Adaptive Management:
A Spoonful of Rigour Helps the Uncertainty Go Down

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Abstract: Adaptive management is a rigorous approach to environmental management designed to explicitly address and reduce uncertainty regarding the most effective on-the-ground actions for achieving management goals and objectives. Unfortunately the term "adaptive management" has been widely misused, diluting both the concept and its application. This paper briefly clarifies what adaptive management really is, and what it can offer to the field of ecological restoration. This is done using several case studies, including habitat restoration in the Columbia River Basin, ecosystem restoration in the Trinity River in California, and recovery of Garry oak and associated ecosystems in British Columbia.

What is Adaptive Management?

In most environmental management domains, including the field of ecological restoration, there are varying degrees of certainty regarding the effectiveness of our actions in achieving desired objectives – due to either gaps in our understanding, or changes in the ecosystems we are trying to manage. Adaptive management provides a way to systematically reduce this uncertainty. It is a rigorous approach for learning through deliberately designing and carrying out management actions as experiments, specifically to learn how the system responds to management and to increase the level of certainty regarding how best to achieve desired results (Walters 1986). It incorporates explicit articulation of hypotheses, designing management experiments to test these hypotheses, and then monitoring outcomes to refine hypotheses and build knowledge (Taylor et al. 1997).

Adaptive management is an approach for proceeding *despite* uncertainty regarding the best course of action. When faced with doubt about what will best achieve the desired outcomes, confidence in management decisions is eroded, and the results may be unexpected or undesired. Adaptive management is a logical, systematic process to help managers gain confidence in their decisions and improve the chances of achieving the desired objectives. The key elements of this process are illustrated in Figure 1.

Often resource managers think that they are doing adaptive management if their program or project involves any semblance of "adapting", either to knowledge or events. Sometimes the term is misused to describe programs involving public participation. These misconceptions have led to dilution and confusion over what adaptive management really means. It is not a trial-and-error, adapt-as-you-go process. Public participation may or may not be required for a successful adaptive management experiment. Successful adaptive management **does** require clear articulation of *What You Want* (the desired outcomes, or the management goals/objectives), and the uncertainties about *How To Get There* (how to achieve these outcomes). These drive the rest of the process, in which alternative actions are explored and a subset is selected for on-the-ground experiments to be applied and monitored in order to learn which alternative is most effective. The adaptive management process includes effectiveness monitoring, evaluation of the results, and the use of this new knowledge to adjust future actions. Such "closing of the loop" is the most commonly neglected part of environmental management, yet it is essential for learning. Rigour is also an essential ingredient. If the management actions are implemented in a way that strays from the design, if the experimental design does not isolate the signal of interest from background noise (through spatial / temporal contrasts, replicates and controls), or if monitoring focuses on the wrong variables, scale or frequency, it will be difficult if not impossible to learn anything meaningful.

Adaptive management does not necessarily have to be large-scale, nor long-term. It can work just as well for small scale management problems for which effectiveness of alternative actions can be determined fairly soon after application. If resources are limited, "passive adaptive management" might be advisable. This involves designing, monitoring and implementing one management experiment at a time. This is in contrast to "active adaptive management" in which several management experiments are implemented and monitored concurrently. The former is initially less resource-intensive, but learning happens more slowly and may not necessarily be cheaper in the long run. Adaptive

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management can also be undertaken retrospectively, by applying the process to actions taken in the past, if there are sufficient historic monitoring data available to discern and evaluate results. A challenge for retrospective investigations however is that past actions and monitoring were probably not rigorously designed to test management hypotheses (Marmorek et al. 2004).

If the reader wishes more information on adaptive management we suggest books by C.S. Holling (1978), Carl Walters (1986) or Kai Lee (1993), or a selection of more recent reports (Taylor et al. 1997, Sit and Taylor 1998, MacDonald et al. 1999, Salafsky et al. 2001).

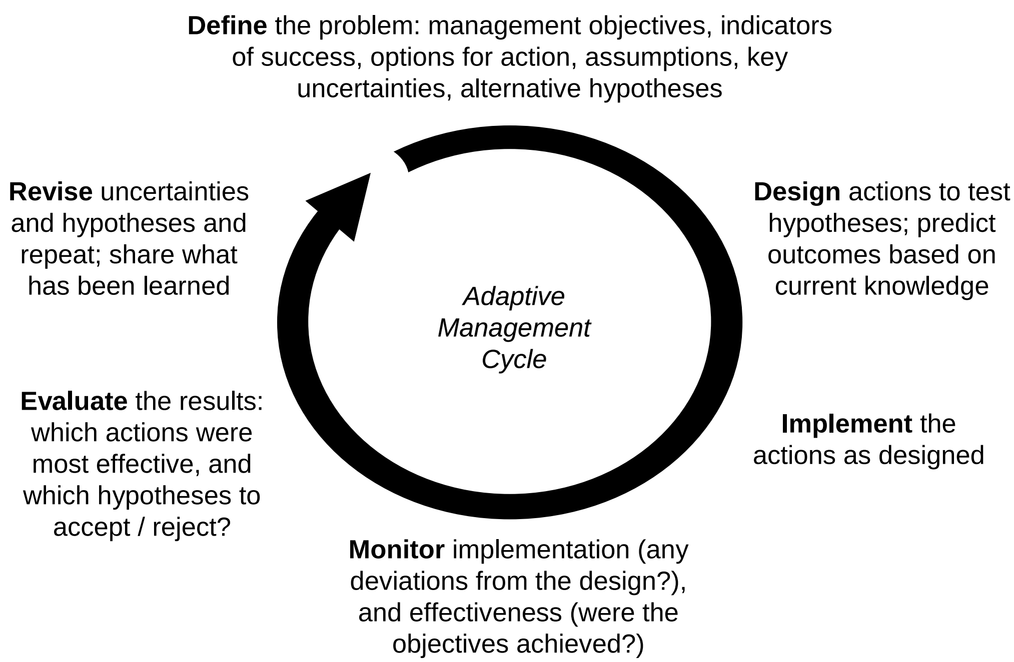

Figure 1. The adaptive management cycle.

How Can Adaptive Management Help Ecological Restoration?

In today's world of growing pressures on our natural resources, and often shrinking budgets for protecting these resources, it is becoming increasingly important to ensure – and demonstrate – that environmental management policies and actions are effective. Where we are uncertain about the effectiveness of our actions, we have a moral responsibility to admit this and then proceed in a manner explicitly designed to help us learn. Admission of uncertainty requires courage by managers and policy makers. Even in cases where we assume that what we are doing is helpful, we should seek to confirm this, as our assumptions may not be correct. For example, some actions to restore aquatic habitat (e.g. removing a dam to open up more spawning and rearing area) may increase habitat capacity but may not actually improve the freshwater survival rates of fish populations which are hovering at a low abundance far below carrying capacity (Figure 2). In some cases the factors limiting the population may be elsewhere, for example early ocean survival (Walters 2004). No amount of restoration of freshwater spawning habitat will address problems in the estuary and ocean. It is therefore of critical importance to take a very hard look at the factors that are most limiting what you are interested in. Adaptive management provides a framework for doing so.

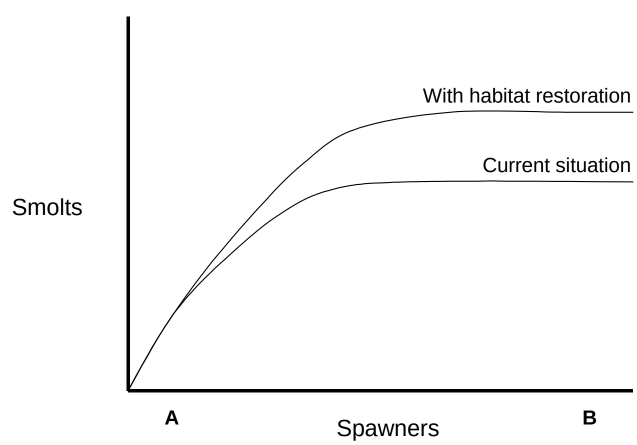

Figure 2. Apparent benefit of a habitat restoration action to increase spawning and rearing area. The action should benefit smolt production if lots of spawners return from the ocean (B), but won't necessarily help increase survival rates at low abundance (A).

Another challenge is that restoration is sometimes primarily geared towards achieving social and community objectives (for example, re-employing laid off forestry workers; providing funding to tribes and local county groups to generate employment) rather than achieving ecological objectives, resulting in little emphasis on rigorous monitoring and evaluation. While social and community objectives may be met, we have no way of knowing whether ecological objectives were achieved. The rigorous design and monitoring principles of adaptive management can also support socio-community goals by demonstrating the success of such programs, or determining why they failed.

Adaptive management is also an innovative alternative to regulation. It can be used to rigorously assess the necessity and adequacy of standards and guidelines, and foster creative solutions to local problems (Murray and Marmorek 2003). Indeed, there are often disagreements among stakeholders on the necessity and sufficiency of standards and guidelines, with industry groups maintaining that they aren't necessary, and environmental groups arguing that they're insufficient to protect ecosystems. An interesting characteristic of the adaptive management approach is that it does not require stakeholder agreement on what regulations are most effective; in fact is designed to resolve situations in which such disagreement exists. The same is true for restoration strategies. If stakeholders can agree on restoration goals and objectives, the adaptive management approach can be used to hone in on the best way to achieve them.

The following three examples illustrate ways in which adaptive management is helping to add rigour to restoration initiatives in both aquatic and terrestrial ecosystems.

Example 1: Habitat Restoration in the Columbia River Basin

Habitat protection and restoration is a cornerstone of current strategies to restore ecosystems, recover endangered fish species, and rebuild fish stocks within the U.S. Columbia River Basin. There are a number of strategies for habitat restoration in the Basin, but there is little quantitative information about the effectiveness of different habitat restoration techniques. A recent retrospective study of past restoration projects in the Columbia Basin (Marmorek et al. 2004) performed an intensive analysis of selected areas with the best biological data for evaluating the effects of restoration actions on fish survival rates. The study also included a review of "blue ribbon" studies (those with relatively strong experimental designs and time series data with adequate duration for detecting the impacts of habitat restoration actions on fish survival). The bottom line conclusions of this work were as follows:

- There are inadequacies in existing research and monitoring for all restoration techniques,
- There is a need for comprehensive physical and biological evaluations of most watershed restoration strategies,
- There is a need to know more about fish *survival* benefits of restoration actions, rather than benefits of restoration on *abundance*, and
- It is important to extend existing successful adaptive management experiments to learn more about the longer-term benefits of those actions.

The retrospective study also found that few restoration projects have explicitly stated hypotheses and structured monitoring to test them, recommending that more attention be paid to where restoration projects and reference areas are located, and the timing of restoration projects. Essentially, not nearly enough effort has been allocated to the Define, Design, Implement and Monitor stages of Figure 1. Efforts on these issues need to be made at a much higher level than that of an individual restoration project, so that groups of similar actions in comparable areas can be jointly evaluated in a strategic manner.

We hope that in response to these and other findings a habitat restoration paradigm shift will occur, changing from independent implementation of individual watershed projects towards rigorously designed and monitored, multi-watershed, adaptive management experiments. This will involve both technical and institutional advances, including improved experimental designs, more consistent monitoring protocols, and much better collaboration across multiple projects and institutions. Progress is slowly being made towards these challenges with a basin-wide effort to develop consistent methods of monitoring and evaluation[1].

Example 2: Ecosystem Restoration in the Trinity River in California

The Trinity River Restoration Program (TRRP) is a large scale effort to restore the watershed inputs and processes which maintain fish and wildlife habitat (USFWS and Hoopa Tribe 1999; U.S. Bureau of Reclamation 2000). Since the completion of dams and diversion canals in 1964, up to 90% of the water yield of the Trinity River was diverted to the Sacramento River Basin. Since completion of this diversion, returns of fall-run chinook salmon have averaged only 20% of pre-diversion levels. The restoration plan for the Trinity River was approved in 2000, and involves many interacting elements:

- more natural and variable flow releases sufficient to clean spawning gravels, build gravel/cobble bars, scour sand from fish spawning areas, provide adequate temperature and habitat conditions for fish and wildlife at different life stages, control riparian vegetation encroachment and assist many other ecological functions;

[1] See CSMEP, the Collaborative Systemwide Monitoring and Evaluation Project. http://www.cbfwa.org/rme.htm

- adding gravel to make up for material blocked by upstream dams;
- reducing fine sediment contributed from eroding upland areas; and
- reshaping channels with encroached mature vegetation to restore floodplains and point bars.

The 2000 Record of Decision outlines how all of this work will be done through an adaptive management framework, with each year's management decisions dependent on the amount of snowpack, and lessons learned from past years' releases. Since on average about 28% less water will be diverted from the Trinity to the Sacramento River, some farmers in the central valley of California are worried, and have expressed their concerns in court. All the right words are there – but how can we make adaptive management really work? Therefore the TRRP has undertaken the development of a Scientific Framework, to be completed over a 16-month period. This Scientific Framework will provide three critical elements:

1. *conceptual and quantitative models* that make the current understanding of the system, the underlying hypotheses driving the restoration program, and key uncertainties explicit;
2. *rigorous monitoring plans* focused on both reducing the uncertainties most critical to management decisions and clearly evaluating progress towards program goals; and
3. a scientifically defensible, practical *feedback mechanism* for revising annual management decisions based on monitored outcomes, databases and models. This feedback mechanism should provide a clear set of rules/guidelines for how annual flow and sediment management protocols will be revised in response to new evidence.

We began working with the TRRP in April 2004. Some of the key challenges we are encountering are common to many restoration projects, and we share them here as they may help others who are also trying to add rigour to restoration efforts:

- How many system performance measures or indicators can be reliably monitored, and for what portion of the overall study area?
- Which of these indicators are critical for rapid feedback to annual decisions, versus decadal-scale documentation of system change?
- How much effort should be allocated towards documenting that change *has* occurred, versus determining *why* it occurred?
- Can a common spatial stratification be used by groups monitoring different ecosystem components (i.e. channel, fish, riparian vegetation, wildlife) so as to improve the opportunities for establishing cause-effect linkages?

Example 3: Recovery of Garry Oak and Associated Ecosystems in British Columbia

Garry oak and associated ecosystems are among British Columbia's most valuable and most threatened ecosystems. They are home to over 90 species designated as "at risk" in the province, and many of these are also at risk nationally and globally. Less than 5% of the original habitat in BC remains in a near-natural condition, and invasions of non-native species pose a serious threat to remaining ecosystems. The Garry Oak Ecosystems Recovery Team (GOERT) uses a diverse array of educational tools and outreach initiatives directed to specific target audiences to contribute to the recovery of these imperilled ecosystems and species. A paper-based Decision Support Tool (Murray and Jones 2002) was recently added to the arsenal to help groups who are interested in engaging in well-planned stewardship activities make decisions regarding whether, and how, to manage invasive species in these valuable ecosystems.

The tool leads users sequentially through a series of questions to help them decide whether to manage for invasive species in a given ecosystem (based on a collection of factors including management objectives, uses of adjacent land, presence of species at risk, and the risk of not taking action), and if so, for which invasive species. Uncertainty is bound to accompany the answers to some of these questions. Rather than being a reason for doing nothing (although there will be times when "no action" is the best decision, all things considered), uncertainty was recognized as an opportunity to learn through adaptive management, an approach designed specifically to accommodate uncertain management situations. The adaptive management cycle was used as the framework for guiding users through thoughtful on-the-ground actions at the site level (Figure 3). It prompts users to employ far greater rigour than would likely otherwise occur, including explicit declarations of uncertainty and expected results *prior* to taking action, and explicit documentation of outcomes (including surprises) and learning *after* taking action and monitoring for effectiveness.

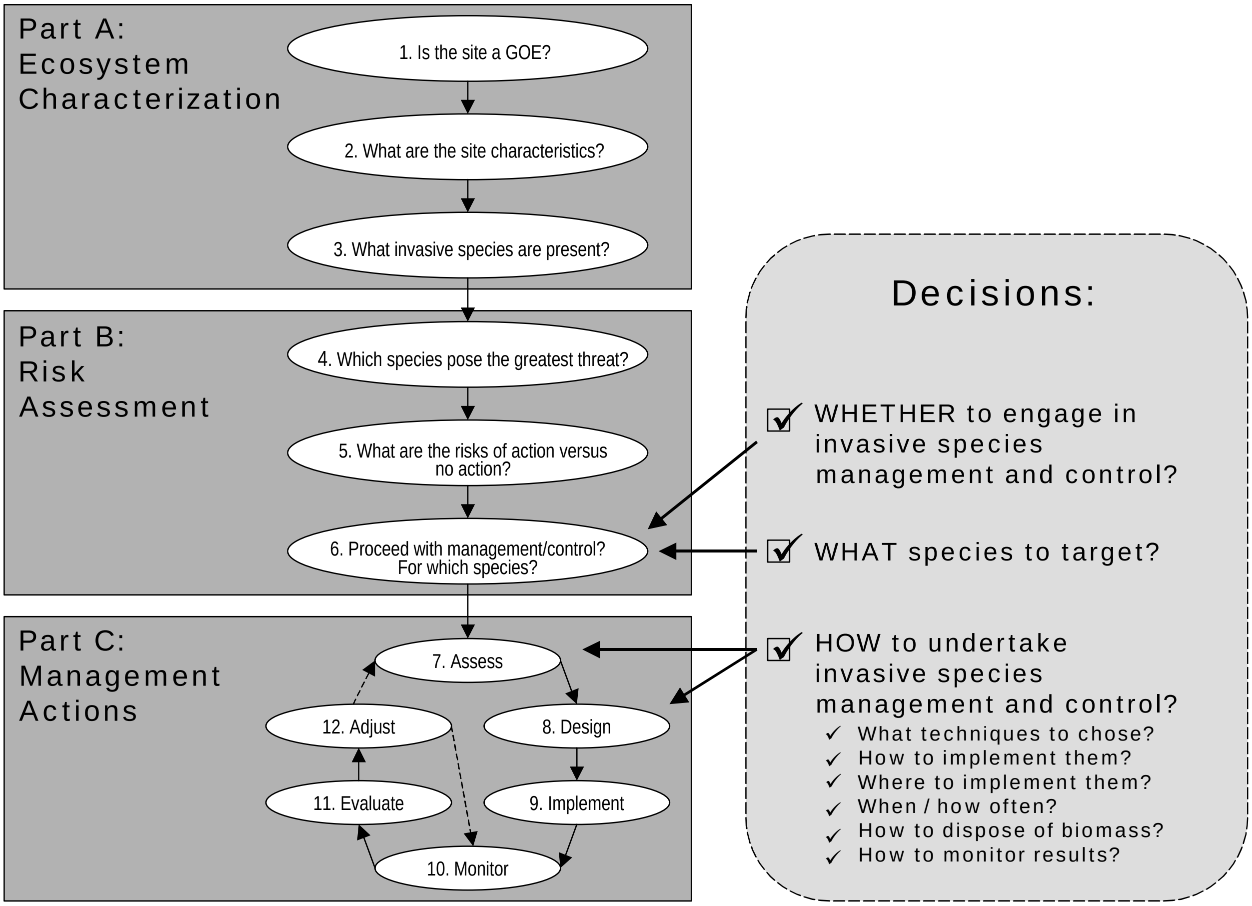

Figure 3. The adaptive management framework in a decision support tool for ecosystem restoration (Murray and Jones 2002).

A report on feedback from preliminary use of the tool (Junck et al. 2004) reveals concern that the monitoring components of most invasive species management programs in Garry oak ecosystems are cursory or haphazard. In practice, most monitoring merely consists of walking the site periodically to check for re-sprouting or new infestations. Few stewards apply scientific methodology to monitoring programs. The report suggests adding more information to the tool regarding how to develop a thorough, scientifically-based monitoring plan (including pre- and post-treatment surveys, especially noting appearance of new native plants or new invasive species, and checks for re-growth/sprouting of controlled invasive species at least every 3 months). Case study examples of good monitoring plans were also suggested. It is apparent from this feedback that there is a need for more rigorous monitoring of these types of recovery activities. Without this rigour, it will be difficult to really learn what techniques for managing invasive species work best in different situations.

This example highlights a challenge in applying rigour to ecosystem management activities undertaken by volunteer stewardship groups. The tool comes in a small binder, and consists of 25 pages of instructions (which walk the user through the three parts shown in Figure 3) plus a brief introduction, recording sheets, and a references section. While some of the preliminary feedback (discussed above) revealed a need for more detailed information, feedback from others included concern that the tool was already too large and the instructions too onerous for some stewardship groups. Therein lies a significant dilemma: as funding for formal ecosystem management and restoration programs decreases, agencies once charged with such mandates increasingly rely on non-government organizations and stewardship groups to fill the gap, but there may be insufficient capacity for these groups to adopt this role effectively. In addition, while many organizations welcome training in adaptive management, others have been openly hostile ("we know what's best; just give us the money for implementation, we don't need to waste money on management experiments and monitoring."). To this argument, the reply is simple: "please provide evidence that your proposed actions will have the anticipated benefits." If the evidence is clear, there is no need to consider an adaptive management experiment. Addressing these problems requires insistence on rigour at the highest levels within all organizations, both government and non-government. This requires extensive training, ideally at meetings which promote inter-entity communication.

Applying adequate rigour to determining the effectiveness of restoration activities requires a trade-off between the Implement and the Monitor stages in Figure 1. A creative approach is to implement AM experiments in a subset of the total area targeted for restoration, conducting rigorous treatment-control monitoring to learn if the actions work. If they do, they can be expanded to a larger area, with less-intensive monitoring (Keeley and Walters 1994, Walters and Green 1997).

Conclusions

There is clearly a need for greater rigour in ecological restoration projects, and we believe that the use of the adaptive management approach in restoration efforts can help with this. We have two choices. We can continue to implement restoration actions without proper monitoring until providers of the funding request proof that their investments have benefit, and risk losing the funding when we are unable to provide the evidence they need. Or we can admit what we don't know, and conduct proper adaptive management experiments to both find evidence for beneficial effects, and learn where we have not been successful so that we can improve.

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