organizations and government agencies that provide funding usually want demonstrations of results on an annual basis. There is a clear mismatch between the reporting cycles of agencies or foundations and the lengths of time that may be necessary to detect the effects of wildlife management. Logic models can be helpful for managers who need to identify intermediate outcome measures for assessing the progress of their conservation activities at shorter time scales. These measures may be more reasonable for meeting the reporting requirements of agencies or funders who want to see "results" in the short-term. Identifying these shorter-term or "proxy" indicators provides managers with greater flexibility in choosing monitoring targets than focusing on the project's target species or ecosystem alone. We will examine the ways in which logic models can facilitate indicator selection in the sections and examples that follow.

Constructing Logic Models

It is very easy to construct a simple logic model or causal chain for a particular activity, by following a few simple steps:

1. Start by listing the specific conservation action or activity at the top of a piece of paper.
2. At the bottom of the piece of paper, list the project's desired outcome.
3. Between the activity and the desired outcome, list as many intermediate steps as are needed to link the two in an unbroken logical progression. As you move down the chain, keep asking the question "and then what happens" at each step, until the activity and goal are completely linked in a chain of logical steps.

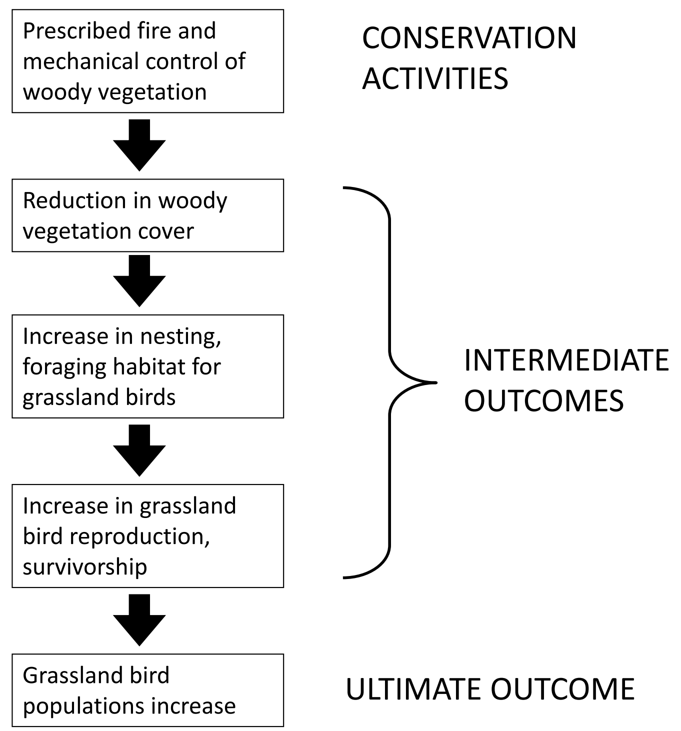
Figure 4.3 is an example of a logic model for a project that is intended to increase grassland bird populations:

Here there are three steps between the specific conservation activities that the manager is planning to undertake, and her big-picture goal for doing these activities in the first place. The activity statement, goal statement, and intermediate steps could be made even more detailed and specific to fit a particular project.

Logic Models Help To Tell a Story About a Project

A well-developed logic model can help managers develop a clear and compelling story about a project. Here's an example of a story that could be developed from the logic model in 4.3:

FIGURE 4.3 Logic model for grassland management leading to grassland bird population improvement.



"The goal of this project is to increase grassland bird populations at our prairie preserve. We will implement a vegetation management regime that includes prescribed fire and mechanical treatments to reduce woody vegetation. As a result of these treatments, we expect increases in nesting and foraging habitat for grassland birds, which should lead directly to increased survivorship and nesting success. We expect that these factors will contribute to an increase in the population of these bird species at our preserve."

Logic Models Can Help Identify Potential Management Indicators

A well-developed logic model can also be of great assistance to managers in designing a monitoring program for a project. Figure 4.4 shows the grassland bird causal chain again, but this time with a list of potential **indicators** (in ovals) or *environmental attributes that could be measured to determine whether or not the project had the desired effect.* To the right of these indicators, our project manager has listed the trends that would be expected in each of her indicators if the project was implemented.

Note that even though the manager has listed potential indicators, she is still one step removed from selecting a "metric" or "measure," a specific environmental attribute that will actually be measured in her monitoring program. This is because there are often multiple ways to measure a particular indicator. For example, "percent woody cover" or "percent open grassland" could be estimated using digitized aerial photography, or extrapolated from measurements made on the ground using a series of sampling plots. The population size and number of nesting bird pairs could be estimated using data from sample plots, transect walks, or determined directly from a complete census (which is usually only feasible for small sites).

This logic model also shows that some indicators are closely related and could probably be combined in an actual monitoring scheme. For example, percent woody cover and percent open grassland are complementary for many grassland sites, meaning that an increase in one of these indicators is accompanied by a decrease in the other, and vice versa. Likewise, the number of nesting pairs of a bird species may be closely related to the overall population size, and may be easier to determine than overall population size for certain species in which males are brightly colored and/or exhibit elaborate courtship displays.

Figure 4.5 shows the metrics or methods that our wildlife manager ultimately selected for her grassland bird project.

FIGURE 4.4 Grassland bird logic model, with potential management indicators in ovals and expected direction of change for each indicator in italics.

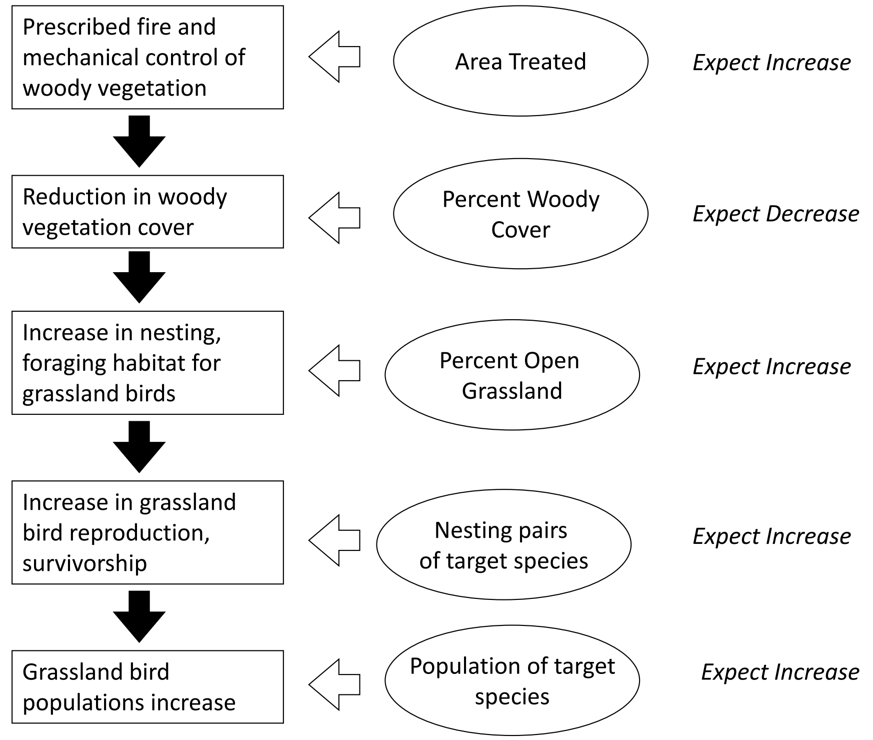


FIGURE 4.5 Grassland bird logic model, with indicators (in ovals) and potential metrics (in octagonal boxes).

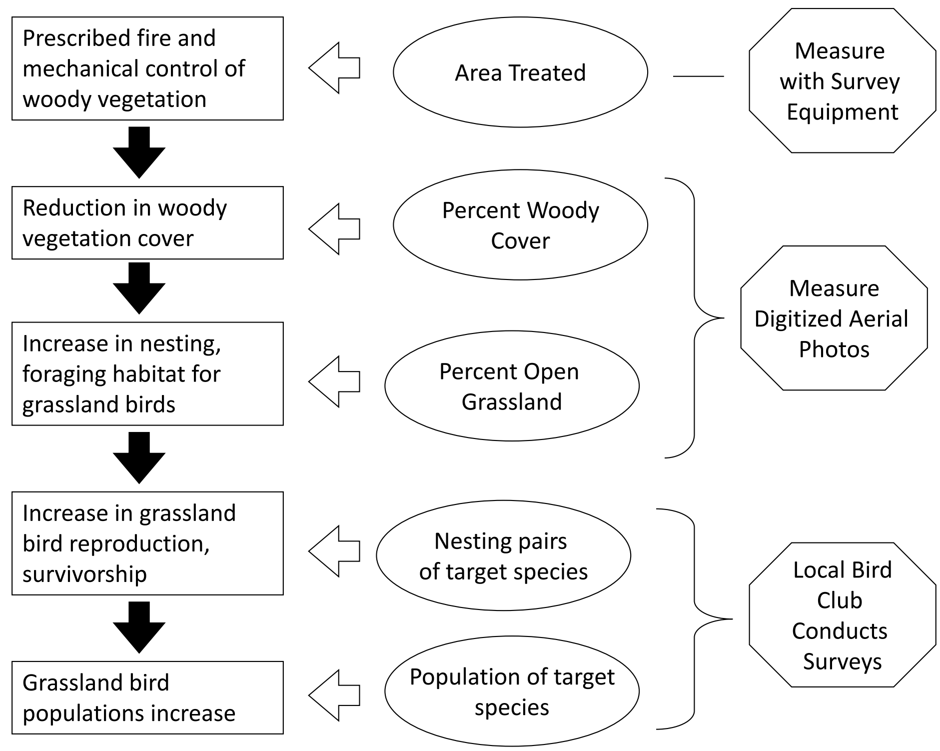
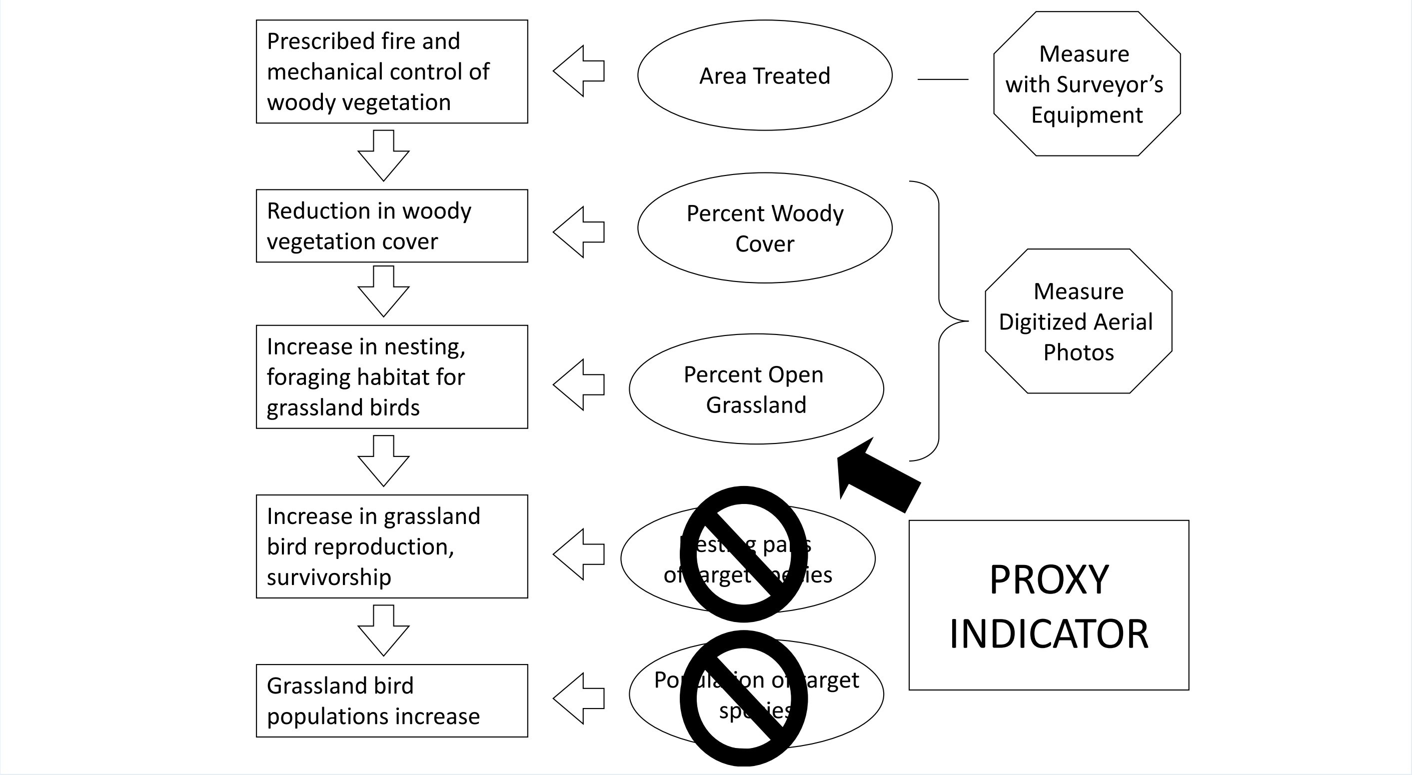


FIGURE 4.6 Logic model for grassland bird conservation, showing how a proxy indicator could be identified when it is not possible to measure conservation outcomes directly.



Developing a logic model for a project can also help in making a choice among multiple possible indicators. In real-world situations, budgetary constraints often limit the size of monitoring programs, meaning that only a few of the numerous potential indicators (and even more numerous metrics) can be actually measured. The logic model shows which of the many possible indicators are closest in logical proximity to the overall goal for the project. If a manager can measure only one thing, it stands to reason that she would want to measure something that directly reflects whether or not a goal has been achieved. For the case we have examined here, this would mean focusing monitoring resources on measuring the bird populations.

Logic Models Can Help Identify Proxy Indicators

In real-world situations, it is often not possible to measure a project's ultimate outcome directly. For many projects, there is a significant time lag between the time when a project is implemented, and when a response could be expected in the wildlife population of interest. In other cases, it may be prohibitively expensive to measure outcomes (as with the return of fish to a major river following dam removal). In such cases, it becomes necessary to measure a "proxy indicator" that provides information, albeit indirectly, on the outcome of your actions and their likely effect on the target.

Figure 4.6 shows how a logic model can be helpful in identifying a proxy indicator. Let's suppose that for whatever reason our manager did not have a way to measure the grassland bird population directly at her site. Going one step back up the causal chain suggests that the next best thing to measuring the bird population would be to measure the percentage of open grassland at her site. This would probably be her best choice for a proxy indicator.

Sample Logic Models for Other Conservation Activities

In the sub-sections that follow, we present a series of sample logic models for a variety of common conservation activities. The format for these models is the same as the example above: the left-hand column represents a series of logical steps linking an activity in the upper left hand corner with a desired outcome in the lower left hand corner. The center column lists possible indicators for each of the steps in the logic chain. The right-hand column lists one possible metric or method by which a manager could measure each of the indicators.

For each of these simple examples, there are of course many other indicators and metrics that could be used besides just the few possibilities that are shown here.

FIGURE 4.7 Logic model for a conservation easement, showing how the protection of a site will prevent further losses of biodiversity.

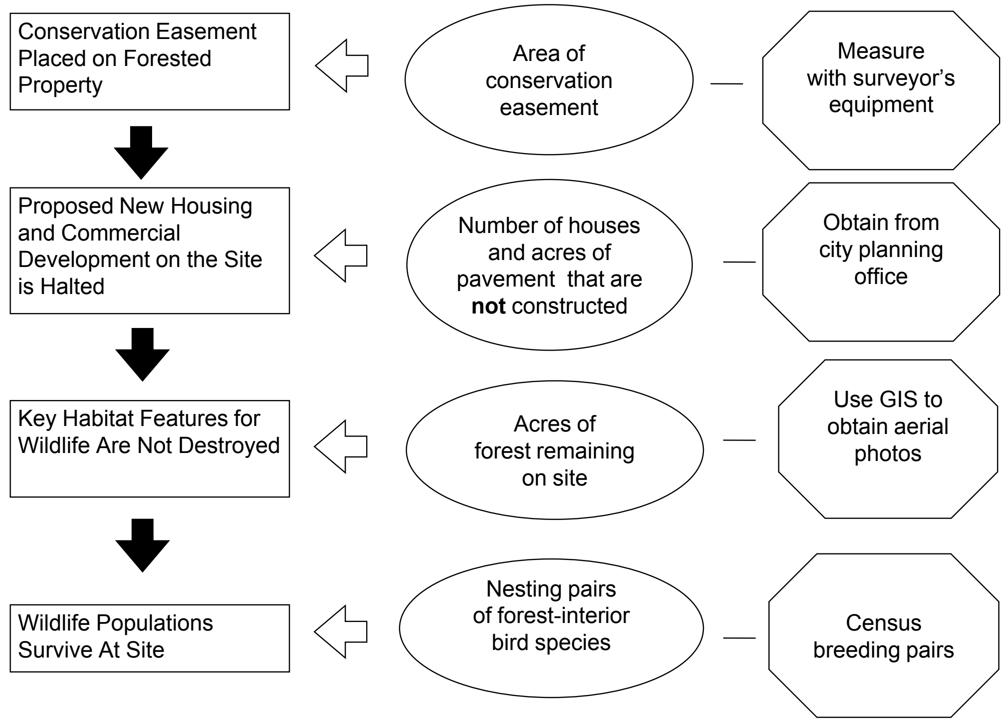
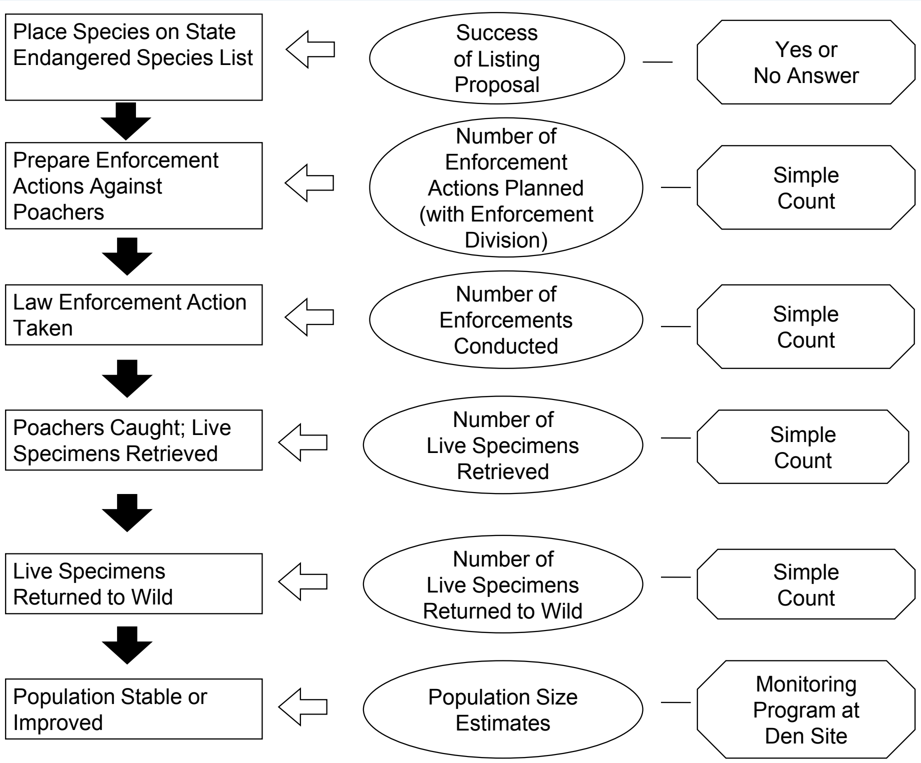


FIGURE 4.8 Logic model showing how regulatory protection will decrease poaching and stabilize population declines in a rare reptile species.



Different management situations and contexts will likely require different management indicators, depending on the specific information needs and interests of individual managers, wildlife agencies, and funding organizations. There will likely also be some variation in the level of detail and the particular steps that are included in the logic chains that are developed for specific projects, even when the actions and desired outcomes are similar. It is clear that there is not necessarily a single "correct" logic model and set of indicators for a particular project. Rather than worrying about finding one "right answer," managers should instead focus on making sure that their logic models accurately reflect their own thinking about a project's outcomes and how the intermediate steps toward those outcomes might best be measured.

Habitat Protection Example

In this example, a restrictive conservation easement is placed on a property that would otherwise be subdivided and sold for commercial development. Figure 4.7 shows a potential logic model for this project. By placing the easement on the property, the conservation group effectively halts any new residential or commercial development on the property, which in turn prevents the destruction of wildlife habitat, which means that wildlife populations can continue to exist at the site.

The indicators and metrics in the middle and right-hand columns show how this conservation group decided to measure its success in this case: by quantifying the acres of quality habitat that would have been lost if the conservation easements had not been put in place.

This example shows how it is possible to think beyond simple measures such as "number of acres protected" and actually begin to quantify the potential impacts to wildlife that were **prevented** by taking a particular conservation action. Such quantification is possible in this case because plans for subdivision and development of the property had already been drawn up by a developer and filed with the city planning office. Thus, it became possible to measure the amount of land that would have been lost if the conservation easement had not been put in place.

Regulatory Protection Example

Many states have their own endangered species laws or other legislation that protects particular species from certain human activities. This logic model (Figure 4.8) shows how legal protection might benefit a rare reptile species.

The specific context here is one of the northeastern states, where rare or endemic reptile species have come under heavy pressure from collectors who wish to sell live, wild-caught specimens to the collector and hobby trade.

By putting regulatory protections in place, the state wildlife agency gives wildlife enforcement officers an important tool for stopping the poaching of rare or endangered reptile species. When wildlife enforcement officers catch poachers with live specimens, these animals could be returned to the wild, lessening the impact on wild populations. The indicators and metrics in this model combine information on law enforcement activities with population monitoring of rare reptile species, to produce a more integrated picture that describes how the effects of these law enforcement actions can directly benefit rare reptile populations.

The model does not include representation of two key aspects of this particular situation: the market for captured reptiles, and the deterrence value of law enforcement actions. Presumably if law enforcement actions are stepped up, there will be a reduction in poaching, unless the market value of the reptiles is so high that it exceeds the statutory penalties for poaching.

Wetland Restoration Example

This example focuses on a very common conservation activity: restoration of hydrology in an area that was formerly a wetland, with the intent of improving nesting habitat for waterfowl. By plugging ditches and planting native vegetation, natural hydrology is restored to the site and the key elements of nesting habitat are established for ducks. Figure 4.9 shows the logic model for this project.

One of the assumptions of this model is that the plugging of the ditches and the native wetland plantings will be sufficient to restore the original hydrology and vegetation of the site. Such an assumption may be naive (suppose, for example, that the native wetland plantings were overwhelmed by invasive plants), in which case additional conservation activities would be needed in order to restore the hydrology and native vegetation at the site.

The indicators and metrics for this model range from the very simple (number of ditches plugged) to the very complex (wetland extent, duck recruitment). A manager whose monitoring budget is limited may wish to consider using one of the intermediate metrics as a proxy for the outcome measure of duck population recruitment. Either the area of delineated wetland or the extent of wetland vegetation could serve as proxy measures in this case.

FIGURE 4.9 Logic model for a wetland restoration project that has been designed to benefit duck populations.

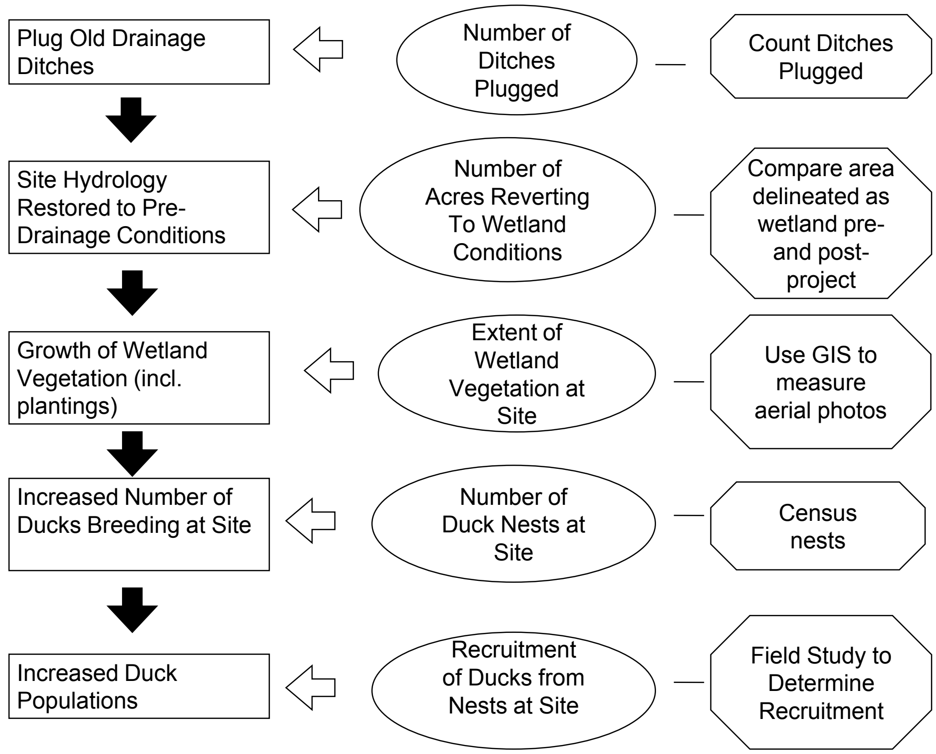


FIGURE 4.10 Logic model for a dam removal project that has been designed to restore passage for migratory fish species.

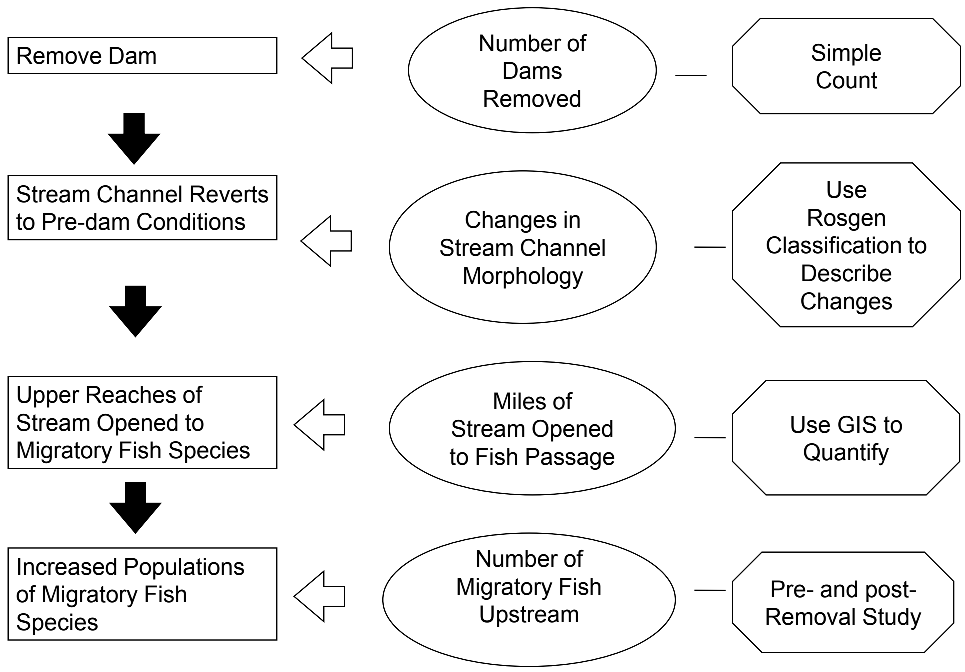
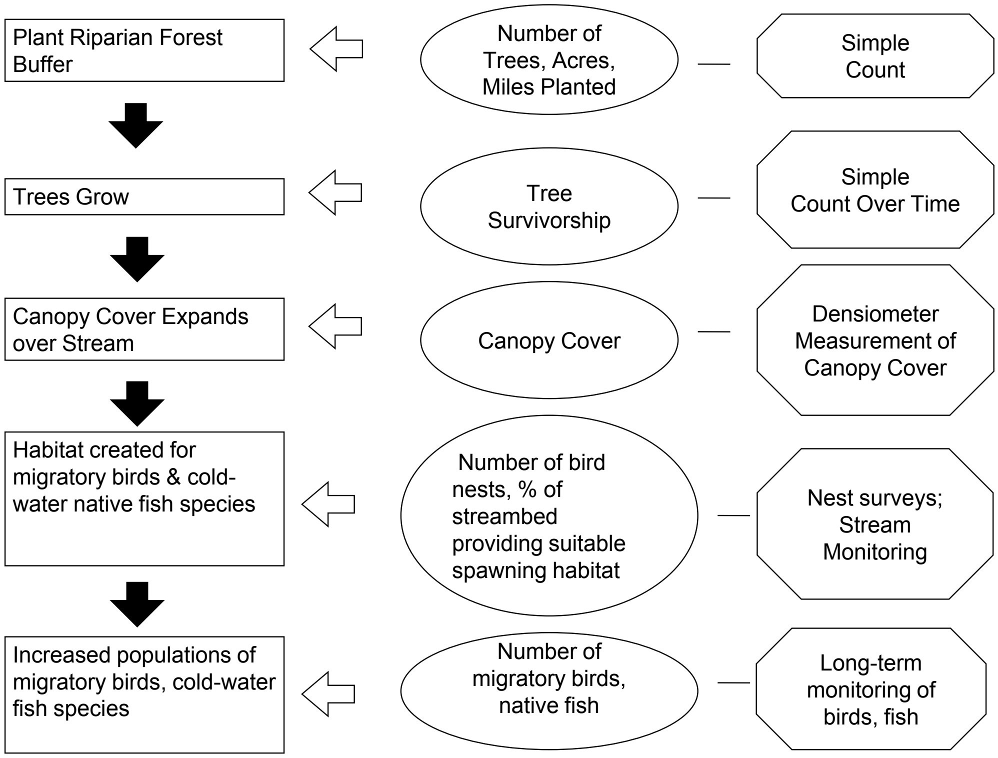


FIGURE 4.11 Logic model for riparian buffer planting, designed to improve habitat conditions for cold-water fish species.



Dam Removal Example

Dam removals are an increasingly common conservation activity, particularly in the northeastern United States where many dams are no longer actively maintained and quickly become safety hazards and eyesores. The conservation justification for removing dams, as outlined in the simple logic model (Figure 4.10), is that such removals will benefit migratory fish species. However, measuring populations of fish species is a resource-intensive activity that is often beyond the capacity of local conservation groups; thus, benefits to fish populations from these projects are typically inferred from the number of miles opened to fish passage (a **proxy indicator**) rather than being measured directly.

There are also a number of critical assumptions built into this model: that dam removal will result in the stream channel reverting to pre-dam conditions, and that the opening of the dam will result in increases to fish populations. It is perfectly possible that one or both of these conditions may be violated in practice: there may be too great a sediment load behind the dam to allow the stream channel to revert completely to pre-dam conditions (in which case the sediment load might still impede fish passage); or there may be other stressors such as predators or pathogens in the fish populations that keep the population at low levels even after the dam is removed.

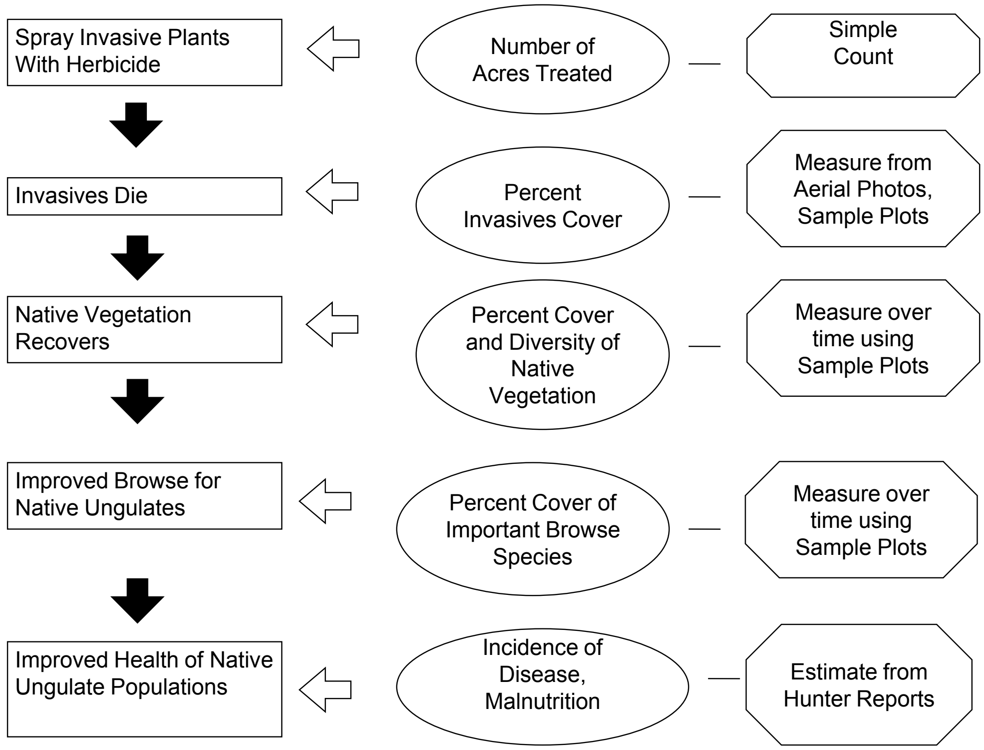
In either case, additional conservation measures would be needed to ensure the desired conservation outcome. A more robust model would take into account these undesirable outcomes and alternative conservation activities.

Riparian Planting Example

Riparian buffer plantings are a priority conservation activity for conservation groups in many parts of the United States. Because these plantings can potentially benefit multiple wildlife species and can also help to improve water quality, they are widely promoted by the U.S Department of Agriculture Natural Resources Conservation Service, the U.S. Fish and Wildlife Service, and the U.S. Environmental Protection Agency.

The logic behind these plantings (Figure 4.11) is fairly simple: trees are planted, grow, and absorb nutrients and other run-off that would otherwise directly enter streams and rivers. The trees can also shade the stream and increase the amount of habitat available for cold-water fish species (as in the logic model below). Note that this simple model focuses only on the benefits that result from the shading of the stream. A more realistic model would include both forms of benefits (nutrient uptake as well as stream shading).

FIGURE 4.12 Logic model for an invasive weed control project, where the intent is to benefit native ungulate populations.



These could be shown on separate but parallel logic paths, with arrows leading from "Trees Grow" to boxes with "Nutrients Absorbed" and "Canopy Cover Extends over Stream."

The performance indicators for this logic chain start with simple "count" variables (number of trees planted, acres and stream miles buffered) and move on to measurements of tree growth (survivorship and canopy cover), and finally lead to measurements of the wildlife populations that are expected to benefit from the riparian plantings (migratory birds and native fish).

Invasive Control Example

Invasive plant and animal species threaten all manner of conservation areas and restoration projects. In this example, a native meadow is being treated to eradicate invasive plants that are out-competing native browse plants for deer and elk. The story told by this logic model is clear: Spraying the invasives with herbicide will lead to direct mortality of the unwanted plants. Through either natural processes or some form of re-planting, native plants are able to recolonize the invaded area. The direct result of the recolonization is improved browse conditions for native ungulates such as deer and elk.

This simple model (Figure 4.12) is unclear about the source of revegetation. Is there a native seed bank that is finally able to sprout once the invaders are removed? Is the site being recolonized by seeds from native plants located outside of the treatment area? Or do native plants need to be re-planted or re-seeded onto the treatment area once the invaders are dead? An important part of refining this logic model would be to clarify this step. Different sources of seed will require different management strategies, from passive (allow natural vegetation to occur) to active (actively seed or plant new vegetation in the treated area). We will discuss methods for clarifying and refining logic models later in this report.

Note that the first performance measure included in this diagram is "Number of Acres Treated." As we have discussed before, this measure has been problematic for wildlife managers, because areas often have to be treated multiple times for invasives, and because different treatments are often applied simultaneously to the same area. In the context of this model, however, this measure acquires an important degree of explanatory power: the model clearly shows that these acres are being treated because they have invasive species on them that are not suitable as browse for elk and mule deer. The amount of area treated matters because it gives us a measure of how much new area of browse might be expected.

Including Education and Outreach Activities in the Logic Model

Wildlife management, like any human activity, takes place within a broader societal context. Many members of society, including hunters, anglers, gardeners, and birdwatchers, greatly value wildlife and have an interest in maintaining healthy wildlife populations. Programs that fund wildlife management activities are critically dependent on these same individuals for their continued survival: wildlife enthusiasts must advocate on behalf of conservation measures at state and national levels, hunters and anglers must continue to purchase licenses and pay excise taxes, and so forth. Given this context, it is essential for wildlife managers to take the time to explain their work and cultivate support from these key constituencies. It is therefore not surprising that outreach and education activities have become a significant part of the daily work of many wildlife biologists. However, in spite of their obvious importance, these activities are often viewed as a lower priority, because they do not directly benefit wildlife or wildlife habitats.

We recognize that these education and outreach activities are necessary and important as first steps towards broadening the base and more effectively coordinating resources for wildlife management. However, it is also important to be able to measure the direct results of these activities, and to show how these other activities can ultimately lead to benefits for wildlife populations.

Examples of these types of other activities include (but are not limited to):

- Coalition building
- Partnership development
- Coordination of activities with other agencies and organizations
- Outreach to new partners outside agency
- Outreach within agency, or within state government
- Outreach to the general public
- Fundraising

In this section, we will explore how wildlife managers might measure the results of these different types of activities. We will also consider how managers might be able to reasonably link these activities to longer-term wildlife conservation objectives.

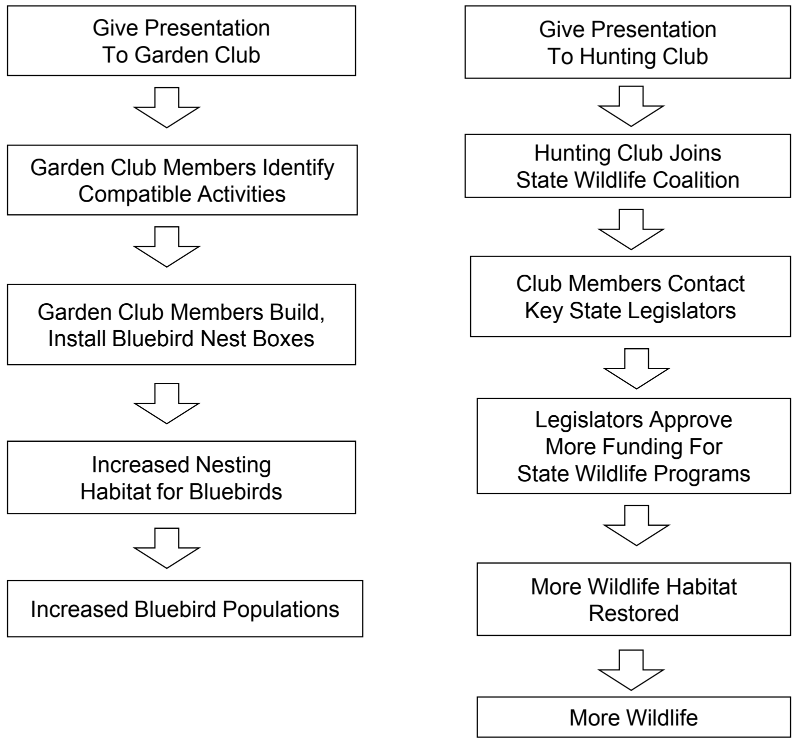
Start with Output Measures

We suggest that managers start by developing some simple short-term **output** measures for their outreach and coalition building activities. The natural tendency here is to immediately reach for very simple measures like "How many times did you show the PowerPoint?" or "How many people attended the meeting." These types of measures are easy to track, but do not really tell you anything particularly interesting about how your outreach activities relate to wildlife conservation.

Some equally simple but perhaps more interesting measures might include:

- How many acres are managed for wildlife by the agencies we have in our coalition?
- How many members are represented by the groups in our coalition?
- How many partners in our coalition do on-the-ground habitat management?
- How many of our partners are able to protect land through fee title acquisition or conservation easements? How many acres have they protected?
- How many [more] dollars will be spent in our state on priority habitat and species conservation work as a result of our outreach and coalition-building efforts?

FIGURE 4.13 Sample logic models for outreach and education activities to a garden club (left) and to a hunting club (right), showing how the engagement of these two organizations can lead to tangible benefits for wildlife populations. Based on the examples in previous figures, can you identify possible management indicators and metrics for the steps in these logic chains?



These measures begin the process of relating very specific outreach and education activities to some of the longer-term benefits to wildlife that we expect will eventually accrue from these outreach and education activities.

Then Use Logic Models to Link Activities to Wildlife Conservation Outcomes

After selecting output measures, the next important step is to be able to tell a compelling story explaining why these kinds of activities are critical for wildlife conservation. This means linking outreach and educational activities through a series of intermediate results to longer-term outcomes, including any direct benefits to wildlife that could reasonably be anticipated. As with the direct conservation examples above, we suggest that a logic model or causal chain may be helpful in developing these stories.

We would caution that it is important that the logic models be realistic, describing what you would reasonably expect would happen in a particular situation, not what would happen in the best of all possible worlds. You do not want to make extravagant claims for activities which, after all, will not be directly affecting the wildlife populations you are hoping ultimately to conserve.

Figure 4.13 shows two very simple examples that illustrate how a simple outreach activity such as a presentation to a local citizens group could potentially lead to more meaningful conservation outcomes. The example on the left leads directly to a desired biological outcome. The example on the right shows how achieving a political (social) outcome can be seen as an effective intermediate step toward achieving desired biological goals of wildlife management.

Testing and Refining Logic Models

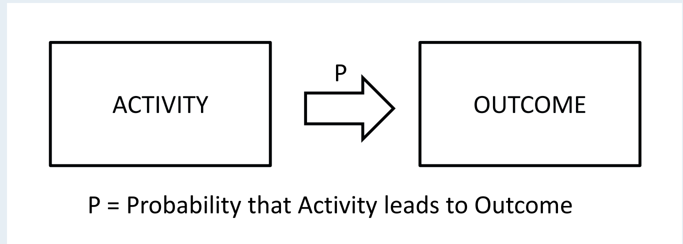
The testing and refinement of conceptual models are critically important components of an adaptive management approach to wildlife conservation. As we learn more about how ecological systems work, we can use that knowledge to improve our models of these systems. As our models improve, so too will our understanding of the appropriate management activities for particular species and habitats. This section reviews several simple tests and methods that are particularly appropriate for the refinement of logic models.

Although logic models can be helpful tools for describing the anticipated effects of a project, several key limitations of logic models have been identified in our conversations with conservation scientists and evaluation practitioners:

- **Oversimplified** – These models reduce complex interactions to a single chain of events. In most real-world wildlife management situations, there are multiple confounding factors and even multiple conservation activities that are associated with a particular conservation target.
- **Linear** – As described here, these models do not reflect dynamic or recursive processes. More complex logic models can be constructed that include branching or recursive processes, but even these models are static relative to certain forms of quantitative models.
- **Non-quantitative** – The causal relationships expressed in logic models cannot be subjected to quantitative analysis without additional information on process rates and transition probabilities. We will discuss methods for approximating these rates and probabilities below.
- **Attribution or determination of cause and effect relationships is problematic** – Logic models only describe hypotheses of causal relationships. They do not provide a rigorous framework for testing hypotheses of causality, or for discriminating among multiple causal pathways.

In addition, it can be shown that, for most real-world situations, the longer the logic chain, the lower the probability that the specified action will lead to the desired outcome. This can even be demonstrated mathematically if we assume that each arrow in a logic chain is associated with a certain transition probability. The transition probability is the likelihood that the activity will in fact lead to the desired outcome (Figure 4.14).

FIGURE 4.14 Simple logic chain.



If, however, we introduce additional steps and intermediate outcomes, the number of arrows increases, such that the overall probability between the activity and the ultimate outcome is now expressed as the product of the individual transition probabilities (Figure 4.15).

For most real-world situations, we would expect that the transition probabilities for each step in the logic model would be between 0 and 1. Each probability is most likely not zero, otherwise the transition that we are describing in the model would be impossible. The individual probabilities are most likely not one, either, as there are usually a number of confounding factors that can prevent a particular conservation activity from leading to a desired outcome.

The overall probability of the logic model (the probability that the activity on the left-hand side leads to the ultimate outcome on the right-hand side) is the product of the individual transition probabilities (P1 x P2 x... Pn).

Because the individual transition probabilities multiply to produce the overall probability of the logic model, adding more steps in the logic chain results in an overall probability that is the same or lower than any of the individual transition probabilities. This makes intuitive sense if we consider a simple example. Suppose a conservation group is interested in increasing the amount of land in protective conservation easements within a particular watershed. The members of the group have developed the simple logic model shown in Figure 4.16 to demonstrate how their outreach activities will lead to their desired outcome of new conservation easements being established.

The group's initial activity is an education and outreach campaign to landowners providing them with information about the benefits of conservation easements. Out of the total population of landowners who received information during the education and outreach campaign, there would be a certain percentage of landowners (P1) who would be receptive to the information that was presented and who would express interest in establishing a new conservation easement on their property (the intermediate outcome). Moving along the logic chain,

FIGURE 4.15 Logic chain with intermediate outcome.

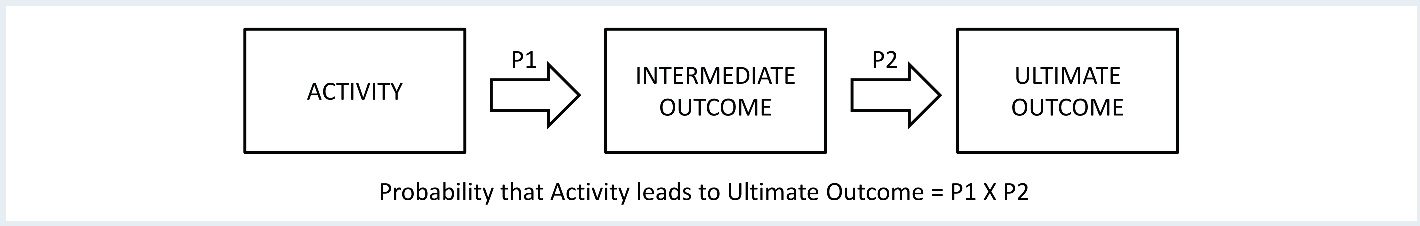
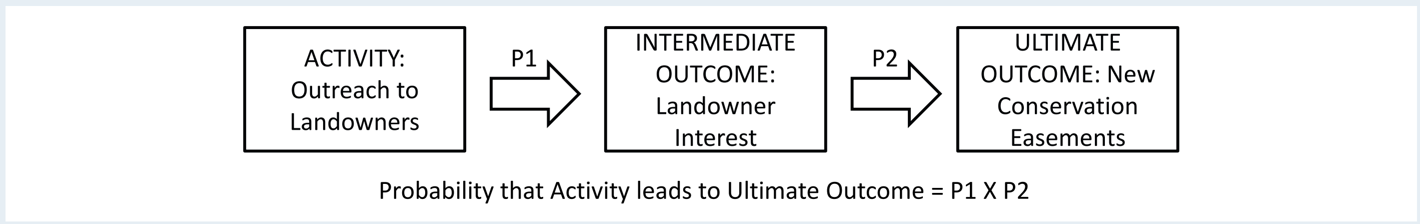


FIGURE 4.16 A logic chain for a landowner outreach project, showing transition probabilities.



the percentage of landowners (P2) who actually followed through and established new conservation easements (the desired ultimate outcome) would most likely be an even smaller subset of the total population of landowners.

As additional steps are added at the end of the logic chain, the overall probability value for the chain decreases. This poses a challenge for the construction of longer logic chains. As shown by the examples in the previous section, many real-world situations have lengthy logic chains linking conservation activities with desired outcomes.

Simple Tests of Logic Models

Given the limitations described above, it is important to test the basic assumptions of a logic model before using the model in an actual monitoring and evaluation program. Here we describe several of the simpler tests that are available for conservation practitioners.

Logical Analysis

All logic models should be carefully reviewed before being included in an actual monitoring and evaluation program and the following questions addressed:

- Do the steps in the model make logical sense?
- Do the outcomes seem reasonable and realistic, given the scale and scope of the activities that are being proposed?
- Do the downstream steps follow logically and necessarily from the steps that are earlier in the chain?
- Are there any major leaps in the logic or process assumptions that have not been explicitly stated?

Literature Analysis

The existing literature on the science and practice of natural resource management, ecology, and biodiversity conservation contains much valuable information about the success and failure of past management activities. This information can provide managers with varying levels of support for the causal pathways that have been proposed in logic models:

- **No support** – The proposed sequence of events in the logic model has not been documented in the literature.
- **Weak support** – The sequence of events postulated in the logic model has actually been documented at least once in the real world.
- **Stronger support** – A causal relationship has been demonstrated between the type of action that is being proposed and the intended result.
- **Strongest support** – It has been demonstrated that this exact action will lead to this exact result, with a high degree of probability.

A literature review is potentially one of the most important sources of evidence in support of a particular logic model.

Multiple Outcome Analysis

It is possible to develop more complex logic models that show multiple possible outcomes for a project. These models may be more "honest" than the simple linear models described earlier, because they can depict possible pathways for project failure, as well as pathways for project success.

The following example (Figure 4.17) shows how a simple logic model can be expanded to show multiple alternate causal pathways linking an activity and its possible outcomes. The boxes across the top represent the set of positive alternatives (everything goes according to plan, and the activity leads directly to the anticipated outcomes). These positive alternatives are the steps that would be included in a conventional logic model. In this multiple outcome model, there are one or more possible pathways at each step, indicated by arrows, which could lead to either positive or negative alternatives. The negative alternatives show ways in which the project could fail.

All of the alternatives in this example are paired. In fact, many of these alternatives are probably continuous variables, rather than either-or choices (for example, the percentage of landowners that would establish new conservation easements is most likely between 0 and 100%, rather than exactly 0% or exactly 100%).

If we consider the number of potential pathways between the activity on the left-hand side and the possible outcomes on the right-hand side, it quickly becomes apparent that there is only one pathway by which all of the desired intermediate and ultimate outcomes would be achieved, and two pathways by which the project would fail to achieve some or all of the desired outcomes. We suspect that this situation (one or a few pathways for success, multiple pathways for failure) is typical of many conservation projects. Analyses of the pathways by which projects could potentially fail can be a valuable exercise for managers interested in designing projects that are resilient to certain types or sources of potential failure.

Simple Quantitative Models

Information about the success and failure rate of actual projects can be used to develop simple quantitative models, using a logic model as a starting point. To return to our outreach example above, let's assume that the conservation group has conducted outreach to 100 landowners in the past year, that 50 of those landowners expressed interest in conservation easements, and that 20 of those landowners have actually established new conservation easements. So the transition probabilities in their logic model are shown in Figure 4.18.

This model shows several things of interest: first, the group can expect, based on past history, that approximately one in five landowners contacted by their outreach program will actually establish conservation easements. Knowing this probability can be helpful to the group in planning their future outreach efforts. Second, the model shows that there are actually two separate probability terms: the percentage of landowners who respond positively to the outreach presentation, and the percentage of landowners who then go on to actually establish new conservation easements on their properties. The conservation group thus has two different areas where it could focus on refining and improving its efforts.

FIGURE 4.17 More complex model showing multiple potential outcomes from a single activity.

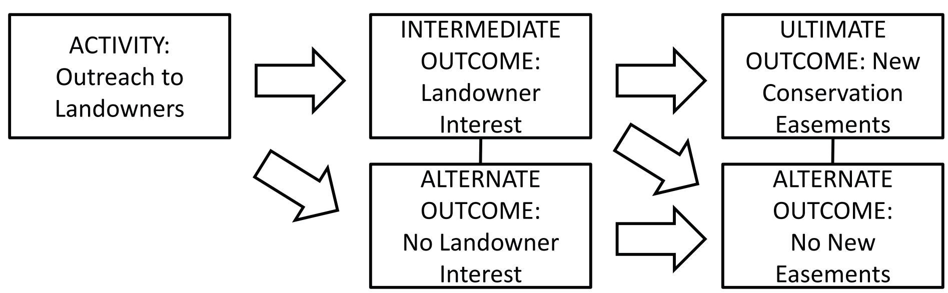
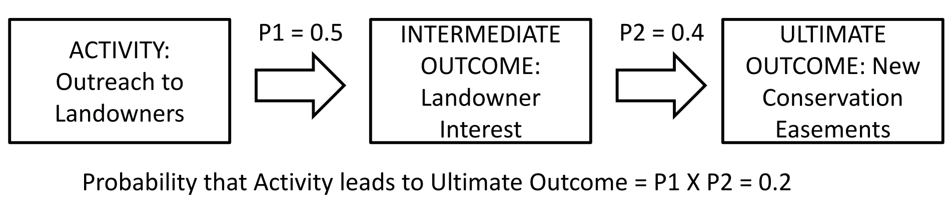


FIGURE 4.18 Simple linear quantitative model.



Focusing on P1 would lead the conservation group to improve its presentations to landowners, thereby increasing the percentage of landowners who express interest in easements. Focusing on P2 would lead the group to focus on identifying factors that lead landowners to actually establish new easements. Perhaps there is a strong tradition of hunting and fishing that provides landowners with a strong incentive to value open spaces. Perhaps there are fluctuations in the local real estate market that make easements more or less attractive to property owners. Perhaps there are other incentives (matching funding, tax breaks) that are available from state or municipal agencies. Or perhaps there are social or cultural factors or perceptions that inhibit the adoption of new conservation easements by landowners in a particular area. Addressing these and other, related questions is an important step towards designing more successful conservation projects.

Testing as You Go: Indicator Analysis

As described above, indicators can be selected that track each step in the logic chain and help to determine whether or not the activity is achieving its desired outcome. This approach has been widely recommended in the literature (e.g., Margoluis and Salafsky 1998), and has been adopted by various conservation organizations in the United States, including The Nature Conservancy.

The indicators for a monitoring program should be selected with great care, by scientists and managers familiar with the ecological system or species in question. Otherwise, it is quite possible to choose indicators that are not responsive at the appropriate time or spatial scales, or that provide information that is downright misleading about the ultimate outcome of a project. Chapter 5 provides more detailed information about the development of indicators for wildlife management programs.

Indicator analysis is a valuable tool for tracking the progress of a project, but should be used only once a logic model has been rigorously examined using one or more of the approaches described above.

Other Tools and Approaches for Developing Performance Measures

In this section, we will look at some other tools and approaches besides logic models that may prove useful to wildlife managers for developing performance measures in particular management contexts.

Identifying Measures for Goals, Objectives, and Information Needs

In their helpful book *Measures of Success*, Margoluis and Salafsky (1998) take readers through the process of designing and implementing monitoring and evaluation plans for biodiversity conservation projects. The authors recommend linking performance measures to the project's **goals and objectives**, as well as to the **information needs of the project's audience**.

Goals are "a general summary of the desired state that a project is working to achieve" (e.g., "Conserve biodiversity in the Kalimantan rainforest" or "Reduce nutrient inputs to Chesapeake Bay") while **objectives** are "specific statements detailing the desired accomplishments or outcomes of a project" (e.g., "Reduce illegal rainforest logging by 50% over 5 years," "Implement nutrient reduction projects on half of the farms in the Shenandoah Valley over the next 10 years"). Each goal may have one or more objectives associated with it.

Margoluis and Salafsky further recommend that project managers identify key audiences for a project (both internal audiences and external audiences) and list **key information needs** for each audience. Information needs may be very specific (the number of whales in a bay), or broad (an overall sense of whether or not a project is worth the money expended on it).

Once goals, objectives, and key information needs for the project's major audiences have been identified, **indicators** are selected for each of these elements. In this system, indicators are environmental or social attributes that can be measured and that change over time during the course of a project or program.

The following flowchart (Figure 4.19) summarizes the method for choosing indicators described by Margoluis and Salafsky.

The authors recommend that indicators be **measurable**, **precise**, **consistent**, and **sensitive**. Measurable means that an indicator can be reported and analyzed using either qualitative or quantitative methods. (Note that resource limitations may also dictate whether or not a particular indicator is measurable.) Precise means that there is general agreement among practitioners as to how a particular indicator is defined. Consistent means that the indicator does not change over time; it always measures the same thing. And sensitive means that changes in the indicator are proportionate to changes in the environmental condition or item being measured: a large change in the indicator reflects a large change in the environment, while a small change in the indicator reflects a small change in the environment (Margoluis and Salafsky 1998).

The Evaluation Logic Framework

The evaluation logic framework is a simpler version of the logic models or causal chains described above. In its most basic form, the logic framework asks project managers to list their project's goal and specific objectives, describe specific activities that they will be undertaking to attempt to achieve an objective, and predict the specific results that they expect will follow from those activities. Some versions also ask a project manager to explain how s/he would measure the results of the activities s/he is proposing.

The logic framework is useful for showing simple relationships between actions and anticipated results. Completing even a simple logic framework for a project can help managers tell a more compelling story about the work that they are doing, and describe both the short-term and long-term results they are expecting to achieve.

Many funding agencies and private foundations in the United States are using logic frameworks and are asking their grantees and applicants to use this tool in developing their proposals. The following example is adapted from materials that have been developed by Matthew Birnbaum at the National Fish and Wildlife Foundation. We have used this example because it is likely to be familiar to many wildlife professionals who seek funding from this foundation.

Here, the logic framework takes the form of a simple table or chart with seven columns and row(s) for each of the project's major activities. In this example, there are no columns on the left-hand side for "Goals" or "Objectives" because the grant application form asks applicants to describe the project's goals and objectives in a different section. For the sake of completeness, we have listed these two essential components below the logic framework table.

FIGURE 4.19 A method for indicator development outlined by Margoluis and Salafsky (1998).

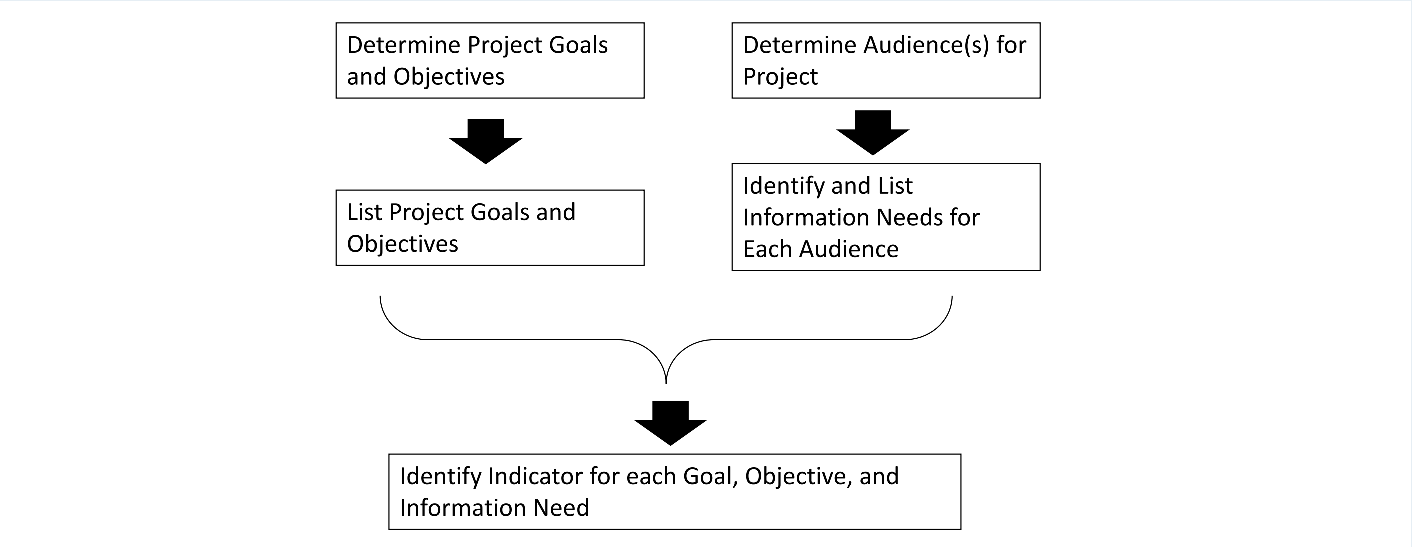


TABLE 4.1 Evaluation Logic Framework

Activity	Output	Outcome	Indicator	Baseline Value	Output Value	Outcome Value
Stabilize eroding streambank	Streambank stabilized	Erosion stopped	Number of feet of eroding streambank	50	0	0
Plant 50' Riparian Buffer	100 new trees planted	Bank stabilized	Number of trees on bank	0	100 at project completion	75 trees surviving after 5 years

Project: A Demonstration Planting of a Forested Riparian Buffer

Goal: To reduce non-point source water pollution from agricultural sources in Adams County, Pennsylvania.

Objective: To stabilize 50 feet of eroding streambank and plant a new riparian forest buffer along Rock Creek adjacent to Farmer Jones' cow pasture.

This logic framework actually has two parts or sections – the three columns on the left-hand side, which provide a short narrative description of the project's activities and results, and the four columns to the right, which describe how the results of the project will be measured using a simple statistic or "indicator."

Logic frameworks are useful in developing simple stories about a project and to describe what would be expected to happen as a result of project efforts. A simple story using the information contained in the logic framework above would look something like this:

"The Friends of Rock Creek are interested in reducing non-point source water pollution from agricultural sources in Adams County, Pennsylvania. To help meet this goal, we will stabilize 50 feet of eroding streambank and plant a new riparian forest buffer adjacent to Farmer Jones' pasture. These activities will stop erosion at this site. The eroding streambank currently has no trees; by the end of the project we will have planted 100 new trees at this site. We expect 75% of the trees to survive at least 5 years."

Notice that this story tells what the group is planning to do, what results are expected over both short-term and long-term time periods, how they will measure these results, and even what they expect the measurements will be. After the project is completed, the project manager can compare her estimates with real-world data (collected through a monitoring program) to see how well her expectations aligned with the actual observed results.

Identifying Indicators of Threats

Salzer and Salafsky (2006) describe an interesting approach for natural areas management that focuses primarily on **threats** to these areas. The approach uses two categories of indicators to help managers choose among potential conservation actions: "early warning" indicators provide advance warning of potential problems and trigger conservation actions when measurements of the indicator cross particular thresholds; and "diagnostic indicators" provide managers with information regarding whether or not a specific action is working as planned.

An "early warning" indicator could be the presence of a new invasive species in an area, or the presence of new off-road vehicle traffic adjacent to a sensitive site. A "diagnostic indicator" might measure how the size of an invasive plant infestation changes with management, or the extent to which specific road closures prevent off-road vehicles from accessing a protected site.

The Salzer and Salafsky method can be applied at any scale but assumes that a specific area for management has been defined. The first question confronting managers is whether specific and substantial threats are facing this area, necessitating management action. If there are no threats, the next question is whether there are known potential threats. If no, then only early warning indicators would need to be measured. If there are known potential threats, then both early warning indicators and diagnostic indicators specific to those threats should be measured.

If, however, there are substantial threats facing the area of interest, then the next question is whether or not there are clear and feasible actions to abate these threats. If the answer is no or even "probably not," then the only course of action would be to apply diagnostic indicators to measure the status and progress of the threat. If there are actions that *might potentially* abate the threats, then the best course of action would be to implement a small-scale test to determine which type of action is most effective, use some form of diagnostic indicators to measure the results of these actions (and assess the magnitude of the threats), and measure "early warning" indicators for other potential threats. If there are actions that would *clearly* abate the threats, the appropriate course of action would be to implement the actions at the scale needed to abate the threats, apply diagnostic indicators to measure the results of these actions, and measure "early warning" indicators for other potential threats.

Focusing on threats seems intuitively as though it would be a successful strategy for biodiversity conservation, with the potential to yield meaningful, measurable results in the short term. This focus may also provide managers with a valuable perspective on a different suite of indicators (threat variables) that could be selected for specific projects. Our review of the literature suggests that methods for measuring and quantifying threats to wildlife populations are less well developed than are methods for measuring status and response variables (which typically refer to species and habitats). The threat classification system developed by the Conservation Measures Partnership (IUCN-CMP 2006) represents a good step in this direction.

Starting with a Few Key Indicators: An Example from the Adaptive Management Literature

Adaptive management has been a part of the tool kit for natural resource managers for several decades and will no doubt be familiar to many readers. The core philosophy of adaptive management is "learning by doing," which means that management actions are regularly assessed to determine what worked and what did not, and the lessons learned are applied to future projects or activities of a similar nature. Chapter 9 provides a broader introduction to adaptive management and its relationship to the State Wildlife Action Plans.

In a more formal context, adaptive management refers to a particular iterative management process, which starts with the development of a logical model (often quantitative and computerized) of the system or process to be managed. The model predicts what will happen if particular management actions are taken, and includes specific indicators that are measured to determine whether or not the model's predictions are accurate. Information is collected during and after the implementation of management recommendations that is used to further refine the model, with the hope that it will generate better predictions in the next management cycle.

An introductory discussion of modeling techniques that should accompany adaptive management is provided in Chapter 9. Interested readers are also referred to more comprehensive treatments such as that of Holling (1978), Walters (1986), Stankey et al. (2005), and Williams, Szaro, and Shapiro (2007). For purposes of this review it is valuable to compare the role of indicators in the adaptive management cycle with the various approaches described above.

Walters (1986) describes a model-based approach for natural resource management. He recommends starting the process of model development by convening a working group that first identifies a few key management indicators and then builds a logical framework around the indicators. The framework includes all factors that might potentially influence each indicator. The process of building the framework continues until the project's management team feels that further elaboration is unnecessary. Other key indicators may be identified during the process of framework development. The completed framework is translated into a more formal, quantitative model (usually programmed in a computer), with the key indicators becoming the output variables from the model.

What is interesting here is that the selection of the key indicators takes place before the development of the conceptual model. Clearly, this is more easily done for certain natural resources such as fish stocks or timber reserves where there are a small suite of key measures such as population size or number of standing board feet that are generally accepted as important indicators by the management community. Such indicators would be measured as part of any management process for these resources. For many non-game wildlife populations and ecosystem or habitat types, it is much less clear what the most critical management metrics would be. In these cases, logic framework or causal chain approaches (which are both simple conceptual models) may be more helpful in identifying potential indicators.

Chapter 5: Sample Indicators for Wildlife Management Activities

As we have seen in the previous chapter, conceptual models can be helpful in identifying potential indicators for a wildlife management program. This chapter is intended to give wildlife managers a sense of the types of indicators that are commonly measured as part of a comprehensive fish and wildlife performance measurement program. We provide descriptions of some of the indicators that are commonly used to evaluate the success of wildlife conservation activities. The primary focus here is on indicators that can describe aspects of wildlife populations and habitats, because these are the primary conservation targets that have been identified in the State Wildlife Action Plans.

The findings in this chapter are based on an extensive review of both peer-reviewed and "grey" literature. Our intent in conducting this literature review was to find as many examples as possible of indicators that have actually been used in real-world settings by wildlife managers or evaluation practitioners. It is often straightforward to describe what aspects of wildlife populations should be measured in an ideal setting with unlimited resources; it is much harder to find measures that will actually work in particular real-world management contexts.

In summarizing these findings, we have found it useful to separate the "things" or attributes that are measured by wildlife managers into two broad categories: **simple metrics**, which are single measurable aspects of wildlife populations or habitats; and **composite metrics**, which are multi-metric indices that combine two or more different simple metrics into a single rank or index value.

While simple metrics are usually measured at the site or local level, they can often be "bundled" across multiple sites to produce statistics that describe conditions at regional, state, or even higher levels. It should be noted that there may be practical or theoretical limits to bundling or aggregating simple metrics. These limitations are discussed in more detail in Chapter 7.

At the end of this chapter we provide a list of potential indicators or metrics for specific types of management or restoration projects. This is by no means intended to be an exhaustive list, but rather is presented to stimulate the thinking of wildlife managers by suggesting potential targets for monitoring and evaluation work. We also include a "Further Reading" list that includes examples of published evaluation and monitoring studies that use these metrics.

Simple Metrics

Simple metrics measure a single aspect or attribute of a wildlife species or habitat. Many of these metrics can be measured directly in the field, while others can be estimated using remote sensing data.

Species Population Metrics

Given that many wildlife management projects are conducted for the purpose of recovering or improving populations of particular wildlife species, it is no surprise that there are a suite of widely-accepted metrics for evaluating the status of populations and species. Probably the simplest (at least conceptually) are "count" variables (number of individuals, number of occurrences, number of populations or meta-populations, and so on). Counts per area or per transect can provide estimates of population density, while repeated counts over a series of time intervals can provide estimates of population trends (Sauer, Link, and Nichols 2003).

For many species it can be difficult to census accurately an entire population, so demographic or population models are used to estimate population size or population trends using data collected through statistically valid sampling schemes (Thompson 2004). The types of data that are actually collected from the wildlife population of interest will depend on the particular management model that is used; but such models often rely on data on occurrence, abundance, reproductive output, age structure, survivorship, migration, and/or mortality (Cantu and Richardson 1997; Shult and Armstrong 1999; Sauer, Link, and Nichols 2003; Thompson 2004).

Species Composition

One of the simplest measures of biodiversity at a given site is the number of species per unit area (also known as species richness). There have been a number of more sophisticated metrics developed to measure biodiversity, but species richness remains popular because it can be readily calculated or estimated from field data. A manager may also be interested in the percentage of species at a site that share some particular ecological property, such as intolerance to disturbance. For instance, the percentage of ecologically sensitive macroinvertebrates is one of the individual metrics that contributes to the Index of Biotic Integrity for freshwater systems (discussed in more detail under "Composite Metrics" below).

Species Distribution

Changes in the distribution or migratory patterns of species can provide powerful indirect evidence of significant changes in the local, regional, or global environment (Sauer, Link, and Nichols 2003; Thompson 2004). At local scales, species distributions in the U. S. are typically quantified as single occurrences using the element occurrence standards developed for various taxa and ecological communities by NatureServe (2002). At larger spatial scales, species distributions are often displayed visually using range or point maps. Depending on the level of accuracy in these maps, changes in the area of species distributions could be quantified using Geographic Information System (GIS) software.

Habitat Extent

Most reporting of habitat protection and restoration activities is done using extent variables, which are based on linear or areal measurements of a particular area, vegetation type, or ecological community of conservation interest. Related measures include the number of acres protected, acquired, or restored; number of new miles of riparian forest buffer planted; size of conservation easement; number of miles of river opened to fish passage. Although easy to measure using GIS, satellite imagery, or standard land surveying techniques, these variables have been criticized in the literature (e.g., Ferraro and Pattanyak 2006) for providing little information about habitat quality or ecosystem processes that are critical for supporting wildlife populations.

Habitat Composition

Composition metrics for wildlife habitat typically enumerate or describe aspects of the vegetative community (Ruiz-Jaen and Aide 2005). Such measures may be quantitative (numbers of plant species, numbers of canopy tree species), or qualitative (lists of the dominant species). At larger scales, habitat composition is usually measured by percent of particular land cover types within an area of interest, often based on a GIS map derived from satellite data or aerial imagery (The Heinz Center 2002).

Habitat Structure

These metrics describe physical parameters of the habitat itself – basal area of a forest stand, average height of vegetation in a grassland community, average height of understory shrubs, sinuosity of a creek, frequency of riffles and pools in a stream reach (Ruiz-Jaen and Aide 2005).

Habitat Function/Process

Many ecologists argue that this is one of the most important categories of variables (e.g., Ruiz-Jaen and Aide 2005), yet it is one of the most difficult to define. Part of the definitional complexity stems from the fact that many structural or compositional metrics also provide clues to ecosystem function. For example, seedling composition, height, and density together provide valuable information about forest stand recruitment and long-term stand dynamics. The depth of the soil organic layer is a structural attribute of soil, yet it also provides important insights into nutrient cycling. Another suite of variables commonly used in assessing ecosystem function are the concentrations of various chemicals and ions (including dissolved oxygen, nitrogen or phosphorous run-off, soil pH).

Some ecosystem processes have their own specialized measurement vocabulary and sets of associated indicators. For example, fire managers have developed their own sets of indicators and metrics to quantify pre- and post-fire fuel loads, burn extent, and burn frequencies (National Park Service 2003).

Resource Variables

These variables describe key resources for wildlife species, such as prey, water, host or food plants, and mutualistic partners (e.g., ants that tend the larvae of Karner blue butterflies). Many resource variables are actually species or habitat measures, which would not otherwise be of management interest, if they were not essential to particular wildlife species. For these variables, managers are typically interested in the presence, abundance, and spatial distribution of the resource.

Research and Monitoring

Basic research is an important ancillary activity to wildlife conservation and is identified as a key activity in many of the State Wildlife Action Plans. Research outputs are typically quantified in the academic sector by counting some combination of 1) number of pages published in peer-reviewed journals, 2) number of articles published in peer-reviewed journals, 3) the impact factor of the journals in which the research is published, or 4) number of citations of a published article (Monastersky 2005). Since many of the research activities conducted or sponsored by wildlife managers will not be published in peer-reviewed journals, other appropriate measures may include number and length of reports, relevance of reports to management decision-making, and the citation or use of particular reports in public or internal discussions about natural resource management.

Monitoring of wildlife populations is another important ancillary activity, and there is an extensive literature on how to design monitoring programs to provide information at a level of detail sufficient to answer specific questions about species or populations of interest (Gibbs, Droege, and Eagle 1998; Sauer, Link, and Nichols 2003; Thompson 2004).

More information about the design of monitoring programs is provided in Chapter 10. Some of the key questions in designing monitoring programs, such as appropriateness of design, sensitivity, precision, and accuracy (Margoluis and Salafsky 1998), could also be used to evaluate these programs. There has been particular interest in the use of volunteer or "citizen science" monitoring programs in recent years, and these programs show particular promise for use in State Wildlife Action Plan monitoring. Citations are provided below to published papers that review select citizen monitoring programs in more detail. In general, these studies are encouraging: with proper training and given simple tasks such as tree identification, citizen monitors achieved levels of accuracy comparable to those of more experienced field naturalists. However, questions have been raised about the design of some "citizen science" efforts, particularly in regards to sampling strategies and the interpretation of results (Sauer, Link, and Nichols 2003). The Cornell Laboratory of Ornithology offers a "citizen science toolkit" (http://www.birds.cornell.edu/citscitoolkit) and online forums that are designed to assist wildlife biologists and other natural resource managers in the development and successful implementation of new citizen science programs.

Regulatory Programs

Regulations that limit or prohibit hunting or collecting are one of the oldest and most widely used tools for managing wildlife, both for game species as well as for endangered species (Leopold 1933). While these programs make intuitive sense where hunting or collecting is a verifiable threat to the continued survival of wildlife populations, there have been few studies that have rigorously investigated the effects of such regulations. The available data are subject to interpretation, as is shown by recent debates between advocates and critics of the federal Endangered Species Act. These debates hinge on whether the number of species recovered (the view of the Act's critics) or the number of species that have gone extinct (the view of the Act's advocates) is an appropriate metric for judging the success of this act. In reviewing this debate, the U.S. Government Accountability Office (2006) argued that neither of these metrics provides a complete picture of species status, and that more information about the time and costs required for full achievement of recovery goals is needed in order to fairly evaluate the effectiveness of the Endangered Species Act. Rodrigues (2006) suggests another metric that may be appropriate for regulatory programs: the number of species that would have become extinct if conservation activities had not occurred. Although this metric is intriguing, it could be populated only with actual data for taxa, such as birds and some mammals, where long-term information about population status, trends, and conservation activities is available.

Composite Metrics

Composite metrics translate multiple quantitative measurements or qualitative assessments into a single metric that may facilitate comparisons between sites or across geographic levels. Such metrics are particularly helpful in combining measurements with different units (e.g., numbers of fish and average fish length) into a single metric for comparative purposes.

Probably the best known composite metric is the Index of Biotic Integrity (IBI) for warm-water streams (Karr 1981), which in its original version combined 12 metrics (reflecting fish species richness and composition, number and abundance of indicator species, trophic organization and function, reproductive behavior, fish abundance, and condition of individual fish) into a single quantitative index scaled from 12 (lowest) to 60 (highest). The values of this index can be compared across stream segments, and the method can be also applied to different orders of streams, allowing some comparisons across different geographic scales.

The NatureServe (2002) or Natural Heritage ranking system is a series of nested ranked variables that measure the conservation status of rare species or unusual vegetation types at different geographic scales. It differs from the IBI in at least two important respects: the nested variables do not scale up according to a strict mathematical formula; and the system relies to a certain extent on expert judgment in establishing the rankings for each element at each level. Species or habitat occurrences are grouped using quantitative and/or qualitative standards into "Element Occurrences" or EOs. Within each state or territory, the rankings and number of EOs are used to establish a state or "S" rank. Within each country, the "S" ranks collectively help determine the national or "N" rank. And the various "N" ranks within a species' distribution help determine its global or "G" rank. (For species found in only one country, the "N" rank is usually synonymous with the "G" rank.)

Some factors used in ranking species or vegetation types in the NatureServe system include:

- Total number and condition of occurrences
- Population size
- Range extent and area of occupancy
- Short- and long-term trends in the above factors
- Scope, severity, and immediacy of threats
- Number of protected and managed occurrences
- Intrinsic vulnerability
- Environmental specificity

A similar combination of metrics occurs in Red List indices, which measure changes in the global conservation status of groups of species that have been comprehensively assessed at least twice using the International Union for the Conservation of Nature (IUCN) methodology (Butchart et al. 2005). Red List indices are a very coarse assessment tool, but nonetheless can be used to demonstrate global changes in the conservation status of broad taxonomic categories, such as birds or amphibians.

Non-biological Metrics

Although many wildlife professionals focus their attention on wildlife species and their habitats, it is clear that wildlife conservation occurs within a broader social context. Human activities are often responsible for driving the processes that help or hinder wildlife populations. For example, suburban development displaces forest-interior bird species but provides habitat for other bird species. Recreational boaters may inadvertently transport aquatic invasive species. And chemical treatments aimed at insect pests may adversely impact bird species. These and other human activities are, in turn, driven by economic forces, quality-of-life issues, and major demographic shifts. Understanding and describing the relationships between these factors and how they might relate to wildlife conservation requires input from social scientists, economists, and evaluation professionals. Such scientists are not always included in discussions about wildlife conservation, because their activities are seen as external to the immediate conservation needs of species and their habitats. However, these scientists may be able to offer valuable perspectives on human actions and motives. In particular, they may be able to identify specific indicators that track social processes that have a direct effect on wildlife and habitat. While an in-depth discussion of potential indicators and metrics for social processes is outside the scope of this review, the interested reader is referred to standard textbooks such as Trochim (2006) for an introduction.

Some Common Variables Used in Monitoring and Evaluating Wildlife Management Programs

Species Management Variables

"Count" variables

- Number of animals/plants
- Number of animals/plants per unit area
- Time series of population numbers
- Abundance (including trends)

Composition

- Number of Species (global)
- Number of Species per unit area
- Percentage of a sample/area that is some particular taxon

Geographic distribution

- Number of occurrences (and changes in number)
- Density of occurrences (and changes to density)
- Range maps (and changes to them)
- Density estimates (distribution of entities across landscapes)
- Movement/migratory patterns

Basic life history or demographic parameters

- Dimensional measurements (length, antler size, maximum size)
- Growth rate of individual organisms
- Life history chronology
- Age or Age class distribution
- Weight or Weight class distribution
- Survivorship/Mortality
- Reproductive output
- Population growth rate
- Sex ratios
- Genetic diversity of individual populations
- Disease prevalence in individual populations

Resources

- Food (Availability, Density, Production)
- Water Availability
- Light (Availability, Heterogeneity)
- Other essential needs, such as the presence of obligate mutualist species

Habitat Extent Variables

- Absolute size of area of conservation interest
- Relative size of area (to amount of developed land, to the total amount of land in a particular vegetation type or ecosystem type)
- Number of protected sites or percentage of area protected
- Biome and habitat content of area
- Species composition of area

Degree of connectivity/separation from other areas

- Landscape composition
  - Percent land use
  - Percent land in "natural condition"
  - Percent land unfragmented within a given distance (e.g., 1 km)
- Immediately adjacent land use to area
- Distance to nearest road / road network extent
- Connectivity to other habitat patches
- Continuity of riparian corridor
- Area of contiguous fire-maintained landscape

Habitat Management Variables (most structural, some compositional or functional)

General

- Biomass
- Floristic quality assessment
- Vegetation Index of Biotic Integrity
- Invasive species (presence/absence, number, percent cover of plants)
- Presence of particular indicator species for ecosystem/habitat type

Soils

- pH of soil water
- Organic soil horizons
- Soil organic matter decomposition
- Soil organic carbon
- Soil bulk density

Forest

- Basal area
- Percent canopy closure (amount of canopy die-back)
- Height of understory, canopy, or supercanopy
- Density of pole trees
- Density of regenerating trees
- Presence/amount of coarse woody debris

Grassland

- Amount of litter
- Depth of litter
- Invasive species (numbers and identities, percent cover, other density metrics)
- Woody species recruitment
- Woody fuel loading (per area)
- Mean height-density obstruction
- Mean height-disc readings per field

Streams and Rivers

- Index of Biotic Integrity (original version [note that most metrics that comprise IBI are "count" or composition metrics])
- Channel depth
- Substrate size
- Substrate embeddedness
- Velocity/depth
- Water clarity
- Water temperature
- Water chemistry metrics (see below)
- Sediment deposition
- Channel flow status
- Channel alteration
- Frequency of riffles
- Bank stability
- Condition of buffer
- Presence/absence of coarse woody debris

Wetlands

- Water clarity
- Water temperature
- Water chemistry metrics (see below)
- Upstream surface water retention
- Upstream/onsite water diversions
- Flashiness index
- Floodplain interaction
- Water table depth
- Surface water runoff index
- Hydrological alterations
- Presence/absence of coarse woody debris
- Biotic patch richness
- Interspersion of biotic patches
- Presence/absence of beaver activity
- Litter cover

Function or Process Variables

(Note: Many of the structural variables listed above under "Habitat Management" also provide valuable insights into aspects of ecosystem function.)

Concentration of some nutrient/chemical

Nitrogen concentration

Phosphorous concentration

Dissolved oxygen concentration

pH of soil, water

Fire

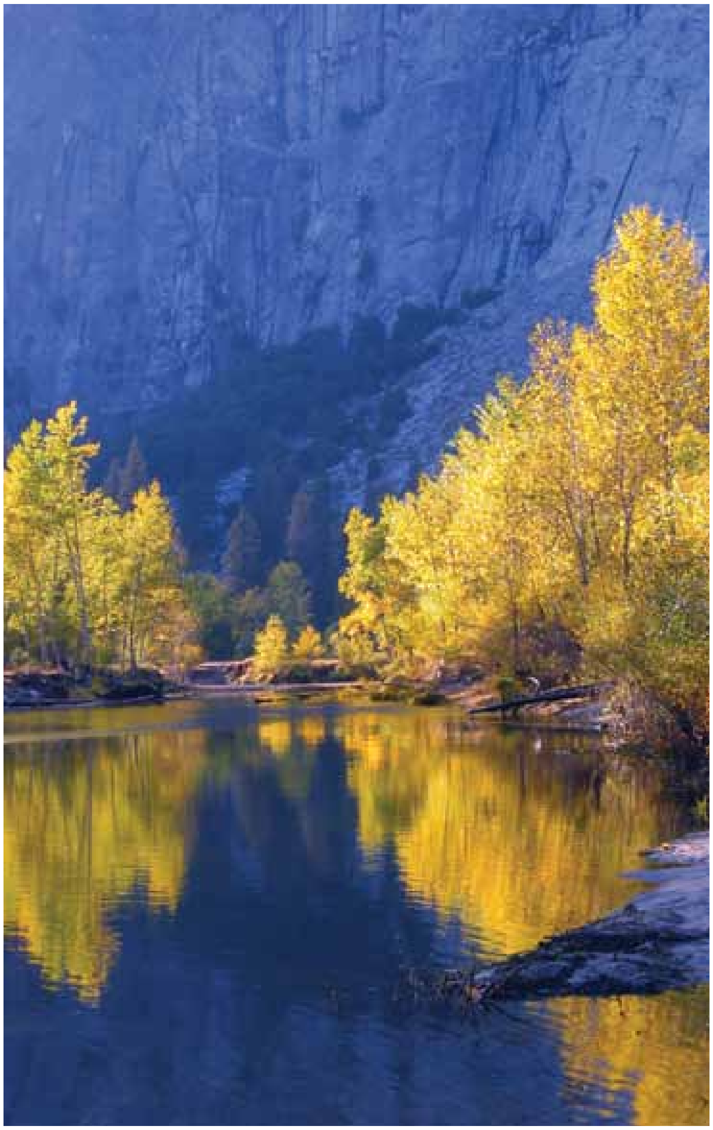
Mean abundance (biomass or percent cover) of the dominant species at the site

Historic ecosystem fire regime

Fire severity

Fire return interval

Recovery time following fire



Further Reading

The following references provide an introduction to the extensive literature on the subject of monitoring wildlife populations and habitats, as well as the use of monitoring information in performance measurement and adaptive management programs. This list is certainly not comprehensive, although we have made particular effort to include references that would be useful for wildlife managers working to develop monitoring and evaluation systems for the State Wildlife Action Plans.

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Chapter 6: Outcome Measures for Wildlife Conservation at the State or Regional Level

In the preceding chapters we have explored how to select indicators to measure the results of particular conservation activities. Much of this measurement will naturally take place at the local level, evaluating the effects of conservation activities at specific sites or in specific conservation areas. In this chapter, we look at why it is also important to measure the status and trends of key wildlife species and wildlife habitats at larger spatial scales and over longer periods of time. Such measures help move the focus of assessment from the short-term outputs that are associated with individual projects or programs to longer-term outcomes that directly address key questions for managers, decision-makers, and the general public such as "How is wildlife doing in my state?" and "What is happening to areas of important wildlife habitat?"

There are a number of practical reasons for developing larger-scale measures. Larger geographic areas may be more consistent with the distribution of species and vegetative communities. State or regional monitoring programs may provide managers with information needed to detect declines in wildlife populations early on, providing an opportunity to implement mitigating approaches before it becomes necessary to list a species under state or federal endangered species laws. Larger-scale measures can also help to measure the long-term accomplishments of wildlife management activities. Monitoring over longer time scales may be necessary because certain wildlife populations may respond slowly, if at all, to management interventions.

It is important to note that large-scale measures are not necessarily appropriate for performance measurement at the local scale. It may be difficult (if not impossible) to determine rigorously the contributions of individual small-scale projects using monitoring data that are collected at a statewide or regional scale. This is especially likely to be true if there have been many different activities over a period of time that are focused on the same conservation target. However, larger-scale measures are still of considerable use to managers in assessing the cumulative effects of a suite of management activities for a particular species over a period of time.

In developing our larger-scale state or regional measures, we have started with the model of State Wildlife Action Plan implementation that we first developed in Chapter 4 (Figure 4.1). For the implementation and outcome steps in this model, we have attempted to identify large-scale, statewide measures that could be used to report on the activities and outcomes from plan implementation. The following figure (6.1) shows how these types of indicators relate to the implementation and outcome steps in our model.

Wildlife Habitat Measures

Many strategies for wildlife conservation focus on the protection, restoration, and long-term management of important geographic areas, vegetation types, or landscape features that are thought to function as wildlife habitat. Examples of such strategies include the 56 State Wildlife Action Plans, each of which lists important "habitats" for wildlife in a particular U. S. state or territory (http://www.teaming.com), and the Habitat Conservation Plans that have been developed for endangered species in the United States at specific sites (http://www.fws.gov/Endangered/hcp/).

Some basic questions regarding wildlife habitat would include:

- What are the most important areas of habitat for wildlife species of conservation interest?
- What are the trends in the extent of these key habitat areas? Are these areas increasing, decreasing, or staying stable?
- How much of these areas are currently protected, either through direct ownership, conservation easements, or some other form of conservation management?
- How are these key habitat areas distributed across the landscape? Are they in large, intact patches, or are they heavily fragmented by roads or other non-compatible landscape uses (such as urban areas, suburban developments, or intensive agriculture)?
- How are the areas that provide poor or marginal wildlife habitat (e.g., urban areas, suburban areas, certain types of intensive agriculture) distributed across the landscape? Are these areas growing in size, and if so, what type(s) of land cover are being lost? (Gaines, Harrod, and Lehmkuhl 2002; The Wildlife Society 2002)

The combination of remotely sensed imagery and Geographic Information System (GIS) analysis offers great potential for the measurement and monitoring of wildlife habitat at larger geographic scales (Scott et al. 1993; 1996). Most conservationists in the United States are familiar with the land cover data sets produced by the state and regional Gap Analysis programs (http://gapanalysis.nbii.gov) and the National

Land Cover Database (http://www.mrlc.gov/mrlc2k_nlcd.asp), much of which is based on imagery from the Thematic Mapper instrument on the Landsat 5 satellite. Imagery from this instrument has a minimum resolution of 30 meters, which has been used to map vegetation cover at the ecological systems level (Jennings no date). Several federal agencies are currently pursuing land cover mapping on a "wall-to-wall," U.S.-wide basis. Landsat imagery can be purchased from the U. S. Geological Survey's Earth Resource Observation and Science program, and updated imagery is available every 16 days (http://eros.usgs.gov/products/satellite/tm.html). Other land cover data products may be available for particular states and regions; interested persons will want to visit the USGS Landcover Institute web site (http://landcover.usgs.gov/) or consult with USGS staff and other providers of remote sensing imagery for further details.

Higher-resolution imagery is also available. Many readers will be familiar with the approximately 1-meter resolution imagery that can currently be found on websites such as Google Earth, NASA World Wind, and Microsoft Terraserver. This imagery is also available from commercial vendors, in particular DigitalGlobe (www.digitalglobe.com), which offers custom full-color imagery and panchromatic (black and white) imagery from the QuickBird satellite at a minimum resolution of 60 centimeters. Land cover classification algorithms originally developed for GAP Analysis (Scott et al. 1993) could potentially be applied to imagery at this level of resolution or, alternatively, wildlife biologists could simply use visual inspection to identify features or areas that are likely to provide high-quality wildlife habitat.

Some landscape-scale questions about wildlife habitat that can be answered using GIS software and appropriate data layers include:

- Extent of particular land cover types of conservation interest
- Extent of land cover types that are unsuitable as wildlife habitat
- Trends in the extent of these land cover types (so long as land cover data layers are available for the same location at specific time intervals)
- Size of individual habitat patches of a particular vegetation type
- Type(s) of land cover that surround a particular habitat patch of high conservation value
- Amount of a particular vegetation type that is in protective or conservation management (provided that a data layer on protected or managed areas is available) (Lang 1998).

A statewide or regional monitoring system for wildlife habitats should address, at minimum, trends in land cover and the extent to which valuable areas of wildlife habitat are in protective or conservation management (Scott et al. 1993; Gaines, Harrod and Lehmkuhl 2002). Agencies and organizations interested in evaluating wildlife habitat conservation activities at state or regional scales should consider investing in the staff and technical equipment necessary to analyze remote sensing data, with continuing investments on a periodic basis to acquire data at an appropriate level of resolution and an appropriate frequency to monitor wildlife habitat areas. Collaboration with state land grant universities and USGS cooperative research units may also be helpful in providing state wildlife agencies with the remote sensing data needed to track the extent and pattern of key vegetation or land cover types.

WILDLIFE SPECIES MEASURES

We turn now from measures of wildlife habitat to more direct assessments of wildlife populations. There is strong interest from the general public and decision-makers in the status and well-being of certain wildlife species (such as game species, songbirds, and fish), and consequently there is an extensive literature that describes how to measure, monitor, and assess various aspects of wildlife populations. We will not review this literature in detail, other than to note that much of it is aimed at particular taxa and small-scale applications (mostly site-specific monitoring).

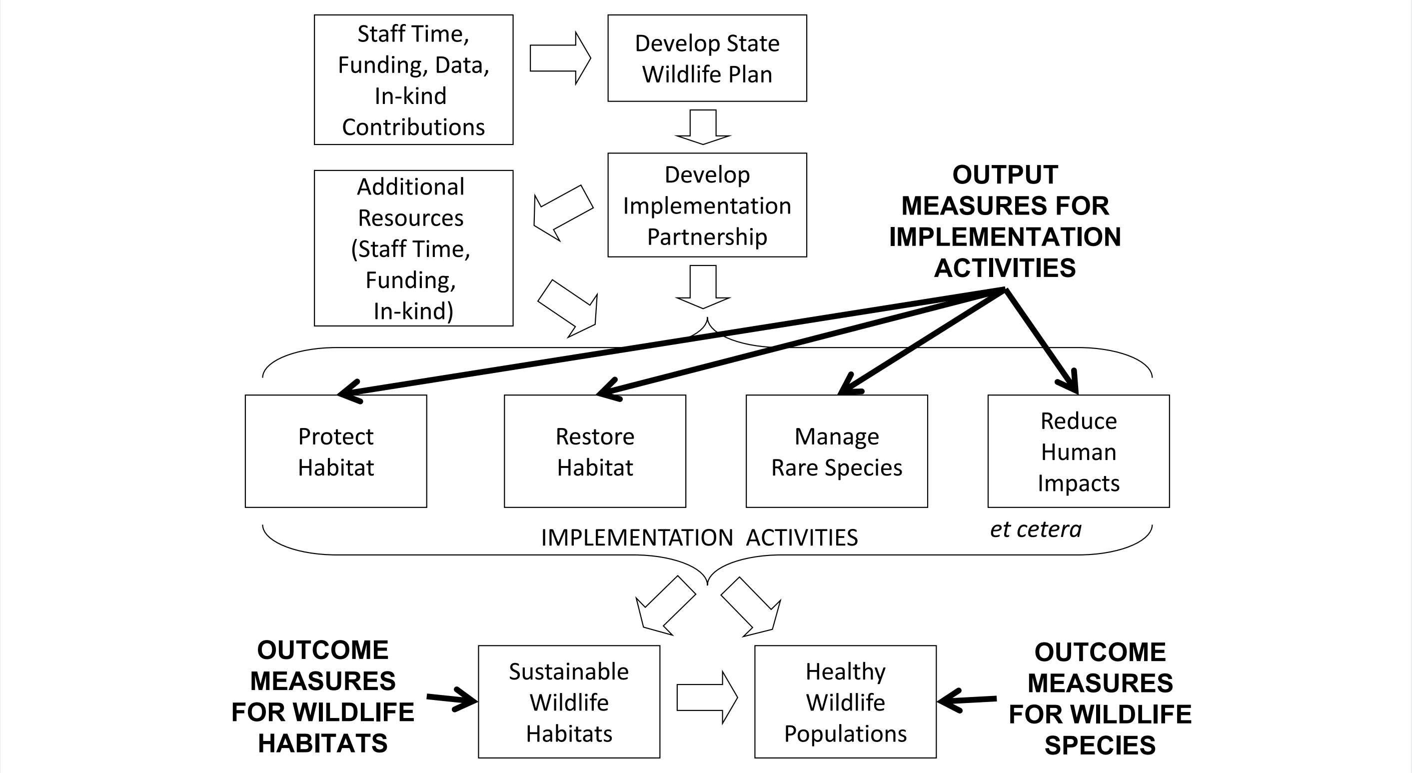
Some of the key questions for assessing the health of wildlife populations on a broader geographic scale include:

- Are population numbers of key species increasing or decreasing in a particular state or region over time?
- Is the area (or range) occupied by these key wildlife species increasing or decreasing over time?
- Are these species of wildlife likely to persist in the state or region? (Gaines, Harrod, and Lehmkuhl 2002; The Wildlife Society 2002)

SPECIES PORTFOLIO APPROACHES

One way to address these questions is to develop monitoring programs that track and report the most relevant population parameters for individual species of conservation interest (Noon 2003). This has been done already for a number of species in the United States, mostly in cases where there is strong interest from the public sector (game species and breeding birds), or where there is a clear regulatory mandate for monitoring (as with many species listed under the federal Endangered Species Act). Individual researchers or agencies in particular states may also have established monitoring programs for particular species that are of scientific or regional interest.

FIGURE 6.1 Conceptual model for the development and implementation of State Wildlife Action Plans, showing the relationship of output and outcome measures to the activities and outcomes of the implementation process.



Unfortunately for state wildlife managers, rigorous monitoring programs are currently lacking for many U. S. wildlife species, including many "non-game" species. For species that lack monitoring programs, it is difficult to make conclusive statements about population size, the magnitude of population trends, changes in geographic distribution, or the likelihood of persistence in a particular state or region. New monitoring programs, with associated staff time and budgets, would be necessary to answer these questions in a scientifically rigorous manner.

Monitoring programs for individual species can be resource-intensive, and the staff and financial resources for monitoring are quite limited in many wildlife agencies (Manley et al. 2004). Consequently, the number of species-specific monitoring programs is likely to remain small for the foreseeable future. Wildlife managers working at state or regional scales will need to adopt a pragmatic approach to single-species monitoring, incorporating available information from existing monitoring programs whenever possible, and establishing new monitoring programs only where there is a clear and compelling management need or significant interest in a species from key decision-makers or the general public.

Despite resource limitations, there are clear benefits to monitoring at least some subset or a "portfolio" of wildlife across a state or a larger geographic region. Some attributes of wildlife populations that could be measured in a statewide or regional monitoring program include:

- Population counts or population estimates (using reliable, tested models and an appropriate sampling design) for the state or region.
- Number of occupied sites or other measures of geographic range for a particular species.
- Key demographic parameters (reproduction, recruitment, dispersal, migration, sex ratios, age structure, etc.) that could inform population models or population viability analyses.
- Trends in counts, estimates, number of occupied sites, or demographic parameters.

The worked example at the end of this chapter describes the development of a species portfolio approach to monitoring the State Wildlife Action Plan in Oregon.

Identify Target Species for Monitoring

Given the limited resources available for monitoring, managers who are attempting to manage wildlife at a regional scale and wish to monitor individual species will need to select targets for monitoring from among the numerous species of wildlife found in a particular state or region. Some basic criteria or factors that may help in selecting these targets include:

- The taxonomy of the target species is clearly resolved (i.e., no potential for confusion with other species).
- Its basic biology, life history, and habitat requirements are reasonably well understood.
- Its geographic distribution within the state is fairly well known.
- Scientifically sound monitoring protocols for the target species are available, including an appropriate sampling design for use at a state or regional level. (Better yet, monitoring data are currently being collected and reported at an appropriate frequency and scale.)
- There is some sense from the scientific community that the target may function as a representative or "umbrella" species for a particular habitat type, or as an indicator of some important ecosystem process or function.
- There is public interest in the target species.
- Funding is available for conservation work focused on the species or its habitat.

Find Existing Data for Target Species

Once managers have developed a list of target species for monitoring, the next step is to determine whether or not there are existing sources of monitoring data for these species. Managers will want to consult with state agency personnel, the state Natural Heritage Programs and local Natural Heritage Program affiliates, university researchers, cooperative wildlife research units, non-profit wildlife conservation organizations, and offices of the U. S. Fish and Wildlife Service. These initial contacts may be able to suggest the names of other individuals who may also have monitoring data available.

As noted above, there are significant gaps in the existing monitoring programs for wildlife in the United States. Probably the best coverage is for game species, although population numbers for many game species are estimated or modeled rather than directly counted (Rabe, Rosenstock, and de Vos 2002). Some federal- or state-listed threatened and endangered species are rigorously monitored; others are not. The USGS Breeding Bird Survey (http://www.pwrc.usgs.gov/bbs/) and the Audubon Christmas Bird Count (http://www.birdsource.org/) are two sources of population status and trend data for birds. A North American Amphibian Monitoring Program has recently been launched and is modeled on the Breeding Bird Survey (http://www.pwrc.usgs.gov/naamp/). Besides these efforts, detailed monitoring data are currently lacking for many groups of organisms (in particular invertebrates, but also for some more poorly known vertebrate groups such as amphibians, reptiles, and non-game fishes). For some of these groups we do not even have reliable methods for censusing populations (see discussion of upland tiger beetles in Knisley and Schultz 1997, for an example).

Develop New Monitoring Programs As Needed (and as Resources Permit)

Developing and implementing new monitoring programs may be necessary for some high-priority species. Given the significant methodological challenges associated with monitoring even the most widespread and well-known species (Rabe, Rosenstock, and deVos 2002; Noon 2003), this will likely be a resource-intensive undertaking (Manley et al. 2004).

There are a number of excellent guides and manuals available for managers who find themselves in the position of needing to design new monitoring programs. Several helpful tools available for free from federal government agencies are the Manager's Monitoring Guide from U.S. Geological Survey (http://www.pwrc.usgs.gov/monmanual/), the Inventory and Monitoring web site of the National Park Service (http://science.nature.nps.gov/im/), and the U.S. Forest Service's guide to monitoring protocol development (Vesely et al. 2006). Managers should also consult with species experts at local universities and conservation organizations as well as staff from federal wildlife and land management agencies who may be able to provide assistance and links to additional resources. Experts should be able to suggest monitoring protocols that are already available for the species of interest, assist in identifying which of the existing protocols would be most relevant to the particular management needs in a given state or region, and help determine which of these protocols could potentially be "scaled up" to a state or regional level.

It is important to emphasize that monitoring programs involve more than simply counting animals: key limiting factors for the species must be taken into account, and a detailed knowledge of the target species' biology, life history, and habitat requirements is often essential. Monitoring programs must be carefully designed in order to measure the most appropriate attributes of the species of concern, which may or may not be the aspects of the species' biology that are most easily measured. Sampling protocols must also be designed with sufficient rigor and frequency and intensity of sampling to ensure that meaningful trends in population size will be detected. Failure to take such factors into account can result in a monitoring program that provides biased or incomplete estimates of wildlife population status and trends (Noon 2003).

Researchers at the U.S. Forest Service and other agencies are currently exploring an interesting new approach known as "Multi-Species Monitoring" (Manley et al. 2004). This approach focuses on breadth of coverage rather than depth, providing simple presence-absence data for a broad spectrum of species, rather than in-depth information on a much smaller group of species. Under such a system, a researcher in the field would visit a single monitoring station or area and perform a number of simple protocols intended to detect presence/absence of a substantial number of species (birds or mammals).

Monitoring protocols could also be combined for in-depth monitoring programs to maximize the efficiency of data collection in the field. One option for managers who must implement a new monitoring program would be to see if the monitoring protocol could "piggy-back" on an existing data collection effort.

Multi-Species Indices and Other Reporting Tools

In addition to reporting status and trends for individual species, wildlife managers may find it useful to report status or trends for ensembles or suites of species. These measures can help provide a concise answer to questions such as **"**How are upland game species doing?**"** and **"**How are shorebirds doing?**"** By consolidating information from multiple species into a single statistic, these indices and metrics provide a handy tool for reporting broader trends in a diversity of wildlife species.

Current approaches can be divided into ***status measures*** (how many or what percentage of a group of species have a particular conservation status at a given point in time?) and ***trend measures*** (how are populations of a group of species changing over time?)

Status Measures

A multi-species status indicator was developed by The Heinz Center and published in *The State of the Nation's Ecosystems* report (2002). The measure is based on the NatureServe ranking system, which assigns a status rank to individual species (Stein 2002). Global status ranks employed by this system include:

GX - Extinct
G1 – Critically imperiled
G2 – Imperiled
G3 – Vulnerable
G4 – Apparently Secure
G5 – Secure

Critically imperiled species are often found in five or fewer locations, imperiled species are often found in 20 or fewer locations, and vulnerable species are often found in 80 or fewer locations. Apparently secure species are uncommon but not rare, and secure species are common – meaning they are both abundant and widespread. Presumed extinct species have not been located despite intensive searches, and possibly extinct species are missing and are known only from historic records, although there is some hope of their rediscovery. There are also parallel sets of rankings for species at the national level ("N-ranks") and subnational or state level ("S-ranks"). Stein (2002) provides further details on the ranks and ranking criteria.

As originally published, The Heinz Center indicator reports the number of species within select taxonomic groups that have been classified as "at risk," where "at risk" is defined as having a global rank of G1, G2, or G3. Taxonomic groups included in this measure are: mammals; birds; reptiles; crocodilians; turtles; amphibians; freshwater and anadromous fishes; freshwater mussels; freshwater snails; crayfishes; fairy, clam, and tadpole shrimp; butterflies and skippers; giant silkworm and royal moths; sphinx moths; underwing moths; papaipema moths; tiger beetles; grasshoppers; dragonflies and damselflies; ferns and relatives; conifers and relatives; and flowering plants.

While The Heinz Center status indicator is based on the NatureServe ranking system, a comparable status metric could be developed using other, similar ranking systems such as the IUCN Red List. The existing "Red List Index" described by Butchart et al. (2004; 2005) measures trends and thus will be considered below.

Indicators that are based on species rankings are only as good as the quality of the underlying ranking system (Burgman 2002; Possingham et al. 2002). Such indicators are also critically dependent on the quality of the assessments that assign ranks to individual species. These indicators do not explicitly include population trend information, although this information may be a factor considered when assigning ranks to species (Stein 2002; Butchart et al. 2005).

Trend Metrics 1 – Rank Change Measures

Like The Heinz Center's status measure, these types of metrics are based on ranking systems such as the IUCN Red List or the NatureServe/Natural Heritage methodology. As the name suggests, rank change measures track the number or percentage of species that have been moved by experts from one rank to another over some period of time.

Probably the best known rank change measure is the Red List Index (Butchart et al. 2004; 2005), which is based on the percentage of species in a taxonomic group that have been moved by experts from one rank to another due to genuine population losses and gains (as opposed to changes in knowledge and taxonomy) between updates to the IUCN Red List. This index has been adopted as a management tool by major international conservation organizations such as Conservation International and the International Union for the Conservation of Nature (IUCN) (Butchart et al. 2005; E. Kennedy, pers. comm.).

Although not yet proposed in the literature, an analogous rank change measure could be developed for other systems that assign status ranks to species, such as the NatureServe ranking system.

These metrics require that the underlying species rankings be updated on a regular basis; otherwise, no trends would be evident. For the IUCN Red List, these updates are conducted on a somewhat irregular basis – in 1988, 1994, 2000, and 2004 for birds; in 1980 and 2004 for amphibians (Butchart et al. 2005). The irregular, multi-year gaps between these updates mean that these measures are relatively insensitive and may miss fluctuations in species status that occur at shorter time intervals. As with The Heinz Center status measure discussed above, the Red List index is only as good as the underlying ranking system and the quality of the rankings that have been provided by species experts (Burgman 2002; Possingham et al. 2002). A more practical limitation of this index is that coverage is only available at the present time for a few taxonomic groups (although further assessments are planned; see discussion in Butchart et al. 2005).

Trend Metrics 2 – Average Change Measures

These measures calculate the average trend in population change for a group of species over a given time interval. There are several published measures, which share similar methods:

- Start by compiling time series of population size for multiple populations or species;
- For each time series, normalize the data points using the size of that population at a given starting time or reference year;
- Calculate the geometric mean of the normalized population trends for all time series over a given time interval.

Gregory et al. (2003) originally described this approach as a way to report average population trends for bird populations in the UK; de Heer et al. (2005) applied a similar approach to the study of population trends for 273 European wildlife taxa, while the Living Planet Index of Loh et al. (2005) generalizes the approach to all available time series for wildlife populations. These types of indices have become quite popular; the bird index of Gregory et al. (2003) has been adopted by the government of Great Britain as a national environmental indicator, while the Living Planet Index has been used by the World Wildlife Fund in its reporting on global environmental condition (e.g., Loh 2000; 2002; Loh and Wackernagel 2004).

One of the major limitations to these measures is that they require absolute measurements, either of population size or of the magnitude of a population trend. Relatively few data series are currently available; for example, the Living Planet Index as described by Loh et al. (2005) has only 3,000 data series for some 1,100 vertebrate species. This is obviously only a small proportion (about 2%) of the world's vertebrate fauna, and the existing data series are heavily biased towards bird and mammal species; thus, it is difficult to make any firm conclusions about the overall status of global biodiversity from such analyses. Unpublished reports also suggest that these measures may be sensitive to outliers (individual trend reports for populations that experience major changes in size, either one-time events or extreme stochastic fluctuations).

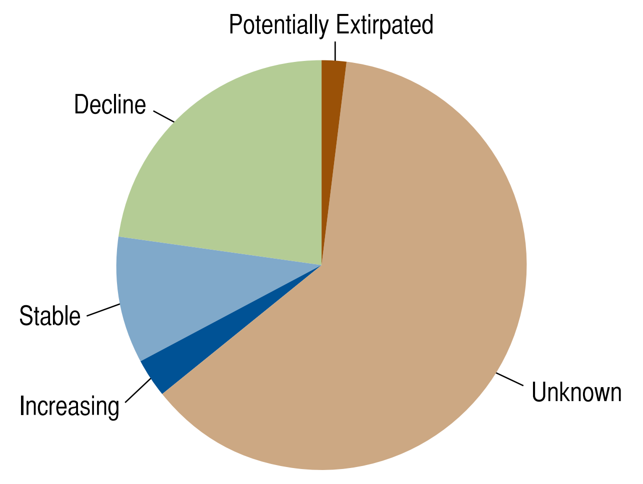
Trend Metrics 3 – The Species Trend Chart

This chart is a simple tool for reporting the population trends of multiple species. The chart reports the percentage of species with populations that are a) increasing, b) stable, c) decreasing, or d) have a trend that is unknown. The set of species to include in the chart is defined by the user. The chart can be populated with quantitative data, qualitative expert assessments, or some combination of them, so long as users are forthright about the quality and sources of the data that are included. We make no claims to originality – a similar chart was depicted by de Heer (2005), although the chart presented by these authors lacked a category for species with status unknown.

For many taxonomic groups in the United States, particularly non-game species, we expect that the chart will look something like the example in Figure 6.2, with most species either in decline or having an unknown status. This is not necessarily a negative thing: there is value in pointing out to decision-makers and the general public just how little we know about most non-game wildlife, and how many species are either thought or known to be in decline. Identifying a problem is the first step in marshalling resources to address it.

Regardless of the species monitoring and assessment approaches that are eventually selected for use at a state or regional level, we suggest that this chart is a useful tool for summarizing and reporting information on population trends across multiple wildlife species.

FIGURE 6.2 Species trend chart, showing proportion of species having population trends that are increasing, stable, declining, unknown, or extinct.



EXAMPLE: USING SPECIES METRICS TO MEASURE THE SUCCESS OF THE OREGON CONSERVATION STRATEGY

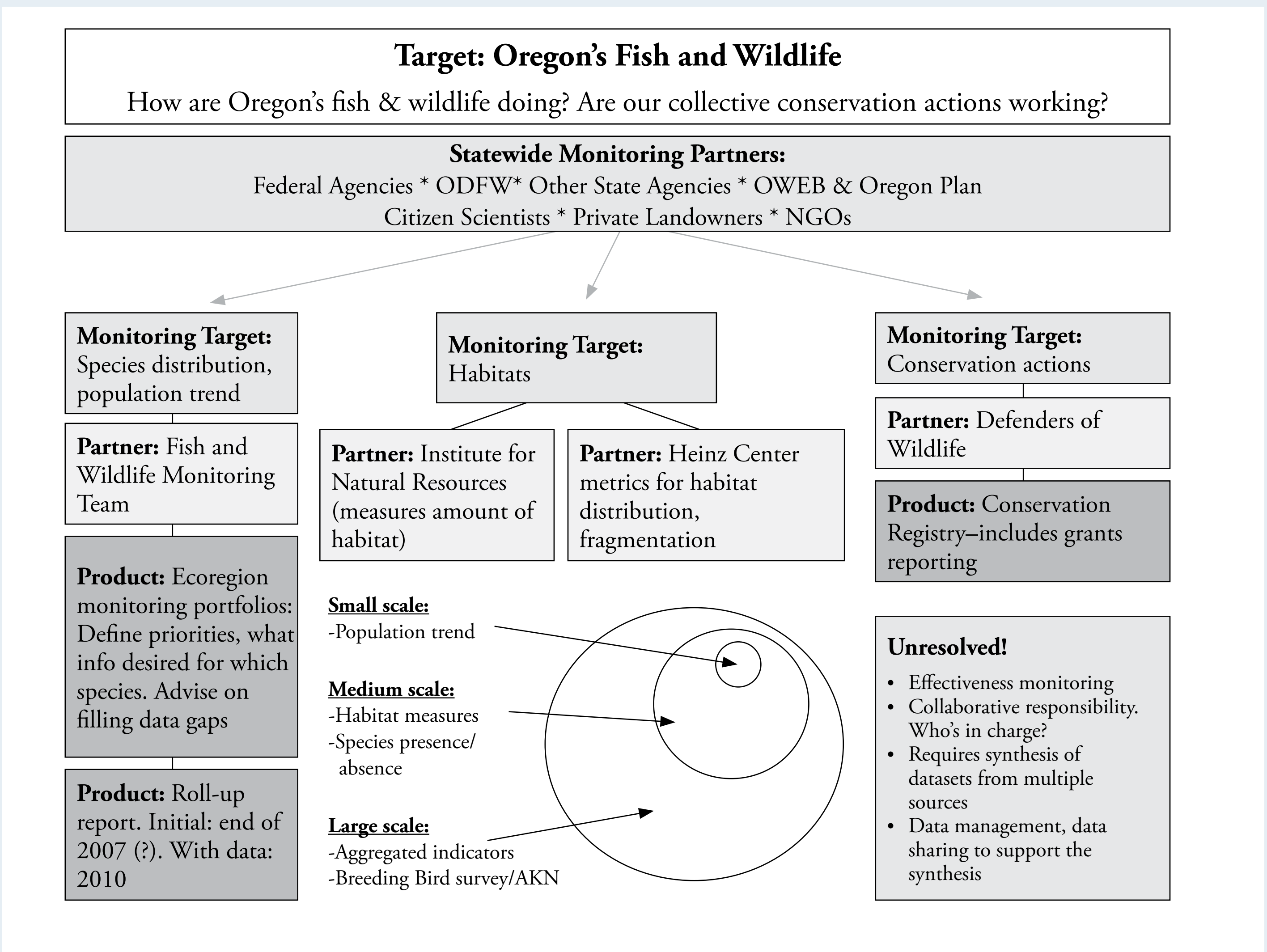
Audrey Hatch, Oregon Department of Fish and Wildlife

THE OREGON CONSERVATION STRATEGY AND IMPORTANCE OF PARTNERSHIPS

The Oregon Conservation Strategy (Strategy) is Oregon's State Wildlife Action Plan (SWAP). The Strategy uses the best available science to create a broad vision and conceptual framework for the long-term conservation of Oregon's native fish and wildlife species. Oregon's Department of Fish and Wildlife (ODFW) has collaborated with many agencies, citizens groups, and organizations in the development of the Strategy. An electronic version of the Strategy is available on the Web at: http://www.dfw.state.or.us/conservationstrategy/ .

Continued coordination by ODFW is needed to build partnerships across jurisdictions and management authorities, in order to implement the priority wildlife conservation actions identified in the Strategy. Similarly, ODFW will partner with non-profits, academics, and other agencies to monitor key species and attributes of ecosystems, and to measure the effectiveness of conservation actions. Figure 6.3 below shows the relationships between these partners and general categories of monitoring targets, as well as some currently unmet needs.

FIGURE 6.3 Relationship between monitoring goals, monitoring targets, and monitoring partners for the Oregon Conservation Strategy.



Like other State Wildlife Action Plans (SWAPs), the Oregon Conservation Strategy is intended to work at multiple scales:

- Statewide
- Ecoregional (for each of the 8 ecoregions found in Oregon)
- Habitat
- Species

At the statewide level, a small suite of key conservation issues has been identified: water quality and quantity; change in land use/land cover; species invasions; barriers to animal movement; changes in flooding and fire regimes; and institutional barriers to conservation action (see Table 6.1 at the end of this chapter). Because Oregon's ecoregions differ in geology, climate, and topography, these major conservation issues may play out differently in the different ecoregions. For example, western portions of the state may experience more dramatic flooding events and have adequate water supply year-round, while eastern portions of the state may experience severe reductions in water availability in late summer that affect water quality.

Priority or "Strategy habitats" have been identified across all ecoregions (see Table 6.2 at the end of this chapter for the list of Strategy habitats). Finally, some 286 priority or "Strategy species" have been identified, along with their specific biological requirements, limiting factors, data gaps, and required conservation actions. This multiple-scale approach follows a "coarse-filter to fine-filter" model, and provides the foundation to build a monitoring program on an ecoregional basis, linking species to habitats and also to key conservation issues.

The Oregon Conservation Strategy contains a chapter on monitoring programs that outlines broad priorities and recommendations while emphasizing that monitoring needs are larger and more complex than any single agency or organization can support on its own. Recommendations include: strengthen data management capabilities; promote citizen science; track and report conservation results; chart conservation actions on-the-ground; employ the latest technology to use the internet to exchange information; and finally, convene a collaborative, multi-agency Fish and Wildlife Monitoring Team.

Oregon Fish and Wildlife Monitoring Team

The Fish and Wildlife Monitoring Team was convened in 2006 to help state and federal agencies and conservation partners leverage resources and work toward common goals. One key partner in ODFW's efforts has been the Oregon Plan for Salmon and Watersheds Monitoring Team, which has already made extensive progress in characterizing watersheds and aquatic resources, particularly throughout western Oregon. The collaborative Fish and Wildlife Monitoring Team works closely with the Oregon Plan Monitoring Team, and many other partners. The Fish and Wildlife Monitoring Team defines "monitoring" in support of the Oregon Conservation Strategy to encompass four major targets:

- Key Conservation Issues – Other agency partners have a role in tracking the status of water resources, and other aspects of the environment. As the fish and wildlife management agency, ODFW is doing lead work to address some aspects of the key conservation issues, such as barriers to fish and wildlife movement. Most of the other conservation issues are best addressed by specific agencies (e.g., Department of Water Resources; Oregon Invasive Species Council; other partners).
- Conservation Actions – These will be tracked via the Conservation Registry coordinated for the Pacific Northwest by Defenders of Wildlife (www.conservationregistry.org).
- Habitats – The extent and pattern of priority "Strategy habitats" will be tracked over time using satellite imagery, collected by USGS (and others) at a scale of 30 meters and updated every ten years. In Oregon, the Institute for Natural Resources, a state agency housed at Oregon State University, has been charged with maintaining these data on Oregon's natural habitats, and will report to the Oregon Progress Board using a Natural Habitats Benchmark.
- Species – Many biologists, wildlife managers, and the public look to species as the ultimate endpoint for conservation action. But with a long list (286) of Strategy species, how does the agency decide where to begin work? Because monitoring needs are complex and there are already many existing programs that meet some (but not all) of the needs outlined in the Strategy, the collaborative group worked out a series of criteria to determine what the priorities for species monitoring would be. Like other products developed for the Strategy, the species monitoring priorities are a work in progress. The criteria and priorities, together, comprise Oregon's Species Monitoring Portfolio.

A Collaborative Monitoring Success Story

In Oregon, a species-focused collaborative monitoring success story was easy to find. Within ODFW, the Aquatic Inventories Project has surveyed stream habitats throughout the state (mostly western Oregon) since 1998 following a statistically rigorous sampling design. In the summer of 2006, field crews began systematically recording amphibian occurrences during their surveys, which added only a few extra minutes to a typical workday, but resulted in dozens of observations of at least nine amphibian species during the first year of work. The data potentially contribute towards development of habitat-based distribution models for these species, contribute substantially to our knowledge of amphibian distribution throughout Oregon, and demonstrate how the Conservation Strategy works to leverage existing resources to collect information.

Oregon Species Monitoring Portfolio

What Is It?

A portfolio is a suite of priority species that will be monitored. The portfolio provides direction and focus for monitoring and conservation efforts. Monitoring of the species in the portfolio is designed to complement ongoing large-scale vegetation monitoring, as well as ongoing efforts to monitor threatened or endangered species.

Why Develop a Species Monitoring Portfolio?

- The Oregon Conservation Strategy called for the need to "link Strategy species to [ecological] indicator species," recognizing that valuable information for decision-making can be gained by monitoring some species that are not necessarily known to be in decline or of immediate conservation concern.
- Managers and members of the public often look to species to tell them whether conservation is working, and to figure out "how things are doing." Monitoring of priority species provides an opportunity to check how ecosystems are functioning.
- Public interest in species monitoring remains high. State fish and wildlife agencies are taking the lead in implementing the SWAPs, and these agencies have always focused on collecting long-term data on animals.
- By monitoring species that are linked to Key Conservation Issues identified in the State Wildlife Action Plan, it is possible to determine whether the management actions intended to address these issues are effective.

How Was the Species Monitoring Portfolio Developed?

Species monitoring portfolios were developed for each ecoregion in Oregon through a two-day workshop that convened professional expertise in species biology. Agency biologists and researchers, academic researchers, and experts from conservation organizations were invited to participate. Many participants were identified because of their previous contributions to the state Natural Heritage Center. The Oregon Natural Heritage Information Center is charged with housing data on vertebrate animals throughout Oregon. The Center communicates regularly with species and taxonomic experts throughout the state, and periodically convenes review teams to provide input on species' status. Many of these same individuals were excellent sources of current, relevant information when developing the monitoring portfolio.

The following steps were used to develop the Species Monitoring Portfolio:

1) For each ecoregion, Strategy species were assigned to Strategy habitat types.

- "Starting lists" were designed to emphasize Strategy species; participants had the option to add additional "indicator" species if they could provide a strong rationale. The American beaver is one example where this occurred: beavers are found throughout the state, and their presence is linked to healthy functioning ecosystems that provide a multitude of benefits for many species. Bird assemblages were another example of where an "indicator" species, or guild, was added to the list of monitoring priorities. In many cases, information on a suite of bird species can be collected from point-count surveys, and linked to ecological condition (e.g., Partners in Flight).
- Resources available to participants included: list of all native terrestrial vertebrates of Oregon; information on the criteria for determining Strategy species; habitat lists and maps; Wildlife-Habitat Relationships in Oregon and Washington (Johnson and O'Neil 2001)

2) Species were ranked according to a set of criteria that included:

- **Monitoring Need** – There is a strong need to collect more data to understand conservation status or key life history attributes for a species.
- **Public Appeal** – The species can be readily monitored on private lands; or, the species can be monitored by citizen scientists.

- **Represent the Landscape** – The species is closely linked with the condition of the habitat type that it is associated with; or the species is known to be highly responsive to one of the key conservation issues.

Result: short-lists for each of the above three categories, per habitat type, per ecoregion.

3) There was a final assessment for the species portfolio for each habitat type: species were selected from the three "short lists."

4) Additional post-workshop follow-up on plants, invertebrates, bats and fish was required because it was not possible to convene all taxa experts at the same meeting.

Result: Species Monitoring Portfolio. Figure 6.4 shows a ranking sheet that was actually used to develop the Species Monitoring Portfolio for a particular ecoregion:

IMPLEMENTATION

The priorities identified in the Species Monitoring Portfolio are being implemented by a process of integration with partner organizations and their efforts. ODFW staff can provide coordination and guidance, but to succeed, the monitoring effort will require significant investment from other organizations and efforts. In many cases, existing monitoring programs are able to incorporate some Strategy priorities with their ongoing work. In other cases, partners might be able to initiate new projects. Where there is need for guidance, Oregon is exploring the following options:

- **Where to Monitor** – We recommend focusing monitoring activities within the Conservation Opportunity Areas, priority landscapes that were specifically identified in the Conservation Strategy. Alternatively, if a spatial monitoring approach already exists, such as the U.S. Forest Service's Forest Inventory Areas, we work to integrate our monitoring activities with the existing approaches.

FIGURE 6.4 Species ranking sheet for three priority ecoregions (grasslands, riparian and wetland, and sagebrush habitats).

			Strategy species?	Data need?	Data need Sub-score	Data need short list?	Partners Rank?	Social Rank?	Public appeal subscore	Public appeal short list?	Strong Habitat Assoc.?	Affected by External Drivers?	Endemic to State?	Rep. Subscore	Rep. Short list?	Comments
Grasslands																
	Bird	Grasshopper sparrow	3	3	6	x	2	2	4		3	2	1	6		
	Mammal	Washington ground squirrel	3	2	5	x	2	2	4		3	3	3	9	x	
	Bird	Western burrowing owl	3	1	4		2	2	4		2	2	1	5		
	Bird	Long-billed curlew	3	2	5	x	3	3	6	x	3	2	1	6		
	Bird	Ferruginous hawk	3	1	4		3	3	6	x	2	2	1	5		
	Plant	Lawrence milk-vetch	3	2	5	x	2	1	3		3	3	3	9	x	deep loess soils in Palouse grasslands
	Plant	Tygh Valley milk-vetch	3	1	4		2	1	3		3	3	3	9	x	bunchgrass grasslands; prairie; open juniper
Riparian and wetland																
	Reptile	Western painted turtle	3	3	6	x	2	3	5	x	2	3	1	6		
	Mammal	American beaver	1	2	3		3	3	5	x	3	3	1	7	x	
	Invert	Columbia Gorge Oregonian	3	3	6	x	1	1	2		3	2	1	6		riparian; spring/seep; detritus
Sagebrush Habitats ***(includes steppe and/or shrublands)***																
	Bird	Sage sparrow	3	2	5		2	2	4		3	2	1	6		
	Reptile	Northern sagebrush lizard	3	3	6	x	2	2	4		3	2	3	8	x	
	Bird	Loggerhead shrike	3	1	4		2	2	4		3	2	1	6		
	Bird	Brewer's sparrow	3	3	6	x	2	2	4		3	2	3	8	x	
	Bird	Swainson's hawk	3	1	4		3	3	6	x	3	1	1	5		

- **What to Monitor** – If there is an opportunity to gather a few additional data points as part of ongoing monitoring work, we recommend collecting information on Strategy species. Over the long term, new statistical tools such as occupancy models will be considered to utilize presence-absence information.

Implementing the Species Monitoring Portfolio will require leveraging existing resources, working priorities into existing efforts, and potentially initiating new surveys in some cases. A variety of partners are involved in implementing the Species Monitoring Portfolio, including ODFW programs such as the Western Oregon Stream Restoration Project and the Aquatic Inventories Project, and Salmon and Trout Enhancement Program. External partners are also involved in directly implementing some of the species monitoring priorities; examples include the Klamath Bird Observatory, City of Portland, and potentially, additional citizen science groups. Moreover, the collaborative Fish and Wildlife Monitoring Team has an important role in helping to implement the Species Monitoring Portfolio.

Staying Grounded While Dreaming Big

State Wildlife Action Plans allow for an unprecedented big-picture snapshot of the condition of each state's wildlife and their habitats. This opportunity brings the recognized need to report on results, but with precious few new resources identified to do so. This is an interesting duality: an opportunity for the ideal, coupled with a practical need. Monitoring practitioners approach the question of monitoring SWAPs with the realization that "the perfect can be the enemy of the good." Each state will need to inventory its existing and ongoing monitoring programs, look for ways that these existing efforts could be better leveraged or integrated, and then identify where new work should take place. You can start by compiling information on existing efforts, then meeting with project leaders to discuss SWAP opportunities for data sharing and synergy. In Oregon some existing efforts that have provided initial opportunities include: Oregon Plan monitoring; Oregon Plan high level indicators; Pacific Northwest Aquatic Monitoring Partnership; Pacific Northwest Biodiversity Initiative. Examples that should apply to every state include:

- Breeding bird surveys (BBS)
- Avian Knowledge Network
- GAP data (or Re-GAP)
- State natural heritage centers

Examples that might apply in some states and are worth exploring include:

- Amphibian Research and Monitoring Initiative
- Threatened and Endangered monitoring programs

Suggestions for Convening and Maintaining a Collaborative Monitoring Team

- ***The task is always going to loom large.*** Busy managers and agency executives often tend to have unrealistic expectations for "collaborative monitoring teams" and the teams' ability to work through complex issues that can encompass the entire spectrum from the highly technical to the policy levels.
- ***Use consistent terminology.*** "Monitoring" and similar terms invoke different meanings to different people, based on their backgrounds, experiences and needs. "Surveys" could mean a one-time search, or repeated measurements using consistent methodology.
- ***Get on the same page with your partners at every meeting.*** Figure out the extent to which you can collect "status and trends" information, compared to "effectiveness monitoring" or monitoring the results of conservation actions (this can be driven by programs' needs and rolled up through something like the Conservation Registry).
- ***Maintain understanding of goals, roles and scope.*** Clear leadership is essential, especially in these critical early months (to years) of implementation. Decide whether the team would function best as its own entity (usually, groups that function in this manner rotate chairperson responsibilities from organization to organization, perhaps on an annual basis), or as an advisory to the state's SWAP or fish and wildlife agency.
- ***Maintain members' interests, while guarding against "mission creep."*** Tools to deal with this issue could include: charter, workplan, and goal statements. Refer to guiding documents continually throughout meeting.
- ***Spread workload; but recognize workload.*** Volunteer teams can result in members' having little time for new work. Information-share to learn what others might offer, then be specific in requests for collaboration.
- ***Consistent representation.*** Turnover between meetings and the lack of time for optimal communication at representatives' "home" organizations are inevitable because of busy work schedules and increasing demands in natural resource agencies and organizations. Turnover can affect the team because it results in less consistency and clarity from meeting to meeting. Clear goal statements and short-term products are some tools to account for inevitable member turnover.

TABLE 6.1 Key Conservation Issues: key processes that are having a significant impact on native species and habitats within each ecoregion, as identified in the Oregon Conservation Strategy.

1. Land use change	Converting from one type of land use to another – whether changing from agricultural areas to urban development, or from unmanaged native vegetation to intensively managed areas – can impact fish and wildlife habitat, reduce habitat patch size, and decrease connectivity between habitat patches.
2. Water quality and quantity	Recent droughts have heightened awareness of the inter-related issues of water quality and quantity. Water quality and quantity problems can greatly impact aquatic species, and are linked to increasing intensities of land use practices, changes in land use, and growing demand for water.
3. Altered disturbance regimes	People have altered historic natural disturbance regimes, sometimes creating a cascade of unintended effects. Fires have been suppressed, increasing forest tree density and fuel loads. As a result, wildfires have increased in intensity, placing both human and wildlife habitat at risk. Flooding has been controlled to a great extent by dams, dikes and revetments (hardened banks), which has altered floodplain function.
4. Invasive species	Invasive species are species not native to ecosystems to which they have been intentionally or accidentally introduced and whose introduction causes or is likely to cause economic or environmental harm. Many non-native species have been introduced to Oregon. While not all non-native species are invasive, some crowd out native plants and animals and become a serious problem. They alter habitat composition, increase wildfire risk, reduce productivity, or otherwise disrupt natural habitat functions.
5. Barriers to fish and wildlife movement	People have built communities, roads, dams and other structures that act as barriers to the movement of fish and wildlife. These barriers reduce total habitat, create challenges to animal dispersal and reproduction and make wildlife more vulnerable to injury and death.
6. Institutional barriers to conservation action	In some cases, institutional barriers prevent landowners from implementing projects that will benefit fish and wildlife. These barriers include the difficulty of obtaining multiple permits, lack of technical assistance, cumbersome requirements for financial assistance, and rules originally passed for one purpose that block another one.

Note: the following ecological processes, or "drivers," were added to the list of key conservation issues discussed at the Monitoring Priorities workshop in October 2006:

- **Climate cycles (includes global climate change)**
- **Nutrient cycles and decomposition (can include contaminants)**

- ***Standards are high, but may be different for the "experienced" monitoring expert, such as many federal or academic partners.*** One major goal of SWAPs is to engage citizens through science and monitoring. The level of rigor in citizen science monitoring programs might be less than many federal and academic partners are used to.
- ***Some new workload is inevitable.*** To do new things, you will need new staff salary lines (Full-time Equivalents, or FTEs). In Oregon, we have identified a need for data management personnel and are working toward potential solutions to fill that need.
- ***Work on short-term products.*** One short-term goal could be to demonstrate to managers how to reallocate some existing funding to accomplish new work identified as part of the SWAP. Accomplishments help to maintain momentum and also help to provide background information to changing representatives on the team.
- ***Link to ESA (U. S. Endangered Species Act) monitoring programs.*** Clearly explain how existing Threatened/Endangered monitoring programs and information can be used to meet SWAP monitoring needs.
- ***Continue to recognize the effort (and FTEs) required to do monitoring, and to integrate monitoring into ongoing departmental activities.***
- ***Value data management:*** Recognize and commit to data management in a way that makes use of existing resources and partnerships (i.e., Heritage Centers, Biotics/Nature Serve nodes, Breeding Bird Surveys and other partners). Educate managers and decision-makers about the importance and utility of natural resources data in decision-making. Update data management infrastructure as technology changes over time.

- ***Continue the dialogue to collect and distribute information about species in consistent formats.*** For example, work with NatureServe to continue this important task, and work towards expanded and dynamic access to species data (for example, support an interactive means to store and display sightings and other citizen science efforts).

As with all aspects of the State Wildlife Action Plans, monitoring is a work in progress. Identifying priorities for species monitoring is an essential first step to provide focus and direction in collaborations with data collecting partners. The process highlights some unmet needs and areas that require further attention for long-term success. It is our hope that this description of our approach to these first steps will provide some ideas to other state programs, while recognizing that the approach taken by each state will differ somewhat depending on program needs, funding, ecology, and other factors.

TABLE 6.2 Oregon Conservation Strategy Habitats, selected across all eight ecoregions in the state.

Aspen woodlands
Coastal dunes
Estuaries
Freshwater aquatic
Grasslands
Late successional conifer forests
Oak woodland and savanna
Ponderosa pine woodlands
Riparian habitats (statewide)
Sagebrush steppe and shrublands
Wetlands

Chapter 7: Linking State and Local Performance Measures to National Environmental Indicators

There is an old saying that "all politics is local," and it is certainly true that the vast majority of conservation actions are as well. One of the most vexing questions facing conservationists is whether or not the numerous conservation activities taking place at the local level are actually having an effect on problems visible at higher levels, such as broader declines in species biodiversity, or the poor state of water quality in many of the nation's rivers and estuaries. These larger-scale problems are of considerable interest to federal government agencies, members of Congress, and the general public. Agencies and organizations that can demonstrate an ability to influence these larger-scale problems will have a competitive advantage in obtaining resources to continue their good work on behalf of fish and wildlife.

Despite the potential benefits of establishing these linkages, there have been few discussions of this topic in the literature, aside from a few early conceptual papers. Noss (1990) explored the concept of an integrated system for monitoring different levels of biodiversity, but suggested that different indicators may apply at different levels, a conclusion also reached by reviewers from The Wildlife Society (2002). While there is an extensive literature on related topics, such as the aggregation or disaggregation of spatial data, these discussions have focused largely on statistical problems associated with the manipulation of particular types or classes of data (Haining 2004). Although these topics are important and undoubtedly relevant to specific situations, the bigger question of whether it is even possible to create a linked framework for national environmental reporting remains poorly explored.

Much work has been done in recent years to develop both national environmental indicator systems (e.g., National Research Council 2000; The Heinz Center 2002; U.S. Environmental Protection Agency 2003; The Heinz Center 2008) and local performance metrics (e.g., Margoluis and Salafsky 1998). Unfortunately there has been relatively little discussion of how these indicators and metrics might be linked into an integrated environmental reporting system. Rather, the questions driving these projects have included: "What are the suite of indicators that best describe environmental condition in the United States?" and "What can I measure to tell if my project is having the desired environmental results?" (The Heinz Center 2002; Stem et al. 2005). When the questions are posed in this way, it can become difficult to see linkages between local performance measurement and national environmental assessment.

Recent authors (e.g., Salzer and Salafsky 2006; Stem et al. 2005) have drawn a clear distinction between two different types of monitoring and evaluation activities: status assessments, which attempt to determine the condition, state, or trend of one or more variables in the environment; and effectiveness measurements, which track changes associated with the implementation of particular management activities. If we follow this approach, then existing national environmental indicators (such as those contained in the "State of the Nation's Ecosystems") would be seen as a type of status assessment, while project- or program-specific metrics would mostly be classified as effectiveness measurements. Stem et al. (2005) use these two categories to classify various evaluative approaches and tools, leading to the conclusion that different approaches are needed for each type of assessment activity.

While there may be important methodological distinctions between status assessment and effectiveness measurement, it is important to note that these two activities often look at similar – or even identical – environmental variables. For example, a manager for a tallgrass prairie site in Iowa may track populations of grassland-dependent sparrows to evaluate the effectiveness of specific management practices such as prescribed fire. At the same time, population numbers of these birds directly inform two of the national indicators in the *State of the Nation's Ecosystems* report (The Heinz Center 2002), and also inform the global "Red List" indicator for bird species (Butchart et al. 2005). Similarities between the types of things that are being monitored or measured suggest that there is value to exploring links between status assessments and effectiveness measures.

One tool for facilitating linkages between national environmental conditions and local conservation actions is the *State of the Nation's Ecosystems* report (The Heinz Center 2002), which includes descriptions of 103 indicators, each of which describes important properties of ecosystem function, structure, and composition. Certain performance measures at the state level can be linked more or less directly to these national indicators, providing a "big picture" perspective for local activities. In this section, we explore possible linkages for three different types of measures: **species status and trends**, **ecosystem extent**, and **landscape pattern**. The State Wildlife Action Plans are used as an example here, although these procedures would likely be relevant in other contexts as well.

Measures of Species Status and Trends

What is Measured at the National Level?

National species status measures (e.g., Master 1991; Stein 2002) and the corresponding *State of the Nation's Ecosystems* indicator for at-risk species (The Heinz Center 2002) are based on the data contained in the NatureServe database. Although not complete for all U. S. species, this database represents the single largest accumulation of information on status and population trends for species in a wide variety of taxonomic groups (including nearly all vertebrates and vascular plants, and fairly complete coverage for select invertebrate groups, such as butterflies and freshwater mussels).

One of the most valuable attributes of the NatureServe database is the consistent set of rankings that are applied to each element (species or vegetation type) in the database. Each species in this database is assigned a global rank based on multiple factors:

- Total number and condition of occurrences
- Population size
- Range extent and area of occupancy
- Short- and long-term trends in the above factors
- Scope, severity, and immediacy of threats
- Number of protected and managed occurrences
- Intrinsic vulnerability
- Environmental specificity

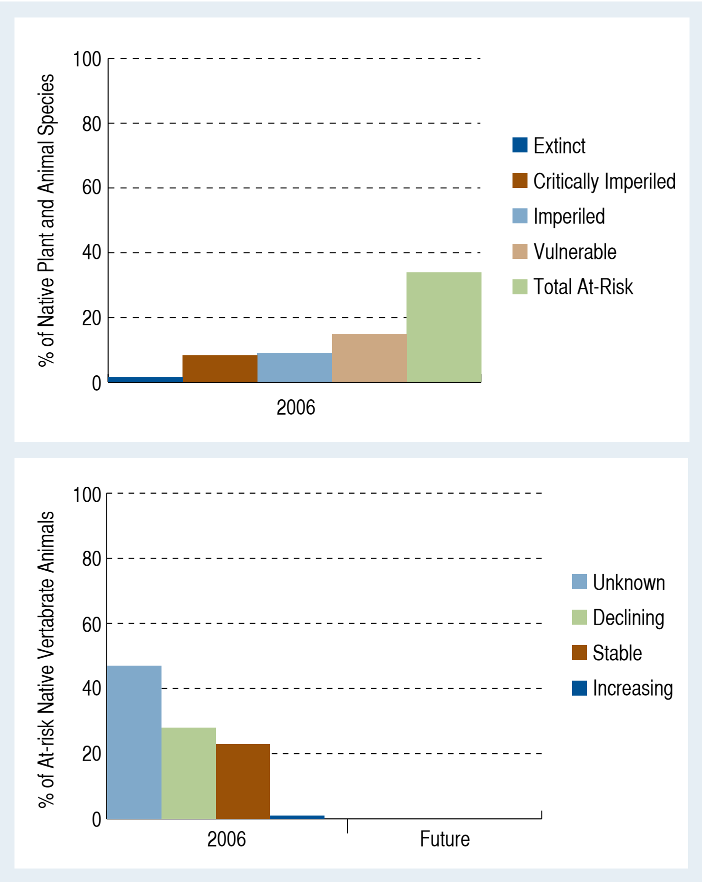
Five global ranks are recognized for extant species in the NatureServe system: G1 ("critically imperiled), G2 ("imperiled"), G3 ("vulnerable"), G4 ("apparently stable), and G5 ("stable"). Each of these ranks correlates roughly with an approximate range of values for both the number and size of occurrences. Critically imperiled species are often found in five or fewer locations, imperiled species are often found in 20 or fewer locations, and vulnerable species are often found in 80 or fewer locations. Extinct or missing species are designated with either an "X" (presumed extinct or extirpated) if there is no expectation that they still survive, or an "H" (possibly extinct or extirpated) if they are known only from historical records but there is a chance they may still exist.

An analogous set of ranks are present at the national level ("N ranks"), and subnational or state level ("S ranks").

As originally published (2002), The Heinz Center's indicator for at-risk species reports the percentage of U.S. species in select taxonomic groups that are ranked G1, G2, or G3. Taxonomic groups included in this indicator include: mammals; birds; reptiles; crocodilians; turtles; amphibians; freshwater and anadromous fishes; freshwater mussels; freshwater snails; crayfishes; fairy, clam, and tadpole shrimp; butterflies and skippers; giant silkworm and royal moths; sphinx moths; underwing moths; papaipema moths; tiger beetles; grasshoppers; dragonflies and damselflies; ferns and relatives; conifers and relatives; and flowering plants.

A recent addition to the 2008 edition of the *State of the Nation's Ecosystems* report is a trend index, similar to that described above, which shows the number of species for which trends are increasing, decreasing, stable, or unknown (Figure 7.1).

FIGURE 7.1 Heinz Center indicator for at-risk species, showing total percentage of native species at risk (top graph) and population trend chart (bottom graph) for native terrestrial and freshwater vertebrates.



Regardless of one's opinion concerning the mechanics or details of the NatureServe ranking system, the factors in the bulleted list above are likely to be of considerable importance in determining the conservation status of a species or in assessing the performance of any species conservation or management activities.

What Could Be Measured at the State Level?

Each State Wildlife Action Plan includes a customized list of "Species of Greatest Conservation Need" identified through collaboration with multiple stakeholders and in many cases reviewed by panels of local or regional experts. Although each state has selected a different suite of species, it is likely that some/all of the NatureServe criteria above will be of use as status and/or effectiveness measures.

We think it will also be helpful at the state level to have a few standardized metrics of both species status and conservation effectiveness, to give state wildlife managers a perspective on the cumulative impact of all of the activities being undertaken to implement their State Wildlife Action Plan.

A simple measure of species status at the state level might look like:

> Percentage of species of conservation interest in a state that have population trends that are:
>
> - increasing,
> - stable,
> - decreasing, or
> - unknown.

Simple measures of species management activities might look like:

> Number of species for which conservation activities were undertaken (either by a particular agency or organization, or with funding from a particular source).
>
> Number of species not already formally protected under state/federal law for which conservation activities were undertaken (again, either by a particular agency or organization, or with funding from a particular source).

Part of the intent in developing the new State Wildlife Action Plans is to identify and implement conservation actions for species before those species become so rare and imperiled that they must be listed under state or federal endangered species laws. The latter measure provides a simple assessment of the number of not-yet-listed species for which activities were implemented.

Many species of conservation interest are poorly known, with significant gaps in our understanding of such potentially important factors as their distribution, life history, population dynamics, and ecology. This is especially true in large and diverse groups such as freshwater fishes, insects, and mussels. Measures of how much new information is collected for these species (such as the number of survey reports, updated status or occurrence data, and peer-reviewed publications) provide managers and higher-level decision-makers with important information regarding the status and improvement of our knowledge of these species.

A simple management measure for the collection of new information might look like:

> Number of species for which improved knowledge of status (number of occurrences, improved population estimates, etc.) has been obtained (either in general, or with funding from a particular source or through actions taken by a particular agency or organization).

Even for species for which life history and ecological requirements are well known, effective adaptive management requires that monitoring programs regularly assess population status and trends. The number or proportion of species for which appropriately designed monitoring programs are in place is a simple measure of the data collection infrastructure that is needed for successful management.

A simple management measure for documenting the presence of an appropriate monitoring infrastructure might look like:

> Number of species for which conservation actions have been taken, and for which monitoring programs are in place that use appropriate sampling methods for the taxa of interest adequate to detect population trends.

How Can States Link to the National Metrics?

Since the national metric for species status relies on top-level data from NatureServe, which in turn receives data from the network of state Natural Heritage programs and affiliates, the linkage between state conservation activities and the national metrics is already provided. To contribute to the national accounting of rare and at-risk species, states would need only to provide updated status and trend information for species via the existing Natural Heritage network and its databases.

In addition, two different state-level species status measures are possible based on The Heinz Center approach. Corresponding state ranks ("S-ranks," listed as S1 through S5) exist for many taxa in the NatureServe database. States could develop indicators that report on the percentage of taxa having each of the different state ranks. Alternately, states could develop indicators that report the percentage of taxa having each of the different global ranks.

Other multi-species metrics are certainly possible – for example, one could report the number or percentage of species with declining, stable, or increasing populations in some taxonomic group or with a particular status (state-listed, federally listed, or identified as Species of Greatest Conservation Need).

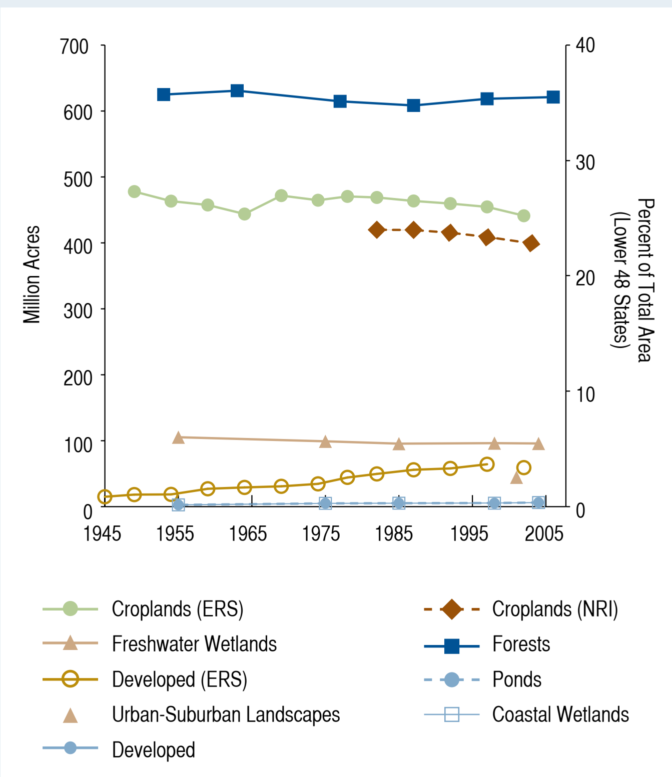
Ecosystem Extent

What is Measured at the National Level?

The Heinz Center's core national indicator for ecosystem extent (Figure 7.2) provides status and trend data for the area (measured in acres) of the six major ecosystem types addressed in the *State of the Nation's Ecosystems* report (coasts and oceans, farmlands, forests, wetlands, grassland-shrublands, and urban-suburban areas). For farmlands, the area of croplands is reported. Data are derived from the 2001 National Land Cover Data Set and the U.S. Forest Service Forest Inventory and Analysis program.

It should be noted that, at present, data are not adequate for reporting at a national level on many aspects of freshwater ecosystems, coasts, and oceans. Data are also not adequate for reporting at a national level on changes from one major ecosystem type to another, nor are they adequate for reporting on the extent of rare ecosystem types.

FIGURE 7.2 Heinz Center (2008) indicator for ecosystem extent, showing land cover and extent trends for eight major ecosystem types.



As more highly resolved land cover data become available, The Heinz Center indicator will also report the extent of ecological systems. The federal Landfire program (http://www.landfire.gov/) shows great promise as one source of such higher-resolution data. This program will map vegetation units in the United States at a 30-meter resolution using the NatureServe Ecological Systems (http://www.natureserve.org/explorer/servlet/NatureServe?init=Ecol) as a standard vegetation classification.

What Could Be Measured at the State Level?

As with species, states will undoubtedly want to develop extent metrics for ecological communities or vegetation cover categories of conservation interest (e.g., tallgrass prairie in the upper Midwest, early successional shrub-scrub in the mid-Atlantic states, sagebrush steppe in the intermountain West). At a minimum, we recommend that these metrics report the amount or percentage of land area within the state covered by each ecosystem or vegetation type of conservation interest. Such metrics would serve most immediately as status assessments (answering the question "How much do we have?") and, measured at regular intervals, would provide valuable information on trends in the extent of ecosystem or vegetation types of conservation interest.

For reporting and tracking purposes, there would be great value in having a consistent vegetation classification used by all states. Such a classification would also enhance interstate cooperation on habitat mapping and land conservation projects. The Landfire database (http://www.landfire.gov) represents one possible approach.

States could also measure the extent of ecological communities of conservation interest that were in some form of protective management. There are, of course, a wide variety of protective management tools ranging from short-term voluntary conservation agreements to state or federal land ownership, and one would need to be clear about what types of management tools were included or excluded. It may also be helpful to distinguish areas of protective ownership ("passive management") from areas where active management (e.g., planting of trees, treatment of invasive weeds, etc.) is occurring. In tabulating acres of active management, it is important to be alert for potential over-counting – otherwise, a 5-acre field that was sprayed twice for weeds over a single growing season might be counted as 10 acres, when in fact only 5 acres actually exist on the ground.

Finally, as a high-level status measure, states could report the extent of the six major ecosystem types addressed in the

State of the Nation's Ecosystems report (coasts and oceans, farmlands, forests, wetlands, grassland-shrublands, and urban-suburban areas).

How Can States Link to the National Metrics?

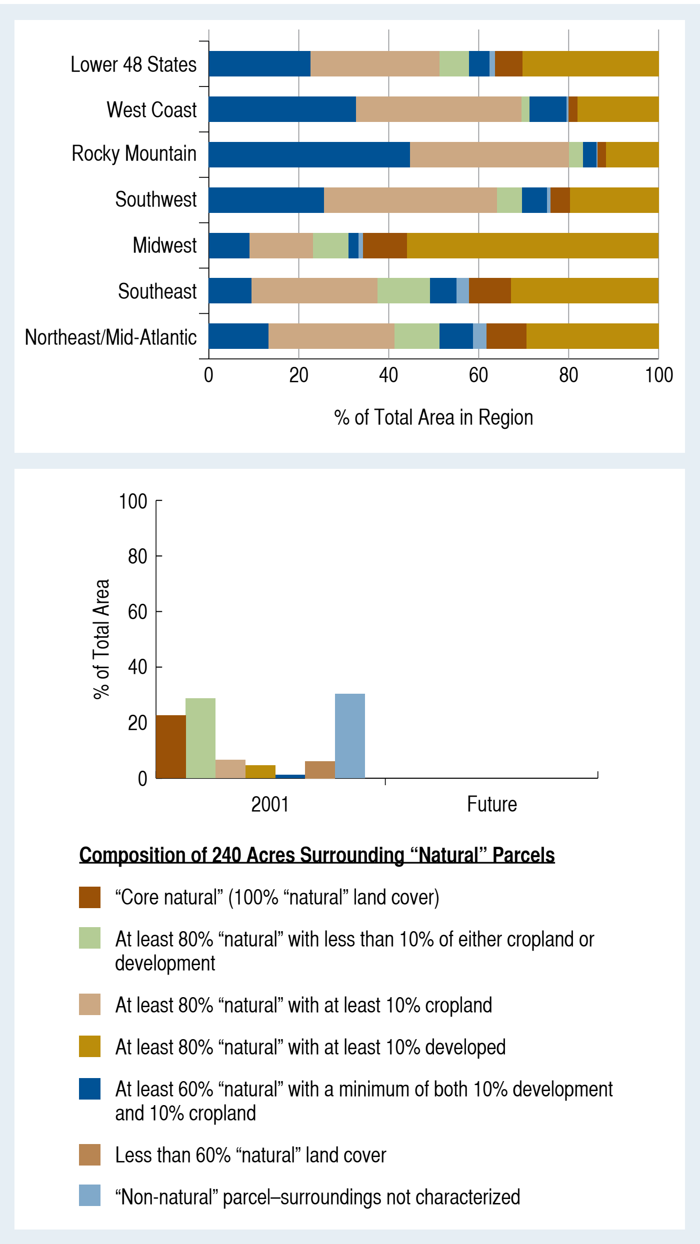
States could report the area of extent of the six major ecosystem types addressed in the *State of the Nation's Ecosystems* report, as well as the extent of ecological communities of interest. Some data could be derived from the 2001 National Land Cover Data Set used in the *State of the Nation's Ecosystems* report. Other products such as those produced by the "Landfire" program (http://www.landfire.gov/) could also be used to facilitate such reporting. For more in-depth analysis, states may also find it useful to obtain their own remotely sensed imagery from government agencies or commercial suppliers.

Landscape Pattern

What Is Measured at the National Level?

The Heinz Center's national Landscape Pattern indicator (Figure 7.3 below) reports aspects of the arrangement and size of patches of "core natural" lands (forest, grassland, shrubland, wetlands, lakes, or coastal waters). The indicator provides an assessment of the degree of fragmentation of larger landscapes, ranging from one extreme where there are large contiguous blocks of unfragmented natural lands, to the other extreme where natural lands have become highly fragmented by conversion to other land uses. Large blocks of contiguous natural lands are known to be important for particular wildlife species (e.g., forest interior-nesting birds, large carnivores), and fragmentation of landscapes is thought to be a driving factor behind processes such as species loss, declining water quality in streams and rivers, and the spread of non-native species.

FIGURE 7.3 The Heinz Center (2008) national indicator of landscape pattern, showing extent and composition of the surroundings of "natural" landscape patches in the United States.



Technical Details of Landscape Pattern Indicator

Because this is a newly developed indicator, we present technical details here that could be used by states and others who are interested in applying this method to their landscapes.

This analysis is based on a digital map of the country that is broken up into more than eight billion 30 X 30 meter square pixels. Specifically, this indicator reports:

- The composition of the surrounding 240 acres of each "natural" pixel (defined below), reported in terms of the relative proportions of three land-cover types: natural, cropland, or development.
- The size and abundance of patches made up of "core" natural pixels (those having 100% natural surroundings).

The data for this indicator are derived from two sources. The primary source is the National Land Cover Data Set. In addition, this land-cover map was augmented with data from Environmental Systems Research Institute, Inc. on roads, which are considered a type of development.

The following National Land Cover Data Set categories were treated as "natural" for this indicator: (11) water; (12) perennial ice/snow; (31) barren land (rock/sand/clay); (41) deciduous forest; (42) evergreen forest; (43) mixed forest; (52) shrub/scrub; (71) grassland/herbaceous; (90) woody wetlands; and (95) emergent herbaceous wetlands.

A square analysis tool (window) was centered on every pixel within the map and then the composition of pixels within the window was recorded. A one-km analysis window was used (although other sizes could be used). For those pixels that had 100% "natural" surroundings, patches were formed, but only for pixels that shared a common edge (i.e., it was not sufficient if the edge of pixels touched). The area of these patches was reported by state, and then these data were summarized by region and across the country as a whole.

What Can Be Measured at the State Level?

The same analytical procedures could be applied at the state level to determine both the size and degree of fragmentation of patches of "natural" landscape (as defined above) within each state. Furthermore, similar procedures could also be applied to other areas of interest besides "natural" lands: rare vegetation types, habitat restoration sites, protected natural areas, or parcels for acquisition. Depending on the specific management question at hand, it may be more appropriate to apply a different window and/or pixel. There is a lower limit to pixel size that is imposed by the minimum resolution of the available data sets (at present, 30 X 30 meters for the National Land Cover Data Set and other products derived from the Landsat Thematic Mapper and Enhanced Thematic Mapper instruments; 60 X 60 centimeters for commercial imagery derived from the QuickBird satellite).

How Can States Link Their Metrics to the National Metrics?

In this case, the linkage between state and national metrics would be provided by having a shared technique that allows reporting on the surroundings and size of patches of "natural" landscapes at both state and national levels. Both measures would show the percentage of lands in various stages of fragmentation, from large blocks of "natural" landscape at one extreme, to the other extreme where natural landscapes are highly fragmented.

Chapter 8: Data Sources, Management and Reporting

This chapter briefly discusses three of the most important topics in designing a system for monitoring and performance measurement: how and where to obtain data, how the data will be managed, and how the data will be managed, stored, and used in various analyses and reports. Agencies and organizations engaged in conservation work will undoubtedly find it useful to invest in a system for collecting monitoring data and tracking activities and results, if they have not already done so. Developing a system for tracking and monitoring performance helps an organization retain and recall information about the work it has done and track its progress towards achieving its conservation goals. It also enables the staff of an organization to learn from their past activities (what works, what does not work, and why).

Data Sources

Existing fish and wildlife monitoring programs may be able to supply some of the data that will be needed as part of a statewide performance measurement program. Sources of monitoring data for individual species may include:

- Existing endangered or threatened species monitoring programs
- Large mammal, sport fish, and game bird programs
- Waterfowl monitoring programs
- NatureServe and the State Natural Heritage Programs
- Breeding Bird Survey
- Christmas Bird Count
- Other citizen science monitoring programs
- Single-species monitoring programs (e.g., sage grouse in Nevada)
- Academic or museum biologists who study individual taxa.

As discussed in more detail in Chapter 6, tracking of changes in vegetation and other habitats can often be done using remotely sensed imagery available from USGS, NASA, and commercial satellite imagery vendors. Such data may also be available from state land use or state planning agencies.

Whenever possible, we recommend using existing data sources and existing monitoring programs. New monitoring programs are often resource-intensive to start and may be difficult for state wildlife agencies to support through lean budget years.

The first example at the end of this chapter describes an innovative use of data from the Breeding Bird Survey and the Christmas Bird Count to develop indicators of bird status and trends in the United States. Such indicators could be developed for birds in an individual state, or for a particular taxonomic group or ecological assemblage of birds within a particular state.

Data Management and Reporting

Many of the standard references on monitoring and performance measurement (e.g., Mack 1996; Margoluis and Salafsky 1998; Busch and Trexler 2003; Rabinowitz 1993; Trochim 2006) give extensive consideration to the problems associated with data management and reporting. We outline a few general principles here that will be useful for natural resource management agencies and organizations, and refer the interested reader to the more extensive discussions in these other works.

Before developing a new data management system, it is worth reviewing the data management systems that already exist within the organization and making a determination as to whether or not those systems will be adequate for tracking and reporting the information that will be collected as part of a new monitoring and performance measurement program. Depending on how these systems were designed and when they were established, they may or may not be suitable for tracking the types and amounts of data that will be generated by a monitoring and evaluation program. Existing information systems may thus need to be upgraded or enhanced in order to incorporate and report new data.

The simplest form of data management is a ledger or notebook that records activities, outputs, and short- and long-term outcomes. However, most state wildlife agencies and conservation groups will have access to spreadsheet and/or database software, which can provide the backbone for a more sophisticated performance measurement tracking and reporting system. Computerized tracking systems greatly expand the ability of an agency or organization to track, analyze, and report its progress.

During our conversations with evaluation professionals and conservation practitioners, we received the following recommendations regarding data management systems for monitoring and performance measurement. Such systems should ideally:

1) Be spatially explicit. The inclusion of spatial information in a data management and reporting system makes it possible to ask a very wide range of questions about the spatial pattern of the data. For those organizations that have already invested in Geographic Information Systems (GIS) software, it becomes possible to address some very interesting questions, the answers to which can help improve the practice and delivery of conservation activities (for example, one could investigate whether successful conservation activities are concentrated in certain communities or watersheds). Even if an organization does not have access to GIS software, collecting spatial data about its projects is still recommended. Including these data in the database makes it possible for the organization to develop a GIS database in the future, and to share the data with other organizations and agencies that already have GIS capabilities.

2) Be simple. The system does not have to be the most complex in the world, nor does it have to track every possible environmental variable. It is better to have a simple system that works and provides managers with a basic level of information that meets their needs, than to have the most complicated system in the world that is infrequently updated and poorly populated with data.

3) Be straightforward. The data management system should be understandable to non-specialists, so that staff can continue to update the database once the original creators are no longer around. Any codes and abbreviations should be clearly explained. Data entries should be kept as simple as possible, without loss of critical information.

4) Be comprehensive. The overall data management system should include as many different types of activities as possible: outreach and educational activities, as well as "on-the-ground" restoration and management work. By including a wide range of activities, the data system will allow managers to investigate possible relationships between different types of activities (for example, are members of the organization who attended a particular outreach event more likely than the other members of the organization to respond positively to a request for volunteer time?).

5) Use standardized terminology for activities and output and outcome measures. The types of activities and outputs/outcomes in the database should be carefully defined and the use of these terms standardized across the organization. This helps ensure that similar data entries are truly comparable across projects and programs.

6) Use separate fields for anticipated outputs and outcomes, as well as observed outputs and outcomes. Some existing conservation databases have fields for outputs and outcomes, but it is not possible to tell whether these are anticipated values (predicted before the project was actually implemented) or observed values (actually measured after the project was implemented. Keeping track of both types of information allows managers to compare their projections about the project's accomplishments with its actual achievements. Hopefully this process will lead to improved estimates of the accomplishments of future projects.

A Reporting Template for State Wildlife Action Plans

The simple outcome measures that were developed in Chapter 6 can be combined with potential output measures into a reporting template. This template can serve as the basis of reports to government agencies and legislatures, funders, and the interested public.

Our selection of potential output and outcome measures is based on the conceptual model of state wildlife plan implementation developed in Chapter 4. As described in Chapter 6, we have selected output measures that track the completion of individual projects and wildlife conservation activities, while at the same time selecting outcome measures that track the wildlife species and habitats which are the conservation targets of the State Wildlife Action Plans. The following diagram (Figure 8.1) shows the relationship between the output and outcome measures described in this section and the conceptual model from Chapter 4 which describes the development and implementation of the State Wildlife Action Plans.

Habitat Measures

For the first measure (Figure 8.2), we report the percentage of acres of key wildlife habitats (as identified in the State Wildlife Action Plan) according to their current management status. In this example, we use the management categories "Conservation Lands," "Other Public Lands," "Developable Private Lands" and "Lost to Development." Individual states may wish to have their own set of categories that best reflect the land management activities in their state. Including the percentage of acres that have already been lost can be helpful in putting current conservation activities in perspective: either a significant portion of these key habitats have already been lost, in which case the remaining areas are especially important for wildlife; or a significant portion of the key habitat areas are still extant, in which case there are significant opportunities for wildlife conservation and management on these lands.

For the second habitat measure (Figure 8.3), we report the percentage of key wildlife habitats (as defined in the State Wildlife Action Plan) that are increasing in area, decreasing in area, stable in area, or converted to development.

FIGURE 8.1 Conceptual model for the development and implementation of State Wildlife Action Plans, showing the relationship of output and outcome measures to the activities and outcomes of the implementation process.

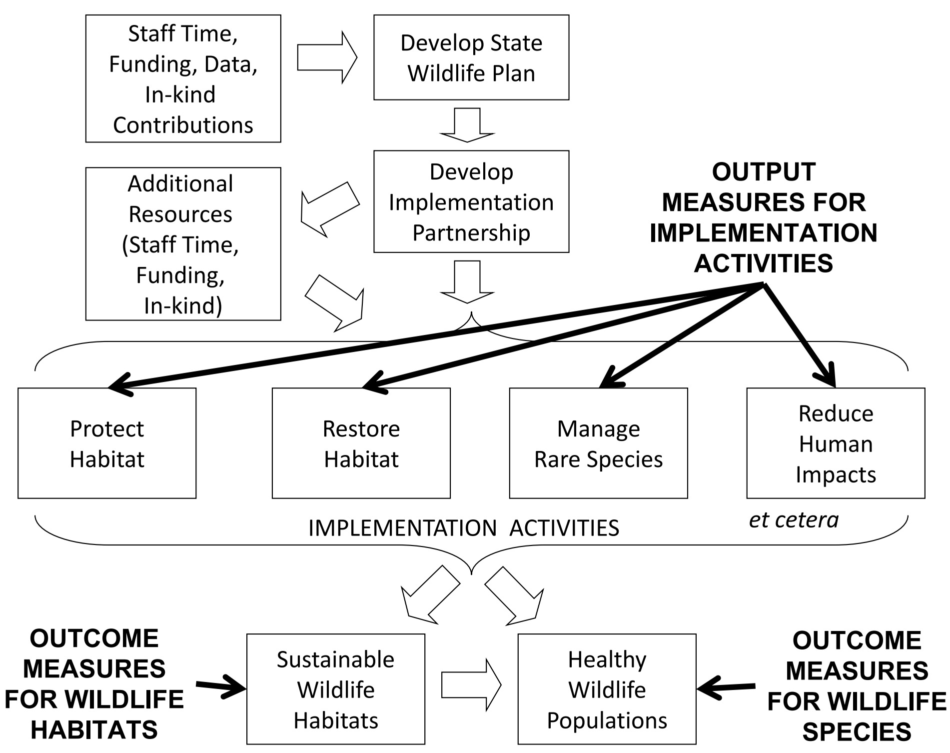


FIGURE 8.2 Management status of key wildlife habitats in our state in 2006.

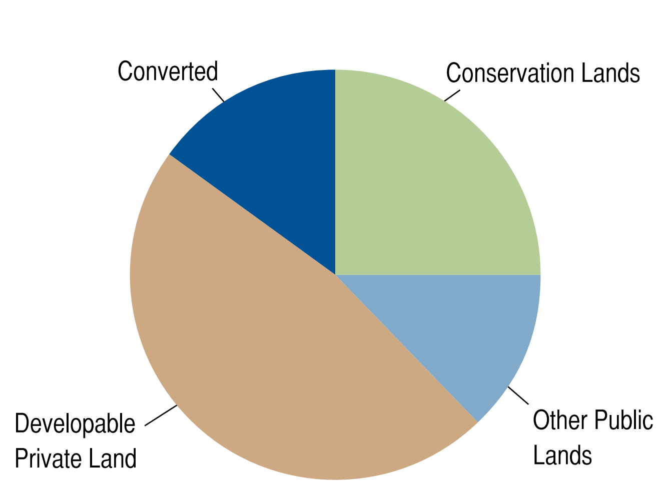
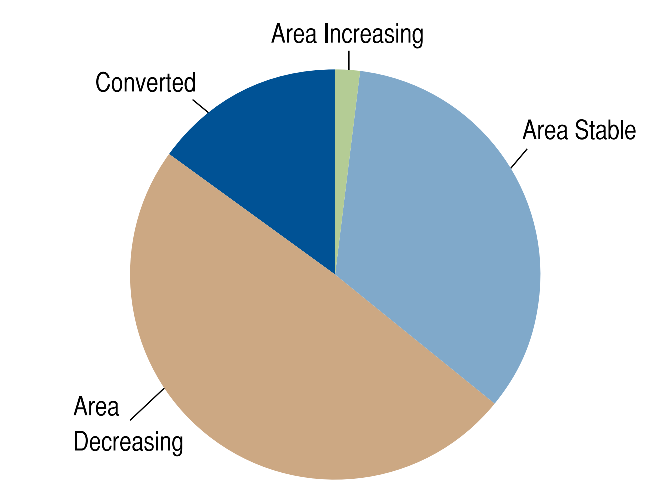


FIGURE 8.3 Trends in extent of key wildlife habitats in our state, 1998-2006.

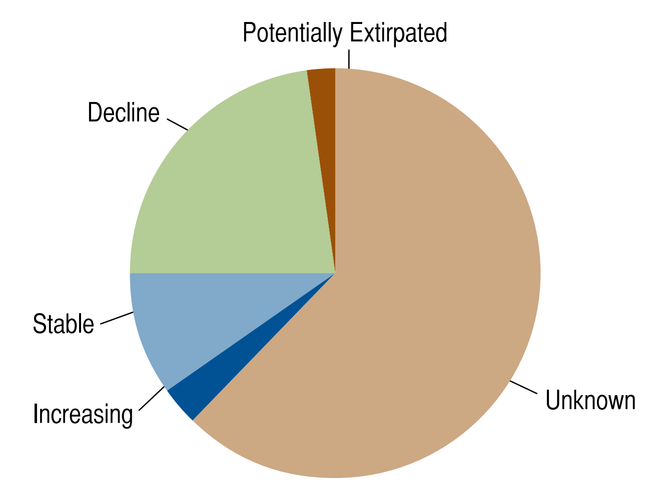


Species Measures

Figure 8.4 shows the species trend chart described in Chapter 6. It provides a useful summary of the direction of population trends of the species of greatest conservation need in a particular state.

The second worked example at the end of this chapter describes how we populated this chart with "real world" data from the Nevada Wildlife Action Plan.

FIGURE 8.4 Population trends in species of greatest conservation need for our state, 2006.



Output Measures

It is also useful to track a series of output measures associated with the implementation projects that have actually been completed. Figure 8.5 shows a very simple bar chart that reports the number of projects in each of the categories established by the International Union for the Conservation of Nature – Conservation Measures Partnership (2006). We have added an extra category for research and monitoring projects, since these activities figure prominently in the State Wildlife Action Plans but were not included in the IUCN-CMP taxonomy of conservation actions.

Of course, other output measures are possible. We recommend that states and organizations develop similar charts that track their progress towards implementing the types of conservation activities that are most relevant for their particular management priorities. Figure 8.6 shows another simple output chart that shows the number of projects that have been completed for each of six broad focal taxa in a particular state.

FIGURE 8.5 Number of State Wildlife Action Plan implementation projects, by major category, 2006-2008.

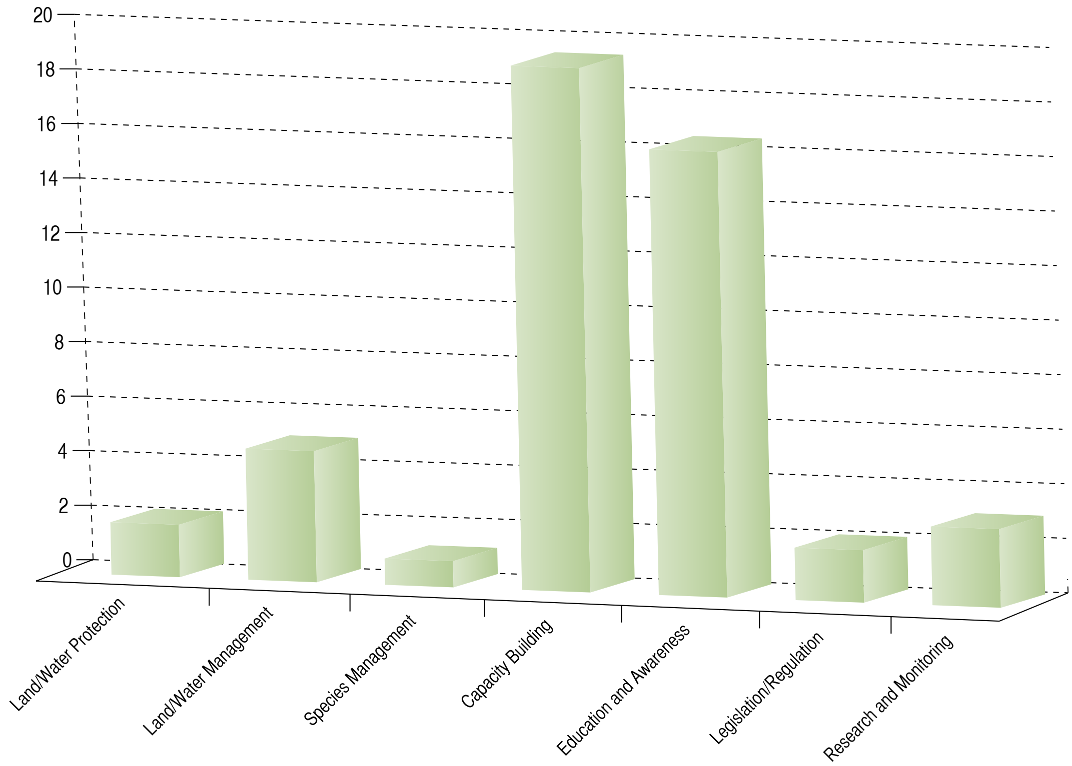
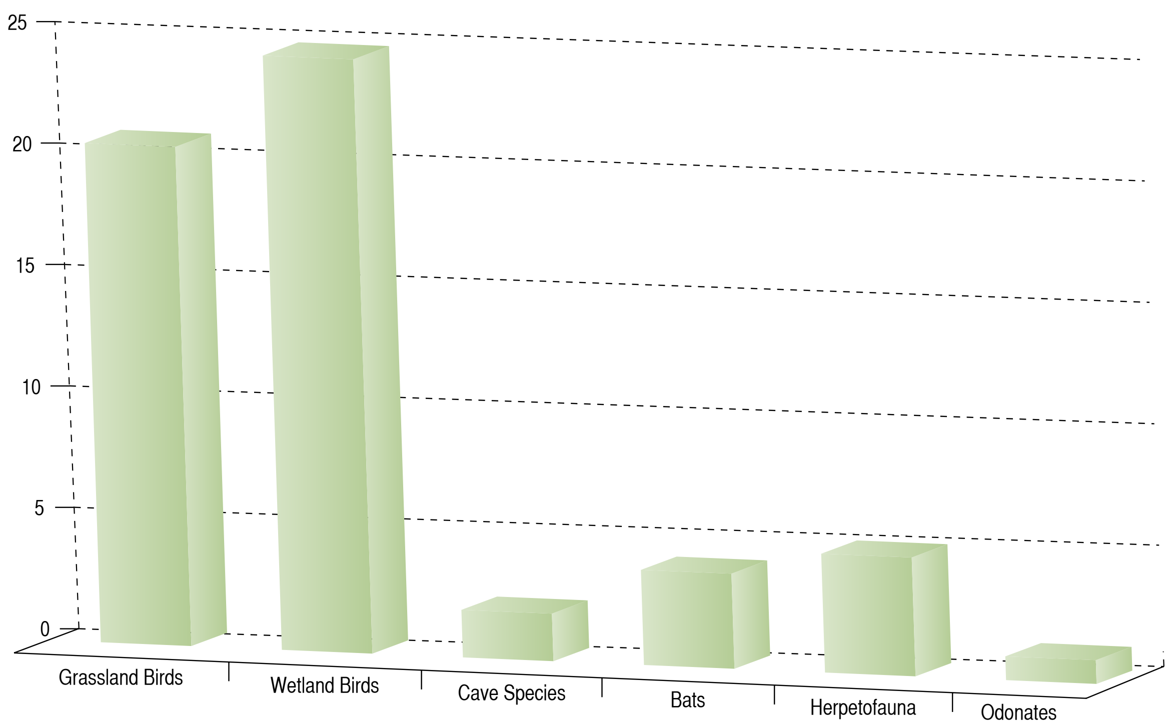


FIGURE 8.6 Number of State Wildlife Action Plan implementation projects, by focal taxa, 2006-2008.



Example: State of the Birds Reports: Birds as Indicators

Gregory S. Butcher and Daniel K. Niven, National Audubon Society

Birds have a long history as indicators of the state of the environment, beginning with the proverbial canary in the coal mine. Perhaps the most powerful indicator that something was amiss came when populations of bird-eating and fish-eating birds such as the Peregrine Falcon and the Bald Eagle declined precipitously because of exposure to DDT and related organochlorines and the build-up of their metabolites in their tissues, causing massive reproductive failure. A similar mass population decline is now occurring among Old World vultures in India, and the culprit has been found to be a veterinary drug, diclofenac. Most recently, lead poisoning has been found to be the main culprit interfering with the recovery of the California Condor. Lead has been shown to be widespread in hunter-killed venison and is a well known human poison; thus, the problems identified in condors are a strong suggestion of problems faced by humans as well.

A more recent trend in using birds as indicators involves state of the birds reports. Almost 10 years ago (Gregory et al. 2000), the Royal Society for the Protection of Birds and the British Trust for Ornithology began an annual series of state of the birds reports for the United Kingdom (U.K.). More recently, BirdLife International produced a global state of the birds report (BirdLife International 2004), and Europe has produced a state of the common birds report (Pan-European Common Bird Monitoring 2006; Pan-European Common Bird Monitoring Scheme 2007). Australia, Spain, and Poland now have national state of the birds reports. Connecticut (Bull 2006) and Washington (Cullinan 2004) have produced state reports.

At the heart of the U.K. and European state of the birds reports is a series of bird indicators: annual indices that reflect population trends of all birds with data, wetlands birds, forest birds, and agricultural birds. In both the U.K. and Europe, governments have adopted these indicators as official and have adopted policies that promote stable or increasing bird populations.

In 2004, Audubon published the first state of the birds report for the United States, based on data from the Breeding Bird Survey (BBS) and the Audubon WatchList (Butcher 2004). Using the BBS, we identified birds that were declining significantly, declining slightly, increasing slightly, or increasing significantly. The WatchList includes a red category for globally threatened species and a yellow category as an early warning system (Butcher et al. 2007). In addition, we divided birds into the following habitat types: grass, shrub, woodland, wetland, mixed/other, and urban/suburban. We found that grassland included the highest proportion of birds with significant declines and the highest proportion of red WatchList species. Shrubland included the second highest proportion of birds with significant declines and the highest proportion of birds on the yellow WatchList. More recently, Audubon identified 20 common bird species that have lost more than 50% of their populations over the past 40 years (Butcher 2007) and has revised the WatchList, in conjunction with the American Bird Conservancy and others (Butcher et al. 2007). Both the Common Birds in Decline report and the new WatchList relied on trend analyses from the Audubon Christmas Bird Count (CBC) in addition to the BBS.

In October 2007, President George W. Bush called for a federal state of the birds report. Since that time, a number of organizations have come together to work on that report. The intention is to include habitat-specific indicators similar to the U.K. and European indicators as the core of this report. U.S. Geological Survey and Audubon (Sauer et al. in press) have already produced a grassland bird indicator using data from the BBS and CBC. The new indicators are expected to add survey data that have been collected for a variety of hunted species (waterfowl, Mourning Dove, American Woodcock) in addition to the BBS and CBC. The BBS web site has traditionally reported other indicators as well: migration type (long distance, short distance, resident) and nesting type (ground, canopy, hole). Canada has recently looked at prey/foraging types because of a concern about aerial insectivores. All these indicators should prove easy to create as 40-year annual indices or in other formats. Other indicators could easily be added, especially if the categories included a good sample size of species well covered by the BBS or CBC.

Breeding Bird Survey (BBS)

The BBS, administered by the U.S. Geological Survey (http://www.pwrc.usgs.gov/BBS/), is the primary source of status and trend information for North American birds during the breeding season. The BBS is a roadside survey that includes 50 3-minute stops one-half mile apart, at which experienced individuals count all birds seen and heard. Surveys are done between late May and early July beginning 30 minutes before dawn. Surveys have been done on more than 4,000 routes; about 3,000 routes are done each year. Data are aggregated by Bird Conservation Region (see section "Geographic units of study" below) and by state. All states except Delaware, Rhode Island, and Hawaii have a sufficient number of routes to produce valid results for a substantial number of species. Only a small portion of Alaska is covered. The survey began in 1965, so our analyses begin with that year.

Audubon Christmas Bird Count (CBC)

The CBC (http://www.audubon.org/bird/cbc/) is the primary source of status and trend information for North American birds in early winter. Each individual CBC occurs within a 15-mile-diameter circle on a single day within two weeks of Christmas. Participants join groups that survey subunits of the circle during the course of the day using a variety of transportation methods (mostly on foot, in a car, or watching at a feeder). Just over 2,000 circles are surveyed each year. Like the BBS, data are aggregated by BCR and by state. Like the BBS, all states except Delaware, Rhode Island, and Hawaii have a sufficient number of circles to obtain valid results for a substantial number of species. South-coastal Alaska is well covered; the rest of the state is sparsely sampled. The first CBC was done in 1900. We begin our analysis of CBC trends with the winter of 1965-66 for comparison with the BBS (which began in 1965) and because earlier CBC data are less comparable to current CBC data due to changes in methods and intensity of effort.

Trend Analysis Methods

BBS and CBC trends and annual indices are derived from a hierarchical model that treats BBS routes and CBC counts as random variables, with means described by a log linear regression with random effects (Link and Sauer 2002; Link et al. 2006). The model includes (for the CBC only) a stratum-specific effect of effort (party-hours). The model is hierarchical in that most of the effects are treated as random variables, including route or circle, year, over-dispersion, and (for CBC only) effort effects. We fit hierarchical models using Bayesian methods, specifically Markov chain Monte Carlo techniques (Gilks et al. 1996, Link and Sauer 2002). We use program WinBUGS (Spiegelhalter et al. 1999) to estimate the variability around the parameters and indices, creating 95% credible intervals that are analogous to confidence intervals derived from other statistical approaches.

TABLE 8.1 Number of bird species in the Breeding Bird Survey (BBS) and/or Christmas Bird Count (CBC) with a particular reliability score (0 ,1 or more, 2 or more, 3)

	Both	BBS	CBC	BBS or CBC
3	43	131	88	176
2+	156	313	216	373
1+	279	395	379	495
0+	309	405	454	550

		CBC					
		3	2	1	0	x	TOTAL
BBS	3	43	24	20	4	40	131
	2	29	60	38	13	42	182
	1	6	16	43	4	13	82
	0	0	2	4	3	1	10
	x	10	26	58	51	0	145
	TOTAL	88	128	163	75	96	550

KEY	
BBS	Breeding Bird Survey
CBC	Christmas Bird Count
3	All scores for sample size, abundance, precision, and range coverage are 3
2	All scores are 2 or 3
1	All scores are 1, 2, or 3
0	All scores are 0, 1, 2, or 3
x	At least one score was x

Reliability of Population Trend Data from Surveys

The BBS and CBC are omnibus surveys designed to determine status and trends for a large number of species over a large geographic scale. As a result, the reliability of BBS- and CBC-derived trends varies greatly among species. An estimate of reliability is valuable for two major reasons: to determine if the trend data should be considered at all, and if trend information is available from more than one source, to determine which source might be more reliable. In this report, we estimate trend reliability using four factors:

1) Number of BBS routes or CBC circles that recorded the species at least twice in 39 years,

2) Average abundance of the species on the routes or circles included in the analysis,

3) Precision of the trend estimate, and

4) Proportion of the breeding range covered by the BBS or winter range covered by the CBC.

For each of these four factors, we assigned a score of x or 0 to 3. We gave a score of 'x' to values considered so low that the trend should not be used; scores of 0-3 are all considered to be acceptable.

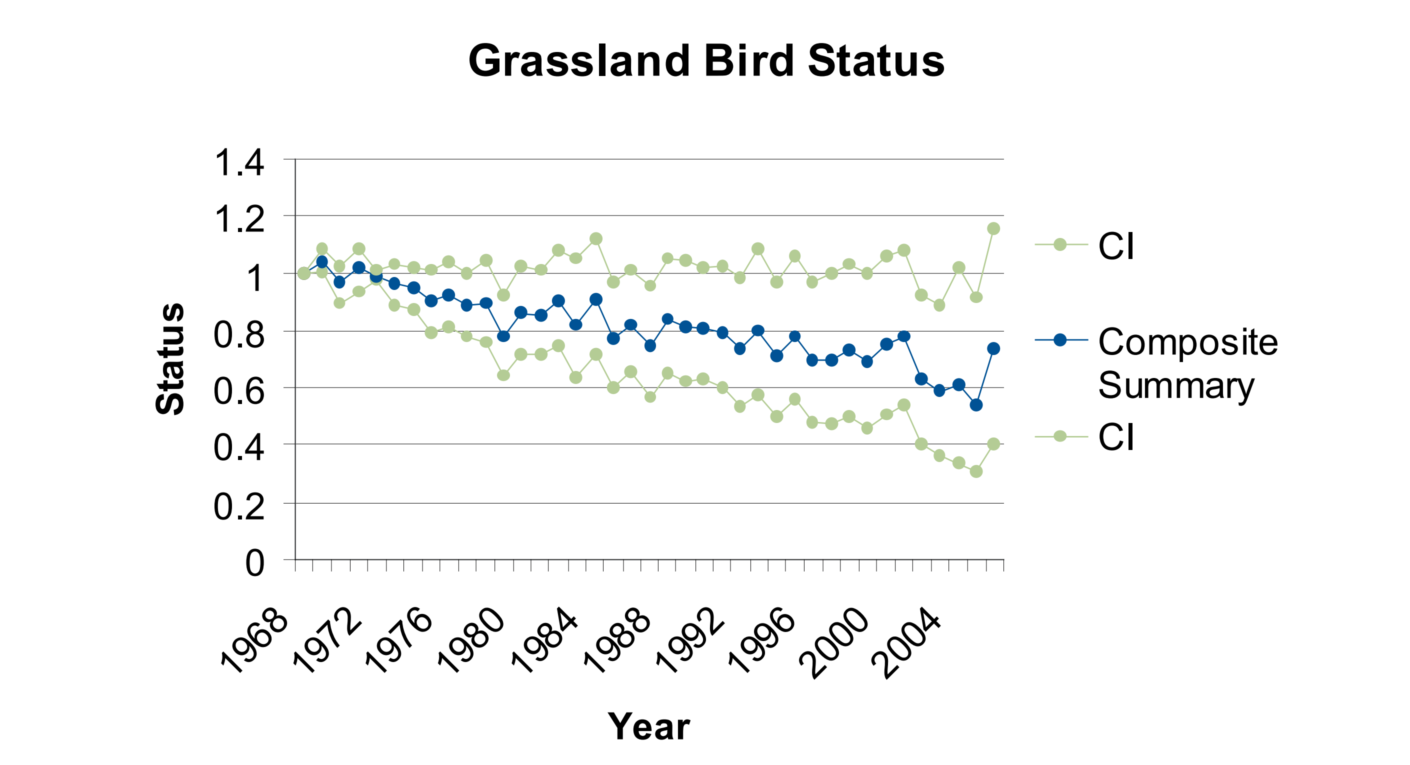
TABLE 8.2 Comparison of BBS and CBC trend categories within species. Species with trends on both CBC and BBS.

		CBC					
		I*	i	S	d	D*	TOTAL
BBS	I*	41	11	5	2	0	59
	i	25	16	13	7	4	65
	S	14	14	15	10	4	57
	d	10	27	24	15	18	94
	D*	0	9	4	9	12	34
	TOTAL	90	77	61	43	38	309

Proportion (and number) of trend categories different

0	1	2	3	4
0.32 (99)	0.40 (124)	0.20 (61)	0.08 (25)	0.00 (0)

FIGURE 8.7 National trend in grassland bird species, based on combined data from Breeding Bird Survey and Christmas Bird Count.



AVAILABLE TREND INFORMATION

Trend information is available nationally for 550 species (Table 8.1). Trend data of high reliability (overall reliability score of 2 or 3 on either CBC or BBS) is available nationally for 373 species. When trends are available for both BBS and CBC, they tend to be similar, but not always (Table 8.2). CBC trends tend to be higher than BBS, both because of observer changes over time on the CBC and more dramatic winter range changes in response to global warming (Butcher and Niven 2007).

INDICATORS

On the BBS website, indicators are the proportion of species with decreasing population trends. Indicators are available for habitat, migration, and nesting substrate.

In the 2004 Audubon state of the birds report, indicators were available for habitat types. The indicators were proportion of red and yellow WatchList species and proportion of species increasing or decreasing.

Recently, Sauer et al. (in press) produced an indicator for grassland birds as an annual index of abundance over the past 40 years (Figure 8.7). This indicator is similar to ones that have been adopted by the U.K. and European governments to determine environmental policy and priorities. Similar U.S. indicators are expected to be created for other U.S. habitat types as part of the federal state of the birds report now in preparation.

All of these indicators (and more) are potentially available to the states as a group or to individual states. A relatively small grant could allow U.S. Geological Survey or National Audubon Society to create these indicators for all states simultaneously. Alternatively, a smaller group of states or a single state could contract with one or the other to produce indicators. In addition, the raw data or the trend data are available from USGS (BBS) or Audubon (CBC).

Example: A Species Trend Indicator for the Nevada Wildlife Action Plan

Jonathan Mawdsley and Robin O'Malley, The Heinz Center

The Nevada Wildlife Action Plan identifies 186 "species of greatest conservation need" (Nevada Department of Wildlife, 2006). Status rankings at the state and global levels are available for 186 species, but data on rank changes are unavailable. Estimates of absolute population size in the state are available for 43 species. Quantitative estimates of population trends within the state are available for six species. Estimates of the direction of population trends within the state are available for 92 species (Nevada Department of Wildlife, 2006).

As might be expected with these limited data, we found it rather difficult to apply many of the multi-species status or trend indicators that have already been described above in Chapter 6. The geometric mean indices could be calculated for the suite of six species for which population trend data are available, but the broader management utility of such limited information is highly questionable. Neither the Red List index nor an analogue based on the NatureServe ranking system is appropriate, given the lack of rank change information. Quantitative estimates of population size are available for 42 species, but as discussed in Chapter 6, it is not clear how one might translate this information into a multi-species indicator. However, sufficient data were available to use The Heinz Center species status index for both state and global rankings.

We decided to modify The Heinz Center index to also report the percentage of species having NatureServe status rankings in additional categories besides vulnerable, imperiled, and critically imperiled. The categories added include status unknown, apparently secure, secure, and the "in-between" ranks such as "G2G3" where the precise numerical rank for a particular species could not be determined. Adding these additional categories allows us to present information about the status of the entire suite of species included in the plan. The modified indicator also reports the distribution of both state and global rankings for the species of concern, since it is possible that a species may be common elsewhere but rare within a particular state. A graphical presentation of this indicator using data from the Nevada Wildlife Action Plan is shown as Figure 8.8.

For the species trend indicator, we adopted a graphical presentation similar to a figure presented by de Heer, Kapos, and ten Brink (2005), which displays the number or percentage of species of conservation interest having population trends that are unknown, increasing, stable, decreasing, or extinct/presumed extinct. A graphical presentation of this indicator using data from the Nevada Wildlife Action Plan is shown as Figure 8.9.

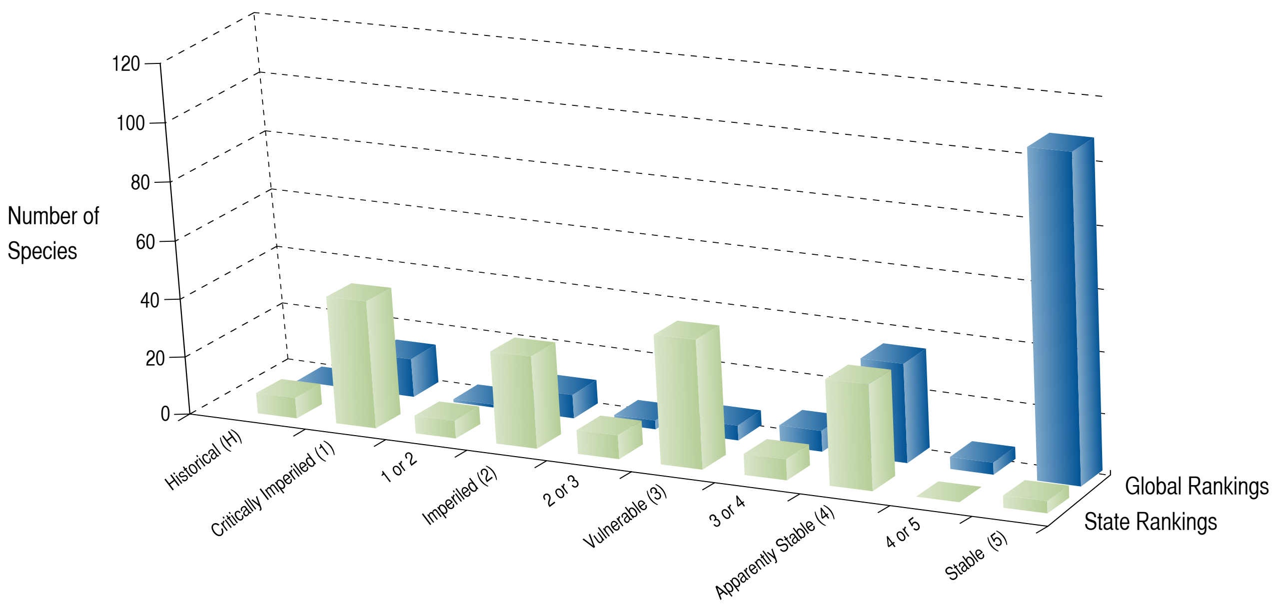
Discussion

The data limitations described above for the Nevada Wildlife Plan are not unique; in fact, our conversations with wildlife managers in 37 other U. S. states indicate that similar data limitations are widespread, at least within the U. S. management context. In the case of Nevada and other U. S. states, budgetary constraints severely limit the collection of additional or better data on wildlife population status and trends (Nevada Department of Wildlife, 2006). There are simply too many species of conservation concern and too few staff and too little funding available for monitoring. In the case of many U. S. states, it is unlikely that more rigorous status and trend data will be available in the near future.

Despite these rather severe limitations, there is an overwhelming need for managers to be able to report something about the status and trends of populations that are under their jurisdiction. State wildlife agencies are under pressure from the U. S. Congress, the White House Office of Management and Budget, the U. S. Fish and Wildlife Service, and their state governments to track and report the progress of their management activities (Nevada Department of Wildlife, 2006; Association of Fish and Wildlife Agencies, 2007). Understanding the status and trends of populations under management is an important part of tracking and reporting progress (Margoluis and Salafsky, 1998).

From a management perspective, we would argue that it is better to design systems that can operate with existing data than to develop rigorous monitoring and reporting systems that will never actually be implemented. In addition to their utilization of existing data sources, the indicators that have been selected here do have several desirable properties. The status indicator shows whether species are globally rare or just rare within the subnational area. In the case of Nevada, the presentation in Figure 8.8 suggests that the state is focusing its conservation efforts on species that are globally common, but rare within the state. The trend indicator highlights important knowledge gaps, as illustrated in Figure 8.9, which shows clearly that estimates of trends are unavailable for over 50% of the species of conservation need in Nevada. The trend indicator also serves as a benchmark for future management, since presumably managers would want to keep the percentage of species that are stable or increasing either the same size or greater, while reducing the percentage of species that are either unknown or declining. The trend indicator also has the advantage of being able to combine data from quantitative estimates as well as qualitative assessments based on expert judgment.

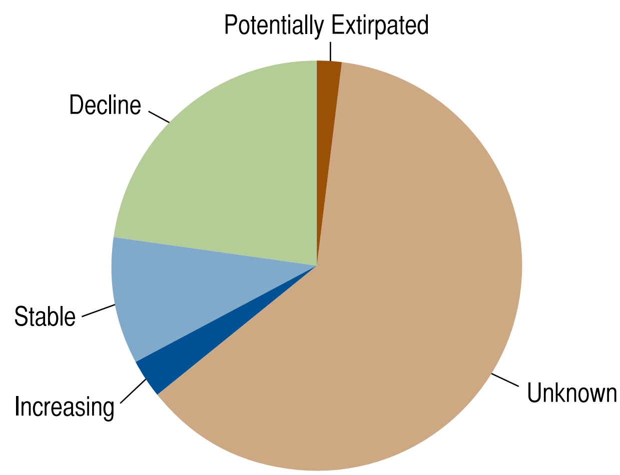
FIGURE 8.8 Status of the 186 "species of greatest conservation need" identified in the Nevada Wildlife Action Plan. Columns show percentage of species in each of the following NatureServe ranks: unranked; historical; critically imperiled (1); imperiled (2); vulnerable (3); apparently secure (4); and secure (5); as well as the four "in-between" ranks 1-2, 2-3, 3-4, and 4-5, which are used when a species cannot clearly be assigned to a single rank. The dark columns are global ranks (GU, GH, G1, and so forth), and the light columns are state ranks (SU, SH, S1, and so forth) for the same set of species.



Of course these indicators have several undesirable properties as well. Both are hard to display as time series; stacked histograms may be more appropriate for time series display. The trend indicator does not explicitly consider the magnitude of trend or the definition of endpoints for a trend. These are not insignificant issues for managers: should a rare bird with only 10 breeding pairs that loses one pair in a single year be placed in the same category as the common and widespread mule deer, which has over 100,000 individuals but has experienced a decline of over 50% since the 1980s? The use of the "stable" category is also problematic, since very few populations will have exactly the same number of individuals from year to year. For widespread species or species with large populations, there is the added complication that some populations may increase while others remain stable or even decrease over the same period of time. If better quantitative data become available, it may be desirable to refine the categories, perhaps by breaking the "declining" and "increasing" groups into intervals.

One final issue identified by our workshop participants is the lack of clear connection between these indicators and specific management activities. This is not a shortcoming of the indicators, which are still useful as summaries of status or trends in the group of species under consideration. Rather, it is a question of "attribution" or the establishment of cause-and-effect relationships between human activities and observed changes in target populations (Davidson, 2005). Some form of experimental design is usually required to establish relationships of causality (Davidson, 2005; Trochim 2006); however, managers often must operate under conditions where experimental designs are either inappropriate or difficult to apply (Cabin, 2007).

FIGURE 8.9 Direction of population trends for the 186 "species of greatest conservation need" identified in the Nevada Wildlife Action Plan.



Chapter 9: Adaptive Management and the Development of Wildlife Monitoring Programs

Dennis Murphy, University Nevada-Reno
Barry Noon, Colorado State University

This chapter provides an essential context for monitoring and performance measurement, by introducing the concept of adaptive management and describing the steps and processes that are necessary for developing a monitoring program for fish and wildlife species and ecosystems.

Adaptive Management

Wildlife and fisheries management has an uneven history with assessing its own performance. Once implemented, management policies often tend to remain fixed, with resource managers trying to maintain a system at some condition that has been predetermined to be an optimum (Gunderson 1999). Not surprisingly, management outcomes are not always monitored to determine if the assumptions of the environmental assessments have proven to be accurate, or if conditions have since changed. This typical situation results in two different problems. First, it can lead to management paralysis, as managers seek in vain for perfect information to support a decision. Second, it can entrench ineffective management strategies and actions. Once managers have endorsed a comprehensive assessment as accurate, they may resist collecting data that could suggest that that assessment is in fact inaccurate. Accordingly monitoring efforts that are explicitly designed to observe ecosystem responses to management actions tend to be discouraged.

Early proponents of adaptive natural resource management recognized that the complexity of natural systems often makes comprehensive assessments of the state of wildlife and fisheries impractical. At the same time, uncertainties about the outcomes from attempts to manage ecological systems and the species they support are inescapable. Key sources of those uncertainties include (see Parma et al. 1998; Regan et al. 2002):

- Natural variation in ecological systems (process uncertainty);
- Inherent randomness of many ecological systems (process uncertainty);
- Inaccuracies of models used to predict the response of managed systems to management actions (model uncertainty);
- Fundamental misunderstandings of variables and the functional forms of models (model error);
- Inaccurate measurements of the state of ecological systems (observation uncertainty);
- Uncertainties arising from the interpretation of incomplete data (subjective uncertainty).

Adaptive management was designed to allow resource managers to act in the face of these multiple acknowledged (and many unacknowledged) forms of uncertainty by designing management actions to reduce uncertainty over time, while permitting change in response to environmental surprises (Holling 1978; Walters 1986). Instead of seeking precise predictions in advance, adaptive management highlights a range of possible outcomes of management actions that target wildlife resources (Walters 1986). It treats management as an element of the learning process rather than as an independent step that follows learning. Wildlife management under the adaptive paradigm is an ongoing process that contributes directly to learning. As a consequence, decisions are nearly always provisional and are contingent upon observed responses to previous management actions.

Adaptive management is also intended to increase the ability of wildlife managers to respond to new information. Management decisions are inherently difficult to change because managers are subject to ordinary human failings -- including a tendency to resist recognizing their own errors. Adaptive management responds by reducing the power of the status quo in at least two ways. First, it begins with the assumption that decisions are provisional and errors will occur. Wildlife managers, who are not expected to be perfect or all knowing, should under adaptive management feel freer to admit to errors and surprises that accompany their best efforts. Second, adaptive management can produce and make publicly available information about management performance that might otherwise remain hidden. That information can then be used to encourage or compel change in management courses and strategies. As the institutional entrenchment of the status quo and resistance to change increases, the importance of rigorous adaptive management, which can produce information with sufficient credibility to overcome that resistance, also increases.

While adaptive management might seem the perfect template for implementing State Wildlife Action Plans, the approach to implementation and assessment is not universally embraced – at least in part because there is not a generally accepted definition of adaptive management. Some disappointment with the implementation of adaptive management to date may be traceable in part to confusion about the meaning of the term, which encourages policymakers, managers, and stakeholders to adopt different expectations. In the absence of a clear definition, the term adaptive management can become a buzzword that does little to constrain management actions (Doremus 2001). It is important, therefore, that policymakers and managers clearly set out what they mean when they use the term adaptive management. The term adaptive management describes a spectrum of management choices with several common elements. The choice of a particular point within that spectrum will depend upon the value of additional knowledge for management and the costs of obtaining that knowledge. The essence of adaptive management is "learning by doing." It is management structured to facilitate development of, and response to, new information – and new, reliable information is a critical objective for State Wildlife Action Plans.

Ways of Acquiring Knowledge

Knowledge can be accumulated through wildlife management actions in three primary ways. The first is "trial and error" learning. Initial management choices are made haphazardly, but the results are monitored, and subsequent choices are based on the success or lack of success of the initial choices. In this case, the manager makes no attempt to synthesize existing information to develop a "best" model of how the system will respond to future management. The second is "passive" adaptive management. Existing data are thoroughly reviewed prior to each management decision, and the decision selected is based on the current, best understanding (that is, the single best model) of how "nature works." Again, results are monitored and subsequent decisions based on the outcomes. The third choice is "active" adaptive management. Under this approach, all existing data are reviewed prior to each management decision, and a range of alternative response models, rather than a single best model, is developed. Management choices are often based on balancing tradeoffs between expected short-term gains under status quo management, against the long-term benefits of learning from gathering additional information about the system. Passive adaptive management can be optimal when uncertainties are minimal, and when opportunities for learning are similar to the more active approach; however, when uncertainties are large, the active approach usually presents more opportunities for learning.

Active adaptive management is difficult, time-consuming, and can be expensive. The challenge of managing adaptively arises from the requirements of experimentation, including the need for: (1) replication and randomization of management treatments, and the need to identify control areas, (2) the formulation of competing models (or hypotheses) of how the targeted ecological system will respond to management actions, (3) an initial assessment of the reliability of the different models (model likelihoods), (4) a statement of each hypothesis (or model) in terms of measurable variables, (5) monitoring the results of the management "experiment" to determine which model of the system is most parsimonious with those results, and (6) updating the model likelihoods based on experimental results and observations. A next round of management decisions is then based on the results of previous management experiments, with greater weight given to the model best supported by the existing data. The process is iterative, continuing until uncertainty about system responses has been reduced to an acceptable level.

What distinguishes adaptive management, passive or active, from trial and error is that the former involves an effort to synthesize existing information into dynamic models that make predictions about the impacts of alternative practices prior to making management choices. No such synthesis or model construction occurs in trial and error learning. Active adaptive management, unlike passive adaptive management, requires that the tradeoff between the short-term costs of experimental management and the anticipated long-term gains from a better understanding of the ecological system be addressed directly. Both of these modes of learning require monitoring of the results of the management action; that is, the only way in which learning is possible is to observe if the managed system responds as envisioned. A lack of concordance between observations and expectations leads resource planners to a revised model (or set of models) of how the system functions and typically to modification of future management options. For the foreseeable future, managing under State Wildlife Action Plans in an adaptive fashion will be necessary because great uncertainties remain about the short- and long-term environmental consequences of nearly all our environmental management decisions. Thus the manager, operating in the adaptive context, is responsible for conducting management so as to incrementally reduce this uncertainty. The rate at which uncertainty is reduced is greatest for the active adaptive management paradigm, and least for the trial and error learning.

Core Elements of Adaptive Management for State Wildlife Action Plans

Adaptive management under State Wildlife Action Plans requires a series of necessary elements that serve to structure the approach and assure outcomes that are reliable.

Explicitly Defined Management Objectives

Clearly stated objectives are an essential component of adaptive management (Holling 1978; Walters 1986). Without explicit objectives and measures of success, managers cannot know whether their actions are effective or require modification (Salafsky et al. 2002). The explicit definition of objectives also increases management accountability (Johnson and Williams 1999). The degree to which management objectives have been accomplished is less ambiguous when management objectives are stated in numerical terms; however, many ecological systems are so poorly understood and species difficult to study that only qualitative objectives are possible. When objectives cannot be stated quantitatively, they must be sufficiently clear and observable to allow evaluation of management decisions.

Use of Ecological Models

The baseline understanding of, and assumptions about, the system being managed must be made explicit to provide a foundation for learning. Specifying a model, or set of models, of expected wildlife and habitat responses to management can highlight gaps in available scientific knowledge. Models are most useful in Wildlife Action Plans if they are cast as a set of alternative predictions of how the system will respond to management; and the sophistication and complexity of the models should be tailored to the decision being made. In the most rigorous form of adaptive management, quantitative models are used to generate alternative hypotheses about the system for purposes of testing (Walters 1986; Walters and Holling 1990). Such models need to contain clearly defined variables that characterize the state of the system and its rate and direction of change. For poorly understood systems or where the scale of risks of the actions being considered are so great that they do not justify the costs of rigorous modeling, useful models can be as simple as schematic diagrams (Margoluis and Salafsky 1998).

Alternative Management Options

Given agreed-upon wildlife management objectives, uncertainty about the ability of possible actions to achieve those objectives is commonplace. That is, existing data typically do not point clearly and conclusively to a single "best" management policy. This is precisely the situation in which adaptive management is most useful. When possible, simultaneously implementing two or more actions in an experimental context will allow the most rapid discrimination among competing models and reduce future uncertainty.

For each decision, a range of possible management choices is considered at the outset in light of the stated objectives and the model of system dynamics. This evaluation takes into account not only the likelihood of achieving the management objectives, but also the extent to which each alternative will generate new information or foreclose future options. In a passive adaptive context, the management decision that currently has the greatest empirical support is implemented; in an active adaptive context, there is a direct comparison of competing alternatives.

Evaluation of Outcomes

Adaptive management cannot be carried out without some mechanism for comparing the outcome of decisions to selected (preferably quantitative) performance measures. Typically this means systematic data collection through a monitoring program that is designed and implemented prior to the management action in order to provide a baseline for comparison. Monitoring should focus on indicators that can register the achievement of the management objectives. Information gained through monitoring is the foundation for the adaptive learning process, providing insights into the accuracy of the system model and the opportunity to improve and adjust the model for future decisions. Managers should decide what to monitor by asking what attributes most unambiguously characterize the state of the system, and what use will be made of the information obtained.

Incorporating Learning into Future Decisions

The overarching goal of adaptive management is to provide for better management decisions in the future. Objectives, models, consideration of alternatives, and formal evaluation of outcomes all facilitate learning. The last element, ensuring that the results of monitoring are factored into the next set of management decisions, closes the loop. There must be an institutional mechanism for feeding information gained through earlier adaptive management steps back into the wildlife management process. Without that mechanism, learning will not improve future management performance. Incorporation of learning can occur through a direct cycle of decision, learning, and modification with respect to a single management choice. Alternatively, or additionally, information gained from monitoring a specific choice can feed into later decisions on similar choices. Adaptive management is feasible (and useful) only where a series of related (or similar) decisions will be made over time, allowing learning from earlier decisions to be incorporated into later ones.

Public Involvement

The scientists who developed the theory of adaptive management proposed initiating the process with workshops, which should bring together ecological modelers, research scientists, managers, and policymakers to clarify objectives and develop models (Holling 1978; Walters 1986), but they did not go beyond that to explicitly call for inclusion of stakeholders from the general public. However, managers attempting to implement adaptive management in complex systems have emphasized the importance of stakeholder involvement. Johnson (1999), for example, writes that "adaptive management tries to incorporate the views and knowledge of all interested parties." Broad public participation is likely to be most important where objectives are contested, where they include social and economic objectives, and where there may be little trust of the management agency. In some cases, the involvement of the public has been declared to be an explicit element of adaptive management. In the Pacific Northwest, the plan for managing national forests, which was developed following the spotted owl "train wreck" of the early 1990s, established ten "adaptive management areas" dedicated to experimental management. The plan specially called for local groups and concerned citizens to work with agency personnel in managing these areas (U.S. Dept. of Agriculture and U.S. Dept. of Interior 1994).

Because adaptive management radically changes the management paradigm, effective public participation necessarily takes a very different form under adaptive management than under traditional management approaches. Under a static management paradigm, which relies on fixed decisions made after comprehensive evaluation, citizen involvement can be limited to the formal evaluation process. But a dynamic, adaptive paradigm of iterative decisions incorporated into a learning process requires continuing communication between managers and the stakeholding public (Shindler and Cheek 1999).

Performance Measures and Monitoring

The ability of State Wildlife Action Plans – and the land and resource managers, landowners and other stakeholders, and scientists who are involved in them – to draw reliable information from monitoring assumes that the monitoring efforts carried out under the plans are reliable. Although most land and resource managers have at least some idea of what monitoring is and what it can accomplish, the almost universal current lack of monitoring data that can be used to inform wildlife management planning efforts highlights the need for more rigorous approaches. This brief overview can address only a small proportion of the issues that confront those who will design and implement monitoring efforts under State Wildlife Action Plans and interpret their results. But it is notable that the few ongoing monitoring efforts that can be identified as truly successful have several characteristics in common – they tend to be highly structured, are grounded in ecological science and use models to convey an understanding of how targeted resources interact in and with the ecosystems around them.

Monitoring as an endeavor has suffered from loose interpretation. Monitoring is not just watching things happen. Monitoring is not just counting. Monitoring is not measuring things in the absence of a clear management context. (Albeit observing, counting, and measuring all play roles in monitoring programs.) Monitoring is explicitly intended to provide information that can help us explain the phenomena that concern us. A frequently cited definition of monitoring in environmental management is "measurement of environmental characteristics over an extended period of time to determine status or trends in some aspect of environmental quality." That deceptively simple definition can serve State Wildlife Action Plans well. However, embedded in that definition are challenges that vex the most experienced researchers and practitioners – which characteristics should be measured, using what measures, where, when, and for how long?

Most participants in monitoring recognize distinct applications of their efforts. Implementation (or compliance) monitoring, for example, is designed to track or verify implementation of a management plan, compliance with a regulation, or performance on a commitment to restore or enhance a resource. Effectiveness monitoring, by contrast, evaluates status and trends of a system and its components that result from a management action in an effort to determine whether the action has achieved the desired target or outcome. Effectiveness monitoring is the focus of Wildlife Action Plans, and the discussion below.

Within the context of effectiveness monitoring, another distinction is important to recognize. Retrospective monitoring (sometimes referred to as effects-oriented monitoring) attempts to identify effects of management on ecosystems by monitoring changes in the status of an environmental attribute, such as the population size of a sensitive species or the composition of a vegetation community. Retrospective monitoring strives to detect environmental changes after they have occurred, and attempts to attribute causation when an effect is found. In contrast, prospective or predictive monitoring (also referred to as stressor-oriented monitoring) attempts to detect factors that cause responses by elements of an ecosystem before undesirable effects occur or before effects become serious.

Both retrospective and prospective monitoring approaches have their merits. They can be complementary in a diversified monitoring program that assesses the effects of multiple management actions in a complicated field setting. But retrospective and prospective monitoring activities are not equally appropriate or useful in every assessment effort. When risks or costs of a failed management action are relatively low, the probability of detecting changes in the system is high, or the lag time between a cause and effect is short, retrospective monitoring may prove effective and may be less expensive than alternative options. However, when risks and costs are high, the ability to detect changes is comparatively low, and lags in system responses are relatively long, prospective monitoring is required. With substantial numbers of at-risk species in their purview, State Wildlife Action Plans must respond to perceived environmental needs with dispatch, using focused management efforts that capitalize on the best available technical information and replace management actions that prove to be less than successful with more effective actions.

Those who will develop the performance measures elements of State Wildlife Action Plans should recognize that many past monitoring programs, including numerous programs that were large in scope and well funded, have failed to inform management. Deficiencies in many past and ongoing environmental monitoring programs include a lack of foundation in ecological theory or consistency with previous data, little justification for selection of measured ecosystem attributes, no clear links between selected attributes and cause-and-effect relationships, no identification of measured values that should trigger management responses, and lack of explicit connections between monitoring results and management decisions.

Steps in the Development and Implementation of a Monitoring Program

1) Set Goals and Objectives

Monitoring programs should be capable of determining whether current or proposed management practices are maintaining the ecological integrity of the target environmental system and the ability of the system to deliver expected goods and services (for example, number of salmon smolts or erosion control by vegetation). Certainly no universal set of goals or objectives characterizes a "high quality" environmental state, or can apply to all ecosystems subject to management and monitoring. But each proposed management action (or ongoing management action for which new monitoring is being proposed) should be accompanied by a set of specific project goals that can guide the development of monitoring objectives. Management goals may take many forms – for example, a target number of brush rabbits, a restored riparian forest with a specific species composition and structure, or a floodplain of predetermined extent inundated for an expected time period. Those goals may be articulated in response to a legal mandate – for example, recovery goals under the Endangered Species Act, or attainment goals under the Clean Water Act. Whatever the basis for the management goal, the goal should be articulated in such a manner that clear, quantifiable objectives can be identified and used to direct the monitoring design.

2) Select Targeted Resources for Monitoring

Resource limitations often restrict the number of species or ecosystem attributes that can be monitored by state wildlife agencies. It thus becomes important to select monitoring targets judiciously. Various processes have been used for target selection by individual states or groups of states. Some states, such as Florida, have used a science-based process to identify species and ecological communities that should be monitored because these entities show a strong likelihood of future declines. Other states, such as Nevada and the states in the Northeastern Association of Fish and Wildlife Agencies, have used a more democratic process, convening groups of natural resource managers who nominate and then vote on a selection of potential targets. Still other states, such as Oregon, have started with a science-based process and then added certain key species of public concern or interest to the suite of monitoring targets. It should be clear that there is no one right process for selecting targets, although it is possible to articulate explicitly some desired properties of monitoring targets.

Criteria for target selection that have been recommended in the literature and in our conversations with natural resource managers include:

- For species, the taxonomy, ecology, and life history is well understood;
- For species, ability to serve as an "umbrella" or "indicator species" for a particular ecological community or ecosystem;
- For species, ability to perform an essential ecological role in a given community ("keystone species");
- For species, significant recent population declines;
- For ecological communities or ecosystems, the community/ecosystem is well defined and its spatial extent mapped;
- For ecological communities or ecosystems, the ability to support species of conservation concern or of public interest;
- For ecological communities or ecosystems, significant recent declines in extent;
- For both species and ecosystems, targets that are highly valued by the scientific or natural resource management communities, or by the general public.

3) Develop a Conceptual Model for the Target

Once a monitoring target has been selected, the next step is the construction of a conceptual model describing the basic relationships between that target, associated stressors or threats, and potential conservation activities.

States that adopt an adaptive management approach to implementing their Wildlife Action Plans will encourage active learning about how the ecosystems and habitats that support wildlife resources work, through management actions, monitoring of the results of those actions, and directed research and other investigations of ecological communities and their constituent species. Through time, the wildlife plans will operate increasingly effectively, as reliable knowledge is gained through carrying out the activities outlined in them. But that knowledge does not just magically emerge from well-intended actions; an approach that is specifically designed to maximize learning opportunities is required. And at the center of that approach conceptual models are found. Conceptual models inform management planning, the development of assessment and monitoring programs, and the design of research efforts. Without conceptual models, there is no reliable adaptive management of wildlife resources.

Conceptual models document a specific version of our hypotheses about how ecological systems function. Conceptual models describe in graphical or narrative form the ecological system subject to management, allowing inference about how that system "works." A model of riparian forest function, for example, would describe the relationships between the vegetation and the animals that depend on it, the hydrological and other physical processes that affect those relationships, and the roles of human activities in disturbing and sustaining the system. Such models help to clarify the verbal descriptions of what we have observed in nature, and force us to think about ecosystem elements and interactions we might otherwise ignore. The formulation of a model naturally leads to the identification of parameters that will need to be targeted by management and measured by monitoring. In the formulation of a conceptual model, the combinations of parameters that drive ecological systems often become apparent, which in turn allows us to rank the importance of different attributes in determining system function. Conceptual models help us to assure that our current and future management actions target the correct ecosystem features and attributes and to maximize the likelihood that our actions will produce the ultimate desired management outcome.

The term model used in conservation planning should not cause land managers and research teams any real anxiety. The requirement that conceptual models accompany and inform actions under the State Wildlife Action Plan really should not be viewed as a burden to be borne by those contributing to plan implementation, but instead as an opportunity to justify and validate management and data-gathering approaches. In requiring conceptual models, a management program is simply asking for a clear articulation of what is known about the ecological system that will be subject to management, assessment, and monitoring – an explicit description of how the planners believe their study system operates.

A conceptual model should clearly identify key system elements, including the wildlife species involved, ecosystem structure, and the processes that link those species with other biotic and physical elements in the system. The model should articulate how the system is impacted by stressors (disturbances, perturbations) from both natural and human-generated sources, and how management can intervene to reverse undesirable conditions or trends. That description can take one or more forms, including box and arrow diagrams (like the illustrations in the Nevada case study that follows, often the most effective and efficient way to describe and illustrate system function), cartoons accompanied by narrative descriptions, simple linear pathway illustrations, or even straightforward text descriptions. Remember that the point of the conceptual model is to convey knowledge about the species of concern, the community in which it is embedded, and the ecosystem processes that support it or put it at risk.

Each conceptual model should be accompanied by a narrative description that more fully characterizes the target, the threats to the target, and potential activities. Such a narrative should clearly identify areas of uncertainty; it should identify what we do not know as well as what we know about the system, and the sources of accepted knowledge from the literature. The model discussion should include available data in its explanations if they are useful in illustrating relationships and other points. And the model and its narrative should make sure to identify limiting factors to ecosystem processes, population sizes, or other system attributes if they are important to directing management efforts.

A few additional points regarding ecological conceptual models. First, they are nearly always incorrect in one or a number of ways because we do not fully understand how our ecosystems operate. Second, if our adaptive management is effective, our conceptual models will improve with time as we learn more. Third, conceptual models are essential to learning in that they make our understanding of how our natural systems work available for review and discussion,

thus they help us to identify areas of uncertainty and seek the information necessary to make better management decisions. And, finally, our conceptual models are the gateway to predictive models. Even simple box-and-sticks models improve the ability to learn by organizing information, highlighting missing information that might be acquired through management experiments, providing a framework for comparing alternatives, and forcing managers to think through their understanding of the system. When we understand our ecological systems much better than we do now, we will be better positioned to evaluate the relative benefits of management options and rank our opportunities in a defensible decision-support framework.

Process Models

We have already described simple process models (known as logic models, causal chains, or results chains) in Chapter 4. These models link conservation activities such as habitat restoration, species management, and public outreach with desired conservation outcomes. These models are particularly appropriate for use with the State Wildlife Action Plans, because the plans already describe a broad spectrum of possible conservation actions as well as the intended conservation targets. In the case of the State Wildlife Action Plans, the desired conservation outcomes are related to the conservation of the Species of Greatest Conservation Need and their associated habitats, ecological communities, and ecosystems.

Development of More Complex Ecological Models

The simple models described in Chapter 4 can be further refined and transformed into quantitative models that represent basic interactions between key ecological variables. Chapter 4 describes simple methods for incorporating estimates of process rates and transition probabilities into linear process models. Additional important information for developing quantitative models includes knowledge of the acceptable bounds of variation of system components, as well as an understanding of normal patterns of variation in input and output among the model elements.

To address all the factors mentioned above, the conceptual model must explicitly incorporate the nested, spatial structure of ecosystems (Pickett and Candenasso 2002). Each level of the hierarchy is defined by a set of state variables that yield scale-defined criteria based on the principle of constraint (Allen and Hoekstra 1992). By state variables we mean those habitat conditions expressed at multiple scales that influence the distribution and abundance of species. The upper levels of the hierarchy define the boundary conditions, and thus constrain the levels below. Constraint arises because the hierarchical levels, or filters, determine the type of ecological community that will be observed. This occurs via a process of filtering out those species whose traits are incompatible with the state of the environmental filters. We discuss filters in more detail in the next section.

4) Select Indicators

Because ecosystems are complex, monitoring programs cannot possibly measure all of their attributes. The health of ecosystems, their responses to restoration, and their susceptibility to long-term change therefore must be assessed using a limited set of indicators (sometimes referred to as performance measures, when the indicators are explicitly associated with the assessment of a particular conservation activity or strategy). The theory and practice of indicator selection is demanding; selection of ineffective indicators will cause a monitoring program to fail.

An indicator is any measurable attribute that provides insights into environmental conditions that extend beyond its own measurement. Indicators are usually surrogates for properties or system responses that are too difficult or costly to measure directly (Leibowitz and Hyman 1999), and indicators differ from estimators in that functional relationships between the indicator and the various ecological attributes are generally unknown (McKelvey and Pearson 2001). Not all indicators are equally informative – one of the key challenges to a monitoring program is to select for measurement ecosystem those attributes whose values (or trends) provide insights into ecological integrity at the scale of the ecosystem. Pragmatic considerations alone dictate that only a small number of indicators can possibly be measured; however, strategies and processes for selecting ecological indicators are complex and poorly developed (Barber 1994; NRC 1995).

A comprehensive monitoring program should include indicators that collectively measure compositional, structural, and functional attributes of ecological systems at a variety of spatial scales (Lindenmayer et al. 2000; Noon and Dale 2002). Composition indicators usually are species-based measurements where the species measured provide insights to the status or trend of the unmeasured species. Concepts such as guild indicator species would apply here (Verner 1984). Function-based indicators include direct measures of processes and their rates. Examples include primary productivity, rates of nutrient cycling, and water flows. Structure-based indicators, measured at local and landscape scales, include elements such as vegetation structural complexity, among-patch vegetation heterogeneity, landscape connectivity and landscape pattern (i.e., the distribution and abundance of different patch types). These metrics are often assumed to constitute a "coarse filter" because of their ability to predict broad-scale patterns of biological diversity (Hunter et al. 1988; Haufler et al. 1996). Both function- and structure-based indicators can be measured at multiple spatial scales ranging from local, to landscape, to regional. In addition, there are composition-based indicators that include the direct measurement of some aspects of a species' life history, demography, or behavior. These are often referred to as "fine filter" assessments because they evaluate the effects of management practices on individual species (Haufler et al. 1996).

5) Develop Sampling Design

Addressing the full breadth of challenges in designing a sampling plan for monitoring after indicators are selected is beyond the scope of this document. However, several key issues deserve mention. First, it is necessary to estimate the status and trend(s) of an indicator within appropriate bounds of accuracy; this demands substantial statistical expertise. Essential to the monitoring program is establishment of expected values (or trends) of indicators as benchmarks against which the indicator states are compared following management actions. Second, values that will be used to trigger management responses must be identified. This requires information on or assumptions about what constitutes an ecological effect sufficiently great to warrant management response or amendment – the effect size – as well as a sampling scheme that is adequate to detect that effect. Only by identifying appropriate trigger points (a value or distribution of values) for management intervention is a monitoring plan made operational. Third, a substantial number of practical issues of design and analysis pervade the development of a sampling frame: boundaries to the ecosystem and the area subject to management must be defined; the temporal resolution and extent of sampling must be established; a sample size appropriate to estimate the value of the indicator must be identified; a survey design that responds to spatial heterogeneity needs to be constructed; and units of measure for each indicator must be chosen.

Challenges for Monitoring Efforts

The term "monitoring" is so commonplace that it seems the endeavor should be one of the more straightforward elements of a State Wildlife Action Plan. But monitoring is anything but simple, and developing an effective monitoring program well may be one of the most challenging elements in the design and implementation of state wildlife management efforts. Good examples of monitoring in support of wildlife management are few; in fact, examples of effective monitoring in any aspect of environmental management, restoration, and other stewardship projects are really hard to find. This is largely because most monitoring programs start and stop with counting or measuring the targets of management action. So while extensive time series of data on local population sizes of species of concern can be found in agency files, data on the environmental phenomena that may be determining population sizes and shaping trends are nearly always lacking. For all the available data, we typically have no reliable information to help explain why wildlife targets are expanding their ranges on the landscape or retreating. We have documented change but not causation, and we are left to guess what the management response should be to achieve our wildlife plan goals.

A lack of reliable knowledge about the causes of environmental change is pervasive; it extends well beyond attempts to track wildlife and their habitats. When the U.S. Environmental Protection Agency attempted to establish a nation-wide "environmental monitoring assessment program" to track critical indicators of ecological health and integrity across the country's wetlands, lakes, forests and other major ecosystems, the National Research Council had to send the program back to the drawing board. In three volumes (National Research Council 1994a, 1994b, 1995), a National Academies committee showed that the program's data collection effort might be able to detect important environment changes in key environmental variables – including some of our states' wildlife targets – but that it could not possibly explain those changes in such manner as to guide management responses. The committee told the agency that to be able to estimate the status, trends, and changes in the nation's ecological resources with confidence, it must clearly articulate programmatic goals, gather data on spatial and temporal scales that are required to detect meaningful changes in the conditions of ecological resources, and develop reliable, scientifically defensible indicators for measuring change – these and other recommendations for elements similarly fundamental to even the most basic monitoring plans.

Turning a census or a counting enterprise into an actual monitoring scheme starts with the recognition that data collection must extend beyond the specific target of management attention, to include the presumed or suspected environmental determinants of that target's status. For wildlife species, a monitoring effort can include collecting data on rainfall, vegetation, prey and predator densities, land use changes within the distribution of the species, possibly dozens of variables that might potentially explain the status of our Wildlife Action Plan targets and their responses to environmental change. Only then can we respond with the directed "wildlife actions" that the national plan was designed to achieve. And it is through the necessary step of developing conceptual models and logic chains that we bring our understanding of the relationships between wildlife, resources, and landscapes to environmental management. The articulation of that understanding allows planners to identify the critical elements of an effective monitoring scheme – the indicators of environmental condition and attributes of wildlife populations that we need to measure to guide management.

Chapter 10: Developing a Monitoring Program for the Nevada Wildlife Action Plan

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The Nevada Wildlife Action Plan is one of 56 State Wildlife Action Plans that together represent a significant milestone for biodiversity conservation in the United States. For the first time, the wildlife agencies in each state and territory have identified species of greatest conservation need, priority ecosystems and habitats, significant threats to biodiversity, key conservation actions, and potential monitoring and evaluation activities.

The states and territories will soon find themselves under pressure from Congress and others to demonstrate that the actions described in these plans can actually achieve meaningful improvements in wildlife populations. At the same time, resources for implementing the plans (including the monitoring and evaluation components) remain quite limited; funding for the federal State Wildlife Grants program has remained level in FY-06 and FY-07 at $67.5 million, or only slightly more than $1.2 million on average for each state and territory.

With such limited resources, the state wildlife agencies need to identify creative strategies for monitoring and evaluation. Ideally, in Nevada these strategies should be relatively inexpensive and take advantage of existing monitoring programs, yet still provide meaningful feedback on plan implementation.

Nevada's well-developed, comprehensive Wildlife Action Plan (WAP), its rich wildlife and fishes diversity, its history of resources stewardship, and experience in assessment and monitoring combine to provide a near-perfect template for developing a model performance measures approach. In partnership with The Heinz Center and the University of Nevada, Reno, the Nevada Department of Wildlife (NDOW) has sponsored a series of three workshops to select indicators for monitoring the status of target ecosystems and species and for monitoring the effectiveness of conservation activities. This series of workshops has brought together technical experts and natural resource decision-makers to identify broad conservation targets, develop conceptual models showing the relationship of stressors and conservation activities for each target, select monitoring indicators for each target, and initiate development of a sampling design for each indicator.

First Workshop: Target Selection and Conceptual Modeling

The first workshop was held on March 6-7, 2008, in Reno, Nevada. The workshop was hosted jointly by Nevada Department of Wildlife and The Heinz Center. Participants included representatives from federal and state natural resource management agencies (U. S. Fish and Wildlife Service, U. S. Bureau of Land Management, U. S. Geological Survey, U. S. Environmental Protection Agency, U.S. Forest Service, Nevada Department of Wildlife, Nevada State Land Agency), non-profit organizations (The Nature Conservancy, Nevada Audubon Society, Great Basin Bird Observatory), as well as academic institutions (University of Nevada-Reno, Colorado State University).

This first workshop addressed three major topics: the selection of targets for management and monitoring; the identification of threats, opportunities, and desired condition for targets; and the development of a conceptual model for each target.

Selection of Targets for Management and Monitoring

The Nevada Wildlife Action Plan includes detailed descriptions of numerous priority ecosystems and species within the state of Nevada. Given that there are limited resources for implementation, and even more limited resources for monitoring and evaluation, it makes sense to identify a modest suite of targets for management and monitoring. In evaluation practice, "targets" are specific environmental conditions or variables that managers are attempting to influence through project activities (Margoluis and Salafsky 1998).

The group as a whole developed a consensus set of conservation targets for priority monitoring work in the state.

Target Selection Exercise

1) Each partner organization lists its own highest-priority conservation targets that are included in the Nevada Wildlife Action Plan, which are written on large sheets of paper and displayed at the front of the room.

2) The group reviews the list and amalgamates similar or related targets. For instance, "springs" and "springbrooks" might be amalgamated into a single category. "High-altitude ecosystems in the White Mountains" and "Alpine

ecosystems" could be amalgamated into a single category. The definition of "similar or related" is determined by the group. Amalgamation continues until the group feels comfortable with the list of targets.

3) Participants use sticky dots to "vote" on the highest priority targets: those most important for the conservation of wildlife and biodiversity in the state of Nevada.

Nevada workshop participants identified three "ecosystem-level" Wildlife Action Plan targets: the Mojave Desert ecosystem, the land cover across the southern fourth of the state; springs and springbrooks, critical water sources for wildlife and biodiversity hotspots across most of the state; and sagebrush ecosystems, the most extensive and widespread vegetation cover type in the state.

Identification of Threats, Conservation Actions, and Desired Future Condition

We wanted to be clear on the management goals and objectives for each of the targets identified in the first exercise. Different goals or objectives can very easily translate into different management activities and different performance measures.

The group divided into a series of working groups, each of which focused on one of three targets identified as highest priority by the larger group: the Mojave Desert, springs and springbrooks, and sage and sagebrush ecosystems.

Each working group brainstormed a list of possible threats to the target, as well as conservation actions that could be taken to counteract the threats. Using the list of threats as well as the participants' knowledge of the target ecosystems, a very simple desired future condition statement was developed for each of the targets.

Threats – The Nevada Wildlife Action Plan identifies numerous potential threats to wildlife and habitat areas. For each target, we listed the specific threats that are thought to influence the target.

Conservation Actions – For each threat or stressor, we listed the potential conservation actions that could be taken to counteract its negative effects on the target. These should be actions that could be realistically taken by NDOW or its partners, with appropriate resources.

Desired Future Condition – For each target, we developed a simple statement of desired future condition (described below for the sagebrush ecosystem). The statement included a description of the desired condition for each of the threats or stressors (e.g., "invasive plants removed," "point source pollution eliminated") as well as statements about the structure and extent of the ecosystem (e.g., "heterogeneous mix of forbs, grasses, and mature sage," "composed of large, unfragmented blocks over 10,000 acres in extent"). Although we did not use individual species as targets in this exercise, a desired future condition statement for a species would include statements about key demographic parameters such as population size, population growth rate, and/or geographic distribution.

Development of a Conceptual Model for One or More Targets

Conceptual models are an important part of the process of developing performance measurement systems. Such models range from simple box-and-arrow diagrams to sophisticated computer models that allow quantitative predictions.

Our workshop break-out groups developed a diagrammatic conceptual model or "system model" for each of our targets. These models use boxes and arrows to show the cause-and-effect relationships between a target, the major threats and stressors that affect the target, and the conservation actions that could ameliorate these threats and stressors.

Although the basic components of these models are quite simple (a conservation target, multiple stressors, multiple conservation actions, and arrows illustrating causal links), the actual models that we developed were quite complex, with multiple arrows showing causal linkages between the individual stressors as well as between stressors and the target.

These models provide important information about how a conservation action would actually help to benefit the target, by identifying threats and stressors that the conservation action would affect. The models also help suggest potential measures of the effectiveness of conservation actions: if an activity is designed to reduce a particular stressor on a target, then measures of the action's effect on the stressor could be a useful measure of effectiveness of the conservation activity. Since most targets are affected by multiple stressors, however, measurements of the target's status and comparison with the desired future condition are needed as well.

The following conceptual models (Figures 10.1, 10.2, and 10.3) were developed at our first workshop. Each model includes a target (selected by the group of natural resource managers attending the workshop), as well as a suite of threats or stressors that could potentially affect the target. The threats and stressors are further divided into direct threats (those that affect the target directly) and indirect threats (those that operate through intermediaries). The arrows indicate cause-and-effect relationships: the factor at the blunt end of the arrow affects the target or factor at the pointed end of the arrow. The models also include potential actions or categories of activities that can be undertaken to ameliorate each of the potential threats.

The first model (Figure 10.1) describes the broad relationships between the Mojave Desert ecosystem in southern Nevada and its major stressors, both direct (such as fire, urban growth, and off-highway vehicles, or OHVs) and indirect (such as climate change and a lack of human appreciation). Potential conservation actions have been described for some, but not all, of these stressors. Note that information needs are also included in this model: there are clear needs for identification of successful mitigation techniques, as well as better information on reptile species distribution and abundance.

The second conceptual model (Figure 10.2) depicts the direct and indirect threats and potential conservation actions for spring and springbrook communities in Nevada. This model highlights some key research needs: the development of viable methods for habitat restoration, and the development of methods of control for invasive species.

Our final conceptual model (Figure 10.3) illustrates the relationships between sagebrush ecosystems, major threats and stressors, and potential conservation activities. Major concerns in this ecosystem center around the interrelated effects of fire and invasive/noxious weeds.

FIGURE 10.1 A conceptual model of the Mojave Desert ecosystem in Nevada, showing the conservation target, factors that directly affect the target, factors that only indirectly affect the target, and potential conservation actions.

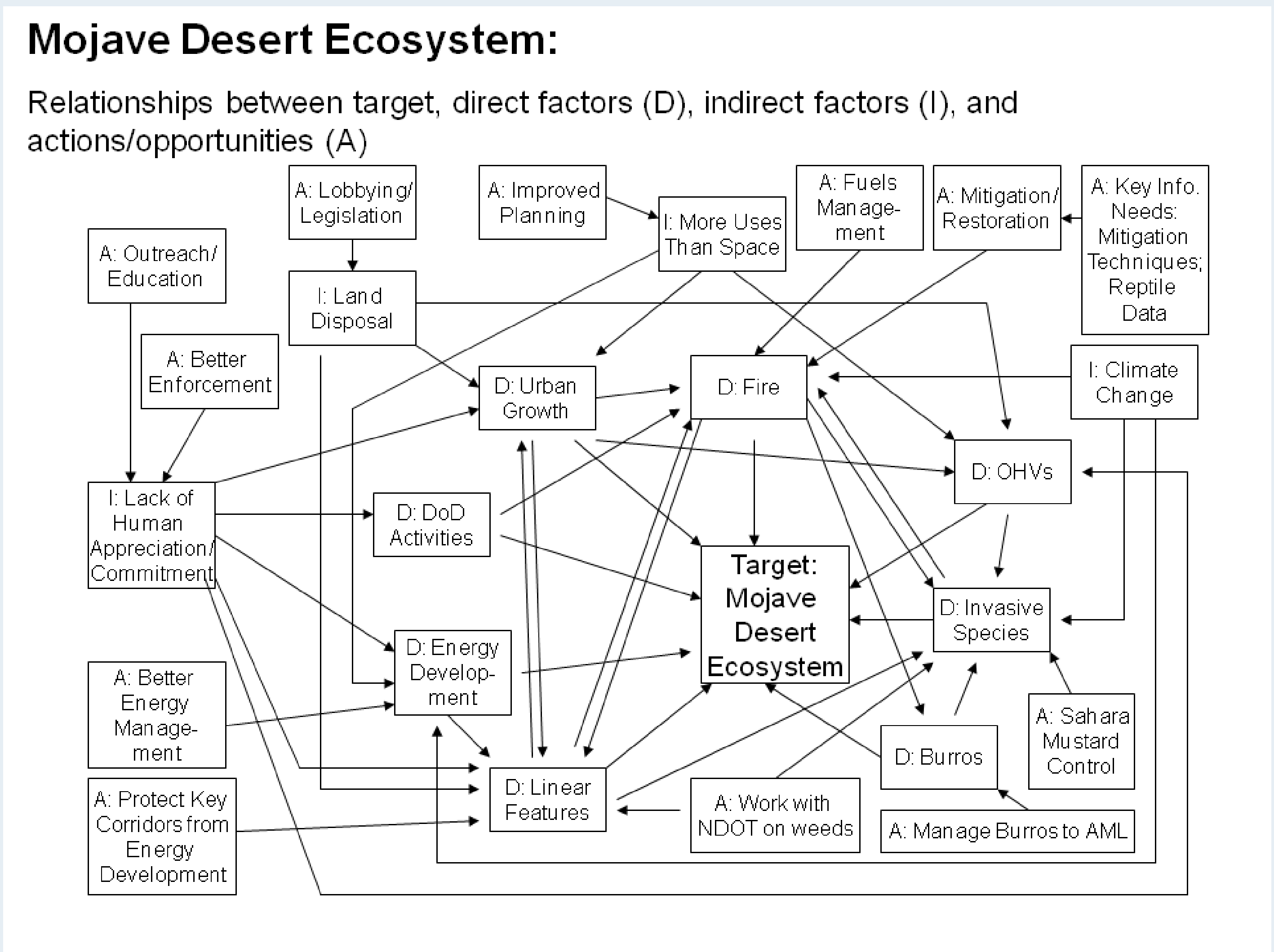
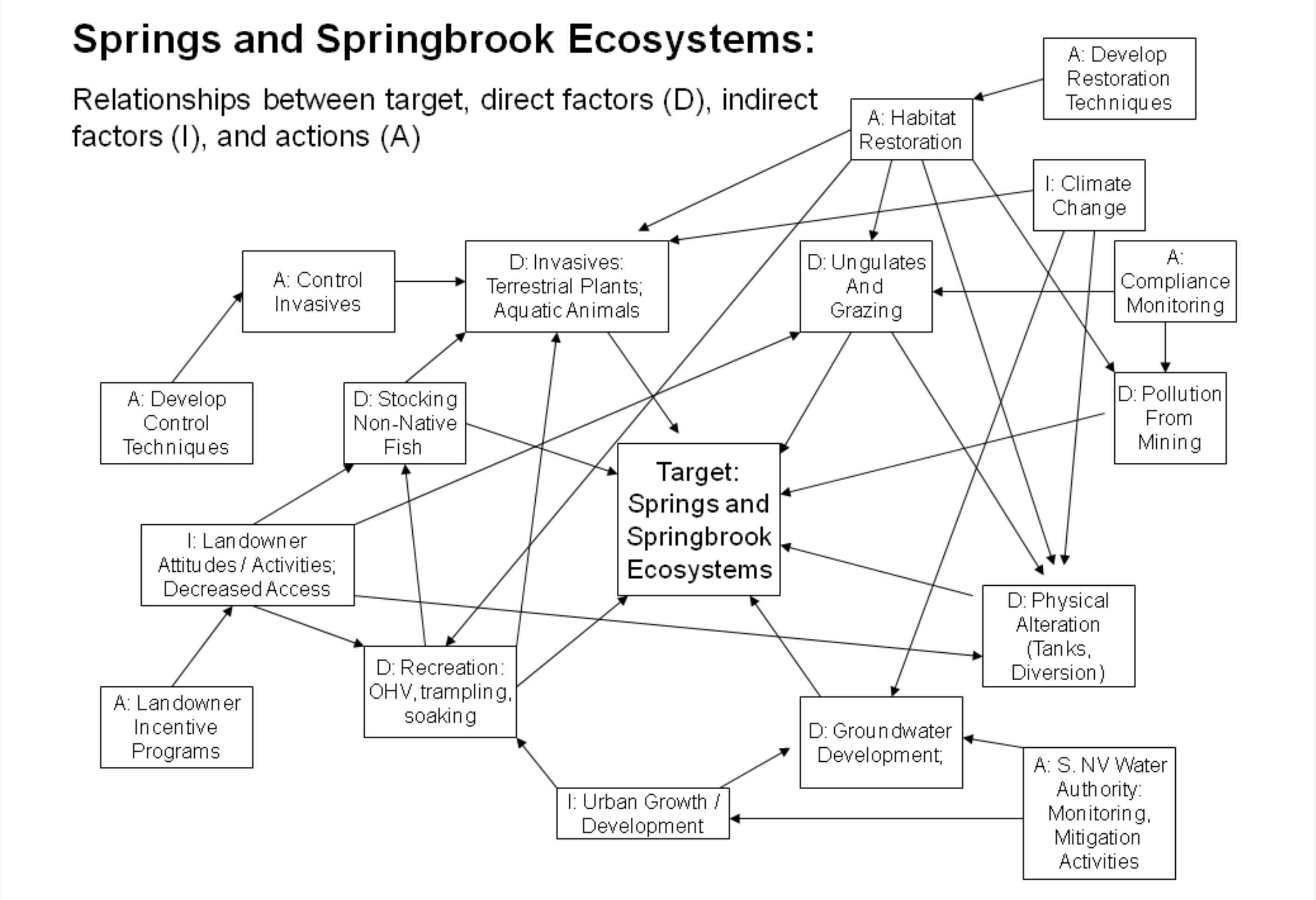


FIGURE 10.2 A conceptual model for spring and springbrook ecosystems in Nevada, with conservation target, factors directly affecting the target, factors indirectly affecting the target, and conservation and management activities.



SECOND WORKSHOP: INDICATOR SELECTION

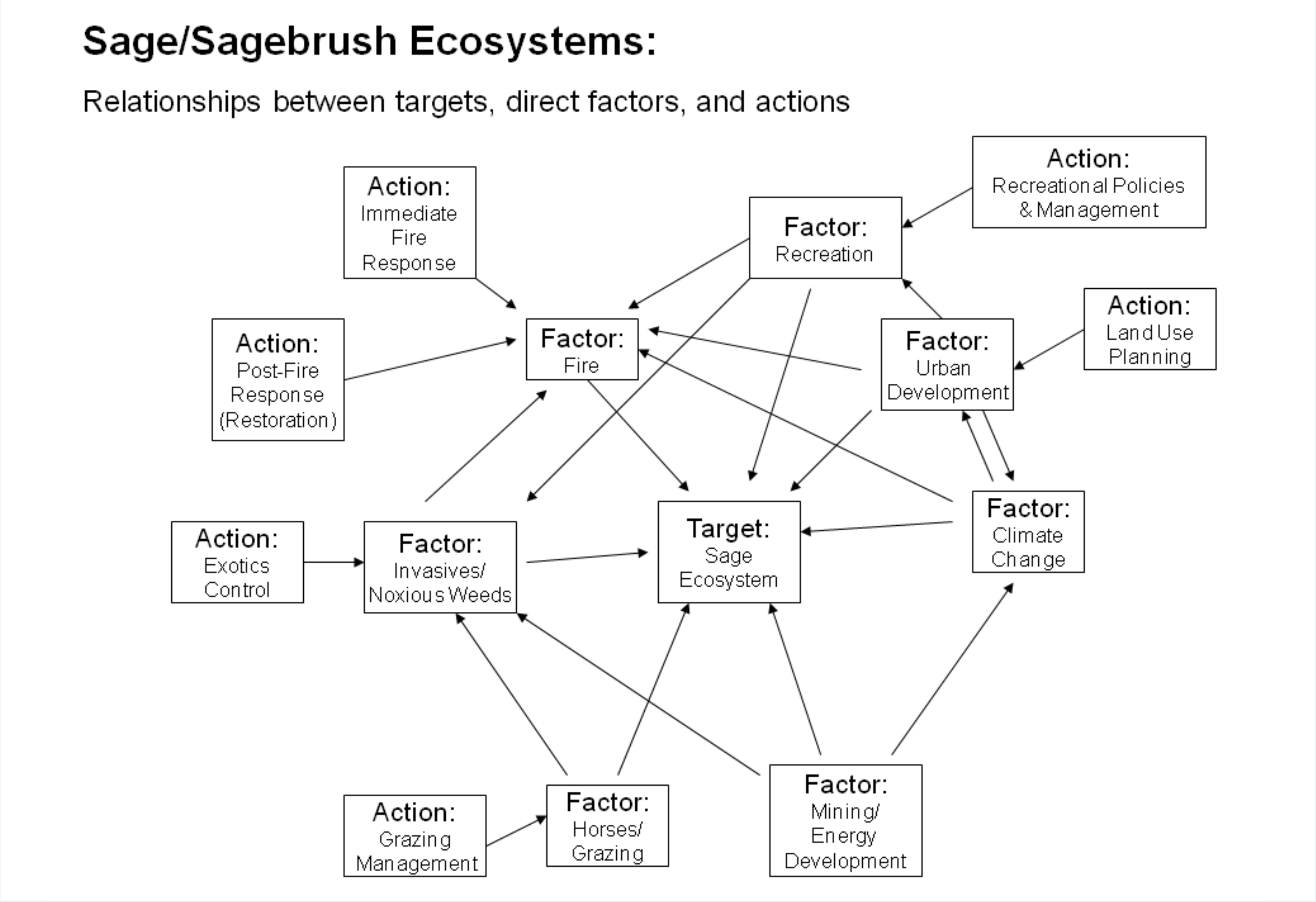
The conceptual models described above were built with the expectation that they would provide the basis for expert ecologists and wildlife managers to identify indicators – the actual vegetative or wildlife population-based parameters that would most likely give Action Plan monitors insights into the status and trend of the target ecosystems' wildlife habitat performance. It was recognized that the next stage of the process would require a set of subject matter experts different from the first committee, and NDOW extended invitations to a set of such experts in sagebrush ecology to form the Sagebrush Technical Advisory Team (STAT). This committee met for the first time on August 15 and 16, 2008, and again on December 4, 2008.

FORMATION OF THE SAGEBRUSH TECHNICAL ADVISORY TEAM

The STAT operated under the programmatic goal from Nevada's Wildlife Action Plan for wildlife in the state's extensive sagebrush lands. It calls for *"Thriving self-sustaining wildlife populations in healthy sagebrush communities on stable soils; vigorous structurally diverse shrub component in various age classes; vigorous, diverse self-sustaining understory of native grasses and forbs."*

The advisory team ultimately adapted that goal statement to a statement of desired future condition for the sage ecosystem with a *draft* preamble that will require policy review by Wildlife Action Plan partners: *The Nevada Wildlife Action Plan supports management activities that will sustain and recover viable populations of the state's desired wildlife and the ecosystems that they depend upon. The Department of Wildlife and its land management partners intend to manage and restore Nevada's sage-dominated lands for desired wildlife species to provide habitats that are sufficiently extensive, interconnected, and widely distributed across the full historical ranges of those species, in an effort to assure the persistence of the state's wildlife heritage.*

FIGURE 10.3 Conceptual model for sage and sagebrush ecosystems in Nevada, showing target, factors, and potential conservation and management actions.



The STAT began by reviewing a set of "desired conditions" identified for the sagebrush ecosystem by the partners working group. These objectives were extracted from Nevada's Wildlife Action Plan; they include:

- Stopping losses and conversion of sagebrush ecosystems and habitat
- Encouraging healthy sagebrush communities on stable soils
- Sustaining sagebrush communities that are consistent with ecological site descriptions
- Managing for sagebrush stands that include diverse age classes
- Restoring vigorous sage community under-stories of native grasses and forbs
- Maintaining these conditions in large, contiguous blocks of sagebrush vegetation across the landscape

The committee learned that these objectives were relatively well-corroborated by independent analysis occurring in such publications as Paige and Ritter's *Birds in a Sagebrush Sea* (1999) and Miller and Eddleson's "Spatial and temporal changes of sage-grouse habitat in the sagebrush biome" (2001), and provided the basis for the following draft description of desired future conditions for Nevada's wildlife and their sagebrush habitats:

For wildlife that require resources that are provided in sage-dominated vegetation communities, the WAP recognizes that a mosaic of sage community types and subcommunities, represented as diverse successional stages across the landscape, will benefit the widest diversity of targeted species. Both dominant shrub species and a rich under-story of native grasses and forbs is required to assure ecosystem function and wildlife persistence. Healthy sage communities that support targeted wildlife are interdigitated with other shrub and woodland communities, dry and wet meadows, riparian strands, seeps, and springs that support native woody vegetation, grasses, and forbs. Sage-dominated

communities are most resilient to natural and human-generated disturbances where they are diverse in composition and structure. Such communities experience wildfire patterns that are patchy because of limited and discontinuous fuels, and are resistant to conversion to less desired community types following landscape-level disturbance events. To sustain viable populations of Nevada's wildlife species under the WAP, managers will need to closely monitor the status and trends of wildlife in sage communities across the state, and anticipate future changes in distribution and abundances, especially those associated with climate change.

Indicator Selection Process

During discussion of WAP sagebrush habitat goals, several key issues were vetted, including recognition that vegetation community variability within the "sagebrush ecosystem" is great and that selection of performance indicators would need to account for that variability with respect to wildlife-habitat relationships. It was also recognized that there is a wide range of perceptions among experts regarding the definition of "healthy" sagebrush communities. "Stop the loss" needed to be addressed within a temporal context, with the recognition that sagebrush cannot be conserved without recruitment from a diversity of age classes and successional stages. Also key to development of performance indicators is an understanding of how different elements of the sagebrush community function to support key wildlife life history requirements.

The STAT elected to address the sage ecosystem as three distinct community types – Wyoming big sage, mountain big sage, and short sage (that is, low or black sage) – each of which supports a distinct suite of wildlife species and require different management prescriptions. The team also recognized the importance of evaluating the contribution to wildlife life history requirements of each community type as breeding habitat (summer range) and survival habitat (winter range). It was noted that the mountain big sage type provides the majority of shrub species diversity that is important to mule deer. The STAT also postulated that under-story grasses and forbs are critical in the performance of sagebrush as wildlife habitat.

With that background, the STAT listed the Species of Conservation Priority from the Wildlife Action Plan, which was intended to constitute a first-cut list of candidate indicators. The list included:

- Greater Sage-Grouse
- Sage Sparrow
- Brewer's Sparrow
- Pygmy Rabbit
- Sage Thrasher
- Black-throated Sparrow
- Mule Deer
- Gray Flycatcher
- Sagebrush Vole
- Merriam's Shrew
- Preble's Shrew
- Ferruginous Hawk
- Bald Eagle
- Burrowing Owl
- Prairie Falcon
- Green-tailed Towhee
- Desert Horned Lizard
- Greater Short-horned Lizard
- Pygmy Short-horned Lizard
- Wyoming Ground Squirrel
- Mountain Bluebird
- Columbian Sharp-tailed Grouse
- Vesper Sparrow

The group added the Sagebrush Lizard to the list of candidates, because of its general recognition as a "sagebrush obligate" species, and White-tailed Jackrabbit, because of recent elevated concern over its conservation since the completion of the Wildlife Action Plan in 2005.

The STAT then explored what is known about habitat elements that are believed to trigger population responses in each species. Species were addressed in the following "habitat type" and functional group categories:

- Mature Shrub
    - Greater Sage-Grouse
    - Sage Sparrow
    - Brewer's Sparrow
    - Sage Thrasher
    - Black-throated Sparrow
- Early and Midseral Shrub
    - Mule Deer
- Tall Big Sage/deep soils
    - Pygmy Rabbit
    - Gray Flycatcher
- Woodland and Rock Ecotone
    - Ferruginous Hawk
    - Mountain Bluebird
- Grasses/Forbs
    - Greater Sage-Grouse
    - Columbian Sharp-tailed Grouse
    - Vesper Sparrow
    - Sagebrush Vole
    - Merriam's Shrew
    - Preble's Shrew
- Sandy Soils
    - Burrowing Owl
    - Dark Kangaroo Mouse
    - Pale Kangaroo Mouse
- Mesic Sites
    - Green-tailed Towhee
- Prey Populations
    - Ferruginous Hawk
    - Bald Eagle
    - Prairie Falcon
    - Horned Lizards
- Generalists
    - Wyoming Ground Squirrel

The STAT developed a list of vegetation and physical characteristics that are associated with the sagebrush ecosystem and are believed to determine habitat suitability for wildlife species. It evaluated how readily the characteristics can be measured. The characteristics included:

- Shrub height and density
- Shrub species diversity and relative abundance
- Understory forb and grass species diversity and abundance
- Diversity of seral stages
- Contiguity of large blocks over the landscape (patch size)
- Habitat configuration (mosaic qualities)
- Availability of surface water
- Soil characteristics (depth, friability, trace elements)
- Rock features (cliffs, monoliths, etc.)

Next, the STAT parsed the vegetation characteristics across the three sagebrush community types:

- Mountain Big Sage – all nine attributes listed above
- Wyoming Big Sage – all attributes listed above except "shrub species diversity"
- Low/Black Sage
    - Shrub height and density (less variable and less pertinent for some species)
    - Understory
    - Seral state
    - Soil characteristics
    - Rock features

As its next task, the STAT identified key stressors that operate to compromise the integrity of sagebrush ecosystems and discussed the impacts of each stressor on the vegetation community characteristics that appear to serve as important wildlife habitat attributes. Team members were in agreement that wildfire, non-native animal species and weeds, and grazing exert significant impacts on and cause important changes in all the key habitat attributes except "rock features." "Stand decadence" was identified as a vegetation condition that suppressed overall ecosystem vigor, with concomitant negative wildlife responses, and its existence was attributed to fire suppression and lack of natural disturbances. Recreation and off-highway vehicle use were identified as important vectors of invasive species, disturbance, and habitat fragmentation. Several stressors were grouped into one set with similar impacts – "urban and exurban development, mining and energy development, and water transport interrupt landscape (ecological) connectivity, and impact wildlife dispersal, including migration, cause habitat fragmentation and loss, reduce availability of surface water, create disturbance, cause direct mortality, and facilitate predation." "Agriculture" was identified as a source of habitat loss and conversion, weed invasion, habitat fragmentation, contaminant pollution, disease, and concentrated grazing in uplands adjacent to agricultural areas. It is important to note that this evaluation of "agriculture" was within the context of sagebrush habitat maintenance and did not constitute an evaluation of the intrinsic wildlife habitat values of agricultural lands themselves, which can be considerable.

Effects of climate change included facilitation of plant invasion; wholesale distributional shifts in vegetation distribution, composition, and structure, and altered availability of surface water; altered soil characteristics; altered fire intervals; increases in disease vectors; altered habitat connectivity; changes in plant phenologies and concomitant perturbations of pollinator relationships; and changes in precipitation regimes. Predator-prey relationships are impacted by artificial anthropogenic subsidies (for example, garbage and roadkill). A population-specific stressor, disease, was prioritized, as was animal harvest, particularly commercial reptile collecting, which is chiefly perceived as a population stressor, but an additional concern is habitat alteration, which frequently accompanies the harvest of certain reptile species.

The STAT next linked the prioritized wildlife species to the vegetation and physical sagebrush. While determining the positive, negative, or neutral responses of the list of priority species to the different attributes, the team also considered the relative dependence of the wildlife species on sagebrush communities, both in terms of presence and "relative density" (defined as the expected densities of a species in sagebrush types when compared to other vegetation types with which they may occur). The conservation status of each species was also considered - whether it was listed or a candidate under the federal Endangered Species Act, its status in the state's "bird plan" priorities, or its priority in the Nevada Wildlife Action Plan (see Table 10.1 at the end of this chapter).

The STAT chose to assess "indicator value" of each species on the list using the following criteria:

- Availability of data
- Specificity of habitat association
- Widespread distribution
- Ease of detection
- Species abundance

These important practical criteria recognize the real logistical and technical limitations placed on potential monitoring efforts. In general, small mammals and most reptiles were rejected because of sampling constraints and challenges, as well as acknowledgement that populations (particularly those of small mammals) have been demonstrated to fluctuate dramatically from year to year in response to environmental triggers that in many cases are poorly understood. The group recognized value in prioritizing high-profile species such as Greater Sage-Grouse, Mule Deer, and Pygmy Rabbit because of standing public focus on these species, and at least for Mule Deer and Sage Grouse, the existence of well-developed monitoring programs. In addition, the STAT recognized the value of monitoring sagebrush-associated passerine birds, not only for their differential coverage of several key habitat attributes, but because, again, a statistically rigorous monitoring program already exists for these species – the Nevada Bird Count administered by Great Basin Bird Observatory – with five years of survey already in hand. The STAT explored the feasibility of attaching simple vegetation surveys to the Nevada Bird Count to take advantage of its extensive sample grid and manpower base.

Certain species were recognized as likely candidates for monitoring, but for reasons other than as indicators of vegetation type or condition. For example, ferruginous hawk is currently under review for potential listing under the federal Endangered Species Act, and is suspected of being susceptible to impacts from energy development across its range. This heightened awareness might very well result in increased monitoring attention to the species, but its value as an indicator of sagebrush ecosystem health is likely not as acute as other species with a more direct association to sagebrush habitat. The White-tailed Jackrabbit has also come under heightened conservation status scrutiny in the last year, but the STAT recognized its rarity and distribution limitations as problematic in selecting it as a statewide sagebrush indicator.

Indicator species selected for each of the three sagebrush types include:

Mountain Big Sage

- Greater Sage-Grouse – suitable all-around
- Loggerhead Shrike – possibly well-connected to lower trophic organisms as a predator, which might reflect community conditions
- Brewer's Sparrow – sagebrush cover
- Sage Sparrow – sagebrush cover
- Gray Flycatcher – sagebrush height and shrub species diversity
- Sage Thrasher – sagebrush cover, height
- Green-tailed Towhee – strong association with mountain big sage, shrub species diversity
- Vesper Sparrow – strong association with early seral stages, perennial bunchgrasses, and steppe
- Black-throated Sparrow – possibly indicative of declining habitats
- Pygmy Rabbit – simple, inexpensive to monitor
- Mule Deer – shrub species diversity and understory

Wyoming Big Sage

- Greater Sage-Grouse – suitable all-around
- Loggerhead Shrike
- Brewer's Sparrow – shrub density/height
- Sage Sparrow
- Gray Flycatcher – tall sage, tall riparian sage, and deep soils
- Sage Thrasher – shrub density/height/age
- Black-throated Sparrow – possibly indicative of declining habitats and strong association with Wyoming big sage
- Pygmy Rabbit – simple, inexpensive to monitor
- Mule Deer – understory, shrub vigor, and thermal cover value

Low/Black Sage

- Greater Sage-Grouse – breeding habitat and early-season forb use
- Mule Deer – abundant winter forage and shrub vigor

Vegetation Sampling

Three site-sampled parameters were selected as habitat performance indicators – shrub height and density, shrub species diversity, and understory. Prospective methods for data collection were explored, with emphasis on measurement tractability and efficiency

- Shrub height and density – line transect, cover board, photo plot. A volunteer might possibly be trained to conduct, but paid biotechnician might be necessary for acceptable data quality.
- Shrub species diversity – line transect.
- Understory – grass and forb abundance measurements could be conducted by a volunteer, but species composition would require trained technicians. Digitized plots for presence/absence – presence would indicate availability. Intensive plot sampling might be necessary to establish more reliable understanding of wildlife and understory connections.

Vegetation sampling parameters measurable through remote sensing include:

- Seral stage
- Available habitat (sagebrush type identification)
- Patch size
- Configuration
- Distance to surface water
- Soils

The STAT next evaluated the ability to monitor the impacts of the major stressors on the key habitat elements within the sagebrush types, with the following results:

- Stand Decadence
  - Fire suppression – yes
  - Lack of disturbance – yes
  - Altered disturbance regime – yes
- Recreation- OHV
  - Vectors for invasive species – yes
  - Vectors for disturbance – no
  - Vectors for roads/trails – yes (GIS)
  - Direct mortality – no
- Urban/exurban Development
  - Direct loss – yes
- Mining/energy development/water transport
  - Ecological connectivity – yes (GIS)
  - Habitat fragmentation and loss – yes (GIS)
  - Availability of surface water – yes (GIS)
  - Disturbance (noise) – no
  - Direct mortality – no
  - Facilitation of predation – no; specialized monitoring necessary
- Agriculture
  - Habitat loss or conversion – yes
  - Invasive species – yes
  - Habitat fragmentation – yes
  - Concentrated grazing in adjacent uplands – yes
  - Pesticide applications – no; additional monitoring as appropriate
  - Disease – no; additional monitoring as appropriate

- Climate Change (direct and indirect)
  - Facilitated invasions of plants – yes
  - Wholesale distributional shifts in vegetation – yes
  - Availability of surface water – yes
  - Soil characteristics – yes
  - Fire interval – yes
  - Disease vectors (susceptibility to pathogens) – no; additional monitoring
  - Connectivity (seasonal movement and migration) – yes
  - Phenology changes – no; additional studies needed
  - Precipitation change – yes
- Predator/Prey Relationships (indirect)
  - Anthropogenic subsidies – no; additional monitoring
  - Roadkills and ravens – no; additional monitoring
- Disease – no
- Harvest/collection management – no; monitoring as needed

Third Workshop: From Indicators to Sampling Design

An expanded Sagebrush Technical Advisory Team convened on December 4, 2008 with the intention to reconfirm selected species-level indicators from an updated list. The group reminded itself of the intention of the performance indicators and measures task for the WAP – that the intended purpose of identifying indicators and measures is to provide the environmental attributes to be assessed in a monitoring scheme that will inform management actions under the Wildlife Action Plan. The objectives of this third meeting were to:

- Further narrow (or otherwise focus) the candidate indicator species list
- Agree on a process to follow for identifying indicator species
- Initiate the identification of monitoring protocols and/or pilot studies necessary to guide the development of a sampling design.

Presentations were made by technical experts who have designed sampling schemes for birds, small mammals, and the herpetofauna that inhabit sagebrush. All aspects of species biology were considered in vetting the list of candidate indicators, as were the life history characteristics that make each candidate either effective or ineffective as a surrogate measure for environmental condition, and an appropriate surrogate measure for the status of co-occurring species. Importantly, the tractability of each species in the potential role as a monitoring target was discussed – that is, could the species be surveyed effectively and efficiently in a monitoring framework that will be constrained by available funding. And, do time-series survey data exist that can provide historical status and trends context, and help to inform the design of the monitoring framework?

Accordingly, the following ***Priority Key Species*** were identified from the candidate list:

- Greater Sage-Grouse
- Vesper Sparrow
- Sage Sparrow
- Brewer's Sparrow
- Lark's Sparrow
- Sage Thrasher
- Mule Deer
- Pygmy Rabbit
- Sagebrush Vole
- Least Chipmunk
- Horned Lizard
- Sagebrush Lizard

These species will serve as initial indicators for the Wildlife Action Plan. It was generally agreed that, even for this comparatively trim species list, a full-scale, geographically dispersed monitoring framework could not be immediately brought on line given the limited information available for most of the priority species. A pilot study was proposed. The pilot study would adopt all proposed survey tools and environmental measurements at a well-distributed subset of proposed study sites across the state. Three or more years of biannual sampling in the pilot study will allow assessment of the efficacy of the initial indicators as targets for the monitoring effort. It is expected that one or more of the initial indicators may prove ineffective in providing information about environmental status and trend, and may be dropped in the monitoring effort or replaced with another species. During the pilot studies it is expected that ecosystem (vegetation community) conditions and indicator species values be identified, which will be used to set initial thresholds for management intervention or restoration action.

Toward a Sampling Design

The STAT discussed the scale of the approach, with primary recognition that scaling was irrevocably tied to available funding. The state has previously been divided into "land resource areas," 10 of which support at least some sagebrush communities. To capture regional (statewide) status and trends of wildlife and the ecosystems that support them, these large "subregions" ought to be subjects of WAP sagebrush ecosystem monitoring. The group set a target of 100 sample sites to be established across sagebrush communities with a minimum of 10 sample sites (monitoring units) in each of the land resource areas. (The pilot study phase will operate at 10 of those 100 sites.) Locations will be selected to represent not only the geographic breadth of the sage ecosystem, but vegetation condition, species diversity, and successional status. Sites should be visited two times a year for data collection (for a total of 200 sampling events per year state wide).

The geographic distribution of sample sites is on a relatively concordant scale with ongoing annual Nevada Bird Count data collection in sagebrush communities; tiering off that current effort in order to take advantage of historical data and continuing survey efforts, using currently employed standard ten-point bird point-count techniques. Sampling strategies for the other taxonomic groups and species were proposed. Greater Sage-Grouse is the one priority bird species that is not expected to be encountered during point-count surveys. Well-developed and long-established Sage Grouse monitoring is ongoing state wide; WAP sample sites, wherever possible, will be located adjacent to active or historic lek sites so as to be able to use those data.

The key logistical challenge is to set up and distribute small mammal traps at each survey site Sherman traps are to be set at 50 stations at each site. Each animal caught will be subjected to ear punch and blood withdraw for genetic and disease baseline monitoring (with expansion of sampling contingent on funding). Evenings on site will include spotlighting for rabbits and mule deer. During daytime, surveys for deer and rabbit pellets and other sign are carried out. Dirt roads will be surveyed for lizards as part of the mammal trap deployment and trap visitation activities. It is expected that lizards (as well as snakes) will be counted along transects by surveyors on the way into the survey site to set mammal traps. Each site will require an overnight survey, but trap set ups will be established early in the day to sample diurnal animals.

Vegetation sampling will address shrubs at two-year or greater intervals using belt transects, with measures of plant species composition and frequencies, and vegetation cover, height, and density. Frequency of herbaceous cover, using step-point sampling, will be measured annually (annual sampling) at 300 points at each site along belt transects; measuring basal and canopy cover, standing dead and residual material, species composition (related directly to dominant vegetation type), cover, and height.

Concomitant data will be gathered on environmental stressors including livestock grazing and horses/burros intensity, precipitation (from data loggers, fire on site and in adjacent areas (as well as history where ascertainable), OHV use, trash, and any indications of disease in sampled species.

Next Steps – Informing a Fourth Workshop

At the end of the third workshop, the STAT took on a set of inter-meeting tasks with committee assignments in order to have a set of draft products. The team committed to drafting a sample scheme pilot study that would demonstrate the actual deployment of site selection, bird survey points, Sherman live trap grid, and search protocols for night-lighting, pellet counts, rabbit sign identification, and reptiles surveys. The pilot study would be featured in a draft proposal with a provisionary budget to be written between meetings. Several members of the team agreed to stage a "mock data run" with a dataset fabricated to appear as if it had been generated by the sample scheme. Other members would run a "strategic framework test" for Wyoming Big Sage by moving through the four steps of "current status," "desired future conditions," "setting management action thresholds," and "evaluation of management opportunities and options." Another committee would initiate discussions to build the Greater Sage-Grouse monitoring element into the sampling scheme. And GIS layers pertinent to the sagebrush ecosystem performance analysis were to be gathered; those layers including Nevada Bird Count survey sites, Greater Sage-Grouse lek locations, Land Resource Area delineations, Southwest ReGAP, and other pertinent coverages. The next meeting is intended to organize these draft products, finalize them, and meld them into a "performance measures project implementation strategy" to move toward actual field implementation.

TABLE 10.1 Information about priority species in Nevada's Wildlife Action Plan.

Species	Status	Sagebrush Dependence	Relative Density	Shrub Height Density	Understory
Kit Fox	Priority	mod	low	0	0
Desert Horned Lizard	Priority	low	mod	0	0
Sagebrush Lizard		mod	mod	0	0
Gray Flycatcher	Stewardship	mod	low	+	0
Sagebrush Vole	Priority	high	high	0	+
Wyoming Ground Squirrel	Priority	high	high	0	+
White-tailed Jackrabbit		mod	mod	0	+
Mule Deer	Priority	mod	mod	0	+
Pygmy Rabbit	Priority	high	high	+	+
Preble's Shrew	Priority	mod	?	?	+
Merriam's Shrew	Priority	mod	mod	?	+
Ferruginous Hawk	ESA petition	low	low	-	+
Western Burrowing Owl	Priority	low	low	-	-/0
Black-throated Sparrow	Stewardship	mod	low	0	-
Greater Short-horned Lizard	Priority	low	mod	0	-
Pygmy Short-horned Lizard	Priority	mod	mod	0	-
Loggerhead Shrike	Priority	low	mod	+	0
Greater Sage-Grouse	ESA petition	high	high	+	+
Brewer's Sparrow	C-PIF MA	high	high	+	-
Sage Thrasher	Stewardship	high	high	+	-
Columbian Sharp-tailed Grouse	Priority	mod	mod	+	+
Green-tailed Towhee	Stewardship	mod	high	+	+
Vesper Sparrow	Stewardship	mod	mod	-	+
Mountain Bluebird	Stewardship	low	low	-	+
Sage Sparrow	Priority	high	high	+	-
Inyo Shrew	Priority	mod	mod		

Shrub Species Diversity	Patch Size	Seral Stage	Configuration	Surface Water	Soils	Rock
0	0	0	yes	0	yes	0
0	0	0	yes	0	yes	0
0	0	0	0	0	0	+
+	0	+	yes	0	yes	0
0	0	-	0	0	yes	+
0	0	0	yes	0	yes	+
0	0	-	0	0	0	0
+	0	-	yes	+	0	+
0	0	+	0	0	yes	0
0	0	-	?	0	0	0
+	0	-	?	0	0	0
0	0	-	yes	0	yes	0
0	0	-	0	0	yes	0
0	0	0	yes	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
+	+	+	0	0	0	0
0	+	?	yes	?	?	0
0	+	+	0	0	0	0
-	+	+	yes	0	yes	0
+	?	-	?	0	?	0
+	-	-	yes	0	0	0
0	-	-	yes	0	0	0
+	-	-	yes	0	0	+
0	-	+	yes	0	0	0
			yes	0		+

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