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Adaptive Management and the Conservation of Natural Resources

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The challenges currently facing resource managers are large-scale and complex, and demand new approaches to balance development and conservation needs and goals. Now more than ever, it is important for resource managers to acquire and use information and knowledge to promote sound management of natural resources. Adaptive management is an approach that shows considerable promise and is broadly seen as a natural, intuitive, and potentially effective way to make decisions in the face of uncertainties. Adaptive decision-making involves the use of management itself to pursue management objectives while also learning about management consequences.

Ever since its introduction in natural resources in the late 1970s, the feedback between learning and decision-making has been a critical feature of adaptive management. A framework for adaptive management highlights the contribution learning makes to management through enhanced understanding to inform decision-making, and the contribution management makes to learning through the use of interventions to investigate resources. Management interventions are often described as experimental "treatments" that are implemented according to a management design. Because its focus is on (human) management with its inevitable ecological consequences, adaptive management is almost always framed in terms of linked social-ecological systems, with the potential for social as well as technical learning.

It is widely recognized that adaptive management is potentially useful for addressing many natural resource problems, namely those for which resources are responsive to management but uncertainty exists about the impacts of management. Features with which adaptive management typically is associated include: (1) The natural resource system being managed is dynamic, with changes over time that occur in response to environmental conditions and management actions, which themselves vary over time; (2) Environmental variation is only partly predictable, and is sometimes unrecognized; (3) Periodic management interventions influence resource system behaviors either directly or indirectly, by altering system states such as resource size, or influencing ecological processes like mortality and movement, or altering vital rates like reproduction and recruitment rates; and (4) Effective management is limited by uncertainty about the nature of resource processes and the influence of management on them. Reducing this uncertainty about ecological processes and structures can lead to improved management, which is the ultimate goal of adaptive management.

Framework for adaptive management. Below I describe adaptive management in terms of a two-phase process that incorporates both technical and social learn-

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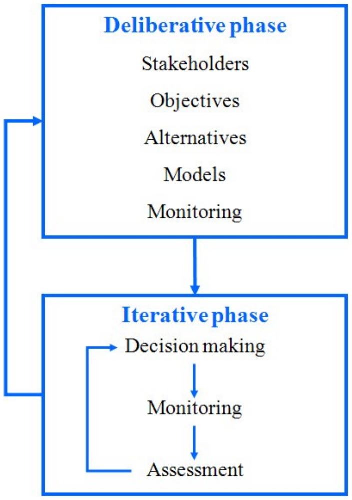

Figure 1. Two-phase learning in adaptive management. / U.S. Department of Interior

ing. Thus, a deliberative or planning phase involves the formulation of the critical components of adaptive decision-making, and an iterative decision phase links these components together in a sequential decision process (Fig. 1). The iterative phase uses the elements of the planning phase in an ongoing cycle of learning about system structure and function and management on the basis of what is learned.

Deliberative phase. In the deliberative phase of adaptive management, key elements in the decision-making process are developed and refined, including stakeholder involvement, objective setting, identification of management options, projections of the consequences of management, and design of monitoring protocols. Stakeholder involvement is widely recognized as critical in all aspects of adaptive decision-making, in particular the framing of a resource problem and identifying its objectives and management alternatives. Objectives serve as benchmarks against which to compare the potential effects of different management actions and evaluate the effectiveness of management strategies. Feasible and acceptable management alternatives are required for decision-making as well as learning. Predictive models forecast the potential consequences of management actions and fluctuating environmental conditions. Finally, monitoring protocols, including choices about what ecological attributes to monitor and how to monitor them, guide the data collection that provides information for both learning and evaluation of management effectiveness.

Iterative phase. In the iterative phase, the elements in the deliberative phase are folded into a sequential process of decision-making and learning. Decision-making identifies actions to be taken based on the current level of understanding and anticipated consequences of management actions on the ground. Follow-up monitoring provides information to estimate resource status, inform decision-making, and facilitate evaluation and learning after decisions are made. Assessment uses data produced by monitoring to evaluate management effectiveness, understand resource status, and reduce uncertainty about management effects. Learning is promoted by comparing predictions generated by the models and data-based estimates of actual responses, so that understanding gained from monitoring and assessment can be used to inform future management actions.

Institutional learning. Adaptive management also provides an opportunity to learn about the decision process itself by periodically interrupting the cycle of technical learning in the iterative phase to reconsider project objectives, management alternatives, and other elements of the set-up phase. Reconsideration of these components constitutes an institutional or social learning cycle that complements, but differs from, the cycle of technical learning. In combination, the two cycles are referred to as "double-loop" learning.

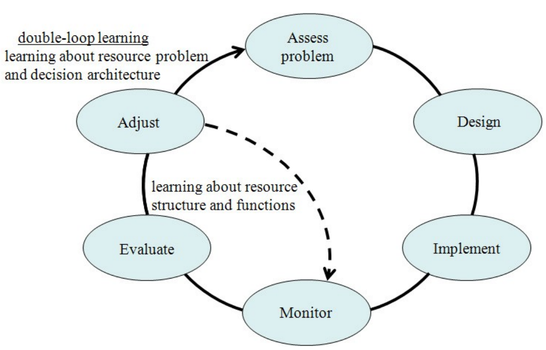

Figure 2. Adaptive management displayed as a cycle, showing technical learning and social/institutional (double-loop) learning. / U.S. Department of the Interior

The need to revisit and adjust the set-up elements of adaptive management often becomes more pressing as management proceeds over time. Stakeholder perspectives and values can shift as management progresses, as previously unanticipated patterns in resource dynamics are exposed and changes in social and cultural values and norms occur. These changes can lead to adjustment of objectives, alternatives, and other set-up elements. In this sense, learning in adaptive management can focus on changes in institutional arrangements and stakeholder values as well as changes in the resource system itself.

Adaptive management is often illustrated with a circular diagram that describes a feedback loop beginning with problem formulation and flowing through decision-making, implementation, evaluation, and feedback into problem formulation (Fig. 2). In the absence of additional structure, such a framework does not distinguish the potential for technical learning and social or institutional learning in a double-loop arrangement. By including an additional feedback loop as in Figure 2, both kinds of learning can be represented, and the framework can be seen to be analogous to that presented in Figure 1.

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Challenges with adaptive management. A number of large-scale challenges are tied to changing institutional and environmental conditions. I mention three challenges here.

Climate change. Directional trends in the environment present an important and difficult challenge to management. An obvious example is climate change, as expressed in terms of a long-term decrease in average precipitation or an increase in the range of ambient temperatures. Directional change can also be important over shorter periods; many anthropogenic forces exhibit large-scale directional change on shorter time scales than climate change. In either case, directional change has the potential to generate non-stationary resource dynamics. This presents a special challenge for a learning-based approach that seeks to understand systems as they are being managed.

Monitoring. The importance of monitoring in adaptive management applications is universally recognized, so much so that some people seem to think that monitoring resource conditions is sufficient in and of itself to make a project "adaptive." Monitoring certainly plays a critical role by providing the information needed for both learning and evaluation of management effectiveness. It is often one of the most time-consuming and expensive aspects of adaptive management, and during times when budgets are restricted or shrinking, there is always a threat that monitoring will be reduced or eliminated. Because some level of monitoring is almost always required for the smart management of natural resources, it is important to sustain support for tracking and assessment of management consequences.

Organizational commitment. Many observers think that the major challenges in adopting adaptive management are fundamentally institutional. Institutions are built on major premises and long-held beliefs that are deeply embedded in educational systems, laws, policies, and norms of professional behavior. An organization's recognition of uncertainty as an inherent part of natural resource management is key to its productive use of adaptive management. There is a natural tension between the tendency of large, long-standing organizations to maintain a strong institutional framework for thinking and decision-making, and adaptive decision-making that relies on collaboration and flexibility, awareness of alternative perspectives, acceptance of uncertainty, and use of participatory decision-making.

Structuring an organization for learning-based management can be hampered by the widespread belief that current practices are effectively adaptive, involving little more than occasionally changing management actions. One consequence is that not enough attention is paid to institutional barriers, and not enough effort is spent on designing organizational structures and processes to accommodate an adaptive style of management. At a minimum, it is necessary to rethink the notions of risk and risk aversion, and establish conditions that encourage and reward learning by individuals.

Future directions. As we face new opportunities and address new challenges, the principles of adaptive management, including transparency in decision-making and an accounting of both uncertainty and scientific understanding, will be increasingly important. Highlighted below are some future directions and growth areas for the application of adaptive management.

Adaptive management and planning. The adaptive management process, described here in terms of linked deliberative and iterative phases of learning and management, can also be usefully portrayed as an ongoing cycle of planning, implementation, tracking, and feedback. (Fig. 3) Organizations involved in resource management and conservation engage to varying degrees in both strategic planning and the tracking of results as plans are implemented. A remaining need is to incorporate learning as a fundamental element of strategic planning and implementation, whereby the learning that results from monitoring and assessment is fed back into future planning. By proactively linking plan implementation to plan

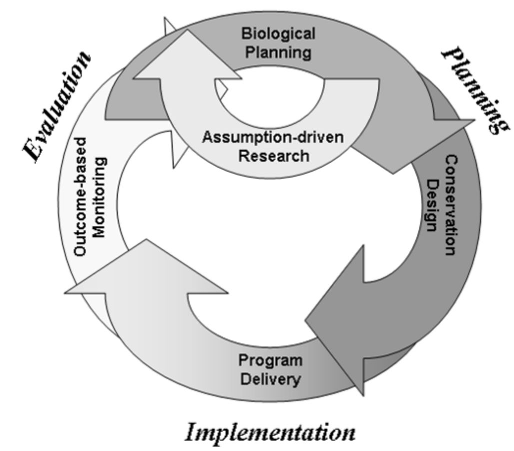

Figure 3. The adaptive cycle in terms of planning, implementation, and evaluation and learning. / USFWS

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development through a learning process, the adaptive cycle of learning-based management is completed and becomes standard business practice.

Synthesis of technical and collaborative advances. Two broad focus groups have worked more or less in parallel, but independently, to develop adaptive management of natural resources. One group focuses on technical issues (models, metrics and propagation of uncertainty, projection of the future consequences of present actions, optimal decision-making in the face of uncertainty). The other group focuses on collaboration (institutions, stakeholders, cooperative interactions, elicitation of stakeholder values and perspectives). It is important to incorporate stakeholder values when identifying objectives, acceptable management alternatives, and models that express stakeholders' perspectives. However, it also is important to frame collaboration in terms of science-based decision-making and the technical requirements for the reduction of uncertainty. At present, the collaborative and technical thrusts in adaptive management are being pursued separately. The challenge is ultimately to join the two in a more unified vision and process in which each reinforces and strengthens the other.

Adaptive management and sustainability. The idea of change over time is fundamental to adaptive management, whether in terms of changing environmental conditions, repeated adjustment of management strategies, or the use of dynamic models that characterize resource changes. By its very nature, adaptive management requires us to sustain resource structures and functions in order to sustain the ecosystem values that contribute to long-term objectives. In particular, adaptive decision-making has to be flexible enough to respond to the inevitable surprises that arise in resource management because only then can ecosystems and their values be dependably maintained in the future. Resilience, vulnerability, and risk all have important roles in adaptive decision-making, and their linkages need further examination and development.

Closing remarks. By highlighting uncertainty and using management to reduce it, the application of adaptive management can be expected to improve understanding of the consequences of management, and thereby improve management based on that understanding. Stakeholder involvement is key, both initially in the design of the management framework and throughout the iterative process. Equally important is the social and institutional learning that is achieved through periodic re-visitation of the "architecture" of decision-making. The tracking and adjustment of evolving stakeholder perspectives, values, and institutional opportunities can be as important as technical learning about the resource system.

The use of adaptive management is critical to achieving the North American Bird Conservation Initiative's vision of "populations and habitats of North America's birds protected, restored, and enhanced through coordinated efforts guided by sound science and effective management." This special issue of *The All-Bird Bulletin* thus highlights examples of adaptive management in the field of bird habitat conservation and management. Articles vary in the adaptive management elements emphasized and frameworks employed; some include social and institutional learning, while others focus primarily on technical advances as part of an iterative cycle of planning, implementation, and evaluation. In all cases, uncertainty of system status and response moves scientists and managers to employ management itself as a tool for learning and improving actions over time, whether it's on-the-ground activities or the decision-making process that leads to them.

Adaptive management holds great promise in expressing and reducing the uncertainties that keep us from managing natural resources effectively. In many cases, the use of management itself in an experimental context may be the only feasible way to gain the understanding needed to improve management. However, the approach does require considerable up-front investment of time and resources to build collaborative networks, to do the hard thinking about system dynamics and management objectives, and to design effective monitoring. The payoff for investing in these activities includes improved management over time as understanding increases. Of at least equal importance is the role adaptive management can play in promoting continuing support and engagement of stakeholders, without whose involvement the management of resources can be contentious, litigious, and ineffectual.

For more information on adaptive management, visit the Department of the Interior website at:
http://www.doi.gov/initiatives/AdaptiveManagement/TechGuide.pdf

Adaptive Management and Structured Decision-making for Shorebirds at Delaware Bay

Gregory Breese, Supervisory Wildlife Biologist, Delaware Bay Estuary Project, US Fish & Wildlife Service

Delaware Bay hosts the largest concentration of spawning Horseshoe Crabs on Earth. So many crabs spawn that they form a continuous line at the swash zone and dig up each other's eggs. The exhumed eggs form a rich source of food for shorebirds, particularly Red Knots. The Delaware Bay is probably the most important stopover in the Atlantic Flyway for the Red Knot because at this critical estuary, individuals double their weight before taking off for their high Arctic breeding grounds.

Continuous line of spawning Horseshoe Crabs at the swash zone. / Gregory Breese, USFWS

Humans also rely upon this abundance of Horseshoe Crabs. Watermen harvest them to use as bait for catching eel and conch (whelk). In addition, the medical industry captures Horseshoe Crabs and extracts Limulus Amebocyte Lysate (LAL) from their blood before releasing them. The LAL is used worldwide for testing anything that goes inside your body (e.g., flu shots, pacemakers, artificial joints, etc) to make sure it is not contaminated by bacteria.

In the 1990s, there was concern that Horseshoe Crabs were being overharvested. The newly established—and unregulated—conch fishery was creating a rapidly increasing demand for harvesting Horseshoe Crabs for bait. The "canary in the coal mine," so to speak, was the declining numbers of shorebirds at Delaware Bay.

Horseshoe Crabs lay their eggs too deep for shorebirds to use, exacerbating the effects of these declines. Wave action and successive waves of spawning Horseshoe Crabs bring some of the eggs to the surface, making them available for shorebirds. Meeting the energetic needs of shorebirds thus requires a "super abundance" of spawning Horseshoe Crabs. So even when it may appear that there are "plenty" of spawning Horseshoe Crabs, there may not be enough surface eggs for shorebirds.

Managing a population for "super abundance"—or excess eggs— relative to the needs of the population is not a typical management strategy. Likewise, managing a fishery for bird needs is not common. Managing for multiple uses (ecological needs, bait needs, and world-wide health safety) is difficult at best. Add these management challenges together and the situation rapidly becomes a divisive debate with little apparent common ground.

A large part of the problem is significant uncertainty about how the system works. How many eggs are needed for a given population level of shorebirds? How important are the eggs to the shorebirds? Are there other factors at work outside Delaware Bay that are driving the shorebird population? This uncertainty feeds the debate and makes setting harvest regulations a tense and frustrating task for the Atlantic States Marine Fisheries Commission (ASMFC).

This was the state of affairs in 2007, when the U.S. Fish and Wildlife Service (USFWS) and the U.S. Geological Survey proposed using adaptive management to the Atlantic States Marine Fisheries Commission. The term "adaptive management" has been used in many ways. In this case, it refers to a structured approach to management decision-making, where the decision is repeated over time, and one or more hypotheses about how the ecological system responds to management are explicitly incorporated and tested to reduce uncertainty over time.

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Creating this adaptive framework took a number of steps. First, training was needed in structured decision-making and adaptive management. Then conceptual models, or prototypes, were built and a small team tested the feasibility of the approach. After determining that this seemed like a good path to follow, the ASMFC Horseshoe Crab Technical Committee and the USFWS Shorebird Technical Committee met to begin the process of learning about adaptive management, to frame the decision, and to establish a modeling subcommittee to oversee the work. Finally, funding was secured and a post doc was hired to do the heavy lifting—developing the models and optimization to determine the best alternative. As the framework was developed, continued joint meetings of the two technical committees were held.


Red Knots double their weight at the Delaware Bay Estuary before migrating north to their breeding areas. / Gregory Breese, USFWS

At the core of this decision is how to harvest Horseshoe Crabs in a way that is supportive of shorebird needs. The committees framed and rewrote the following decision statement a number of times, eventually settling on the current wording:

"Maximize harvest of Horseshoe Crabs in the Delaware Bay with constraints that (1) harvest of female crabs is valued only when Red Knots exceed an abundance threshold or female Horseshoe Crabs exceed an abundance threshold. (2) Harvest of males is valued only when males do not limit Horseshoe Crab reproduction (conversely, Horseshoe Crab population growth rate will not increase with additional males in the population)." (A Framework for Adaptive Management of Horseshoe Crab Harvest in the Delaware Bay Constrained by Red Knot Conservation, November 2009)

While this may not be the most intuitive decision statement from the bird side of the debate, it captures well the decision from the Horseshoe Crab harvest management point of view. Harvest is the management action being considered. There is value to harvesting Horseshoe Crabs, but that value depends upon whether the harvest has a negative impact on shorebird populations. If the harvest has no negative impact on Red Knots, and it can be done in a sustainable way, it should be maximized if possible.

Since the value of conserving shorebirds may be in conflict with Horseshoe Crab harvest, constraints are placed upon the harvest, depending upon Horseshoe Crab or shorebird population sizes. Since the 1980s, the Red Knot population using Delaware Bay has declined and is currently at a low level, most likely due at least in part to reduced egg supply. So the harvest of female Horseshoe Crabs (which produce eggs and dig up each other's eggs) will only have value in this adaptive management framework when the Red Knot population is above a threshold size of 45,000. And the harvest of male Horseshoe Crabs will only have value if there are enough male Horseshoe Crabs to fertilize all the female Horseshoe Crabs spawning on the beach. This translates to a minimum value at a ratio of two males to every female on the beach during spawning, increasing to a maximum value at three males to every female.

In addition, it was recognized that there is uncertainty about what factors outside Delaware Bay may be driving shorebird populations. Some factor could be driving the shorebird population down, despite plenty of Horseshoe Crab eggs in Delaware Bay. So there is another constraint which says that if the female Horseshoe Crab population exceeds this threshold, set at 11.2 million, harvest is still valued because it is assumed that the eggs are not limiting shorebirds with that many female crabs in the Delaware Bay population. These statements were

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translated into mathematical "utility functions" that can be used with the population models to determine the best harvest level for a given population of Horseshoe Crabs and Red Knots. This optimization process, or finding the best harvest level, is done via computer programming that simulates the populations over time and repeats the runs multiple times to incorporate stochasticity—or randomness—for some parameters. The output from this program is a large look-up table that gives a harvest recommendation for a given population size.

Population models are used to test various hypotheses to learn more about the system and be adaptive in decision-making. Four population models are used: one for Horseshoe Crabs and three competing models for Red Knots, with the latter differing in how important a role egg supply at Delaware Bay plays. One model essentially ignores the egg supply in the Bay, thus testing whether factors outside of Delaware Bay are driving the Red Knot population instead of the egg supply. The second model uses egg supply (expressed as bird weight gain) to affect fecundity only. This tests whether egg supply affects productivity, but not survival of adult birds. The third uses egg supply to affect both adult survival and productivity.


Three competing models test the roles of horseshoe crab egg supply at Delaware Bay. / Gregory Breese, USFWS

Over time, as management decisions are made and the population changes monitored, it is likely that one or more of these three models will do a better job of predicting population changes than the others. Greater confidence (higher weights) can then be assigned to the better-performing models, giving them more influence in determining the best harvest action to take. Eventually, this should provide insight and reduce the uncertainty about how important the egg supply at Delaware Bay is for Red Knots.

Using adaptive management and structured decision-making has had great value in the divisive debate of setting Horseshoe Crab harvest regulations. By using a structured approach—driven by clear objectives with explicit hypotheses tested over time—uncertainty and concerns can be unequivocally incorporated into the models. For example, the concern over whether a male-only harvest might change the sex ratio on the beach enough to reduce egg fertilization was expressed by members of the technical committees as the models were being developed. This was incorporated into the framework by adding a utility function that limited the value of harvesting Horseshoe Crabs if the male-to-female ratio went below a threshold of two males to one female.

This fall, the ASMFC is using the adaptive management framework to set harvest regulations for the first time. The regulations will go into effect for the 2013 season. Meanwhile, the Red Knot is currently undergoing a listing determination.

While many threats to Red Knots are still present, it is believed that the threat from reduced food resources due to overharvest at Delaware Bay has been eliminated as long as the adaptive management framework and the critical monitoring programs that the framework depends upon remain in place.

To access the Adaptive Management Framework Report to the Atlantic States Marine Fisheries Commission, go the Commission's web site and look under Managed Species – Horseshoe Crab: http://www.asmfc.org/.
To read more about the Red Knot, visit: http://www.fws.gov/northeast/redknot/.

Creating Old-growth Forest Conditions for Red-cockaded Woodpeckers in the Georgia Piedmont: Using Adaptive Management to Plan Long-term Cutting Strategies

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Many bird species rely on the availability of old-growth forest habitats to carry out parts of their life cycle. Managers of these species face the challenge of making forest management decisions today that will assure a supply of old-growth forest habitat at key times and key places in the future, perhaps decades beyond their tenure. Rates of tree growth, competition by non-desired species, possible stand destruction by storms and other extreme events, and how each is affected under a changing climate, are all factors that the manager must take into account in decision-making. Uncertainty about any of these processes makes the decision particularly challenging, as today's actions may set a course of forest stand development that is hard or expensive to correct if better knowledge about the system is eventually gained over time.

Red-cockaded Woodpecker is an obligate species of mature pine forests in the southeastern United States. / Michael McCloy

The Red-cockaded Woodpecker is an obligate species of mature pine forests in the southeastern United States, occurring from Texas to North Carolina. The bird is most widely recognized as a resident of longleaf pine forests of the Coastal Plain physiographic province, but it also occurs outside of this pine type and outside of this province. In any setting, the habitat requirements are almost universal: a sparse overstory of mature pines with a few very old trees suitable for excavation of cavities, a nearly absent midstory, and a fire-maintained, herbaceous understory.

The Piedmont National Wildlife Refuge, located in central Georgia at the southern limit of the Piedmont physiographic province, is a mixed loblolly pine and hardwood forest that is managed for the woodpecker and other forest bird species. The Refuge and the adjoining Chattahoochee-Oconee National Forest host the largest population of Red-cockaded Woodpecker in the Piedmont province. For this reason, the U.S. Fish and Wildlife Service's recovery plan identified the complex as an important target for population recovery.

The National Wildlife Refuge System developed guidance on the amount and age class distribution of annual regeneration cutting required to create and sustain old-growth conditions. However, these prescriptions were modeled mostly on experience with longleaf pine forests of the Coastal Plain, and they follow static formulas that do not adequately recognize current age class composition. They also do not take into account the rate of succession from pine into hardwood in the Piedmont province. If this rate is relatively rapid, then the ability to create old-growth pine forest is limited, and a different management path would be needed to achieve this outcome. Unfortunately, this rate of succession is unknown, meaning that the most favorable outcome and the best path to it are also unknown.

How can forest regeneration cutting be planned so that this uncertainty is taken into account while pursuing the goal of attaining and keeping the most old-growth pine habitat over the long term? We developed an adaptive management framework to guide silvicultural management at the Piedmont National Wildlife Refuge, in which annual decisions about regeneration cutting are informed both by the current age class composition of the forest and by current knowledge about the rate of succession.

The fundamental objective of refuge managers is to establish a self-sustaining population of Red-cockaded Woodpecker, but as the bird's biology is so closely tied to old-growth habitat, attaining and sustaining a stream of old-growth forest over time is a pre-condition for that objective. Therefore, our decision framework sought to maximize old-growth forest acreage over an indefinite time horizon.

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Each year, managers are able to estimate the distribution of forest over four age classes of pine (0-16 years, 16-40, 40-80, 80+) and a single class of upland hardwood. Because the refuge relies on private contractors to cut and market the timber, the menu of feasible management actions is limited to harvest within each of the three merchantable age classes of pine: 16-40, 40-80, and 80+. Thus, the decision framework provides an annual recommendation of how much timber, refuge-wide, is to be taken from each of the three classes. Once decisions about total harvests are made, a compartment rotational schedule and supporting models determine where to spatially allocate the harvests.

Red-cockaded Woodpecker site located at Piedmont National Wildlife Refuge. / Piedmont NWR, USFWS

At the heart of the decision framework is a set of models that make alternate predictions about the effects of regeneration harvest under three competing hypotheses about rate of hardwood succession. These hypothesized rates cover the range of plausible values for the unknown parameter—from a low value that suggests that succession does not pose a threat to achieving and sustaining a high volume of old-growth habitat, to a high value that suggests that the goal will be elusive and hard-fought. Aside from the succession rate parameter, the models are identical. They predict next year's distribution of forest among the five seral classes as an outcome of this year's distribution, harvests taken from the marketable pine classes, random losses of forest overstory due to environmental disturbances (fire, wind, insects, etc.), and successional conversions of pine to hardwood.

We used a special optimization algorithm that accounts for how the forest changes through time in response to managers' actions and to random disturbances. Moreover, the algorithm takes into account how relative belief in each of the three succession rate hypotheses changes in response to those same inputs. That is, some harvest actions are expected to be informative about succession rate, whereas others are not. If uncertainty about succession rate is so great that it is expected to impede decision-making for a long time, then an optimal harvest action might be one that attempts to purposely "poke" the system to get a response that quickly resolves the uncertainty. In this way, some short-term forest gain is sacrificed in order to learn some key information that helps to maximize long-term outcomes. In other situations, an aim to learn may be set aside if the forest is in a precarious state for quickly generating or maintaining old-growth habitat. In such a case, a conservative, short term action formulated around a pessimistic scenario would be the best option. The optimization algorithm evaluates these tradeoffs and provides an optimal recommendation for harvest that is keyed to current forest class composition and current belief in each hypothesis.

Monitoring is the engine that drives the decision-making process forward. An annual assessment of forest class distribution serves three purposes. First, it describes the current state of the forest, which is the entry point to the decision tool. Second, it informs the manager about progress toward the main objective of accumulation of old-growth forest. Third, it updates knowledge about the rate of hardwood succession by comparing predictions of outcome by the three competing models against the observation of what was actually produced. To the extent that a particular model provides a closer prediction than the others, it wins greater influence in the next round of decision-making. If this model were to consistently predict better than the others, uncertainty about the behavior of the system is progressively reduced, and management would eventually "adapt" around the predictions of this particular model.

All of the technical pieces of an adaptive management framework for forest regeneration cutting at the refuge are now complete. Unfortunately, annual refuge-wide monitoring of forest status is challenging and has not been implemented. Therefore, until a strategy for monitoring can evolve, this decision-making framework remains on hold. However, the framework is instructive in demonstrating how the enterprises of science and management can be integrated to achieve desired conservation outcomes, particularly when the path to those outcomes remains unclear.

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Managing Habitat for Florida Scrub-Jays at Merritt Island National Wildlife Refuge

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For a variety of reasons, making management decisions is often challenging. Sometimes managers have difficulty predicting the response of the ecological system to various management interventions. In other cases, the management objectives may be complex, contradictory, or in dispute. In still other instances, all of the possible alternative actions for achieving management objectives may not be apparent. For these reasons, there have been increasing calls in the conservation community for a structured approach to decision-making, including application of adaptive management principles.

Fragmentation and fire suppression threaten habitat of the endemic Florida Scrub-Jay. / David Breininger

Formal methods of decision-making in natural resource management combine dynamic models of an ecological system with a statement of objectives, so that the outcomes of alternative management actions can be evaluated. A common decision-making problem involves a temporal sequence of decisions, where the optimal action at each decision point depends on the state or condition of the ecological system. The manager's goal is to develop a decision rule (or management strategy) that prescribes an optimal action for each possible system state. Examples of this kind of decision problem in conservation include direct manipulation of plant or animal populations through harvesting, stocking, or transplanting, as well as indirect population management through manipulation of habitat.

A key challenge in a so-called sequential decision process is accounting for uncertainty in the predictions of management outcomes at each time step. This uncertainty may stem from incomplete control of management actions, errors in measurement and sampling of ecological systems, environmental variability, and incomplete knowledge of system behavior. A failure to recognize and account for these sources of uncertainty can significantly depress management performance and, in some cases, lead to severe environmental and economic losses. Accordingly, there has been a growing interest in methods that can account for uncertainty about the dynamics of ecological systems, and their responses to both controlled and uncontrolled factors. And the popular notion of adaptive resource management involves efforts to account for how the degree of uncertainty may change over time, and how that might affect subsequent decisions.

We have been applying these methods of structured decision-making and adaptive management at Merritt Island National Wildlife Refuge (MINWR) in an effort to help ensure the local persistence of Florida Scrub-Jays. The Florida Scrub-Jay is an endemic species that is designated as threatened under the Endangered Species Act. Scrub-jays are restricted to Florida scrub (hereafter, just scrub), which is a rare habitat characterized by evergreen oaks, shrubby palms, and shrubs of the heather family. Scrub is maintained by frequent fire, and landscape fragmentation and fire suppression have resulted in many scrub communities in Florida that are no longer capable of supporting scrub-jay populations. Prescribed burning has thus become the primary management tool in reserves where the viability of scrub-jays and other scrub species is an important objective. Consequently, managers at MINWR are routinely faced with a decision of whether to conduct a prescribed burn in a particular management unit. In addition, scrub sites with a long history of fire suppression first require restoration, which involves cut-

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ting of all the scrub so it can be burned effectively. Decisions concerning restoration and prescribed burning are difficult because of an incomplete understanding of fire dynamics, plant community succession, and the responses of scrub-jays to management and a variety of other environmental factors.

Based on an objective to ensure long-term persistence of scrub-jays, we determined that managers should strive to maximize the amount of medium-height scrub. The optimal management action thus depends on the composition of scrub heights in a particular management unit. Restoration, in which all of the scrub is cut to ground level and then burned, is the optimal action only if a management unit is dominated by tall scrub. This is due to the short-term sacrifice in scrub-jay reproductive success associated with restoration. Burning tends to be the optimal action when there is little short scrub left on either restored or unrestored sites. This helps maintain a temporal stream of the preferred, medium-height scrub, while avoiding the tall scrub that is difficult to burn. Finally, the optimal action is to do nothing whenever the amount of short scrub is ≥20 percent, regardless of the composition of the other scrub classes and whether the unit was previously restored or not. The likely reason for this is that short scrub mostly transitions to the preferred, medium-height scrub in the absence of any intervention. Perhaps most importantly of all, however, we concluded that even an optimal use of restoration and burning would not be expected to ensure persistence of scrub-jays over the long term.

Medium height scrub is the optimum habitat for Florida Scrub-Jays. / Fred Johnson, USGS

Our structured approach to decision-making led to a number of interesting insights and provided a useful first step in the development of an improved habitat management program for scrub-jays at MINWR. First, our analysis clarified the difficulties associated with ensuring the persistence of a species that requires mid-successional habitat. Such habitat is transient by definition, and maintenance of adequate amounts of such habitat may be very difficult. This difficulty points to another important message of our analysis—that effectiveness of management may be much more limited than is appreciated or recognized. Appreciating the limits of current management actions is important and is not an uncommon outcome of serious decision analysis. This recognition is now prompting MINWR managers to think hard about developing new approaches to habitat and/or scrub-jay management that have better potential to ensure scrub-jay persistence.

Since we conducted our initial analyses MINWR has taken a more aggressive approach to the problem of managing scrub-jay habitat. New aerial imagery has been acquired that will allow a better understanding of scrub dynamics and associated sources of variation. The Refuge, in collaboration with one of the authors of this article, has intensified and expanded efforts to monitor the demography of scrub-jays in response to management activities. Finally, and perhaps most importantly, the Refuge has begun to explore innovative management techniques for setting back succession in tall scrub, and for ensuring that scrub-jay habitat requirements beyond proper scrub height (such as bare ground) are achieved and sustained. Thus, our decision analysis effectively promoted so-called “double-loop learning,” in which the basic elements of adaptive management (objectives, actions, predictive models, monitoring) are periodically revisited and revised to more effectively address conservation goals.

Postscript: In spite of the challenges, MINWR has recently made significant progress in managing habitat for Florida Scrub-Jays. An aggressive program to restore old-growth scrub, combined with improved burning strategies, has helped improve the chance that scrub-jays will persist on the refuge. The principal challenges now confronting MINWR managers are to reduce the inventory of tall scrub and to provide more sandy openings in medium-height scrub. Prescribed burning continues to be a useful tool, but managers now have evidence that

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Adaptive Management of Shrub Habitats to Support High Priority Early-Successional Species

Lindsey Fenderson, Biological Science Technician, Rachel Carson National Wildlife Refuge, U.S. Fish and Wildlife Service

Native shrublands have declined significantly throughout the Northeast and are growing increasingly scarce. Forest maturation and development have fragmented and reduced the availability of early-successional habitat. Additionally, flood control, beaver management, and fire suppression regimes have severely limited the renewal of this ephemeral resource. In many areas, young forest is as rare as old-growth forest.

Four national wildlife refuges in the northeast are testing management strategies, such as prescribed burns, for creating and improving native shrubland habitat for trust species. / USFWS

Consequently, many shrubland-dependent species, such as the Blue-winged Warbler, have become increasingly rare. Shrub communities provide critical breeding and non-breeding habitat for regionally declining Neotropical migrants, as well as the New England Cottontail, a Candidate Species for federal listing under the Endangered Species Act. Although the New England Cottontail has the greatest dependency on these dwindling shrublands, numerous other species utilize these important early-successional habitats, including 136 species of butterflies, moths, birds, reptiles, other mammals, amphibians and beetles, all of which have been identified in northeastern states as Species of Greatest Conservation Need. Additionally, several shrub-dependent bird species, such as the American Woodcock and Golden-winged Warbler, have declined significantly in the Northeast from lack of habitat availability and have been identified by Atlantic Coast Joint Venture plans as priority species of concern.

Preservation of shrubland-dependant species will therefore require restoration and maintenance of early-successional habitat. However, unlike managing for grasslands and mature forest, techniques for creating and maintaining early-successional habitat are not well established. We have insufficient knowledge concerning the most effective means for creating new native shrublands, and methods for maintaining these communities are also needed, since these ephemeral habitats typically undergo rapid succession. Moreover, developing shrublands are frequently colonized by non-native invasive plants that may degrade habitat quality for these target early-successional species. We currently have a limited understanding regarding the best methods for managing shrub-dominated habitats that contain invasive plants.

Adaptive management provides a way for resource practitioners to improve management practices and achieve management goals more effectively when there are uncertainties regarding the best approach. Adaptive management complements empirical studies to promote good management decisions given the current state of knowledge. Whereas experiments can help answer specific management questions, adaptive management techniques are more appropriate when a management decision must be made, but uncertainties exist regarding potential management impacts and outcomes. Not just a "trial and error" approach, adaptive management is a structured decision-making process that entails careful consideration of all possible management actions for the stated objective, predicting multiple alternative outcomes of implementing those actions, identifying uncertainties, and estimating the risk associated with each possible outcome. Models are then developed to test the predicted outcomes of proposed management actions. Once management actions are implemented, monitoring data is collected at regular

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intervals to evaluate the response of the system. These data are used to update the models in each time-step and compare the effectiveness of the management strategies, thereby improving future management actions by promoting learning and the reduction of uncertainty in an iterative process.

An adaptive management approach is thus ideal to address the key uncertainties in managing for high-quality native shrublands. There is an urgent need for actions that promote these habitats, despite the uncertainties regarding invasive species management impacts and balancing desired outcomes with economic feasibility. To address this need, four national wildlife refuges—Rachel Carson, Parker River, Eastern Massachusetts Complex, and Rhode Island Complex—are participating in an adaptive management study designed to determine how to manage these critical shrub habitats against invasive species while simultaneously maintaining structure and habitat value for trust resources such as breeding and migratory landbirds and New England Cottontail. This study will allow refuges to test different management alternatives to learn how best to preserve biological diversity and ecological integrity while providing native shrub habitat for priority early-successional species. The overall project objectives are to:

- Identify best management practices for converting grassland to native shrubland.
- Identify best management practices for enhancing and improving the quality of current shrub habitat.

The Eastern Towhee is one of numerous migratory birds that will benefit from the creation of native early-successional habitat in the Northeast. / Bill Thompson, USFWS

Two or three specific primary objectives were identified by each refuge: Create high-quality winter habitat for New England Cottontail (Rachel Carson and Rhode Island Complex); provide high-quality shrubland habitat for fall migratory birds (Parker River, Eastern Massachusetts Complex and Rhode Island Complex); and preserve biological diversity and ecological integrity (all refuges). Each refuge selected a minimum of two sites for implementing one of the management scenarios (converting old fields to shrubland or converting perceived low quality existing shrubland to native, high quality shrub habitat). Finally, two competing models were developed for each refuge, to determine whether a low-intensity management treatment, or a somewhat more expensive moderate-intensity management treatment, is most effective at transforming habitats to desired conditions. Key uncertainties addressed by this project include:

- Is it feasible, cost-efficient, and prudent to create and maintain high-quality native shrublands?
- What are the best management strategies and what are the costs for restoring native shrublands?
- How many years will it take to achieve desirable vegetation communities and structure, and what are the short-term costs to resources of concern (migratory birds and New England Cottontail)?
- Does dormant season fire increase stem densities (i.e. improve New England Cottontail winter habitat cover)?

Protocols were established for seven monitoring metrics to evaluate the relative success of the treatments and models. Refuges with a New England Cottontail focus survey for cottontail presence/absence on the site and inventory stem density cover. Refuges with priorities of providing native shrub habitat for fall migratory birds monitor the vertical vegetation density of the patch with Robel pole measurements and quantify fall avian berry abundance and availability. The relative frequency of native species, a desired conditions index, and percent invasive species cover metrics were used by all refuges to monitor the ecological integrity of the managed sites. Monitoring data were collected in 2008, prior to initial management activities, to document initial site conditions, test protocols, and facilitate power analyses. A range of treatments were implemented across the four refuges beginning in 2008, and subsequent data have been collected biennially through 2012. Monitoring at two-year intervals will inform models designed to assess which treatment options best meet habitat objectives.

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Due to the response time required to observe changes in vegetative structure and communities, more time is needed to accurately assess the results of the implemented treatments. While the models are providing some preliminary information concerning best management practices for native shrubland, system responses lag behind treatments. Refuges plan to continue monitoring for several more years to determine the best model.

The New England Cottontail is in critical need of dense shrubland habitat to improve its winter survival and population status. /John Greene

Nevertheless, having standardized monitoring protocols across multiple refuges permits regional comparisons and offers a landscape-scale context for refuge issues. Additionally, a collaborative approach provides efficiency through division of labor and resources, and further improves problem-solving capabilities with group learning and knowledge. The lessons learned on these four refuges will be applicable to all the refuges and land management agencies throughout the Northeast that are managing for shrub habitat, especially those that are threatened by non-native invasive plant species and are utilized by migratory birds and/or New England Cottontail.

For more information, contact Lindsey Fenderson at lindsey_fenderson@fws.gov.

From Scrub-jay, *Page 11*

demonstrates it must be used frequently and under environmental conditions that promote its efficacy. We also have determined that limited cutting of tall scrub (rather than restoration involving cutting of all scrub) in combination with burning can be expected to prevent scrub-jay abundance from declining. Additional management costs would be incurred, but the increase would be expected to be relatively small even if, as we assumed, cutting is ten times more expensive than burning. Total cost could be further reduced if managers could find ways to increase the effectiveness of burning, such as burning when conditions are hotter and drier than those typically permitted because of smoke and fire hazards. Even under the best of circumstances, however, it appears there would need to be some form of management intervention in each management unit every 1-2 years.

A prescribed burn reduces scrub height at Merritt Island NWR ./ M. Epstein

For more information, contact Fred Johnson at fjohnson@usgs.gov or download a technical article describing the study at http://www.fwspubs.org/doi/pdf/10.3996/012011-JFWM-003.

The Integrated Waterbird Management and Monitoring Initiative: Structured Decision-making in an Adaptive Framework

Jorge Coppen, North American Waterfowl Management Plan Coordinator, U.S. Fish and Wildlife Service

Is there enough of the right habitat, in the right places, and at the right times for waterfowl, shorebirds, and wading birds (waterbirds) during migration and in winter? Management decisions made at flyway, regional and local scales are often made without the necessary cross-scale coordination that is required to effectively answer this question for migratory species such as waterbirds.

Many national wildlife refuges (NWR) and state wildlife management areas (WMA) were acquired for the primary purpose of supporting migrating and wintering waterbird populations. Local managers need quantitative information about the overall and relative value of these lands, and how they help sustain waterbird populations during the non-breeding season. It is often difficult, however, for local managers to place their wetlands in a flyway context and identify the most important habitats and waterbird species within a strategic approach.

National wildlife refuges and state agencies devote substantial time and energy to monitoring migrating and wintering waterbirds. Waterbird monitoring efforts would benefit, however, from standard protocols, a central database, and coordination, which would promote science-based planning and decision-making for these species.

The Integrated Waterbird Management and Monitoring (IWMM) project. The IWMM project combines management objectives, standardized monitoring protocols, databases, and decision modeling in an adaptive management framework at flyway, regional, and local scales to guide management decisions about where to focus time and other resources for habitat management and restoration. Management decisions are thus adaptively linked within and across scales, making them more efficient, effective, and transparent. The overall goal is to provide precisely the information that is needed for better management decisions to support waterbird populations throughout the Atlantic and Mississippi Flyways.

For example, by integrating waterbird movement models with structured decision-making, the IWMM models will provide recommendations on how best to distribute financial resources at the regional level and which habitat management strategies are most effective and efficient to undertake at the local level based on where waterbirds are located through time (Fig. 1).

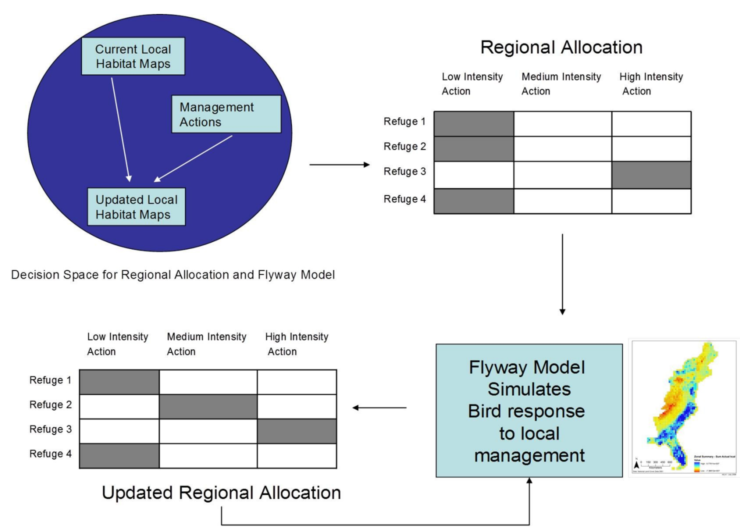

Figure 1. Diagram of decision-making framework and model updating (arrows) at three spatial scales

Annual decisions must be made about which management strategy, and where, is most appropriate to achieve objectives. This integrated model set guides resource allocation and habitat management decision-making in support of continental waterbird population goals. Priorities at the flyway scale are stepped down to inform regional scale decisions. The regional/state also takes into consideration their priorities. Here the decision is to how best to direct financial and human resources to support migratory bird objectives. Objectives and priorities at the individual management sites (e.g., NWRs, WMAs, private lands) then can be evaluated and approved in the context of flyway/continental and regional/state goals and objectives. Once management objectives are approved, resources (e.g., funds or staff) are allocated to sites so that objectives may be met most efficiently.

Existing waterbird conservation plans that identify priority species and population objectives will be used in conjunction with the IWMM flyway model to set regional and local waterbird priorities. This process can be stepped

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down to develop site-specific planning documents. It works by altering the initial allocation and repeating stochastic dynamic programming and simulation steps, until the stopping criterion has been reached (Fig. 2). The optimal solution is reached when the simulated results of management approach the most cost-effective scenario for addressing habitat gaps observed in the flyway scale habitat map.

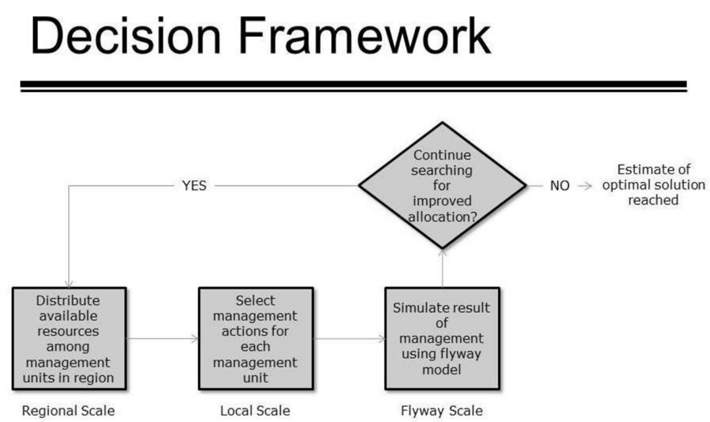

Figure 2. An algorithm searches for an optimal allocation and determines both the stopping criterion and the method for altering the allocation among sites.

The Role of Monitoring. Monitoring information collected at the local scale can be rolled up to address questions at larger scales. The information gained through monitoring and evaluation will be used to inform models at each respective scale with some monitoring information providing utility for decision-making at multiple scales.

For example, the regional-scale modeling exercise attempts to allocate resources across landscapes most efficiently to fill in habitat gaps observed in a flyway-scale habitat map. Monitoring of local-scale habitat conditions and bird response are used in an adaptive management loop which feeds back to the regional-scale resource allocation models.

Given limited resources, a key challenge involves dovetailing cross-scale monitoring and evaluation frameworks to serve two sets of objectives: biological and fiscal. By using consistent monitoring protocols to inform management decisions, we can better detect if locally managed lands are collectively meeting large-scale waterbird habitat quantity and quality requirements. As new information is obtained through monitoring and evaluation procedures, the IWMM models will be updated to provide revised recommendations reflecting the most current scientific understanding available. This ultimately results in feedback reports to local and regional decision-makers.

Monitoring protocols are designed to be simple enough that volunteers can be trained to conduct the monitoring efforts. For population monitoring protocols, we are currently exploring opportunities for aerial surveys paired with ground surveys in select locations to identify methods for cross-walking aerial and ground surveys. Additionally, the costs of management actions are also captured for purposes of informing regional scale resource allocation decisions. The standardized monitoring protocols will allow for flyway-wide compilation of data, shorter learning times compared to multiple, isolated monitoring efforts, and over time, maximum collective value of managed wetlands for migrating and wintering waterbirds.

The Flyway Model. At the flyway scale, the primary decisions involve resource allocations for an appropriate quantity and quality of habitat at a set of stop-over and wintering sites to meet the energetic demands of the target populations of migrating and wintering waterbirds. The alternatives are portfolios of stop-over and wintering sites along the flyways where waterbird habitats exist as a result of active management. Management of these sites focuses on increasing patch quality (increase forage and roosting habitat quality, lower disturbance) and/or increasing patch quantity and density (habitat acquisition). The challenge is to optimize recruitment or non-breeding survival via these two options. These decisions are made by management agencies and coordinated through the migratory bird joint ventures.

The Flyway Model incorporates publicly available GIS layers (e.g., National Land Cover Database) to develop a map based on kilo-

Flyway model inputs include:
- GIS maps of calories, disturbance level, amount of shoreline
- Bird parameters (species specific)
- Weather
- Start and end locations (species specific)
- Body condition at beginning of migration (species specific)

Flyway model outputs are:
- Spatial depiction of bird use days
- Daily survival and migration survival
- Measure of variance due to weather, starting body condition, bird parameter variability
- Sensitivity of individual inputs to output metrics
- Updated calorie maps

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calorie, disturbance, and shoreline parameters. If a critical location is currently unprotected or is lacking appropriate habitat quantity or quality to meet waterbird needs at appropriate times, important areas for protection can be identified and further management at important sites will receive greater attention and resources during any given year.

The Regional Model. Priorities at the flyway scale are stepped down to inform regional scale decisions. At the regional (or state) scale, we can allocate resources (funds or staff) to those management sites where the greatest waterbird return on investment can be realized. Regional/state decision-makers will evaluate waterbird priorities and allocate resources for the attainment of waterbird objectives at individual local sites. Allocation of resources is a continuum from equal allocation among management sites, to all resources being assigned to one management site.

The Local Model. Due to the dynamic nature of wetlands, different conditions within a wetland are often presented to a manager each year. At the flyway scale under different climatic conditions, one location may become more important than another in any given year based on the energetic needs of the birds. Annual decisions must be made about which management strategy, and where, is most appropriate to achieve objectives based on flyway, regional, and local models.

Managers develop and propose priority objectives for individual local sites such as refuges, state wildlife management area, and private lands, and document them in management plans. Using the outputs of the flyway and regional models to inform the local-scale models, management actions can be allocated and coordinated across individual sites to maximize the benefits to waterbirds (Fig. 3).

In the IWMM initiative's local scale models, management actions encompass all potential habitat actions individual site managers can undertake. Potential actions range from passive "allow nature to take its course" management, to acquisition of new lands, to manipulations implemented within wetlands (e.g., drawdown, prescribed burn, discing, herbicide treatment, predator control, etc.). Management alternatives may include a combination of these actions. Together, the different combinations of actions form alternative management scenarios. Alternative actions and scenarios are aimed at managing the quantity, quality, and availability of wetland habitats under the constraint of available resources to achieve goals and objectives for waterbirds at flyway and continental scales.

For more information, visit the web portal:
http://iwmmprogram.ning.com

Regional model inputs include:
- Budget available for each region, state, other managed land
- How each site is evaluated (flyway model and local model)
- Relative importance of each species/guild
- Flyway model habitat status map
- Local model data

Regional model outputs:
- Distribution of resources
- Change at local and flyway scale due to allocation (rolled up from local scale monitoring)

Local model inputs include:
- Management actions (including do nothing)
- Costs
- Transitions for each action (i.e., how the land cover changes): habitat quality metrics, availability metrics, disturbance metrics
- Objectives- relative bird weights
- Bird habitat preferences (HSI), roosting and feeding
- Current land cover

Local model outputs include:
- Bird response to management
- Habitat response to management

Simple Example – Management Actions

Site	Action	Cost
Local Site A1	Low Intensity	$10.000/yr
	Medium Intensity	$50,000/yr
	High Intensity	$90,000/yr
Local Site A2	Low Intensity	$30,000/yr
	High Intensity	$80,000/yr
Local Site B1	Low Intensity	$60,000/yr
	Medium Intensity	$100,000/yr
Local Site B2	High Intensity	$90,000/yr
Local Site B3	Medium Intensity	$50,000/yr
	High Intensity	$90,000/yr

Figure 3. Example allocation of management actions across local sites.

The 2012 Revised North American Waterfowl Management Plan: A Call for Integration and Innovation

Jim Ringelman, Director of Conservation Programs – North Dakota, South Dakota, Montana, Ducks Unlimited

Bold advancements in waterfowl conservation are usually spurred by crisis. The depletion of waterfowl populations by market hunters prompted the Migratory Bird Treaty Act and the creation of the federal refuge system. The drought of the 1920s, motivated the Duck Stamp Act and the founding of waterfowl-focused, non-profit organizations like Ducks Unlimited. The duck crisis of the early 1980s prompted the creation of the North American Waterfowl Management Plan (NAWMP) and the Joint Venture (JV) approach to delivering conservation, which celebrated its 25th anniversary in 2012.

Greater Scaup is found primarily on lakes, ponds, and bays and is mostly marine in winter. / Dave Menke, USFWS

NAWMP accomplishments during the last 26 years speak volumes about the effectiveness of the JV model. Since 1986, NAWMP partners have invested more than $4 billion in the protection and restoration of 15.7 million acres of wetlands and associated habitats. Of equal importance, they have helped shape land use, agricultural programs, and other public policies critical to sustaining continental waterfowl populations. These accomplishments were guided by scientific investigations and sophisticated planning tools, which ensured targeted and effective program delivery.

Today, we are facing another crisis, this time unrelated to waterfowl numbers. Some contemporary concerns, such as accelerating habitat loss, are all too familiar to conservationists. Others, most notably an eroding base of support for conservation programs, are new challenges. Collectively, they have motivated stakeholders to come together to reassess the status of waterfowl conservation and confront the challenges of a new age. That reassessment kindled interest in revising the NAWMP. But why is a new Plan necessary when ducks and geese are doing so well?

Record high commodity prices are accelerating the plowing of grasslands across the prairie, eliminating the nesting cover for upland-nesting ducks. Isolated wetlands like prairie potholes have lost federal protection in the U.S., and future Farm Bills and weak state and provincial wetland policies are unlikely to inhibit future wetland drainage. Increased energy consumption has led to new policies that drive increases in domestic energy production. Oil, gas and coal developments are disrupting boreal, arctic, coastal and even prairie ecosystems. Erosion of shorelines, salinization of freshwater coastal marshes, and "dead zones" in estuaries and the Gulf of Mexico continue to degrade critical winter habitat. As world demand for food, fiber and energy increases, so too will these impacts.

Against this social and environmental backdrop, the waterfowl management community came together and agreed that the time was right to take a fresh look at the challenges ahead and reconsider the way that business was being done. A revised NAWMP would be the foundational planning document, but first the viewpoints and concerns of the waterfowl management community had to be heard. To accomplish this, fifteen consultation workshops were held in the U.S., Canada and Mexico. The participants, who represented a diversity of occupations and expertise, were asked to reconsider the fundamental goals of waterfowl management and suggest measurable, step-down objectives to achieve those goals. The input from these workshops was used to formulate three goals for a revised NAWMP: (1) Abundant and resilient waterfowl populations to support hunting and other uses without imperiling habitat; (2) Wetlands and related habitats sufficient to sustain waterfowl populations at desired levels, while providing places to recreate and ecological services that benefit society; and (3) Growing numbers of waterfowl hunters, other conservationists and citizens who enjoy and actively support waterfowl and wetlands conservation.

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A *New Goal for People*. Population and habitat goals have always been foundational to the NAWMP, but an explicit goal related to people is new. Why did people emerge as a primary goal in a waterfowl plan? Essentially it's because we have tended to take people for granted. The NAWMP, which was revised in 2012, advocates that the needs and desires of people must be clearly understood and explicitly addressed. This important distinction—humans as a focus of management actions versus simply a recipient of management outcomes—was intended to motivate the waterfowl community to expand its understanding of waterfowl hunters, viewers, and the public through social science research, and empower managers to establish and act on human objectives in concert with habitat and population programs.

The NAWMP 2012 Revision includes a new goal for clearly understanding and addressing the needs and desires of people. / George Gentry, USFWS

One trigger that motivated this goal was the decline in waterfowl hunters, who have provided financial support for waterfowl conservation for nearly 80 years. In the U.S., sales of Duck Stamps have generated more than $850 million—funds that have been used to help purchase or lease over 6 million acres of waterfowl habitat. Hunters have also been effective advocates for policies that fund programs and conserve habitat. So historically, ducks have needed hunters as much as hunters have needed ducks. But we tended to take this symbiotic relationship for granted until the late 1990s, when we began to see that the old paradigm—abundant waterfowl and liberal regulations will result in more hunters—no longer applied. Duck numbers were rebounding, but hunter numbers were not.

As NAWMP partners considered the challenge of hunter recruitment and retention, they also realized that the long-term sustainability of waterfowl conservation will depend on broadening the base of support to include other dedicated "users" such as birders and photographers. In contrast to the decline in hunters, interest in viewing waterfowl is popular and growing. Today, some 15 million people in the U.S. travel a mile or more from home to view waterfowl. That's over 10 times the number of waterfowl hunters in the U.S.! Some of these individuals already support conservation through the purchase of Duck Stamps, entrance permits, or through membership in conservation organizations. Enhancing non-consumptive user support and activism for conservation will be critical to the future of waterfowl.

Lastly, in this age of increasing fiscal austerity, one cannot hope to sustain public funding for conservation programs unless support from the general public grows. But how does one accomplish this with a public that is increasingly disconnected from nature? The revised NAWMP suggests two approaches. First, one can foster a greater emotional attachment by increasing the opportunities for people to view and interact with waterfowl through, for example, urban refuges or enhanced educational opportunities at select wildlife areas. Second, one can appeal to people's concerns over declining water quality, increased flooding, and other environmental concerns that are ameliorated by habitat projects for waterfowl. The new NAWMP recognizes the need to "connect the dots" so the average citizen recognizes that an investment in waterfowl conservation is also an investment in things they care about. This will require public engagement strategies of a kind never before undertaken by our community.

More Effective and Efficient. A second dimension to the 2012 revised NAWMP is a recognition of the need for waterfowl management to become more efficient and effective. From the outside looking in, waterfowl management would seem to be a well-oiled machine that has been operating for nearly a century. However, both the efficiency and effectiveness of our systems need to be improved. For example, the flyway system, which manages population and harvest, operates on a very strong scientific foundation. However, its vertical institutional structure harbors significant inertia and thus does not always adapt quickly to change. The 2012 revised NAWMP advocates that the flyways examine how they can become more adaptable, and consider how their investments and decisions can help address all three goals of the revised NAWMP.

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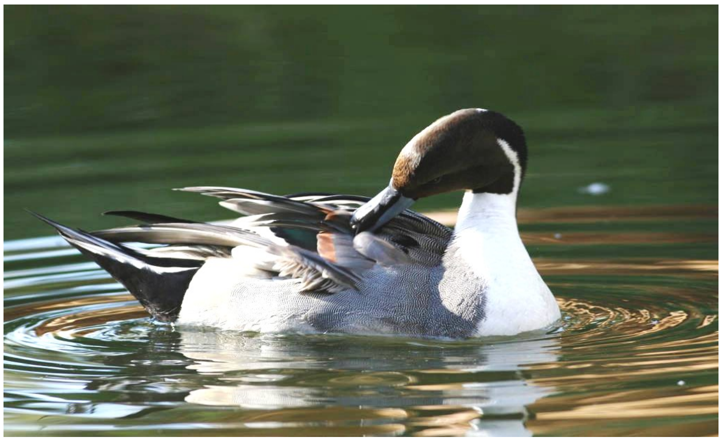
The habitat management community, embodied by the migratory bird JVs, is a younger and more horizontally integrated system. Decisions are made at local and regional scales and, unlike the flyways that make most decisions on annual time steps, JVs tend to look towards a longer time horizon. However, the regional partnership nature of JVs can tend to disperse conservation resources, as opposed to focusing them in areas most critical nationally and continentally. The challenge of focusing resources on the most important landscapes is advocated in the 2012 revised NAWMP.



One of the earliest nesting ducks in North America, Northern Pintail begin nesting shortly after ice-out . / Dan Cox

Lastly, there is a vital need for an institution that uses contemporary social science research to better understand and address the needs of people and their roles in conservation. Thus, the NAWMP proposes the creation of a Human Dimensions Working Group that would bring scientific rigor to our management decisions related to people. In retrospect, this third leg of the waterfowl management stool is long overdue.

The challenge is to essentially connect these three streams of waterfowl management— population management, habitat conservation, and human dimensions—so they function as one engine that drives all of waterfowl conservation and management. The theme of integrating these three streams figures prominently in the 2012 revised NAWMP. It involves the creation of a linked decision framework that would have everyone working towards common and coherent objectives, coordinating management actions, and evaluating our collective progress.

Such a system of management would consider social as well as ecological matters, and would feature the familiar elements of an informed decision process, specifically: (1) objectives that are measurable and provide unambiguous guidance to decision makers, (2) system models that link objectives and ensure coherence across scales, (3) targeted monitoring programs that track progress toward objectives and facilitate learning and adaptation, and (4) institutional processes and structures that facilitate integration and adaptation. This last element will require an organizational culture and processes that support creativity, flexibility, justified risk-taking, and a focus on learning.

Managers and researchers will quickly recognize that this new system reflects an adaptive management framework—a structured, iterative process of planning, implementation and evaluation. The merits of adaptive management were highlighted in the 2004 update to the NAWMP, where the approach was advocated for conservation planning and delivery within JVs. At that scale of management and learning, managers would ask themselves “Are we doing things right?” And, occasionally, the deeper question of “Are we doing the right things?” The NAWMP revision contemplates an even larger adaptive management question: “Do we have the right processes and institutions in place to achieve our goals?” The answer to that question will guide waterfowl conservation in the decades ahead.

NAWMP partners have achieved much in the last quarter-century, but many challenges remain. Today’s world is fundamentally different than when the Plan was conceived in the early 1980s. The new NAWMP reaffirms a commitment to waterfowl conservation in all its dimensions and sets a course to meet future challenges by becoming more adaptable, more efficient, and more relevant. The innovative work of thousands of waterfowl conservationists over the last century has positioned the waterfowl community to evolve and succeed yet again.

North America was endowed with the greatest diversity and abundance of waterfowl on earth. The 2012 revised NAWMP will steward and secure that legacy for current and future generations. For more information on the 2012 NAWMP Revision and to download the Plan, visit http://nawmprevision.org/.

Restoring the Wild Heart of South San Francisco Bay: The South Bay Salt Pond Restoration Project

Laura Valoppi, U.S. Geological Survey, Lead Scientist, South Bay Salt Pond Restoration Project

Tony Bennett's iconic song about leaving his heart in San Francisco conjures up images of the Golden Gate Bridge and trolley cars. But there is another heart of San Francisco, the wild heart, which a partnership of state, federal, and private foundations are working to restore. The center of all this activity is near Silicon Valley, at the south end of the Bay, home to such technology companies as Google, Facebook, and Apple.

Salt marsh habitat in San Francisco Bay supports marsh-dependent animals such as the California Clapper Rail, Black Rail, and Salt Marsh Harvest Mouse. In 2003, the partnership purchased over 15,000 acres of industrial salt ponds from Cargill Corporation, and began the largest wetland restoration project on the West Coast. The 50-year South Bay Salt Pond Restoration project is in its tenth year of restoring the wild heart of South San Francisco Bay. By the end of 2014, 1,600 acres will have been restored to full tidal flows, 1,440 acres restored to muted tidal, and 710 acres reconfigured to enhance habitat for waterbirds.

California Clapper Rail is a federally endangered species that relies on saltmarsh habitat in San Francisco Bay. / Pelican Media

These ponds were constructed between 100 and 150 years ago out of the original saltmarsh habitat. The industrial ponds produced various salts for food, water conditioning, and industrial, agricultural and packaged deicing markets. In that ensuing period, a number of shorebirds, waterfowl, and other waterbirds moved in and started using the ponds for feeding, breeding, and resting. The San Francisco Bay is on the Pacific Flyway and a key area for migrating and wintering shorebirds, being part of the Western Hemisphere Shorebird Reserve Network. Even the threatened Western Snowy Plover started to nest on the dried salt flats of some ponds, which resembled the beach habitat where it historically nested.

The shorebirds, waterfowl, and other waterbirds that use the salt ponds have habitat needs generally not provided by the saltmarsh. Salt ponds, being areas of open water, provide abundant invertebrates for the waterbirds to forage on, and the levees and islands within the ponds provide roosting and nesting habitat. The mature saltmarsh habitat provides limited open water areas, being composed mostly of marsh plain that is densely vegetated with salt-tolerant plants. Some mature marshes contain open areas—called panes—that are devoid of vegetation and can collect water, thus providing forage habitat for waterbirds. But these pannes are of limited size. So converting the salt ponds to salt marsh, to support the marsh species, would displace the waterbirds that use the salt ponds.

Thus the partnership faced a dilemma—how to restore the ponds to saltmarsh habitat for the number of rare and endangered species that inhabit it, while not displacing the shorebirds, waterfowl, and plovers that now use these ponds for breeding, wintering and during migration? An environmental analysis established that as much as 50 percent of the pond acres could be converted to saltmarsh habitat without adversely impacting waterbirds, and that as much as 90 percent of the pond acres could be converted to tidal marsh, if the partnership could manage the remaining ponds intensively for the needs of the waterbirds.

An adaptive management plan (AMP) was developed with various monitoring components, including shorebird use of ponds during migration and overwintering; use by breeding terns, avocets, and stilts; and nest success and abundance of Western Snowy Plover. Timeframes, spatial scale, management triggers, applied studies, and management actions were developed for each monitoring parameter. For example, the AMP has a restoration target

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A New Paradigm of Adaptive Learning—Meeting the Bird Conservation Challenge

John D. Alexander, Executive Director, Klamath Bird Observatory

The science–management divide and the inability to integrate bird conservation tools and objectives within federal land management processes might be attributed to the nature of the separate cultures within the science and natural resource management communities. Federal resource management agencies have well-developed research capacities, including a research branch within the U.S. Forest Service and the U.S. Geological Survey's Biological Resource Division, that were developed specifically to address the needs of resource management decision-makers. However, cultural differences between scientists and managers make crossing the science–management divide a challenge, even within the federal agencies.

To bridge this divide, the federal land management and scientific communities must engage in improved mutual learning. Such mutual learning will require that land management decision-makers consider learning as a core aspect of their business It will also require that the scientific community better engage in the effective delivery of science-based information and tools.

Modern higher education evolved out of Renaissance and Neoclassical intentions to advance human well-being. However, the pursuit of moral and social improvements through knowledge and academics has become limited as universities have become more departmentalized. Disciplines have been isolated as silos with little interaction between and among them. In academia theory is favored over application. For example, the academic promotion system emphasizes discipline-specific publication and gives little regard for community involvement through science that is relevant to current societal challenges. Traditionally, this system has not recognized the importance of delivering science in formats that management and policy decision-makers are likely to use. This academic paradigm results in little collaboration among academic disciplines and between academic researchers and management and policy-decision makers. It also results in ineffective science delivery. Additionally, research has rarely been considered a legitimate task for managers and has instead been left to the researcher who transfers "technology" to decision-makers.

This one-way transfer of knowledge, from scientist to management decision-maker, represents an old instructive and imposed paradigm of learning. A greater interest in interdisciplinary research is emerging. An alternative learning paradigm replaces the one-way transfer of knowledge with a more transformative, mutual learning process. Such a participatory process results in working from within the system as opposed to intervention from outside the system; this offers a self-evaluation process as opposed to evaluation that is externally imposed.

Non-governmental organizations have an important role to play in making this paradigm shift in learning. NGOs are often free from many of the political and bureaucratic confines that slow change and limit the application of novel approaches to problem-solving in both academic institutions and federal agencies. The practical nature of NGOs offers a unique opportunity for applied-, policy-, and management-relevant research collaborations with land management agencies, the development of learning communities, and the building of connections between academia and the real world problems that academic science seeks to resolve. There is an opportunity for NGOs to serve as a bridge that spans the science–management divide and play a role in advancing the effective implementation of bird conservation objectives within the land management planning and implementation process. The unique capacities of NGOs inherently offer solutions to problems that can be difficult to resolve within academic institutions and federal agencies, including bridging the science–management divide.

Adaptive Management. Science-based conservation tools and the multi-species approach to bird conservation can be used to advance the adaptive management model. Management is a learning process involving continuous experiments, with the assumption that scientific knowledge is provisional. The adaptive management theme allows managers to remain flexible and adapt to uncertainty by continuously incorporating results of previous actions.

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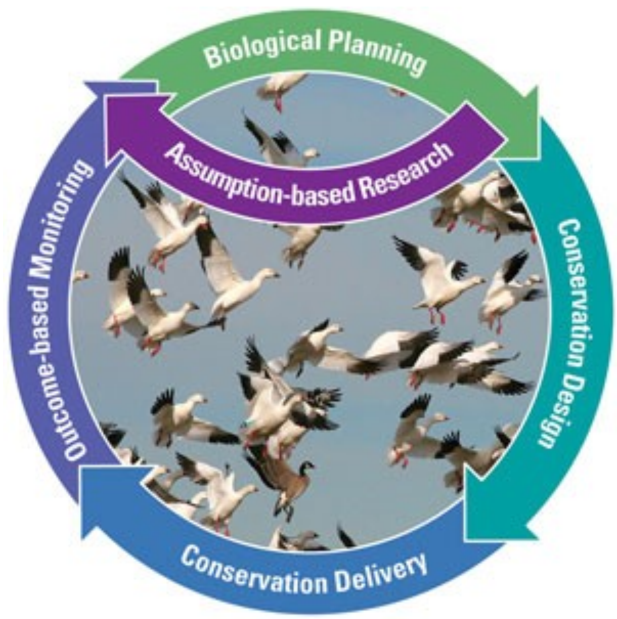
Adaptive management is a systematic approach for improving resource management by learning from management outcomes. Science-based tools feed directly into adaptive management. An adaptive management framework allows resource challenges associated with ecosystem management, such as system viability and sustainability, to be identified in a more inclusive context. Inclusive means involving staff-level managers and executive leadership in an institutional culture of learning. The adaptive management framework represents a continuous feedback loop that involves (a) assessment, (b) design, (c) implementation, and (d) monitoring and is now being explicitly integrated within large-scale federal ecosystem management programs. However, associated monitoring is not being adequately implemented by resource management agencies. Monitoring questions are rarely based on quantitative biological targets and instead simply ask if certain actions were successfully implemented to the degree intended.

Within the adaptive management framework, strategic habitat conservation (SHC) uses the best available information, data, and ecological models for setting and achieving conservation objectives at multiple scales. The conservation community increasingly relies on landscape approaches that integrate scientific information with management decisions. SHC does this through the implementation of biological planning, conservation design, conservation delivery, and monitoring and research in an iterative, adaptive management process.



The iterative, adaptive framework of Strategic Habitat Conservation includes five elements. / USFWS

SHC is a means for conserving populations and the ecological functions that sustain them. Multi-scaled, measurable population objectives are a key component of SHC. Biological planning must use the best scientific information available, with recognition that our understanding of ecological conditions is never perfect; therefore, managing uncertainty through an iterative cycle of planning, doing, and evaluating is essential. A systematic, well-documented approach to SHC that explicitly accounts for potential errors assures defensible and transparent management actions, decisions, and recommendations. The suites of objectives, tactics, and tools associated with conservation strategies must adapt and change as new information enters the SHC cycle.

Partnerships among managers, scientists, and stakeholders are essential, both for management and for developing conservation strategies. Partnerships allow for integrated priority-setting and effective allocation of resources. Each partner attempts to realize its particular mandate while working cooperatively to deliver a common conservation strategy that achieves multiple objectives across programs, ownership boundaries, and landscapes. In this way, the U.S. Fish and Wildlife Service envisions working collaboratively with partners to develop and implement a cooperative landscape approach to species and habitat conservation.

Integration of bird conservation with federal land management programs will allow science-based conservation tools to serve the adaptive management model. This will help bird conservationists realize their intended conservation-management paradigm of multi-scale ecosystem conservation through the use of a systematic approach for improving resource management by learning from management outcomes.

Modeling by Example: Using Management- and Policy-relevant Science to Integrate Bird Conservation and Federal Land Management

John D. Alexander, Executive Director, Klamath Bird Observatory

Partners in Flight (PIF) has developed a conservation planning approach (hereafter referred to as the PIF approach) that can serve as a model for integrating bird conservation objectives into land management programs through the adaptive management model. This approach involves (a) assessing the conservation status of bird species at continental and regional scales, (b) identifying habitat characteristics important for species of concern, (c) implementing land management actions that improve habitat characteristics for those species, and (d) monitoring the response of those species to evaluate the effectiveness of management actions. This approach can serve as a catalyst for implementing adaptive management.

Regional scale monitoring programs have detected declines for Purple Finch in the Northwest. / Dave Menke, USFWS

Adaptive management is a systematic approach for improving resource management by learning from management outcomes. It has been traditionally conceptualized as a circular feedback loop with six components. Working through this framework, land managers: (1) assess issues and develop management objectives; (2) design management actions to achieve objectives (e.g., desired conditions); (3) implement management actions; (4) monitor the results of management actions; (5) use monitoring results to evaluate the efficacy of the management actions in achieving the objectives; and (6) adjust treatments, prescriptions, plans, and policies accordingly.

Working with federal land managers to implement PIF bird conservation objectives involves using management- and policy-relevant science to link bird conservation objectives and management issues. Putting this strategy into action, we used results from research and monitoring efforts in the Klamath Siskiyou Bioregion, to demonstrate how the PIF conservation approach can be implemented within the adaptive management framework to integrate bird conservation objectives with priority land management challenges.

Assessing Populations and Designing Conservation Objectives. Bird conservation plans present a synthesis of priorities and objectives to guide landbird conservation actions. To design and implement meaningful bird conservation plans, conservation issues must be assessed at multiple scales. Traditional conservation efforts based on a single-species approach, often driven by the Endangered Species Act, are not adequate for addressing continent-wide bird population declines. The PIF proactive approach to conservation considers a suite of focal species with the ultimate goal of reversing population declines before Endangered Species Act listing becomes necessary.

A continental assessment of all landbirds was completed in 2004 (http://www.partnersinflight.org/cont_plan/). Population trends generated from the Breeding Bird Survey (BBS), a continent-wide bird monitoring program, and species distribution information, were used to identify species of high conservation concern at a continental scale.

To assess the status of bird species at regional scales, the Oregon-Washington and California PIF chapters instituted multiple regional monitoring programs. The Klamath Bird Monitoring Network (Network) is an example of such a program. The Network was designed to (1) monitor regional bird population trends for comparison with BBS results, (2) determine the distribution of species of concern in southern Oregon and northern California, and (3) develop habitat relationship models.

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The Network facilitated regional assessments using mist-netting and point count data collected with standardized protocols employed at different spatial and temporal scales. Regional data from the Network's long-term (> 10 year) constant-effort mist-netting stations corroborated BBS data that suggest declines for Swainson's Thrush, Orange-crowned Warbler, Black-throated Gray Warbler, MacGillivray's Warbler, and Purple Finch populations. Point count data refined our knowledge of the distribution and habitat relationships of bird communities in the Klamath Siskiyou Bioregion. We confirmed that elevation, plant species composition (i.e., habitat type) and vegetation structure are important factors for determining species distribution.

Orange-crowned Warbler near Upper Klamath Lake in Winema National Forest. / Dave Menke, USFWS

Results from analyses of population status and habitat requirements of species of concern helped guide land management in the Klamath Siskiyou Bioregion. They provided a foundation for regional habitat-based conservation plans and contributed to continental bird conservation planning. Variables used to describe the distribution of birds (e.g., vegetation structure and volume) are the same variables often used to describe current and desired conditions in the land management planning process.

Effectiveness Monitoring Results and Adaptive Management. Land management agencies are required to monitor the effectiveness of their management actions to determine if they are meeting desired ecological conditions. Birds can serve as useful tools when evaluating management actions and designing conservation efforts because they occupy a diversity of ecological niches and respond to a wide variety of habitat conditions. In addition, compared to other taxa, birds are inexpensively detected using standardized avian sampling protocols and therefore bird monitoring serves as a cost-effective tool for monitoring many species simultaneously. Thus, birds serve as "focal species" whose requirements define different spatial attributes, habitat characteristics, and management regimes of healthy ecosystems.

We evaluated the ecological effects of a Bureau of Land Management (BLM) fuel reduction project in oak woodland and chaparral habitats on the BLM's Medford District in the Klamath Siskiyou Bioregion. We used point counts to compare the abundance of PIF focal species in treated and adjacent untreated habitats. Our results suggested that small-scale treatments that retained shrub patches benefited edge-associated birds, including regionally declining Purple Finches. These results corroborated information in the regional bird conservation plan for landbirds in lowlands and valleys regarding the importance of edge habitats for some species. Our data also suggested that the fuel reduction efforts retained shrub patches resulting in no measurable decline in shrub-associated bird species. However, our results did raise a concern about negative impacts of treatments on species that use small snags.

The BLM Medford District's multi-disciplinary management team incorporated these results into subsequent treatment projects, altering treatment prescriptions to include the retention of small snags. These revised prescriptions not only addressed the needs of edge and shrub associated species, they also maintained key features for snag associates. Monitoring bird response to land management continues to play a crucial role in the management of the oak-shrub-conifer matrix on BLM's Medford District.

Extending the PIF Strategy to Land Managers Throughout the Klamath Siskiyou Bioregion. Federal agencies manage the majority of forested and shrubland landscapes across the West and therefore offer some of the best opportunities to implement bird conservation objectives at large scales. PIF has a long history of partnership with these agencies; however, land management decisions do not consistently consider or align with PIF conservation objectives. Increased effectiveness monitoring, with PIF focal species as indicators of current and desired ecological conditions, would result in better-informed management decisions with regard to bird conservation.

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Encouragingly, in the Klamath Siskiyou Bioregion, land management agencies are beginning to use the information from the analyses of the Network's data to design oak woodland treatments to be more consistent with PIF habitat-based conservation objectives. Additionally, increased collaborations within the PIF conservation approach are engaging land managers to evaluate the impacts of other land management projects, including larger-scale fuel reduction treatments in oak woodlands and small-scale fuel reduction treatments in riparian habitats. Furthermore, as landscape-level fuel reduction programs are being planned, regional land managers are consulting with PIF conservation planners to design the spatial distribution and replication of treatments that serve as a frame for well-designed effectiveness monitoring studies. Thus, there is growing opportunity to more widely incorporate the PIF approach into land management throughout the Klamath Siskiyou Bioregion.

The Pacific-slope Flycatcher is a Partners in Flight focal species and serves as a surrogate for older forests with a mix of deciduous trees in the canopy. / Jim Livaudais

By integrating the PIF approach within local land management planning processes, it can serve as a catalyst for sustainable land management within the adaptive management model. Such integration results in three conditions that have been suggested as ideal for successful implementation of adaptive management:

1. *Cost-effectiveness*. Because the use of bird monitoring is a cost-effective tool to monitor the ecological effects of management, and is integral to the PIF conservation strategy, it works well within ecosystem management.

2. *Engagement with leadership*. PIF conservation planners are engaging management leadership by identifying conservation opportunities within priority land management objectives.

3. *Consensus among stakeholders*. Broad stakeholder consensus is being built around resulting land management actions that meet both land management and bird conservation objectives.

The integration of the PIF conservation approach within local land management planning should not only support agency efforts to implement adaptive management, but also result in greater opportunities for implementing bird conservation objectives within land management programs.

For more information, contact John Alexander at jda@KlamathBird.org.

Partners in Flight uses focal species to ensure conservation is directed at a range of important habitat conditions, including multi-layered late-successional forests with a mix of coniferous and deciduous trees in the canopy. / Bob Altman

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of maintaining numbers of migratory shorebirds at pre-2005 baseline numbers, if known, or as close to that baseline as can be determined. It is assumed that a decline of 20 percent below baseline of wintering and migrating shorebirds would be significant and would trigger configuration and management of ponds for foraging shorebirds.

Starting in 2005, the partnership installed 43 water control structures in the 56 ponds, allowing Bay water to flow into these ponds for the first time in over 100 years. This substantially decreased the salinity of many of the ponds, since under industrial production, salinities are much higher than Bay water so salts can be concentrated for harvest. Monthly bird surveys of all the ponds have been conducted during high tide since 2003. Surveys assess changes over time, but also identify pond characteristics preferred by different shorebird species (e.g., depth of water, salinity, proximity to other features, etc.). These pond characteristics can then be built into future ponds to enhance target species abundance.

Since 2003, overall wintering bird use of the ponds has increased 125 percent, with a significant increase observed since 2005. Western Sandpiper, the most abundant wintering small shorebird in San Francisco Bay, has increased use of the ponds by 180 percent. Scaup, a diving duck, has had about the same winter use of the ponds since 2003. It was not clear how salt-pond specialist species that prefer higher salinity ponds such as Eared Grebe and phalaropes would respond to lowering pond salinities. Eared Grebe winter use of the ponds has declined 156 percent since 2003. Currently under construction are a set of ponds with high (80-100 parts per trillion), medium (40-8-ppt), and low salinity (20-40 ppt) predicted to be favored by salt-pond specialists, and other features favored by waterbirds (e.g., islands, shallow mounds for shorebird roosting). Of particular interest is the waterbird response to the higher salinity ponds to see if it's worthwhile managing more ponds for higher salinity.

Another restoration target is to maintain numbers and breeding success of avocets, stilts, and terns using the ponds. One of the first major management actions the partnership embarked upon was to try to significantly enhance a few of the ponds with characteristics known from previous studies to be preferred by breeding waterbirds, such as islands. In a pond called the "Bird Laboratory," 30 islands were built in round and oblong formations to compare the efficacy of the two shapes. Islands were constructed by scraping the pond bottom up into mounds, with moats of deeper water habitat around the islands to support fish. Increasing the number of places for birds to nest, rest, and feed, we predicted, would increase breeding waterbird use.

Kite photo of the Bird Laboratory pond, showing round and linear shaped islands, with varying depths of water in the surrounding pond. / Pelican Media

Construction was completed and Bay water entered in September 2010. Within a few weeks, birds started to forage in these ponds. The following spring, surveys documented great nesting success—193 American Avocets. But as the bay mud dried out, large cracks formed and some of the chicks fell in and perished. Before the next nesting season, we roughed up the surface of six of the islands to get rid of the cracks. However in 2012, only 2 of 30 islands were used for nesting. Most of the nesting occurred on the salt panne dedicated to Western Snowy Plovers.

The decrease in nesting on the islands from 2011 to 2012 may be due to the cracking, or to the presence of gulls that came into the pond, or other factors. We are still analyzing the last two years of data from our Bird Laboratory, as well as islands from other ponds, to determine more specifically the island characteristics nesting birds favor in terms of slope, height of island, proximity to other features, and other factors. So far researchers have determined that more islands per pond do not necessarily mean more nests per pond—putting a few islands in

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Managing Native Prairies Adaptively in the Northern Great Plains

Terry Shaffer, Research Statistician and Jill Gannon, Ecologist, Northern Prairie Wildlife Research Center, U.S. Geological Survey, and Clint Moore, Assistant Unit Leader, Georgia Cooperative Fish and Wildlife Research Unit, U.S. Geological Survey

Much of the native prairie managed by the U.S. Fish and Wildlife Service (Service) in the Prairie Pothole Region (PPR) of the northern Great Plains is extensively invaded by the introduced cool-season grasses Smooth Brome and Kentucky Bluegrass. Management to suppress these invasive plants has had poor to inconsistent success. The central challenge to managers is selecting appropriate management actions in the face of biological and environmental uncertainties.

In partnership with the Service, the U.S. Geological Survey developed an adaptive decision support framework to assist managers in selecting management actions under uncertainty and maximizing learning from management outcomes. The framework was built around practical constraints faced by refuge managers and included identification of the management objective and strategies, analysis of uncertainty, construction of competing decision models, monitoring, and mechanisms for model feedback and decision selection. Nineteen Service field stations, spanning four states of the PPR, participated in project development and currently rely on the Native Prairie Adaptive Management (NPAM) system to guide decision-making regarding management of invasive cool-season grasses on native prairies. The cooperating field stations share a common management objective, available management strategies, and biological uncertainties. While the scope is broad, the project interfaces with individual land managers, who provide refuge-specific information and receive updated decision guidance that incorporates understanding gained from the collective experience of all cooperators.

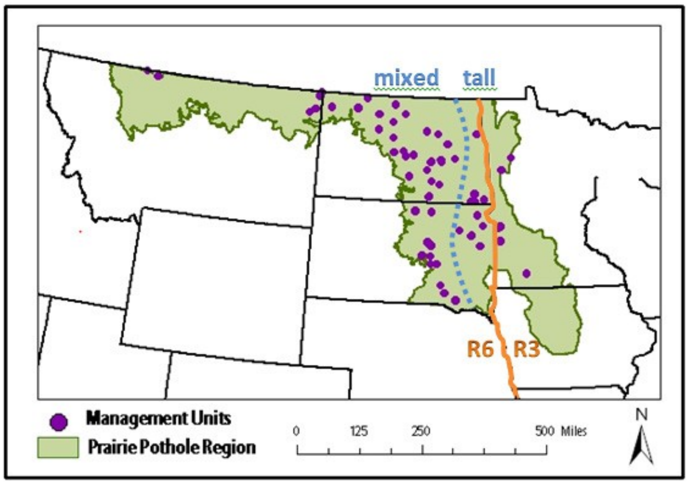

Figure 1. The NPAM area of focus is native prairie on Service-owned refuge lands, across the Prairie Pothole Region, within FWS Regions 3 and 6. Depicted here is the boundary of the U.S. portion of the PPR and the locations of the management units of participating refuge stations. Also denoted is the FWS regional boundary and the boundary between mixed-grass and tallgrass biomes.

During an initial scoping workshop, cooperators developed a consensus management objective: increase the composition of native grasses and forbs on native sod while minimizing cost. Cooperators agreed that decision guidance should be provided annually and should account for local, real-time vegetation conditions observed on the ground. Over the course of development, two prototypes of the decision framework were considered. The final framework recognized four alternative actions that managers could take in any given year: (1) Graze – targeted use of grazing ungulates to achieve defoliation; (2) Burn – application of prescribed fire as the single form of defoliation; (3) Burn/Graze – a combination treatment; and (4) Rest – no action. Numerous species of grassland birds, including Grasshopper Sparrow, Baird's Sparrow, and Sprague's Pipit will benefit from the results of this adaptive framework.

The study area included both northern mixed-grass and tallgrass prairie (Figure 1). Native vegetation in mixed–grass prairie has a strong cool-season component and thus the dominant native species have a phenology similar to that of Smooth Brome and Kentucky Bluegrass, making management of those species challenging. In contrast, tallgrass prairie has a strong warm-season native component, leading to existence of cool-season windows, periods of time in the spring and fall when cool-season invasive grass species are actively growing and vulnerable to damage via select management actions, but warm-season grass species are not active and are thus less susceptible to damage via the same actions. This dichotomy between prairie types necessitated the development of separate but parallel decision support systems for tallgrass and mixed-grass biomes.

Management units are parcels of native prairie that receive a single management treatment at any one time over their entire extent. At any particular time, the vegetation state of each management unit is characterized by the

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amount of cover of native grasses and forbs and the type of invasive grass that is dominant. In addition, each unit has a defoliation state which reflects the number of years since the last defoliation event and an index to how intensively the unit was managed during the previous seven years. State-transition models are used to predict a unit's state in year *t+1* from its state in year *t* and a prescribed management action in year *t*. Alternative models are built around key uncertainties that make choice of a management action difficult. Three uncertainties revolve around whether the effect of management actions depends on (1) type of dominant invader; (2) past defoliation history; and (3) level of invasion. Two additional uncertainties are considered when choosing a management action for tallgrass units: (4) the effectiveness of grazing within the cool-season window as a surrogate for burning when Smooth Brome is the dominant invader; and (5) the differential effect of active management outside the window versus rest outside the window.


Native prairie at Chase Lake National Wildlife Refuge. / Neil Shook, USFWS

Because data on the probability of transitioning from one state to another under the various models were lacking, expert opinion and elicitation were used to parameterize the models. In addition, cooperators participated in elicitation exercises to extract their beliefs regarding the value of having native prairie versus the cost of achieving it. Quantifying the subjective expression of utility in this way allowed for mathematical representation of the management objective into an objective function. By maximizing the objective function, cumulative utility is maximized, leading to the identification of a sequence of decisions that will achieve the management objective.

The NPAM system adopted a vegetation monitoring protocol that was rapid, relatively inexpensive, and familiar to many of the cooperators. The monitoring protocol served three purposes: (1) determining current vegetation and defoliation states of each unit; (2) evaluating progress toward the management objective; and (3) assessing predictive performance of the alternative models. The management year runs from September 1 to August 31. Management can occur anytime during that period and monitoring takes places from late June to mid-August. Cooperators enter vegetation data and management information into a centralized database by August 25. Given the current state of the system (vegetation and defoliation states) and the current understanding of the system (or the "belief state"), identifying the current best management decision is a matter of looking up the combination (i.e., system state and belief state) in the appropriate (i.e., mixed- or tallgrass prairie) optimal decision table.

Given complete uncertainty at the outset of decision-making, initial assignment of equal belief weights to each model was believed reasonable. The decisions in the optimal decision table that correspond to this current level of understanding constitute the current optimal decision policy. By August 31 of each year, individual cooperators are provided with a recommended management action for each of their management units for the upcoming management year. Upon receiving the management recommendations for their units, managers consider the recommendation, along with other relevant information, and at some point during the year, one of the management alternatives is carried out. This iterative cycle of making and implementing a management decision, predicting the response, monitoring the outcome, comparing predicted versus observed outcomes, updating model weights, and recommending a management action for the next cycle is expected to result in an accumulation of weight on a representative model of system dynamics, thereby increasing understanding needed to effectively manage native prairies.

Invasion of native prairies by introduced plants is an incremental process, whereby small changes in composition over one to five years go unnoticed, in part because plant populations fluctuate with environmental variation characteristic of grassland ecosystems. Restoration and maintenance of prairies will require an improved understanding of factors contributing to current ecosystem dysfunction and, conversely, those necessary for restoring ecosystem health. The NPAM initiative is rooted in principles of adaptive management, thereby affording the opportunity for grassland managers to pursue management objectives while acquiring information to reduce uncertainty and improve future management. For more information, visit https://sites.google.com/site/rcrpnativeprairie/the-project.

The North American Bird Conservation Initiative (NABCI) is a coalition of organizations and initiatives dedicated to advancing integrated bird conservation in North America.

The vision of NABCI is to see populations and habitats of North America's birds protected, restored, and enhanced through coordinated efforts at international, national, regional, state, and local levels, guided by sound science and effective management.

The goal of NABCI is to deliver the full spectrum of bird conservation through regionally based, biologically driven, landscape-oriented partnerships.

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For subscription or submission inquiries, contact the Editor, Roxanne Bogart, U.S. Fish and Wildlife Service, 802-872-0629 ext. 25 or Roxanne_Bogart@fws.gov. To download back issues, visit http://www.nabci-us.org/news.html.

The All-Bird Bulletin publishes news updates and information on infrastructure, planning, science, funding, and other advancements in the field of integrated bird conservation and management. Include author's name, organization, address, telephone and fax numbers, and e-mail address. Pictures are welcome but not necessary.

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each pond may be preferred. Medium-sized islands that are linear in shape are preferred over the round shape—so a few linear islands will be built in ponds to be constructed in 2013. Western Snowy Plover breeding success has been low and variable within the project area and Bay-wide. In fact, populations have been declining over the last several decades in the San Francisco Bay area. The project has a restoration target of providing habitat to support 250 breeding plovers—an ambitious aim given that the estimated total number of plovers is 249 in the entire San Francisco Bay in 2011. We are predicting that the addition of nesting islands, and an active predator control program, would enhance nesting plovers.

Western Snowy Plover with chicks. / Caitlin Robinson Nielsen

Results indicate that nesting success ranges from 15 to 62 percent in the project area. A remote camera documented a number of avian and mammalian predators depredating the plover nests, despite efforts to provide habitat and manage predators. A principle avian predator is the California Gull, whose population has exploded in the Bay area since the mid 1980s—the South Bay hosts the majority of the Baywide population.

A Snowy Plover habitat enhancement study was conducted from 2008 to 2011, to test the hypothesis that visual camouflage of the nest and chicks would increase nest success. Oyster shells were placed by hand at a density of 5 – 8 shells per square meter over several plots. In all three years, more Snowy Plovers nested in shell plots than in control plots; though hatching success was variable, preliminary results support an increase in hatch success. Fledging rates were variable, with from 0 percent to 25 percent, which was lower or the same as fledging rates elsewhere in the Bay. The partnership is still working to control predation of plover nests, and to figure out other ways to enhance the ponds to increase breeding success.

The results of these adaptive management experiments are critical for us to understand how birds use various salt ponds and what features and characteristics they prefer, so that we can design future ponds to maximize bird use and meet restoration targets established in our adaptive management plan. For more information, visit our website: http://www.southbayrestoration.org/.

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