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Making Good Use of Adaptive Management

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Founded in 2002, the Center for Progressive Reform is a 501(c)(3) nonprofit research and educational organization comprising a network of scholars across the nation dedicated to protecting health, safety, and the environment through analysis and commentary. CPR believes sensible safeguards in these areas serve important shared values, including doing the best we can to prevent harm to people and the environment, distributing environmental harms and benefits fairly, and protecting the earth for future generations. CPR rejects the view that the economic efficiency of private markets should be the only value used to guide government action. Rather, CPR supports thoughtful government action and reform to advance the well-being of human life and the environment. Additionally, CPR believes people play a crucial role in ensuring both private and public sector decisions that result in improved protection of consumers, public health and safety, and the environment. Accordingly, CPR supports ready public access to the courts, enhanced public participation, and improved public access to information.

This white paper is a collaborative effort of the following Member Scholars and staff of the Center for Progressive Reform: **Holly Doremus**, University of California Berkeley Law; **William L. Andreen**, University of Alabama School of Law; **Alejandro Camacho**, University of California Irvine School of Law; **Daniel A. Farber**, University of California Berkeley Law; **Robert L. Glicksman**, George Washington University School of Law; **Dale Goble**, University of Idaho College of Law; **Bradley C. Karkkainen**, University of Minnesota Law School; **Daniel Rohlf**, Lewis & Clark Law School; **A. Dan Tarlock**, Chicago-Kent College of Law; and **Sandra B. Zellmer**, University of Nebraska-Lincoln College of Law; and **Shana Jones**, CPR; and **Yee Huang**, CPR. This paper draws in part from Professor Doremus's article, *Adaptive Management as an Information Problem*, in the *North Carolina Law Review* (forthcoming, 2011).

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Introduction

Over the last two decades, natural resource scientists, managers, and policymakers have increasingly endorsed “adaptive management” of land and natural resources. Indeed, this approach, based on adaptive implementation of resource management and pollution control laws, is now mandated in a variety of contexts at the federal and state level. Yet confusion remains over the meaning of adaptive management, and disagreement persists over its usefulness or feasibility in specific contexts.

With its emphasis on adjusting methods based on systematic monitoring of ongoing results, adaptive management recognizes the inherent uncertainty that complicates natural resource management efforts and offers a strategy for filling information gaps. However, documented instances of successful adaptive management of public resources are rare. Funding structures and agency cultures often stand in the way of learning. Furthermore, unless carefully designed, adaptive management programs threaten management accountability and can be used to avoid politically controversial limits on economic activity.

This white paper is intended to help legislators, agency personnel, and the public better understand and use adaptive management. Adaptive management is not a panacea for the problems that plague natural resource management. It is appropriate in some contexts, but not in others. Drawing on key literature as well as case studies, we offer an explanation of adaptive management, including a discussion of its benefits and challenges; a roadmap for deciding whether or not to use it in a particular context; and best practices for obtaining its benefits while avoiding its potential pitfalls. Following these recommendations should simultaneously improve the ability of resource managers to achieve management goals determined by society and the ability of citizens to hold managers accountable to those goals.

Key Lessons for Adaptive Management

- Adaptive management can be useful in addressing environmental problems characterized by incomplete understanding and dynamic systems.
- Adaptive management works best when it is tailored to the problem; is designed to ensure accountability and enforceability; promotes useful learning; and is supported by sufficient funding.
- Adaptive management is not always the appropriate strategy. It should not be used to delay or evade legal requirements; where no opportunity exists to revise or reevaluate regulatory decisions; where mistakes may be irreversible; or where learning is unlikely on the relevant time scale.

What Is Adaptive Management?

The concept of adaptive natural resource management was developed in the 1970s by ecologist C.S. “Buzz” Holling and fisheries biologist Carl Walters. They argued that limited knowledge about natural systems called for a structured, iterative approach to environmental management. The goal of this approach was to reduce uncertainty over time by systematically incorporating learning into management. They called for managers to design their actions as scientific experiments, monitoring the outcomes, and adjust management direction in light of what the experiments revealed.

The Elements of Adaptive Management

The essence of adaptive management is a commitment to learning and a systematic approach to doing so. Detailed definitions of adaptive management abound, but there is general agreement that it embraces these elements:

- **Explicitly stated goals and measurable indicators** of progress toward those goals;
- An **iterative approach** to decision-making, providing the opportunity to adjust decisions in light of subsequent learning;
- **Systematic monitoring** of outcomes and impacts;
- **Feedback loops** so that monitoring and assessment produce **continuous and systematic learning** that in turn is incorporated into subsequent rounds of decision-making;
- Explicit **acknowledgement and characterization of risks and uncertainties**, identification of key uncertainties for management purposes; and
- An overarching goal to **reduce uncertainty over time**.

A distinction is often made between “active” and “passive” adaptive management. In active adaptive management, management actions are designed as experiments to test hypotheses about the system. For example, forest managers uncertain of the effect of post-fire logging on sensitive species might decide to log some areas while leaving others untouched. Passive adaptive management does not rely on deliberate experiments, instead choosing the strategy thought most likely to work but using monitoring to inform refinement of the predictive models and updating of the management hypotheses. In a passive adaptive management strategy, forest managers would implement post-fire logging in the locations and to the extent they believe it will promote desired forest conditions. They would intensively monitor the outcome and be prepared to learn that at least some elements of their initial decisions were mistaken. Both active and passive adaptive management should be distinguished from ordinary trial-and-error, a less structured decision-making approach in which management interventions are tried *seriatim*, evaluated on an *ad hoc* basis, and either retained or discarded based upon a general assessment of how well they achieve their goals.

Adaptive management is frequently coupled with collaborative or consensus-based decision-making. The two are, however, conceptually distinct. Adaptive management is a process for learning and adjusting management. In theory, it can be used with any sort of decision-making process that the particular management context permits. Consensus-based or collaborative management processes apply specific procedures to making management decisions, engaging a variety of stakeholders and attempting to reach consensus rather than imposing actions in a top-down way.

Managers should exercise special caution in using adaptive management in conjunction with consensus-based decision making because the need for consensus adds a potentially insurmountable barrier to changing management direction in response to new information. Adaptive management provisions, for example, are increasingly popular in hydropower relicensing settlement agreements, which often have a very large number of parties. Some settlement agreements require that all parties agree on changes to management in response to monitoring data.¹ That sort of provision inhibits management adjustment simply because it is difficult to get all the parties together to consider changes. Though there may be other benefits from requiring stakeholder consensus, divergent stakeholder interests also tend to make management changes difficult because the parties may not agree on what has been learned or what changes are desirable.

Adaptive Management in Practice

Since the mid-1990s, the concept of adaptive management has held a prominent place in natural resource management policy in the United States, embraced by agency heads and line managers alike and increasingly finding its way into agency guidance, regulations, and statutory mandates. The concept is not without controversy, however. Resource users and the regulated community sometimes argue that adaptive management does not provide sufficient regulatory certainty, exposing them to the risk of costly unanticipated changes and making long-term planning difficult or impossible. For their part, many environmentalists argue that adaptive management places too much open-ended discretion in the hands of agency managers, reducing accountability and exposing environmental values to the risks of agency capture and bureaucratic inertia.

As practiced by resource management agencies, adaptive management often falls well short of the scientific ideal. Statutory and agency definitions of adaptive management vary widely, as do the objectives and implementation protocols of the agencies and programs. Most of the definitions employed are decidedly imprecise. Key questions—including how learning will be accomplished, exactly how it will improve management decisions, and how managers will be held accountable to statutory goals—typically are not addressed. As a result, in many cases the term “adaptive management” has become at best uninformative and at worst a smokescreen for unbounded agency discretion and a wobbly commitment to program objectives.

The Everglades: Without Clear Goals, Adaptive Management Goes Nowhere

The Comprehensive Everglades Restoration Plan (CERP) illustrates one instance where adaptive management has failed primarily because it was mandated by Congress in an inappropriate context. The CERP was adopted in 2002 in an effort to restore the ecological functioning of the Florida Everglades.² Congress intended “to restore, preserve, and protect the South Florida ecosystem while providing for other water-related needs of the region, including water supply and flood protection.”³ The \$8 billion cost of the restoration plan was to be shared equally by the federal government, through the Army Corps of Engineers, and the non-federal sponsor, the South Florida Water Management District (SFWMD).

Heavy emphasis has been placed on satisfying stakeholders’ economic interests rather than the environmental mandates, and this imbalance places a chokehold on experimentation, learning, and adaptation. In response to stakeholders’ demands, the CERP devotes a great deal of attention to the use of ever more heroic engineering techniques to expand water supplies and ensure flood control for South Florida’s exploding population. Meanwhile, it gives low priority to the improvement of necessary sheet water flows—the primary ecological hallmark of the Everglades. As a result, the CERP remains in a planning mode, rather than an adaptive implementation mode. In a 2007 review, the Government Accountability Office observed that no CERP projects had been completed and that the only progress that had been made involved a few, select CERP-related pilot projects designed to understand nutrient removal in abandoned agricultural fields.⁴

Why has such a well-funded attempt at adaptive management faltered? One factor is the articulated goal of the CERP, which strives to have it all: ecosystem restoration as well as uninterrupted water supply and flood protection. As in other cases where private economic stakes are high, regulated entities and other stakeholders want certainty and stability. If scientists cannot predict outcomes with a great degree of certainty, experimentation in many instances, if not most, simply will not take place. As a result, the Everglades plan is stuck on modeling and data collection rather than learning through active experimentation and resolving uncertainties in favor of ecological resilience.

A second factor is the basic congressional directive for all Corps’ decision-making, which gives the agency discretion to proceed with a project whenever benefits “to whomsoever they accrue” exceed costs.⁵ These grants of broad discretion free the Corps to establish priorities based on politics instead of principled reasoning and evidence. As a result, the American public has been saddled with hundreds of questionable dams, levees, and other structures justified only by dubious cost-benefit analyses. In a study of Mississippi River management in 2004, the National Research Council issued a sweeping indictment of the misguided methodology used by the Corps to justify replacing locks and dams on the upper river.⁶ The CERP appears to suffer from similar flaws.

When Is Adaptive Management Appropriate?

Because uncertainty is typical of environmental and natural resource problems, adaptive management is an important tool. When misused, however, it can provide an excuse to delay politically uncomfortable decisions and to inhibit effective public oversight. The first step for policymakers considering prescribing adaptive management or managers considering implementing it should be to evaluate its fit in the particular context.

Adaptive Management Can Help Address Incomplete Understanding and Changing Systems

Adaptive management can help address two challenges common to environmental problems: incomplete understanding and changing systems. Environmental systems are frequently highly complex and poorly understood. Gaps in baseline data are common. Furthermore, many natural processes and systems are inherently dynamic and non-linear, producing unforeseen and even unforeseeable changes in the natural system on a human time scale. Superimposing rapid global climate change on systems that were already dynamic has made the situation even more complicated.

In light of uncertainties and environmental change, it may be difficult to identify management strategies that will achieve applicable management goals. Those circumstances call for provisional management decisions and the structured learning adaptive management can provide. Adaptive management is especially appropriate when uncertainties make management choices difficult, but the prospects for reducing uncertainty appear good.

Adaptive Management Is Not Always the Answer

Adaptive management should only be used in contexts where it is likely to improve management. It seeks to ensure progress over time toward meeting the objectives of a management experiment in the face of scientific uncertainty, while collecting, synthesizing, and applying new scientific information. It is an iterative process that collects information and applies it to determine whether ongoing management is on track or needs to be adjusted to changed conditions or newly learned information.

But adaptive management is not a panacea. It requires more resources than conventional management, because doing it right requires taking the time to carefully analyze the system at the outset, monitor the results, and periodically reassess and revise. It imposes unfamiliar demands on management institutions for long-term commitment of human and financial resources. It imposes greater demands on stakeholders, because they must monitor decisions and the decision-making process over the life of the project. Because it implies that decisions are always tentative, adaptive management may also increase or extend controversy and conflict. Finally, it may require trading the anticipated best outcome in the short-term for long-term learning and improvement.

Because of these costs, adaptive management should not be undertaken lightly. Managers should not assume that it is the right strategy for every management context. It should be used only if the management improvements it promises over time justify the trade-offs it imposes.

ESA 'Incidental Take Permits': Misuse of Adaptive Management to Evade Legal Requirements

Adaptive management is no substitute for legally required pre-action environmental analysis or for compliance with legal standards. It is not appropriate to rely on promises of future adaptive management as a justification for going ahead with actions that would otherwise not be allowed.

Unfortunately, that is precisely how adaptive management has been used in connection with applications for "incidental take permits" under the Endangered Species Act (ESA), which allow accidentally harming or even killing a listed species. Under the ESA, every federal agency must ensure that actions it takes, funds, or permits do not jeopardize the continued existence of any listed species. The U.S. Fish and Wildlife Service (FWS) and National Marine Fisheries Service (NMFS) can permit "take" of listed species if the applicant submits a habitat conservation plan sufficient to meet that standard. The ESA, in other words, sets a minimum standard for information levels. Before the Services can issue incidental take permits, they must know enough about the impact on the species to be sure that the permitted action will not cause jeopardy. FWS, however, takes the position that it can issue a permit, even when there is substantial uncertainty about the effect on protected species, if the plan includes adaptive management provisions.⁷

This approach is plainly wrong. Adaptive management cannot justify that initial "go/no go" decision. Whether or not to allow environmentally harmful actions must be decided on the basis of the available information and according to the relevant legal standards.

When to Use Adaptive Management

In order to ensure that adaptive management is employed only where it is appropriate, before deciding to implement it, resource managers should undertake, and policymakers should require, an explicit, formalized analysis of the prospects for learning and its expected value for management. That analysis, which should be reviewed by leading technical experts outside the management agency and periodically re-examined, can serve valuable internal and external ends. Internally, it can force managers to confront their assumptions about the system and their information needs, providing the kind of intellectual discipline that prepares the groundwork for learning. A thorough pre-adoption review of the prospects for adaptive management can lead to a better adaptive management program if one is ultimately adopted. Externally, it can provide a different kind of discipline, enhancing accountability to management goals by forcing managers to explain how they expect adaptive management to help them achieve those goals.

The Three Prerequisites for Adaptive Management

Adaptive management is premised on the assumption that learning is both plausible and valuable. It makes logical sense only if three conditions are satisfied. First, there must be an information gap that is important to management choices. Second, it must seem possible to fill that gap on a management-relevant time scale. Third, it must seem possible to adjust the initial decision over time in response to new information.

- **Information gaps.** Adaptive management is useful only if learning is needed in order to achieve management goals. Unless information gaps limit resource managers' ability to evaluate their choices, they do not need adaptive management to facilitate later adjustment. Because there is so much we do not know about natural systems, this requirement will rarely turn policymakers away from adaptive management. Nonetheless, directly confronting it is important. Defining important information gaps requires the definition of clear management goals, an essential but often overlooked element of successful adaptive management. Explicitly identifying information gaps focuses attention on areas where learning would be most helpful. It is also the first step in identifying why information is missing, and how it might be obtained.
- **Good prospects for learning.** The second requirement for successful adaptive management is the ability to learn. Adaptive management will not improve management outcomes unless important information gaps are narrowed over time. Although it can be difficult to evaluate the likelihood or cost (in resources and time) of learning, making a rough stab at that analysis is crucial to understanding whether adaptive management will be useful. It should take into account the sources of uncertainty, potentially confounding environmental variables, the ability to experiment and the resolving power of available experiments.
- **Opportunities for adjustment.** Finally, adaptive management requires the ability to change management direction in response to learning. Initial management steps must not become immediately locked in, either formally by law or informally by reason of their practical effect. Adaptive management cannot help when there is no way to correct an initial mistake, as when the decision in question is to allow irreversible alteration of the environment. For example, EPA should not rely on adaptive management to ensure that mountaintop removal mining does not violate water quality standards⁸ unless it knows that the water quality effects of filling streams with mine debris are reversible.

Nor is adaptive management useful when the legal framework or institutional structure calls for a single decision not subject to later reconsideration, or when practical or legal constraints on implementation allow only one management choice. For example, if the Corps of Engineers rigidly interprets the law to require the maintenance of a 9-foot navigation channel in a river it manages, there will be no

point in applying adaptive management to that aspect of river operations because no opportunity exists to consider alternative management strategies.

Adaptive management is also inappropriate if budget constraints make management changes unlikely. This problem arises in the context of ESA “incidental take” permits. FWS has issued a “no surprises” regulation, promising permittees that they will not be required to provide additional land or money for conservation if their approved habitat conservation plan turns out to be insufficient to conserve target species. It is therefore crucial that the plan explicitly provide for corrective measures. Otherwise, FWS may have to bear the costs of adjusting a failing plan, and given the reality of inadequate federal conservation budgets, costly management adjustments are unlikely to be made.

Evaluating the Usefulness of Adaptive Management

Unless these three factors—significant information gaps, opportunities for learning, and opportunities for adjustment—are all present, adaptive management is a non-starter. But the analysis is more nuanced, particularly with respect to the prospects for learning. Before committing to adaptive management, resource managers should evaluate the expected value of learning for achieving management objectives and compare that value to the costs and complications learning will impose. The analysis should be in writing, available to the public for comment and, for large-scale, long-term, or highly controversial projects, reviewed by independent experts.

Determining the Usefulness of Adaptive Management

- (1) Describe the applicable management goals.
- (2) Articulate the model of the managed system.
- (3) Compare the model to the management goals to highlight what the learning outcomes will be and to make apparent the uncertainties.
- (4) In certain high stakes contexts, conduct independent peer review of the model and evaluation of learning prospects.

The analysis should begin by setting out the applicable management goals. To the extent that statutory goals are, as is so often the case, vague or conflicting, they should be clarified at the outset. In other words, an agency planning or considering undertaking adaptive management should identify what it views as its management goals as well as the metrics it believes will indicate achievement of those goals.

The next step is articulation of a model of the managed system. The model need not be elaborate. Depending upon the management goals and level of knowledge at the start, it can be as simple as a schematic diagram or brief narrative, or as elaborate as a detailed computer model. Its function is both to discipline managers’ thinking and to make that thinking accessible to stakeholders. It should highlight key elements of the system for management purposes, their interconnections, their relationship to the management goals, and their expected response to management alternatives. It should explicitly acknowledge uncertainty and competing hypotheses.

Comparing the model to management objectives should highlight what managers hope to learn through adaptive management. In particular, it should make apparent the areas of uncertainty or competing hypotheses that are important to achieving the desired management outcomes.

The regulation of duck hunting in the United States is a longstanding and relatively successful example of adaptive management.⁹ The management goal is sustainable harvest; therefore, the key management question is how hunting mortality will affect population abundance and productivity. The key uncertainties are whether most of the birds killed by hunters would have died from other causes or whether their deaths must instead be added to natural mortality; and the extent to which reproduction declines with increasing population density.¹⁰ Using mathematical models corroborated by comparison to monitoring data, researchers showed in 1996 that harvest levels could be deliberately varied to distinguish between the two possibilities, and thus accelerate learning.¹¹

There are often trade-offs between learning and resource protection, however. In the duck hunting example, harvest levels that would produce the fastest learning also posed the highest risk to the population. Those trade-offs must be evaluated in context. A variety of decision analysis tools can be used for that purpose.¹² Managers should have some flexibility to choose the tool appropriate for their context, providing they explain that choice. Whatever tool is used, the analysis must be done explicitly and transparently; must consider the available avenues for investigation, observation, and testing hypotheses; and must be clear about the extent to which future benefits are discounted. This sort of analysis is not an empty exercise. It can reveal that learning is less valuable than managers had expected,¹³ or that “active” adaptive management, using deliberate management experiments, adds little to simple observation of the results of more conventional management choices.¹⁴

In cases of very high value resources, very high uncertainty, or very sharp political conflict over management choices, managers should seek independent peer review of both the model and the analysis of prospects for learning. This preliminary analysis stage, before managers commit to specific decisions, is the point at which peer review can be most helpful, and is least likely to be perceived as a threat to agency autonomy or authority. Peer review can sharpen the agency’s attention to gaps in its knowledge, unrecognized assumptions, and new or emerging methodologies.

Reviewers should have independence from the agency’s mission, culture, and process, so that they are able to take a fresh look at, and demand a clear explanation of, the problem. They should, however, have enough support from agency leaders to ensure that agency personnel take the peer review process and resulting critiques seriously. Ideally, a standing review committee would periodically evaluate progress. Managers who must report every year to the same review committee are more likely to seriously address that committee’s concerns than those who receive a one-time report but will never be faced with tough follow-up questions.

Best Practices for Adaptive Management

Even when use of adaptive management is justified, adaptive management programs must be carefully designed and implemented. The learning that makes adaptive management valuable requires a cycle of monitoring, evaluation, and reconsideration that is unfamiliar to most regulatory and resource management agencies. Furthermore, while adaptive management requires some flexibility, it can allow agencies to ignore statutory objectives in response to focused political pressures if that flexibility is not adequately constrained.

Adaptive management programs should always include features designed to increase the probability that management will generate useful learning, ensure that management agencies remain accountable for meeting their statutory goals, and reduce the likelihood that political pressures will turn management from those goals. Four principles should guide the development of any adaptive management program. We articulate these principles below, with specific recommendations to implement them.

Tailor the Strategy to the Problem

The first principle is to acknowledge that not all management problems are the same. The adaptive management strategy thus should be tailored to fit the problem and the management context.

To begin with, management goals must be as clear and explicit as possible. Some proponents of adaptive management argue that the goals themselves should be evaluated and reconsidered as part of the adaptive management cycle. However, management goals for public or quasi-public natural resources are most appropriately determined in the policy arena. These goals are a function of social values, not of technical understanding. Adaptive management is the forum for technical experts with time to devote to a management problem. Management goals reflect values that may shift over time and should be subject to reconsideration in the appropriate political forum, exogenous to the adaptive management process.

Managers should be able to explicitly define what they hope to gain by using adaptive management. Before implementing it, they should identify relevant uncertainties in the understanding of the system that additional information might reduce; consider the costs and time frame for developing that information; and articulate what management changes could be made in response to revised understanding.

Managers considering adaptive management should also think proactively about the particular challenges an adaptive management program may face in a particular context. If, for example, some impacts of a proposed action may be irreversible, managers should authorize or take the action incrementally, so that there is an opportunity to learn and correct before the impacts are too severe. If there are limits on the ability to correct after the fact, opportunities for correction should be built into the initial approval.

Ensure Accountability and Enforceability

Adaptive management is premised on the promise that management direction will be changed as needed to account for new information or altered circumstances. But change can be difficult, controversial, or costly. Barriers to change can be especially high in the context of management and conservation of the environment and natural resources. Decision-makers often must go through lengthy and contentious processes before choosing an initial course of action, so they may be understandably reluctant to consider making major modifications to that course, especially if that risks reopening difficult questions or displeasing important constituencies.

One of the most significant weaknesses of adaptive management to date has been that agencies have promised future adaptation but not delivered it. Therefore, one of the most important prerequisites for successful adaptive management is devising a workable strategy *up front* to ensure that changes actually take place when new information shows them to be necessary.

In order to ensure that adaptation occurs, management plans should set forth clear benchmarks for adapting to new information or changing circumstances. The trick, of course, is that decision-makers cannot predict exactly where new information may lead or what new circumstances might prevail. Nonetheless, initial management plans can establish clear thresholds that will trigger future adjustments to management, or at least put in motion specific procedures for making adaptation decisions. For example, a management plan affecting the habitat of a species of concern might list specific management changes to be made in the event that monitoring indicated a threshold amount of decline in the target species' population.¹⁵

Alternatively, the initial management plan might outline a specific new decision-making process that would occur in the event of such a decline. If this route is taken, however, there must be assurances that management will be changed within a specified period of time to address the decline. Merely including a requirement for reconsideration of management direction—in other words, a mandatory process without mandatory results—is not sufficient.¹⁶

Transparency is essential to ensuring that adaptive management is accountable and successful. Without clearly specified criteria and processes for making adjustments to a management plan, adaptive management can become a tool to rationalize uncertainty or cover flaws in initial decisions, rather than a mechanism for improving management over time. Adaptive management strategies that set forth transparent means of making changes are more likely to produce scientifically accurate adjustments that carry credibility with stakeholders and interested parties.

Finally, the adaptive management plan must be adopted in a way that makes it not only binding on the management agency but enforceable by interested citizens. In the absence of an enforceable commitment to act, interested citizens may encounter virtually impenetrable judicial roadblocks if the decision to change management direction or not is viewed as a matter entirely within the agency's discretion.¹⁷ Natural resource management agencies often face intense and asymmetric political pressures. The costs of conservation tend to be focused on a small community of resource users. Not surprisingly, the resource users are often highly vocal and frequently influential in their opposition to strong conservation measures. In that context, citizen enforcement can be a crucial mechanism for keeping agencies true to statutory mandates.

Promote Directed Learning

To fulfill its potential, adaptive management must identify opportunities for learning that will improve management and take advantage of those opportunities. Systematic learning requires that managers have an explicit model of the system. The model need not be elaborate; a basic conceptual model can effectively highlight key uncertainties. It need only clarify hypotheses or expectations about the system and the relevance of those expectations to management. It is important that both the model and the starting assumptions about the system be made available to the public and that the entire process of learning about the system be transparent, independent of political judgments, and credible.

Using their model of the system, managers should identify needed data. Systematic monitoring to collect that data is essential to adaptive management, but monitoring should not be treated as an end in itself. Data must not sit on a shelf. The learning effort must include systematic and ongoing data interpretation and evaluation, as well as data sharing within and between agencies so that learning diffuses from one action to others.

Managers should look for opportunities to set up controlled experiments where those experiments are feasible and can be expected to yield useful information. They should not, however, make a fetish of experimentation. Many managed systems do not lend themselves to experiments, either because it is too difficult to control background variables or because there is no room for failure. Like data collection, experimentation is not an end in itself. It should be used strategically where its benefits exceed its potential costs, but not otherwise.

Perhaps the most difficult element of adaptive management is ensuring that learning translates to appropriate management changes. Agencies engaged in adaptive management need to create the right incentives for learning. Career advancement and budgets should be tied to learning, not solely to "bean-counting" measures of success, and not to reduction of political controversy. Effective adaptive management requires political courage. In high-profile conflicts, management agencies must have the backing of their legislative and executive branch bosses.

Ensure Sufficient Funding

Finally, adaptive management cannot succeed without funding that is both stable and sufficient. Adaptive management is not a way to cut costs. A rigorous and well-structured adaptive management program necessarily involves significant monitoring and assessment costs. Adaptive management should not be used unless it offers sufficiently valuable opportunities for learning to offset those costs. If the choice is made to use adaptive management, sufficient funding must be dedicated to support monitoring, data analysis, and the implementation of management changes. Federal agencies, for example, are misusing adaptive management if they rely on it in the context of NEPA analysis to justify issuing a Finding of No Significant Impact, thereby evading the statutory requirement to prepare a detailed environmental impact statement, without analyzing the costs of learning and adjustment and dedicating sufficient funding to cover those costs.¹⁸

Funding for adaptive management must not be dependent upon the annual appropriations process. Funders must understand that learning and adjustment take time, and that the process will be inhibited if management agencies must constantly scramble for funds in a contentious political environment. Adaptive management requires a measure of political independence that cannot be provided without stable funding for a term sufficient to support learning. Adaptive management programs, therefore, should be supported by specifically dedicated funds. Those funds may be provided by a permittee, as they are in the context of ESA incidental take permits; by dedicated tax revenues without the need for further appropriations; or by a targeted multi-year appropriations measure.

Conclusion

Adaptive management is a promising strategy for many resource management problems. It offers a means of approaching information gaps that otherwise might be paralyzing, and it reminds us that many iterative decisions can benefit from active learning and re-evaluation. Nonetheless, adaptive management is not a magic bullet. It adds costs, can undermine accountability, and can prolong or heighten controversy.

In some contexts, the use of adaptive management is flatly inappropriate. Promises of future adaptive management cannot justify authorizing environmentally damaging activities unless those harms will in fact be reversible. Nor can they substitute for legally mandated pre-project environmental reviews or threshold judgments about the acceptability of environmental harm. In other contexts, decisions about whether or not to use adaptive management are more nuanced, requiring an explicit, publicly available analysis of information gaps, prospects for learning and ability to adjust management strategies over time.

When used, adaptive management programs must be carefully designed to maximize the benefits of learning and minimize the costs of flexibility. Key elements of a good adaptive management program include clearly articulated goals and plans for learning, enforceable commitments to revise management decisions, and assured funding for the lifetime of the plan.

Endnotes

- ¹ See Holly Doremus, Elizabeth Buehring, and Matthew Gerhart, “Hydropower Relicensing in a Changing Environment: Barriers to and Opportunities for Improved Coordination and Flexibility,” Project Report (Aug. 2007).
- ² Water Resources Development Act of 2000, Pub. L. No. 106-541, § 601, 114 Stat. 2572, 2680 (2000).
- ³ *Id.* § 601(e)(3).
- ⁴ U.S. GOV’T ACCOUNTABILITY OFFICE, SOUTH FLORIDA ECOSYSTEM: RESTORATION IS MOVING FORWARD BUT IS FACING SIGNIFICANT DELAYS, IMPLEMENTATION CHALLENGES, AND RISING COSTS (2007), available at <http://www.gao.gov/highlights/d07520high.pdf>.
- ⁵ 33 U.S.C. § 701(a).
- ⁶ NATIONAL RESEARCH COUNCIL, WATER SCIENCE AND TECHNOLOGY BOARD, REVIEW OF THE U.S. ARMY CORPS OF ENGINEERS RESTRUCTURED UPPER MISSISSIPPI RIVER-ILLINOIS WATERWAY FEASIBILITY STUDY: SECOND REPORT 9-10 (2004), available at http://www.nap.edu/openbook.php?record_id=11109&page=10.
- ⁷ U.S. Fish and Wildlife Service and National Marine Fisheries Service, Habitat Conservation Planning and Incidental Take Permit Processing Handbook 3-24 (1996); U.S. Fish and Wildlife Service, Notice of Availability of a Final Addendum to the Handbook for Habitat Conservation Planning and Incidental Take Permit Processing, 65 Fed. Reg. 35242 (June 1, 2000).
- ⁸ See Letter from Shawn M. Garvin, EPA Regional Administrator, to Colonel Robert D. Peterson, U.S. Army Corps of Engineers District Engineer Re Hobet Mining LLC Surface Mine No. 45 (Jan. 4, 2010).
- ⁹ The U.S. Fish and Wildlife Service, which regulates hunting of migratory waterfowl, has used a strategy it calls adaptive harvest management since 1995. Fred A. Johnson, William L. Kendall and James A. Dubovsky, *Conditions and Limitations on Learning in the Adaptive Management of Mallard Harvests*, 30 WILDLIFE SOC. BULL. 176, 176 (2002). That strategy has produced significant learning, in the form of updated probabilities assigned to the four competing models employed. *Id.* at 180.
- ¹⁰ *Id.* at 177-178.
- ¹¹ Byron K. Williams, Fred A. Johnson & Khristi Wilkins, *Uncertainty and the Adaptive Management of Waterfowl Harvests*, 60 J. WILDLIFE MGMT. 223 (1996).
- ¹² See, e.g., Eli P. Fenichel and Gretchen J.A. Hansen, *The Opportunity Cost of Information: an Economic Framework for Understanding the Balance between Assessment and Control in Sea Lamprey (Petromyzon marinus) Management*, 67 CANADIAN J. FISHERIES & AQUATIC SCI. 209 (2010); Julien Martin, Michael C. Runge, James D. Nichols, Bruce Lubow, and William L. Kendall, *Structured Decisionmaking as a Conceptual Framework to Identify Thresholds for Conservation and Management*, 19 ECOLOGICAL APPLICATIONS 1079 (2009); Tracy M. Rout, Cindy E. Hauser, and Hugh P. Possingham, *Optimal Adaptive Management for the Translocation of a Threatened Species*, 19 ECOLOGICAL APPLICATIONS 515 (2009).
- ¹³ Ray Hilborn and Carl G. Walters, QUANTITATIVE FISHERIES STOCK ASSESSMENT: CHOICE, DYNAMICS AND UNCERTAINTY 494 (1992) (“Often this step in the analysis reveals that there is a “robust” policy that should do well, no matter which model is correct, so that only minor gains would be expected from having better information.”).
- ¹⁴ Fred A. Johnson, William L. Kendall, and James A. Dubovsky, *Conditions and Limitations on Learning in the Adaptive Management of Mallard Harvests*, 30 WILDLIFE SOC. BULL. 176, 179, 182 (2002).
- ¹⁵ For an elaborate example, see Plum Creek Timber Company Native Fish Habitat Conservation Plan (2000).
- ¹⁶ See *Natural Resources Defense Council v. Kempthorne*, 506 F. Supp. 2d 322 (E.D. Cal. 2007).
- ¹⁷ See *Norton v. S. Utah Wilderness Alliance*, 542 U.S. 55, 62–66 (2004) (rejecting environmental groups’ claims that the Bureau of Land Management should take action to prevent damage to public lands caused by off road vehicle use and evidencing great deference to agency resource allocation decisions).
- ¹⁸ See CEQ Final Guidance for Heads of Federal Departments and Agencies, Appropriate Use of Mitigation and Monitoring and Clarifying the Appropriate Use of Mitigated Findings of No Significant Impact 7-10 (2011), 76 Fed. Reg. 3843, 3848-3851 (Jan. 21, 2011) (stating that agencies should not use “mitigated FONSI” unless they have the authority and funding to implement, monitor, and fine-tune the mitigation measures).

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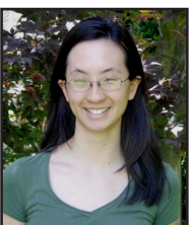
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