Adaptive Management: What, Why, and How?

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Introduction

Almost three decades have elapsed since the targets of environmental conservation and recovery expanded from species and habitats to entire ecosystems. This paradigm shift was prompted in part by recognition that focusing on species or habitats was not sufficient, that life-sustaining processes operate over much larger geographical scales, and interact among many more ecosystem components, than were typically provisioned for in conservation and restoration strategies prevailing at the time. But the concept of 'ecosystems' is itself a moving target, not only in that they continue to change and shrink to meet human needs for space and resources, but also in the sense that humans cannot be separated from Nature. Awareness has grown about the value and vulnerability to humanity of 'ecosystem services' (e.g. Biggs et al. 2012, Mace et al. 2012, Schneiders et al. 2012). Human well-being is belatedly gaining recognition as a prime objective in the management not only of ecosystems, but of complex 'social-ecological' systems (e.g. Schlueter et al. 2012, Summers et al. 2012). And making provision for climate change and sustainability now pervades our outlook (e.g. Bellard et al. 2012, Doney et al. 2012, Kiron et al. 2012). We are only beginning to learn how to conserve and restore ecosystems in the Anthropocene (Crutzen and Stoermer 2000).

One feature of this movement that is little changed, at least in principle, is acceptance that an 'adaptive' approach to ecosystem management should be the most effective. Since its introduction in the late 1970s (e.g. Walters and Hilborn 1978), an adaptive approach has become the default mode of environmental management. Yet assessments of its performance state that implementation of adaptive management (AM) "has failed more often than not", and AM has "failed to live up to its high expectations" (Allen and Gunderson 2011). This article focuses on adaptive management, addressing what it is, why it is the default approach in ecosystem management, why it can fail, and how it is being applied in the context of Puget Sound recovery.

What is AM?

An adaptive approach to management is required whenever decisions about how to achieve a complex goal must be made under uncertainty. This almost always applies to ecosystem recovery because desired outcomes (such as responses of species to remedial actions), and driving factors (such as the behavior of humans, and weather-dependent processes) often cannot be predicted. When these factors interact with each other uncertainty is compounded. Progress therefore entails a deliberate 'learn-and-adjust-as-you-go' approach that has become known as adaptive management (AM). In essence, it is like guiding a tall ship through uncharted reefs using plum line soundings. A 'theory of change' is specified (a description of why and how a desired change is expected to happen in a given context), actions effected to achieve that change, progress monitored relative to stated goals, and a new course adopted if actions do not bring about the desired change.

The concept of AM is therefore simple, but experience has shown that adopting an adaptive approach should be based on more than uncertainty. Williams et al. (2009) proposed a key to determine when adaptive management is the most appropriate approach to decision making (Box 1). Note that 'uncertainty' is not their first criterion (it is the fourth). In their opinion, stakeholder participation (step 2), modeling (step 5), and legality (step 9) are also qualifying criteria, among others.

Box 1: When is it AM?

Williams et al. (2009) proposed a 9-step key to determine when adaptive management is the appropriate approach to decision making:

1. Is some kind of management decision to be made? No – decision analysis and monitoring are unnecessary when no decision options exist. Yes – go to step 2.
2. Can stakeholders be engaged? No – without active stakeholder involvement an adaptive management process is unlikely to be effective. Yes – go to step 3.
3. Can management objective(s) be stated explicitly? No – adaptive management is not possible if objectives are not identified. Yes – go to step 4.
4. Is decision making confounded by uncertainty about potential management impacts? No – in the absence of uncertainty adaptive management is not needed. Yes – go to step 5.
5. Can resource relationships and management impacts be represented in models? No – adaptive management cannot proceed without predictions generated by models. Yes – go to step 6.
6. Can monitoring be designed to inform decision making? No – in the absence of targeted monitoring it is not possible to reduce uncertainty and improve management. Yes – go to step 7.
7. Can progress be measured in achieving management objectives? No – adaptive management is not feasible if progress in understanding and improving management is unrecognizable. Yes – go to step 8.
8. Can management actions be adjusted in response to what has been learned? No – adaptive management is not possible without the flexibility to adjust management strategies. Yes – go to step 9.
9. Does the whole process fit within the appropriate legal framework? No – adaptive management should not proceed absent full compliance with the relevant laws, regulations, and authorities. Yes – all of the basic conditions are met, and adaptive management is appropriate for this problem.

The authors stressed that "if the answer to *any* question in the key is negative, then an approach other than adaptive management is likely to be more appropriate".

Types of AM

There is no lack of opinion about what constitutes adaptive management (e.g. Taylor et. Al 1997, Allen et al. 2011, McFadden et al. 2011, Moore et al. 2011, Williams 2011, Rist et al. 2012, Walsh et al. 2012). Collectively, this literature has clarified a variety of approaches that have or have not worked in different contexts.

But because each AM application must be tailored to local conditions, at some level each must be unique. Inevitably, the term has been applied to a wide range of approaches that may not qualify by all criteria in Box 1, or may differ qualitatively in other ways. Several modifiers have been used to distinguish different types of AM:

- ***Evolutionary problem solving*** refers to almost any management change resulting from learning by shared experience (Anderson et al. 2003), a cumulative process of comparing, selecting, and adapting practices that seem to work.

- ***'Passive' AM*** refers to successive actions being based on accumulated information available at each decision point. In an example from Puget Sound, 20 ferry terminals needed to be rebuilt and expanded, beginning in the mid 1990s.

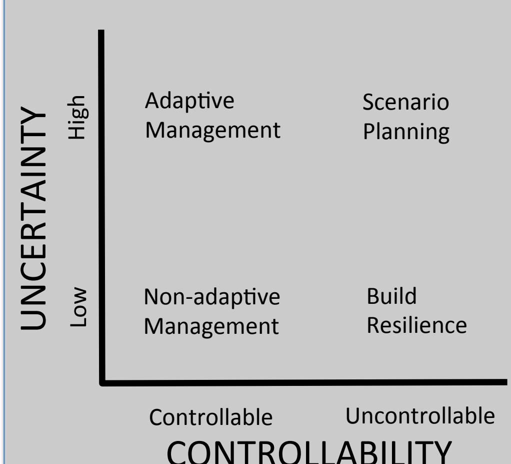
Given legal strictures against loss or damage to eelgrass, research and monitoring were needed to discover how to minimize potential impacts of the new terminals on eelgrass, including from pilings and propeller scour (Thom et al. 2005). The rebuilding process was viewed as a sequence of learning opportunities, beginning with the terminal at Clinton on Whidbey Island. It was found that a narrower and longer terminal design would cost more, but reduce impact, particularly if more natural light was let through the terminal itself; slips were reoriented along instead of towards the shore; pilings were found to create mini-reefs that rain down shell debris, encouraging Dungeness crabs to settle and destroy eelgrass – so fewer pilings were used. Eelgrass was replanted before construction, progress monitored, and lessons applied to later terminal designs. This is a good example of how individual projects implemented early in a series can be designed to serve as guides to inform following projects.

- ***AM is 'active'*** when management options are tested by experimenting with or deliberately perturbing a system to discover which of several competing alternatives offers the best way forward (Walters and Hilborn 1978; Walters and Holling 1990). A frequently cited example is the effort to optimize the frequency and flow of water releases from the Glen Canyon dam, intended to simulate flooding events on the Lower Colorado River (e.g. Cross et al. 2011, Robinson 2012). Another example from the Everglades sought the minimum number and size of levee breaches that would allow actual sheet flow to mimic sheet flow modeled without levees and canals. The approach involved making three breaches of different size, and comparing their effects on actual sheet flow – a quintessential AM experiment.

These are listed in order of increasing difficulty – and thus diminishing incidence – of implementation. Learning by shared experience requires ability and intent to recognize and capitalize on instructive events and outcomes, by observation and comparison. This type of learning probably accounts for most progress in AM, but can be limited by ineffective communication between those who learn the lessons (typically, recovery practitioners), and those in a position to act on them (say, planners or policy makers). Gregory et al. (2006) proposed four categories of criteria to help decision makers choose passive or active AM strategies as a response to ecological uncertainty in environmental management: dealing with spatial and temporal scales, dimensions of uncertainty, the evaluation of costs and benefits, and institutional and stakeholder support.

Factors that limit the feasibility, scope, and rigor of adaptive management are the same as those that limit science: increasing geographical scale, thematic complexity, and thus cost all limit the degree to which an intervention can be 'controlled' (Halbert 1993; Hilborn and Ludwig 1993). In AM experiments, rigor is often sacrificed for practicality, but even so, active AM at the ecosystem level is rare because ecosystems are generally too large and too complex to control experimentally.

Figure 2. When **not** *to apply AM (after Peterson et al. 2003, and Allen and Gunderson 2011)*

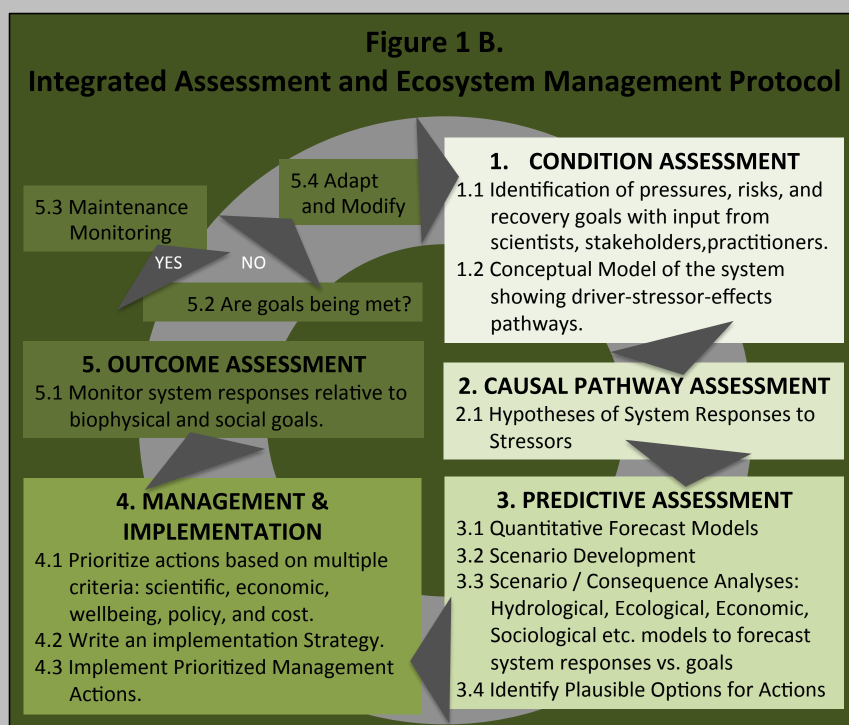


'Controllability' was not listed among the qualifying criteria for AM by Williams et al. (2009; Box 1), but probably should have been. Attempting to apply AM in uncontrollable situations has been cited as a major reason for widespread failure of AM (Allen and Gunderson 2011). Uncertainty and lack of control often flourish together, and in these cases scenario planning may be a more rewarding approach to management (Figure 2). If there is confidence that actions will have desired effects, but the system is otherwise uncontrollable – a rare combination – building resilience wherever possible provides a heuristic approach (Folke et al. 2010; Figure 2).

A programmatic approach

Natural resource managers began to apply AM in the mid-1980s (e.g. Walters 1986), and today few would claim any other management approach to ecosystem recovery to be superior. In the interim a programmatic approach to implementation has become synonymous with AM, typically comprised of recurring cycles of five or six steps: assess options, design actions, implement actions, monitor effects, evaluate impacts, and adapt strategies accordingly, then return to step 1. This programmatic approach has a long history in business management, and is widespread in public health management, but did not become established in conservation and restoration until the early 2000s (Groves 2003). Many versions have been proposed (e.g. Williams et al. 2009), but the most prevalent is based on a version codified in 2005 by the Conservation Measures Partnership, known as *Open Standards for the Practice of Conservation* (Conservation Measures Partnership 2013, Schwartz et al. 2012; Figure 1a). This version was adopted by the Puget Sound Partnership in 2009, and has been refined to suit local

Figure 1. Steps in AM cycles as described in (A) *Open Standards for the Practice of Conservation*, and (B) Reiter et al. 2013.



conditions (Redman et al., 2013).

The concept continues to evolve, for example, to make more explicit the role of research. Reiter et al. (2013) added a management step to the description of ecosystem-based management by Levin et al. (2009, 2012; see also Tallis et al. 2010), and called it the *Integrated Assessment and Ecosystem Management Protocol* (Figure 1 B).

Challenges

Experience has shown that the theory of AM is far easier to grasp than to apply. Many factors prevent AM from realizing its full potential in ecosystem recovery. A few are sketched below.

1. ***Managing expectations and negative perceptions.*** Resistance to AM is common, especially to the notion of recurrent strategic planning and experimentation. AM is sometimes perceived as too complex or too expensive to implement: *Why waste time and money on planning, when action is all that is needed?* Negative perceptions of AM may escalate when ecosystem indicators decline before they improve, or even when improvement is simply delayed. Effective communication is the leading solution to these problems. How we communicate about AM depends in part on the level of risk. More risky projects or models require more sensitive handling, couched in terms of potential consequences, benefits, and trade-offs. If the path to recovery is long and uncertain we need to build that expectation into stakeholders' outlook and understanding. Trusted scientists with high credibility are needed to communicate technical information about AM *within context*. Above all, applications must be simple, clear, affordable, and easily implemented in order to avoid a backlash of perception that AM is complex and expensive.

2. ***Investing too little in AM.*** In the short term, adaptive management costs more than approaches that do not explicitly aim to reduce uncertainty, or measure impacts. Over the long term, the investment should pay for itself many times over. Those concerned about cost effectiveness can relate to the notion of risk: *How confident does one need to be about outcomes before investing millions in recovery actions?* Having confidence that actions will yield desired outcomes is clearly superior to merely hoping that they will. AM becomes more palatable when there are critical and clearly stated uncertainties that need to be addressed. Making critical uncertainties explicit and compelling tends to generate support.

   How much is enough? In theory, however much is needed to reduce uncertainty. In practice, limits tend to be imposed by other criteria. An informal evaluation of Puget Sound projects in the 1990s found only 29 with data relevant to this question (Ron Thom, pers. comm.). Estimates of the added cost of AM ranged from 0% to 26%, and averaged around 7%. Quotes on amounts typically spent on monitoring project impacts suggested that 5% is common. The US Army Corps of Engineers allocates 3% for monitoring projects in the Everglades after the construction phase, but none to planning an adaptive approach in advance. AM should cost about 10-15% of the total spent on recovery, an amount dictated more by what is acceptable than sufficient.

3. ***Measuring cumulative impacts of local AM actions and programs on the entire ecosystem*****.** One assumes that processes operating at the landscape or seascape level affect local site resilience, and also the reverse, that site level actions combine to positive effect at the system level. Typically, however, the signal of local recovery actions cannot be detected over the noise of other factor

effects and interactions, natural and non-natural, at large scales. To address this problem, Diefenderfer et al. (2011, 2016) introduced a levels-of-evidence (LOE) approach that facilitates assessment of the cumulative landscape effects of individual restoration actions taken at many different locations. First developed to assess clinical effects of medical treatment at the population level, the LOE approach was adapted to measure cumulative effects of multiple restoration projects on the 235 km tidally influenced portion of the Lower Columbia River Estuary (LCRE). Acknowledging that the analysis of cumulative impacts is complicated by ecological processes that may be additive, synergistic, or antagonistic, the authors considered the relative merits of various types of evidence assembled to build a case for the most likely hypothesis to explain cause and effect.

AM in Puget Sound

Compared to ecosystem recovery programs nation-wide, Puget Sound's ranks among the more ambitious in size, scope, and complexity. In effect, it aspires to discover how a modern social-ecological system can thrive sustainably. A plausible approach is to break down the problem into manageable components, and, where appropriate, adopt an adaptive approach to management (where not appropriate, see Figure 2). The components include key attributes like fresh water quality and quantity, habitats such as estuaries and floodplains, species like salmon and sea birds, as well as injurious human impacts and behaviors such as shoreline armoring. Referred to collectively as 'Vital Sign' indicators, they form the kernels around which recovery plans known as 'Implementation Strategies' are being crafted. They were chosen such that, when their separate goals are met, their combined effects will restore a semblance of ecosystem functionality, although not to pre-development levels.

Designing a recovery plan for each of these is exacting, and managing them adaptively is even more so. Where appropriate, the impact of recovery actions must be measured to confirm they are having the desired effect – and modified if they are not. Lessons learned at one locality can be adapted and propagated more broadly, provided they are sufficiently documented. For a given Vital Sign indicator, adaptation requires familiarity with the strengths and weaknesses of ongoing recovery programs, ability to recognize successes from failures, and authority to adapt the program accordingly.

An adaptive approach is not new to Puget Sound (e.g. Peters et al. 2014), but it must be propagated and strengthened to demonstrate net benefits of actions, justify continued support for recovery, and build confidence that the investment is worthwhile.

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