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Making Conservation and Restoration Count

Guidance for Effective Monitoring and Evaluation

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The United States' tradition of conserving fish, wildlife, habitats, and iconic cultural resources dates back to the 19th century. As the country was prospering from rapid industrialization, it was clear that the environment was beginning to suffer. President Theodore Roosevelt wrote: "We have become great because of the lavish use of our resources. But the time has come to inquire seriously what will happen when our forests are gone, when the coal, the iron, the oil, and the gas are exhausted, when the soils have still further impoverished and washed into the streams, polluting the rivers, denuding the fields and obstructing navigation." Roosevelt became known as "the conservation president" for his efforts to protect resources for future generations.

TONTO NATIONAL FOREST, ARIZONA

At the heart of conservation science is the understanding that people and the environment are inextricably linked. People rely on ecosystems for myriad benefits including clean water, food and fiber, regulation of climate, defense against disease and storms, recreational opportunities, and inspiration from the beauty of the land and sea. Clear cutting forests is not only unsightly and damaging to biodiversity and ecosystems, but also threatens the nation's clean water supply, nearly two-thirds of which originates from forest streams. Loss of coastal wetlands not only reduces habitat for wildlife but also increases the risks of harm to people in coastal regions from hurricanes, storm surges, and flooding.

The United States has spent billions of dollars on conservation and restoration efforts aimed at preserving or restoring a healthy balance between human needs and the natural environment. Each project has its own set of goals and objectives. Surprisingly, however, recent studies indicate that such efforts often have insufficient monitoring to determine if conservation and restoration goals have been met. Drawing from a number of expert reports of the National Academies of Sciences, Engineering, and Medicine, this booklet provides guidance on why monitoring and evaluation are important and how they should be carried out to make conservation and restoration efforts count.

SEDIMENT IS SLOWLY REBUILDING EAST TIMBALIER ISLAND, LA, TO ITS ORIGINAL FOOTPRINT.

The Case for Monitoring

OYSTER HARVESTING, CHESAPEAKE BAY

Hit by decades of heavy fishing, deadly diseases, and environmental degradation, native oysters in the Chesapeake Bay were decimated to less than 1 percent of historic levels by the early 2000s. While in 1980, the Chesapeake Bay accounted for roughly 50 percent of the U.S. oyster harvest, more recently, the region has produced only 1−5 percent of the total domestic supply. The declines occurred as the oyster population suffered from introduction of two oyster diseases, continued harvest, and declining water quality. Because oysters are filter-feeders, the decline also reduced water clarity and hence the growth of sea grasses in the Bay.

Efforts to restore native oysters failed to document any progress for many years, casting doubt that restoration of the Bay was possible. However, studies have shown that most projects lacked the monitoring needed to generate decision-relevant information. For example, a study published by Kennedy et al. in 2011 found that "of the more than [2000] oyster restoration activities undertaken, a relatively small number were monitored," and where monitoring did occur, "the kinds and types of data required to determine explicitly the success of restoration were generally not recorded."

At sites where different restoration approaches were carefully evaluated, researchers were able to distinguish the main factors controlling native oyster recovery. Monitoring showed that reducing fishing pressure could protect oyster reefs from physical disturbance and enhance disease resistance. Also, the monitoring results showed that increasing the height and extent of an oyster reef could support greater oyster abundance and density over time. In contrast, low-relief reefs and a relatively small restoration footprint (< 1 acre)—common features of many past Chesapeake Bay restoration efforts—were insufficient to support oyster recovery for more than a few years.

Monitoring and evaluation also provide an opportunity to learn and improve construction methods for restoration projects. Oyster restoration efforts were falling short of expectations until monitoring and evaluation revealed that the typical practices used to construct oyster reefs (deploying shells off barges using water cannons) produced low quality reefs that did not establish a self-sustaining population. In contrast, constructing reefs by dumping shells overboard from buckets produced reefs with greater height and a much more precisely placed substrate for oyster growth. In one study, oyster density increased from a pre-restoration value of fewer than 1 oyster/m^2 to more than 250 oysters/m^2 when reefs were built using water cannons; this improved to more than 1,000 oysters/m^2 using the new construction method of unloading shells by the bucket (see Figure 1).

Even though the benefits and importance of monitoring are well documented, many projects fail to put a monitoring plan in place that will allow outcomes to be evaluated and needed adjustments to be made. The problem may stem in part from the misconception that monitoring is an "add-on" that doesn't directly contribute to the conservation or restoration project. Additionally, monitoring plans may be unsuccessful for many reasons, including:

- Lack of political will and/or public support
- Lack of sustained funding or effort
- Unclear or unstated program goals
- Lack of metrics that are clearly linked to project objectives
- Insufficient consideration given to data management and analysis.

Given the risk of investing in conservation and restoration activities without any accountability for construction or effectiveness, or a mechanism to understand why some projects fail and others succeed, monitoring is a critical investment.

FIGURE 1 The number of oysters in a barren spot in the Chesapeake Bay (*photo A*) improved to about 250 oyster/m^2 with the construction of "low-relief" reefs (*photo B*), but numbers of oysters soared to 1,000 oysters/m^2 when "high-relief" reefs were constructed (*photo C*).

Making Monitoring an Integral Part of the Plan

SAN MARCOS SPRINGS, TEXAS

In many areas of the country, one of the biggest drivers of conservation and restoration efforts is water scarcity. In these regions, people rely on groundwater resources to supply water for drinking, growing food, and supporting the commercial and industrial activities that drive the local economy. An increase in human water use in many regions, from the Columbia River to the Sacramento Bay-Delta to the Florida Everglades, has reduced flows, putting ecosystems at risk and sparking fierce debates over how water should be allocated.

The Edwards Aquifer in south-central Texas is just such a groundwater resource. It is the primary source of drinking water for one of the fastest-growing cities in the United States, San Antonio, and it also supplies irrigation water to thousands of farmers and livestock operators. The Edwards Aquifer is also the source water for several springs and rivers, including the two largest freshwater springs in Texas that form the San Marcos and Comal Rivers. The unique habitat afforded by these spring-fed rivers has led to the evolution of species that are found in no other location on Earth.

Because of the reduced flows to the streams during times of drought, eight of the region's unique species are listed under the federal Endangered Species Act (ESA). To help protect the listed species, the Edwards Aquifer Authority and four other local entities created a 15-year comprehensive Habitat Conservation Plan. The plan seeks to effectively manage the river–aquifer system to ensure the viability of the ESA-listed species in the face of drought, population growth, and other strains on the aquifer.

The Habitat Conservation Plan, which was approved in 2013, describes a plethora of restoration activities designed to maintain and enhance the habitat of endangered species. The plan also calls for development of a hydrologic model to predict how stream flows might change in response to management actions and development of ecological models that predict how species populations might change under a variety of conditions. Those models have helped elucidate several management goals and targets.

While the physical, chemical, and biological characteristics of the Comal and San Marcos Spring and River systems have been monitored since 2000, measuring progress toward the specific goals and objectives in the Habitat Conservation Plan necessitates more targeted monitoring.

As an example, submerged aquatic vegetation had been routinely mapped throughout both river systems every five years. Under the Habitat Conservation Plan, this mapping has become more frequent and has been targeted to those regions of the river where active management is underway. The goal is to determine whether efforts to remove invasive vegetation and replace it with native vegetation are actually accomplishing the goal of increasing habitat acreage for the endangered fish. Another example is the recent addition of fish tissue sampling of selected contaminants to augment the existing water quality monitoring program. Tissue sampling should help identify those chemicals most likely to be harmful to the listed species, allowing the overall water quality monitoring program to become more focused on contaminants of concern.

ENDANGERED SPECIES: (*LEFT*) FOUNTAIN DARTER, IN THE SAN MARCOS AND COMAL RIVERS, AND (*RIGHT*) TEXAS WILD RICE, IN THE UPPER SAN MARCOS RIVER.

Elements of an Effective Monitoring Plan

GREEN SEA TURTLE GRAZING SEAGRASS

In April 2010, the explosion on the *Deepwater Horizon* oil rig resulted in the largest oil spill in U.S. history. The spill released an estimated 205.8 million gallons—about one third of the nation's daily consumption of oil—into the Gulf of Mexico. Arguably one of the nation's busiest waterways, the Gulf of Mexico ecosystem directly or indirectly supports the 20 million people in the region with productive commercial and recreational fisheries, a $50 billion tourism industry, and an energy sector that produces about 30 percent of the nation's oil and 20 percent of its natural gas.

Gulf of Mexico ecosystems are already vulnerable to many stressors including habitat loss, overfishing, impacts of flood control on sediment, degraded water quality, and pollution. The oil spill caused additional damage to wetlands, coastal beaches and barrier islands, marine wildlife, seagrass beds, and other habitats in the Gulf of Mexico. Losses include, for example, an estimated 20 percent reduction in commercial fishery landings and damage to as much as 1,100 linear miles of coastal salt marsh wetlands.

Litigation following the *Deepwater Horizon* spill has resulted in $16 billion being set aside for restoration in the Gulf of Mexico. Already, multiple projects are being planned or are underway. This effort represents both a tremendous opportunity to restore critical ecosystem functions and a tremendous responsibility to ensure that these investments yield real and lasting improvements for the Gulf ecosystem and the people who rely on it. Determining whether progress is being made will only be possible with a rigorous monitoring and evaluation program, spanning scales from small, individual projects to Gulf-wide assessments of ecological recovery.

The *Deepwater Horizon* spill added a new stressor for plant and animal species in the region, some of which were already under stress. For example, all five species of sea turtles indigenous to the Gulf of Mexico are threatened or endangered. Plans for sea turtle restoration in the Gulf of Mexico following the *Deepwater Horizon* spill are based on the goal of addressing all injured life stages.

A starting place for a monitoring plan is to develop a very good understanding of the habitats or species to be restored. Conceptual models are useful tools that provide a visual or narrative framework that connects key environmental and social factors to ecosystem structures. Such models can be used to identify and highlight key uncertainties that inform monitoring design choices and adaptive management planning. For example, as shown in Figure 2, conceptual models can help pinpoint the stages where evidence is weakest and can be informed through experimentation.

Guided by the conceptual model, the next step is to determine the management decisions monitoring will inform (see Figure 3 on page 11). This includes setting specific restoration goals for the project. Project goals should be translated into clearly articulated objectives with quantifiable outcomes by which the success of the project as a whole will be judged. For example, one objective for Gulf sea turtles is to increase the survival of sea turtle hatchlings.

Restoration monitoring can be designed to meet three specific purposes: (1) **construction monitoring** to assess whether projects are built or implemented and are initially functioning as designed; (2) **performance monitoring** to assess whether restoration

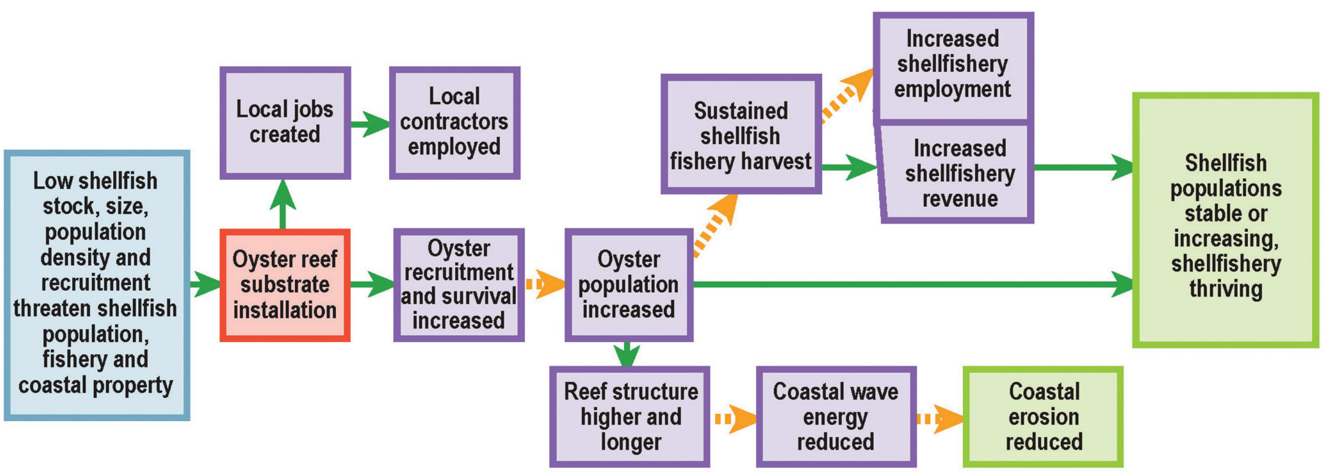


FIGURE 2 A hypothetical conceptual model for a proposed oyster reef can help guide a monitoring plan. The model lists the drivers and pressures on the system (*blue box*) and the goals (*green boxes*) of a specific restoration action (*red box*). The conceptual model shows the hypothesized system responses (*purple boxes*) to the restoration action. Green arrows indicate where there is confidence in a system response. The orange arrows indicate where evidence in predicting a response is weakest, and thus where monitoring efforts might be needed to inform the restoration effort.

goals and objectives have been or are being met; and (3) **monitoring for adaptive management** to test different approaches or resolve other uncertainties in a restoration project. Adaptive management can be used when there is insufficient knowledge to provide high confidence in the outcome of a specific goal.

As an example, for the objective of increasing the survival of sea turtles hatchlings, monitoring actions might include the following:

Construction monitoring. Sea turtle nests are often relocated into corrals to reduce predation on sea turtle eggs. In this case, construction monitoring might entail measuring the post-construction amount of beach protected and documenting the number of nests successfully relocated.

SEA TURTLE HATCHLING AND EGGS

Performance monitoring. Performance monitoring might include measurements such as visual counts of intact nests, hatchlings, and hatchling turtle tracks. To attribute change to the restoration effort, measurements should compare hatchling success to an unmodified nesting site to estimate the extent of change due to the intervention.

Monitoring for adaptive management. To address uncertainty about the causes of relocation-related egg mortality, a project could be designed to test different methods for relocating nests to determine which has the least impact on hatching success. Monitoring is essential to evaluate which measures are most effective in supporting the production of hatchlings to assist in the recovery of the population.

The final development of the monitoring plan should be based on the consideration of each of the following elements, shown in Figure 3 (next page):

- **Metrics** are specific measures that help assess whether objectives are being met. They can be developed from conceptual models or existing guidance documents. For example, to assess the objective of increasing the survival of sea turtle hatchlings by reducing beach predation, the numbers of nesting females, hatchlings produced, and level of predation could be measured during relevant time periods at beach sites where interventions (e.g., predator exclusion corrals) have been implemented. Those numbers can then be compared to beach sites where interventions have not been implemented (i.e., reference or control sites).

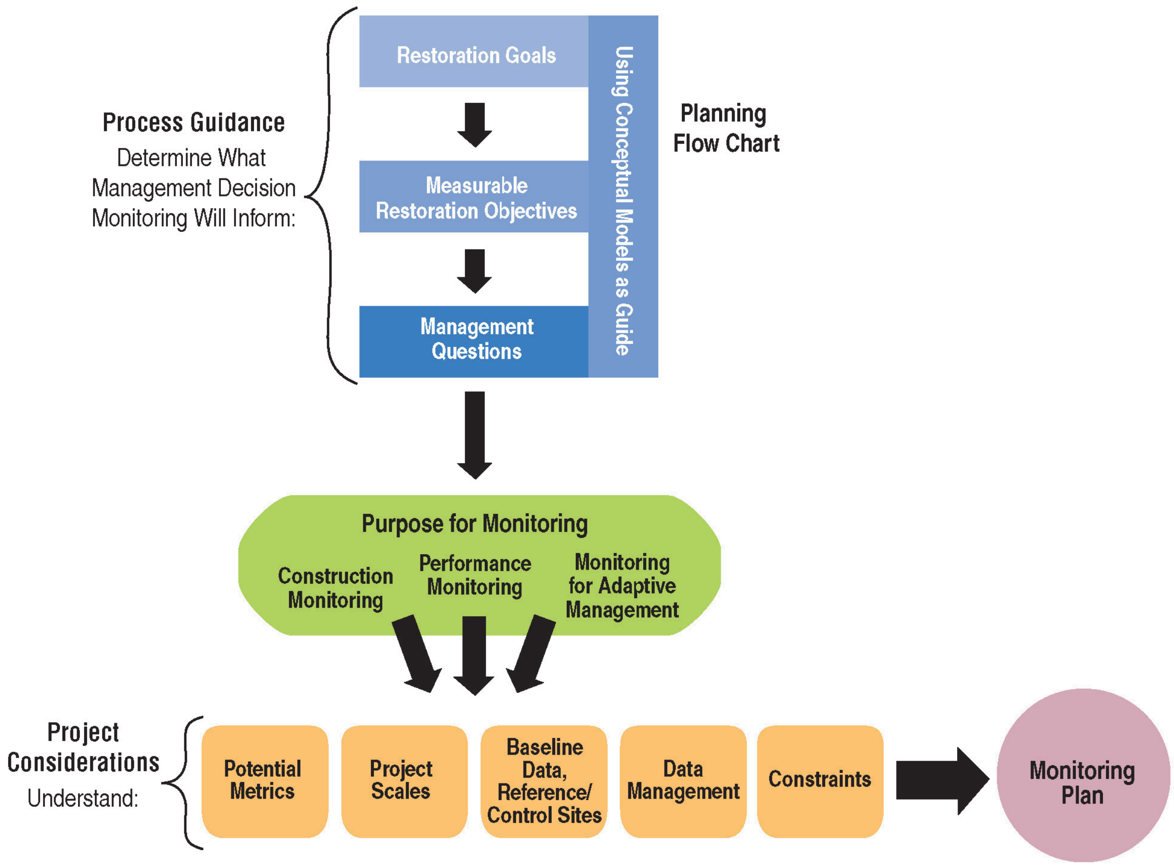


FIGURE 3 The initial steps of the planning process determine the information needs and what management decisions will be informed. These management questions then determine whether construction or performance monitoring is sufficient or whether the project would benefit from an adaptive management approach. Based on the purpose of the monitoring and on considerations of potential metrics, project scales, available baseline data, data management, and constraints, the monitoring plan can be developed.

- The **appropriate spatial and temporal scale** at which relevant metric(s) operate helps determine specific plans for restoration. For example, many sea birds and sea turtles cover large distances during their life histories and may encounter different threats in different habitats that correlate with their life stage (e.g., hatchling and non-reproductive adult). While turtle eggs and hatchlings on beaches are susceptible to predation by seabirds, raccoons, and even some types of crabs, the adults in the open ocean have relatively few predators, but are susceptible to getting caught in fishing gear. Hence monitoring may depend on different factors that are specific to a location and may operate at different scales (nesting beach versus regional ocean).
- The availability of historical information that is collected prior to restoration can serve as **baseline data** and provide valuable information for setting performance targets and evaluating whether those targets are met. Baseline data collected prior to a disturbance that prompted restoration may provide quantitative targets for restoration, although natural variability and unanticipated environmental effects may

affect results. Comparative monitoring of **reference and control sites** can help address that concern, when sites are well-matched to the restoration project site.

- Understanding the **constraints** associated with a given restoration project is critical in developing a monitoring plan that is practical and can be implemented and sustained over the required timeframe. In addition to cost limitations, there may be constraints associated with the sampling process such as restrictions on when and where samples can be taken, spatial restrictions (e.g., site access), equipment and/or resource restrictions, and personnel limitations.

- A **data management plan** should cover aspects such as quality assurance and quality control, metadata, data publishing, and policies and platforms for data sharing. Data stewardship is an important element to ensure that synthesis efforts can assess restoration effectiveness at larger spatial scales and also enables assessment and documentation of lessons learned from restoration outcomes.

Standards for Data Collection and Stewardship

The full value of monitoring cannot be realized without dedicated effort to ensure responsible data stewardship. These plans would include identification of an appropriate long-term, reputable digital repository where the full body of data and metadata will be submitted and stored in standard formats. Collaboration and coordination on monitoring designs, selection of metrics, and the development of standardized protocols will enhance consistency, improve quality, and increase utility of the data collected. All restoration projects should be required to include a written data management plan with deliverables and strategies to ensure compliance.

When to Use Adaptive Management

Because ecosystems are so complex, it is often not possible to predict how a particular site will respond to a specific restoration activity. Adaptive management is a structured process to determine how well the phases of conservation and restoration are meeting objectives based on the available information, and to adjust plans as needed to better achieve those objectives. Adaptive management is most suited for situations where:

1. There is considerable uncertainty regarding the response to the intervention;
2. Reduction in uncertainty could improve the project outcome and aid future restoration management and decision making; and
3. Especially for large projects with long time frames, sufficient institutional capacity and commitment as well as stakeholder support is available to sustain an adaptive management approach.

If the response of the system to the restoration intervention is well known, adaptive management is not needed. For example, given the depth of experience and success of osprey nest platforms, adaptive management is probably not necessary for installation of additional platforms.

To employ adaptive management based on monitoring and evaluation outcomes, the anticipated change due to restoration must be detectable against the background of natural variability over a short enough time period (about a decade or less). A decision tree (Figure 4, below) offers a line of questions to help determine if adaptive management is appropriate.

Active adaptive management, where several restoration methods are tested simultaneously, is called for when improved understanding is needed quickly. Especially for Gulf-wide endeavors, implementation of the wrong strategy at such a scale would be costly in terms of resources, recovery time, and public support.

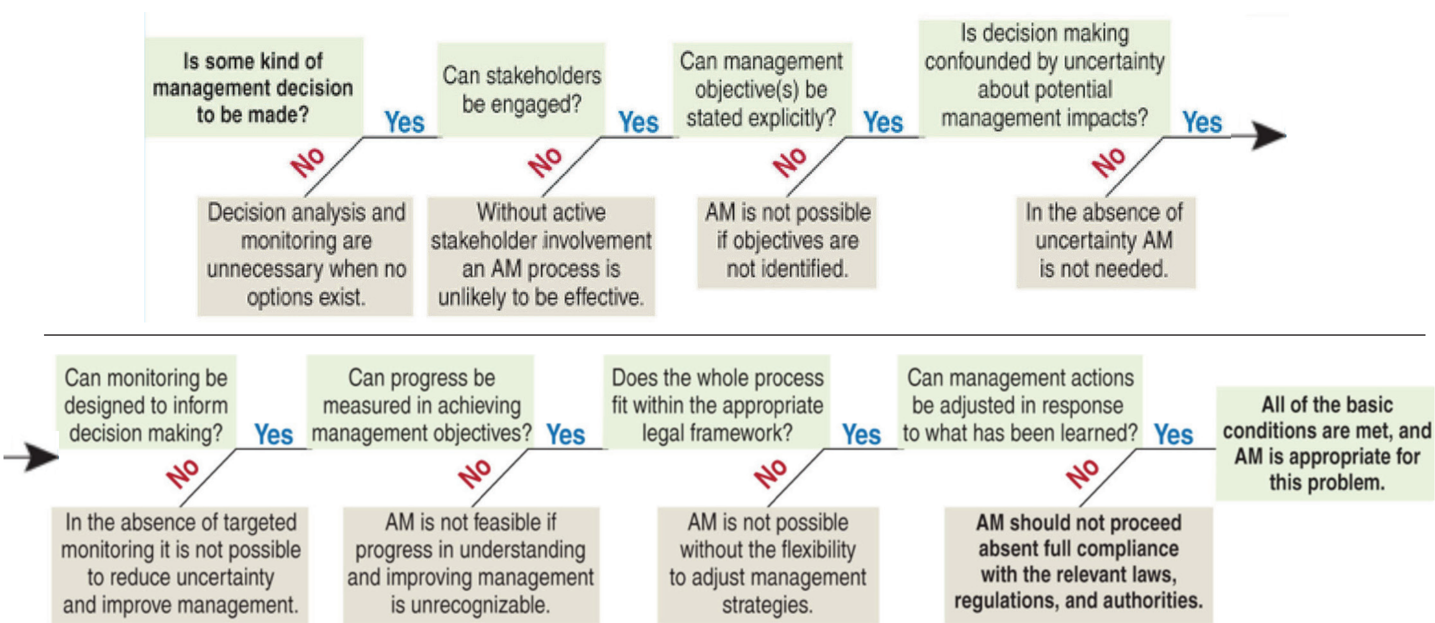


FIGURE 4. *A decision tree to determine whether a project would benefit from adaptive management*

Monitoring at the Landscape Level

FLORIDA EVERGLADES

For many conservation and restoration projects, goals and objectives can be achieved only by implementing a suite of projects that extend to the larger ecosystem or targeted species habitat. For example, the recovery of a migratory bird species may require restoration of habitat areas that span a continent. Wetland restoration to curb coastal erosion requires an understanding of the sources and sinks of sediments beyond any project site, and the success of a given site may depend on the success of conservation and restoration activities in adjacent areas or projects higher up in the watershed.

Decades of restoration efforts in the Everglades illustrate how challenging landscape level efforts can be. Considered a national treasure, Florida's Everglades once encompassed about 3 million acres that stretched from Lake Okeechobee to Florida Bay. Its diverse wetlands, sloughs, and adjacent upland communities supported a rich array of plant and animal life. However, a century of alteration for flood control and water supply for urban and agricultural development has reduced the Everglades to less than half its original size and impaired its waters with contaminated runoff. The profound hydrologic changes have affected wading birds and wildlife, and today, nearly 70 animal species in South Florida are listed as threatened or endangered.

Large-scale restoration planning for the Everglades began in the 1990s. The Comprehensive Everglades Restoration Plan (CERP), a joint effort of the state of Florida and the federal government launched in 2000, was an unprecedented project that envisioned the expenditure of billions of dollars in a multidecadal effort to achieve ecological restoration. The effort focused on reestablishing historic water flows in the Everglades to create a water system that simultaneously serves the needs of both the natural systems and human needs in South Florida. The progress of the CERP is reviewed in reports issued every two years by the National Academies of Sciences, Engineering, and Medicine.

From the beginning of the CERP project, it was recognized that a well-designed and supported program of monitoring and assessment was essential to determine whether the funds and resources were being used wisely. Determining what to monitor can be challenging, however. It's unrealistic to measure everything everywhere. Restoration programs struggle to develop sustainable long-term systemwide monitoring plans that contain costs while providing the data necessary to assess restoration progress, communicate that progress to the public, and support adaptive management as appropriate.

In the Everglades, performance measures of both ecosystem conditions and critical ecosystem stressors have been developed (e.g., salinity, soil and phosphorous concentrations, water flow patterns) so that monitoring can help determine cause-effect relationships. A set of system-wide indicators were identified that could communicate information to the public about the general functioning of the ecosystem and responses to changes brought on by restoration activities. While budget pressures have forced restoration managers to reduce the scope of monitoring over time, efforts are made to ensure continued monitoring of the most essential attributes of the Everglades system.

WHOOPING CRANE, EVERGLADES

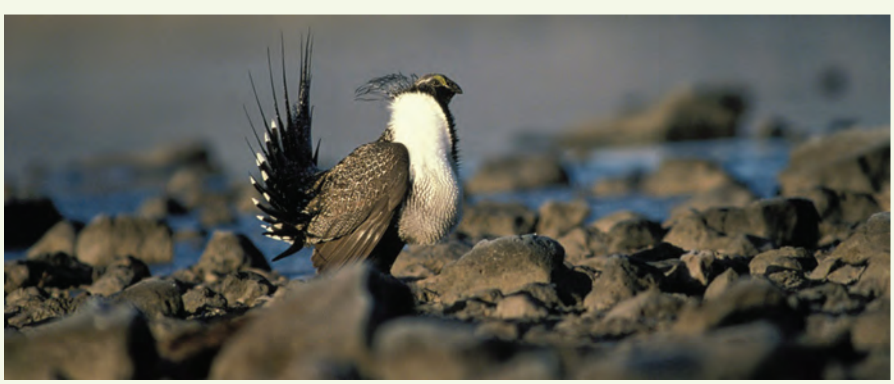
Collaboration at the Landscape Level

Despite the strong support for landscape approaches, many conservation activities in the United States continue to proceed in a piecemeal fashion, in part because of the way programs and institutions have been established over time. For example, the primary responsibility for species management falls to states; however, federal agencies are tasked with managing migratory birds, eagles, marine mammals, and endangered species. Furthermore, several federal statutes and regulations confer authority to federal agencies for managing and conserving the habitats on which species—managed by the states—depend.

One example of effective collaboration is the effort to help the greater sage-grouse that inhabits the sagebrush grasslands found in 11 western states and two Canadian Provinces. Once numbering in the tens of millions, the greater sage-grouse plays an important ecosystem role. However, the population declined precipitously under increasing pressure from agricultural development, sagebrush control efforts, urban and exurban development, large wildfires, invasive species, and most recently, energy development.

In 2000, the Western Association of Fish and Wildlife Agencies, the state of Nevada, and several federal agencies combined resources to prepare a strategic approach for conservation of sagebrush ecosystems and the greater sage-grouse. In addition, several of the 11 states identified core habitat areas considered essential for the sage-grouse and identified objectives and strategies to guide conservation efforts. After decades of decline up until about 2003, the U.S. Fish and Wildlife Service found in 2015 that "the greater sage-grouse remains relatively abundant and well-distributed across the species' 173-million acre range and does not face the risk of extinction now or in the foreseeable future."

Recognizing the broader need for landscape-scale conservation, in 2009 the U.S. Department of Interior launched the Landscape Conservation Cooperatives (LCC) Network made up of 22 individual, self-directed conservation areas in the United States, including the Pacific and Caribbean Islands, and parts of Canada and Mexico. The network was established with the main objectives to facilitate collaboration across jurisdictional boundaries, develop shared conservation priorities and common science needs among partners, and create conservation strategies to be implemented by participating agencies or other partners. LCC funds and emphasis on the landscape scale have been helpful in supporting continuing work on the sage-grouse.



GREATER SAGE-GROUSE

Synthesis and Evaluation of Monitoring Results

Synthesis involves the aggregation, integration, interpretation, and communication of the results of a compendium of restoration activities. Synthesis may include activities such as:

- Aggregation and analysis of monitoring data from multiple localities to assess resource-specific restoration progress over larger spatial scales and longer time periods;
- Compilation, integration, and analysis of local biological survey data and environmental monitoring data to evaluate restoration effects on wide-ranging organisms such as fish, birds, and marine mammals;
- Aggregation and analysis of physical and biological data over multiple projects and years to identify key ecological factors and interactions affecting restoration outcomes for specific species and habitat types; and
- Integration of ecological and societal benefits of restoration through an ecosystem services approach to analysis of environmental and socioeconomic data.

Synthesis of monitoring results at both the project-level and across multiple projects provides greater accountability on restoration progress for state officials, Congress, and the public. One example of synthesis is the set of reports provided by the Comprehensive Everglades Restoration Project (CERP). Since 2006, CERP has issued five status reports based on analysis and synthesis of data collected and has developed other synthesis documents. Those reports are intended to explicitly link science to decision-making and provide reports to inform Congress of progress toward restoration goals.

There are a number of organizational models to support and facilitate synthesis activities ranging from independent centers such as the National Center for Ecological Analysis and Synthesis (NCEAS) to single institution or multi-institution programs, such as the University of Maryland's Center for Environmental Science, which produces the Chesapeake Bay Report Card. A competitive contract and grant program provides another way to promote synthesis activities by funding individual investigators and collaborating teams who propose and perform data synthesis within their existing organizations.

SEA TURTLE HATCHLING

Conclusion

In the face of ever more complex and large-scale problems, the need to conserve functioning ecosystems and restore those that have been damaged will continue. This work not only protects the future of natural systems, which have value in their own right, but also supports our own species' future by safeguarding the myriad ecosystem services on which we depend. To ensure that these efforts provide the expected benefits, monitoring and evaluation cannot be optional.

Only with a well-designed and executed monitoring and evaluation plan will it be possible to demonstrate whether ecological objectives were achieved and what can be done to revise the project to achieve more successful outcomes. Ideally, every restoration project will have a monitoring and evaluation plan. While acknowledging the many real challenges of taking those steps, from securing funding to finding the needed expertise, the guidance summarized in this booklet is based on real efforts that prove it can be done—and that it makes a difference.

ROOTS OF RED MANGROVE TREES IN THE EVERGLADES NATIONAL PARK

This booklet draws its content from the following reports from the National Academies of Sciences, Engineering, and Medicine, which are developed by committees of experts.

Effective Monitoring to Evaluate Ecological Restoration in the Gulf of Mexico identifies best approaches for monitoring and evaluating restoration activities conducted in the Gulf of Mexico in response to the 2010 Macondo Well *Deepwater Horizon* oil rig explosion.

Review of the Edwards Aquifer Habitat Conservation Plan is a three-part series that reviews the Edwards Aquifer Authority's Habitat Conservation Plan (HCP). That plan seeks to effectively manage the river-aquifer system to ensure the viability of the endangered species in the face of drought, population growth, and other threats to the aquifer.

A Review of the Landscape Conservation Cooperatives examines the Landscape Conservation Cooperatives, a network of 22 conservation areas created by a Secretarial Order of the U.S. Department of the Interior in 2009.

Progress Toward Restoring the Everglades, The Fifth Biennial Review. As mandated by Congress, the National Academies provides periodic independent reviews of progress of the Comprehensive Everglades Restoration Program (CERP), which is a $16 billion 30– to 40–year effort to restore the Everglades.

This booklet also builds on examples and uses cases from the scientific literature and other expert sources, notably the practitioner's guide ***Conservation Planning: Informed Decisions for a Healthier Planet*** by Craig R. Groves and Edward T. Game.

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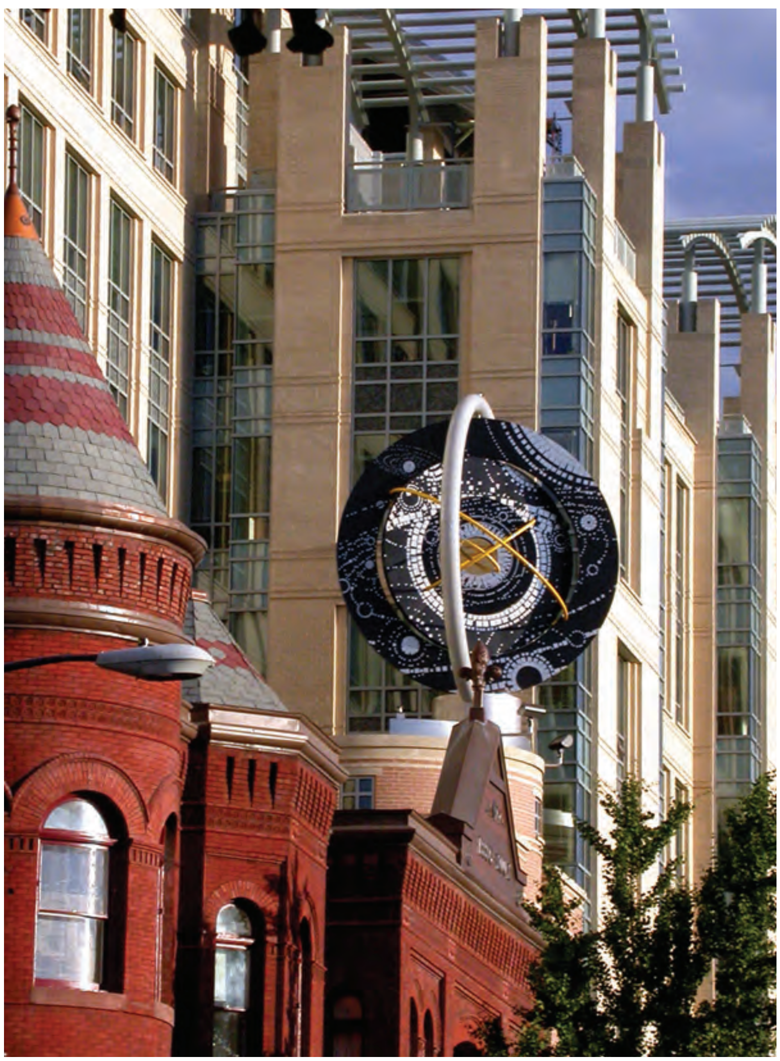

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