ADAPTIVE MANAGEMENT: A SCIENCE-BASED APPROACH TO MANAGING ECOSYSTEMS IN THE FACE OF UNCERTAINTY

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SUMMARY

Adaptive management is a systematic approach for improving environmental management by learning from management outcomes. We believe that protected areas management can benefit greatly from this approach which allows management to proceed despite uncertainty, and reduces this uncertainty through a systematic process for learning. We describe this approach as a six-stage process: problem assessment, experimental design, implementation, monitoring, evaluation and management adjustment. For each stage we provide some examples for protected areas management, and outline some of the real world constraints which must be considered. However, adaptive management is more than just a procedure; it also requires curiosity, innovation, courage to admit uncertainty, and a commitment to learning.

1. INTRODUCTION

The concept of adaptive management was first developed in the 1970s at the University of British Columbia and the International Institute for Applied Systems Analysis in Vienna (1). While it has been applied to a range of resource and ecosystem management problems throughout North America and elsewhere in the world (2, 3, 4), it has not yet been widely applied to conservation projects (5). We believe that protected areas management can benefit greatly from this approach which allows management despite uncertainty, and reduces this uncertainty through structured learning. This paper out lines the key elements of adaptive management in easy-to-understand terms, explains how it can be applied to protected areas management, and provides some relevant examples. It concludes with a recognition that adaptive management is much more than a technical, science-based process. Rather, it is a bold approach to management, which requires creativity, curiosity and a long term commitment to structured learning.

2. WHAT IS ADAPTIVE MANAGEMENT?

Adaptive management is a systematic approach for improving environmental management and building knowledge by learning from management outcomes. Contrary to common belief, adaptive management is much more than simply "adapting as you go". It involves exploring alternative ways to meet management objectives, predicting the outcomes of each alternative based on the current state of knowledge, implementing one or more of these alternatives, monitoring to learn which alternative best meets the management objectives (and testing predictions), and then using these results to update knowledge and adjust management actions.

Adaptive management differs from traditional management approaches in that it allows management activities to proceed despite uncertainty regarding how best to achieve desired outcomes, and despite inevitable change and surprises. In fact, it specifically targets such uncertainty: it compels ecosystem managers to be open and explicit regarding what is not known about how best to achieve conservation and management objectives, and provides a science-based learning process characterized by using outcomes for evaluation and adjustment ("closing the loop"), illustrated in Figure 1.

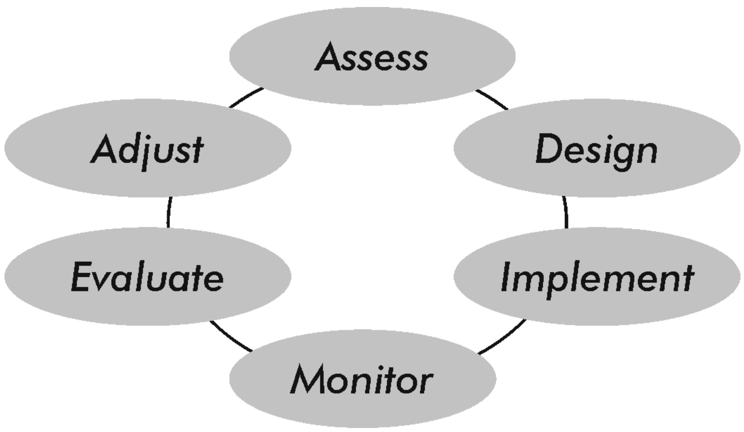

Figure 1. The Adaptive Management Cycle. (Source: (6)).

3. HOW CAN IT APPLY TO PROTECTED AREAS MANAGEMENT?

3.1 Assess the Problem

The starting point of adaptive management is to thoroughly assess the problem. This requires practitioners to clearly characterise the management problem, including the following elements:

1. Objectives – Clearly stating the conservation or management objectives for the protected area(s) or the sites in question. This should focus on fundamental objectives rather than means objectives, or on "what you want" rather than "how to get it" (7). For example, is the primary role of the protected area to conserve biodiversity, protect special features such as old growth forest or salmon habitat, preserve cultural heritage features, or support recreation? What is the relative importance of each objective to different stakeholders?

2. Actions – Identifying alternative conservation or management actions that could be taken to achieve these objectives, focusing on those actions that balance risk with opportunities for learning. For example, if the objectives of a given area include conservation of habitat for bald eagles, what are the different management approaches that can be employed to achieve this? Alternatives might include closing these habitat areas to visitors year-round, seasonal restrictions during nesting season, encouragement of sensitive use through education programs and signage, and/or efforts to increase the abundance of prey such as salmon.

3. Indicators – Identifying indicators that could be monitored to determine if the actions are actually achieving the objectives. For example, bald eagle abundance, the number of bald eagle nests in use,

or bald eagle fledgling success might be useful indicators of the success of bald eagle habitat conservation.

4. Uncertainties – If there is uncertainty regarding which management alternative will be most effective, or uncertainty regarding the outcomes of some of these alternatives, this should be clearly stated. This becomes a valuable assessment of the current state of knowledge, and provides the opportunities for learning that characterize the adaptive management approach. For example, what features of bald eagle habitat are most critical to nesting success, and how might these features be affected by both contemplated management actions and factors beyond management control such as global warming?

5. Hypotheses – Identifying alternative hypotheses that characterize different/expert opinions on how the indicators might be affected by alternative actions, using best guesses from current knowledge and tools such as modeling. If there is uncertainty regarding how bald eagle abundance might respond to the implementation of different management actions, what is the range of reasonable responses that different experts *think* will occur, and why? Alternative hypotheses should be articulated in relation to the indicators that have been identified, specifying the kinds of indicator responses expected under each hypothesis. For example, how might eagle abundance or the number of active nests change in response to each alternative action given dry, average, or wet years?

This assessment should also be repeated at regular intervals as the system changes or as learning occurs, which may give rise to the need to modify management actions or select new indicators. While each set of management actions will hopefully resolve some existing uncertainties, they will likely reveal new ones and therefore require new predictions. Assessment is likely to be the most onerous the first time through the adaptive management cycle, as practitioners become familiar with what these elements mean and how to apply them in practice.

3.2 Design the Management Experiment

The next stage in the adaptive management cycle involves using information from the assessment to design a management experiment that will both achieve management objectives and concurrently test hypotheses regarding critical uncertainties. Testing hypotheses allows one to learn how to better manage the system in the long term via a deliberate short term management experiment (Figure 2). It is very important to explore alternative designs, given the inevitable tradeoffs between statistical power (ability to test hypotheses), cost, feasibility, and the ability to meet conservation and management objectives while avoiding unacceptable risks. Longer experiments have greater statistical power to distinguish among alternative hypotheses, but cost more to implement and delay the benefits of implementing the best policy (8).

Risk is a critical issue when species are threatened or endangered. In general, it's best to implement adaptive management on populations which have not reached such low abundances, so that a "fail-safe" experiment can be conducted. Even with threatened or endangered species, one can legitimately ask, "Is the long-term risk of **not** doing the management experiment greater than doing it?" Peters and Marmorek (9) provide an example of this form of analysis for endangered Snake River chinook salmon.

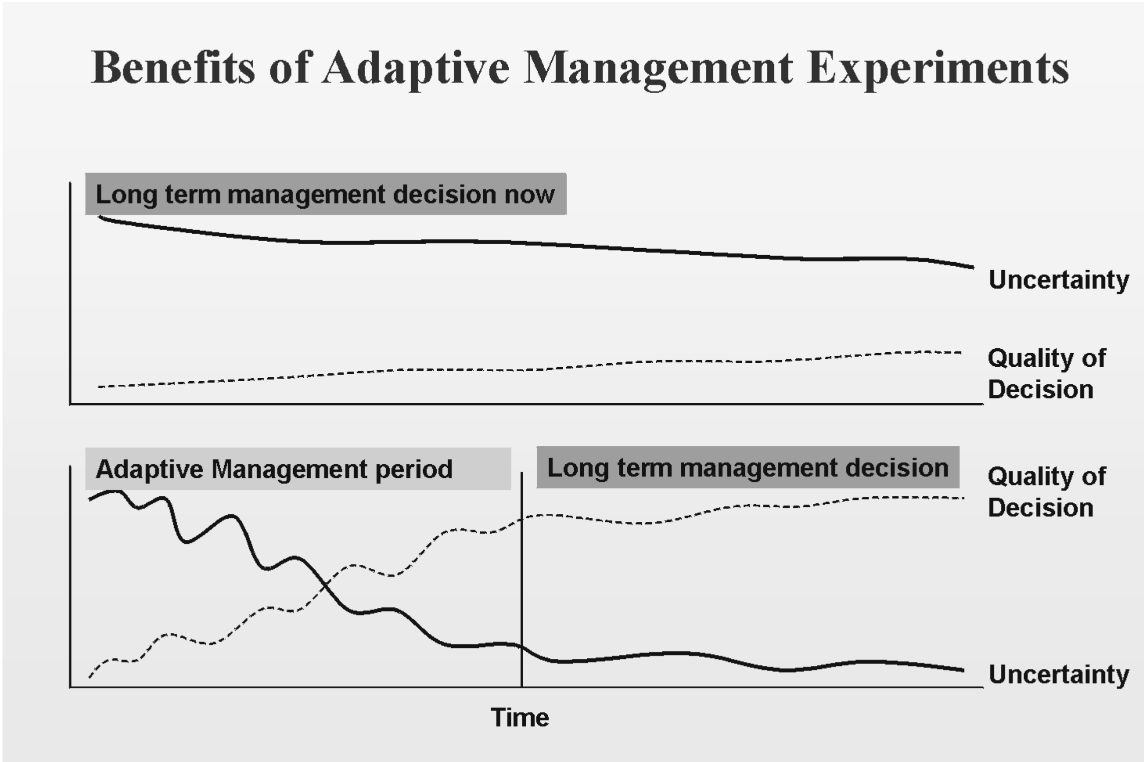

Figure 2. Upper Panel: immediately implementing the apparently 'best' long term management decision and then monitoring its effects results in only a slow decrease in uncertainty and only slight improvements over time in decisions. Lower Panel: A deliberate, well-designed adaptive management experiment can reduce uncertainty much more quickly and result in a far superior long term management decision.

This is one of the more challenging stages in the cycle, as learning from adaptive management experiments is a function of what the practitioner can and cannot control. Can sufficient contrasts be created in time and/or space through the management experiment to distinguish the effects of alternative actions from background noise (natural variability)? Sufficient replicates and avoiding confounding are also issues to consider, and a range of tools are available to assist with this (10, 11).

One excellent way to assess the impact of a management action is to measure an indicator before and after the treatment is applied in both treated sites and control sites. This is called a BACI-P (before-after, control-impact, paired) design (12, 13, 11), and requires multiple measures over time to maximize the chance of distinguishing true treatment response from natural variability. Of course no two areas are ever the same in nature, and they don't need to be. This approach examines the differences between control and treated areas and how these differences change after management actions are applied. It is important to engage the expertise of a biometrician to ensure that the sampling design is sufficient to detect effects that are environmentally important, given the natural variation in indicators over time and space. Only some factors are under the control of the practitioner of adaptive management (Figure 3).

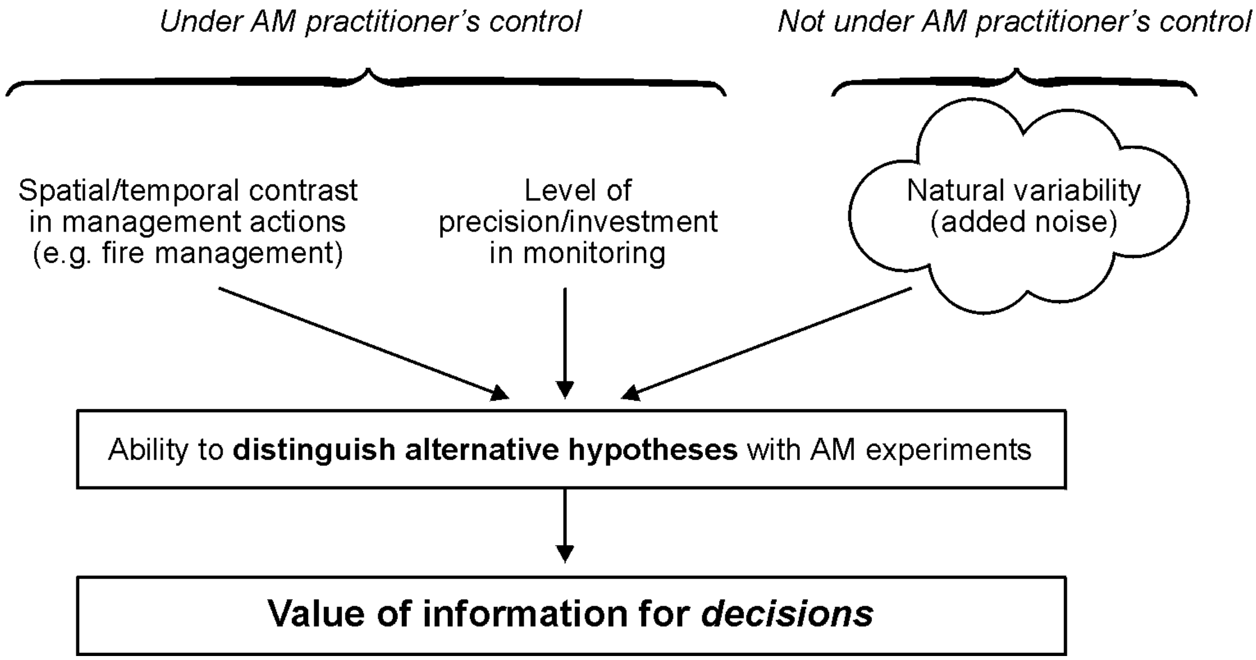

Figure 3. Only the spatial / temporal contrast in management actions, and the level of precision / investment in monitoring is under the control of the AM practitioner. He or she cannot control natural variability, other than by 'filtering' it out by the use of controls which are subject to similar natural variation as treated areas, but do not receive the experimental management action. Together the three illustrated factors determine how well alternative hypotheses can be evaluated, which in turn affects the ability to make improved long term management decisions.

The design must detail on-the-ground management activities and specify exactly what is to be done at each site, how, and when. This design should contain sufficient detail to ensure that all the prescribed activities to include in the management experiment are properly carried out. It should also detail what monitoring must occur: measurements to be taken, when, where, and how.

Another important element of this stage, and one which helps distinguish adaptive management from traditional environmental management, is the explicit prediction of outcomes based on the experimental design. How do you expect the indicators to respond to the management actions? Making predictions based on the best available knowledge greatly increases the ability to learn and build on this knowledge when predictions are compared to observed results.

3.3 Implement the Management Experiment

At this point, the management activities are carried out as designed. If deviations from this design are necessary for unforeseen reasons, this is not a large problem as long as the deviations, and the reasons for them, are clearly documented. Maintaining the integrity of the experimental design is critical for continuity between the assessment and evaluation stages, and this continuity is critical for reducing uncertainty and building knowledge. If the experimental design is not implemented as expected, and this is not clearly recorded, the opportunity for learning will be lost – or worse, it will lead to erroneous conclusions.

3.4 Monitor the Results

Two types of monitoring are important for accurate interpretation of the results. Implementation monitoring is required to ensure that the activities were undertaken as prescribed, which is important for the reasons described above. In public areas such as parks, this presents an added challenge: for example, signage restricting access to certain sites might have been posted as planned, but did park visitors actually respect these notices and avoid bald eagle habitats? Implementation monitoring requires not only monitoring what the managers did, but also the actions of others where they have the potential to influence the achievement of the conservation or management objectives.

Effectiveness monitoring is required to learn whether the activities worked: were the fundamental objectives achieved? (While monitoring the response of park visitors to signage as described above may reveal the effectiveness of the signage in modifying visitor behaviour, it does not provide insights regarding the effects of this change in visitor behaviour on the fundamental objective of bald eagle habitat conservation.) Effectiveness monitoring targets the indicators listed in the assessment stage of the cycle, and allows an assessment of actual "on the ground" outcomes. For example, did the number of bald eagle nests or bald eagles increase compared to control areas and pre-treatment conditions? While this is critical for learning which hypotheses were correct, it is not sufficient, and must also be combined with information on what activities actually took place in order to draw accurate inferences. Confounding factors (e.g. windstorms, forest fires) can sometimes confuse even the best designed management experiments, but also can provide unexpected opportunities for learning if a rigorous monitoring program is in place (14).

3.5 Evaluate the Results

This stage focuses on learning whether the predicted outcomes were accurate, and gaining knowledge about what activities best achieve the desired objectives. Analyse the monitoring results to learn which hypotheses can be rejected, which are strongly supported, and which hypotheses are neither strongly supported nor rejected. Which activities moved the system towards the fundamental conservation or management objectives and which did not?

3.6 Adjust the Experiment, Policy or Practices

This stage most distinguishes adaptive management from traditional environmental management by explicitly prompting changes based on what has been learned. Ideally, the management responses to each possible outcome of the experiment should be pre-planned before the experiment is implemented as part of the design. This will help serve as a "reality check" regarding what types of adjustments are possible.

4. EXAMPLES

4.1 Managing Visitor Behaviour in Recreation Sites

An adaptive management experiment was done in British Columbia in 1996 to learn what management strategies might work best in minimizing recreation conflict in Forest Service outdoor recreation sites (15). The management problem involved concerns about public and staff safety, escalating conflict between recreation site users and other resource users, site degradation, noise and vandalism. Possible management strategies to address these problems fell into two main categories: indirect techniques for influencing recreation behaviour, such as physical alteration of sites (e.g. improving roads and campsites) or information provision, and direct techniques for controlling and enforcing recreation behaviour, such as warden patrols, restricting certain kinds of use (e.g. all terrain vehicles, or fire-building), or rationing use (e.g. through quotas). While direct techniques were considered be more likely to address the management problem, their potential to compromise the recreational experience in these natural and primitive recreation sites was also noted. Direct techniques are also more expensive, and agencies considering these need confidence they will be effective. While most visitor satisfaction studies involve the use of preference surveys without the implementation of an experimental design, in this case an adaptive management experiment was designed to obtain a better understanding of the effectiveness and acceptability of both direct and indirect management strategies.

The goal of the experiment was to evaluate the effectiveness of three alternative management actions: on-site hosts providing 24-hour supervision, security and site maintenance (considered an indirect strategy); periodic enforcement patrols by a uniformed RCMP officer and a uniformed Forest Service officer (considered a direct strategy); and a combination of hosts and patrols. These were chosen because they had previously been used elsewhere in the province, were the most feasible to implement compared with alternatives, and were considered by the Forest Service as most likely to be effective.

The management experiments were carried out in the Merritt Forest District, the Okanagan Valley, and the city of Vancouver. The management treatments were applied during four long weekends when use levels were expected to be the highest, and management problems anticipated to be most severe. Effectiveness of each treatment was determined through visitor surveys, to measure their satisfaction with their camping experience with regard to noise, pets, ATVs, other motor vehicles, and overall site management. Visitor surveys were also conducted during four regular weekends where no treatments were applied, as a control. In addition, visitor preferences were also surveyed.

The visitor satisfaction results suggest that site hosts, either alone or in combination with patrols, were more effective than patrols alone in improving visitor satisfaction in relation to these problems. However, the visitor *preference* results suggest a higher level of support for Forest Service patrols than for hosts. This seems to indicate that visitors prefer an option that may in fact be less effective, and highlights the importance of the experimental approach: without it the erroneous conclusion may have been reached that patrols would be the most effective action. The authors were also surprised to learn through the surveys that there is considerable opposition to a “no supervision” option, which was counter to common belief that visitors seek these type of recreation sites because they prefer fewer restrictions.

This was considered by the report authors as a good application for adaptive management for several reasons. First, there was little known about how visitors would react to a change in management strategy in sites where the traditional management style was very low key. Second, there was a high level of uncertainty regarding which management actions would be most effective in these settings. Third, it presented an opportunity to examine the causal relationships between management actions and visitor satisfaction through experimental design rather than relying solely on visitor preference for hypothetical management strategies. Some very valuable information was learned by taking an experimental management approach. For example, visitors strongly support some form of supervision in heavily used sites. Indirect strategies such as site hosts may be effective for addressing problems related to visitor behaviour, and direct management strategies such as RCMP/Forest Service patrols may not be necessary at some sites, despite their ability to enforce regulations.

Additional information on the experimental design, analysis of results, conclusions and recommendations can be obtained from the source paper (15).

4.2 Managing Invasive Species in Garry Oak Ecosystems

A decision support tool has recently been developed for the Garry Oak Ecosystems Recovery Team in British Columbia to help land managers decide whether, and how, to control for invasive species in Garry oak ecosystems (16). This example illustrates how adaptive management can be applied at both the strategic and operational levels, towards restoration efforts in these endangered ecosystems.

First, the tool uses an adaptive management framework to guide users through the assessment, design, implementation, monitoring, evaluation and adjustment of actions to manage and control invasive species at any given GOE site. This is an example of operational level adaptive management, where the cycle is applied *within* Garry oak ecosystems, to learn what works best at that location given the site-specific characteristics, risks and challenges.

Second, the same adaptive management framework has been used at a strategic level to design a process for implementing, monitoring, evaluating and adjusting the tool itself (17), as illustrated in Figure 4. This will allow the Recovery Team to monitor use of the tool and success of invasive species management activities *across* Garry oak ecosystems, and will facilitate faster learning at a regional, "bigger picture" level. This knowledge can be used to further inform operational level activities as more is learned, and to coordinate operational-level adaptive management experiments as new uncertainties arise.

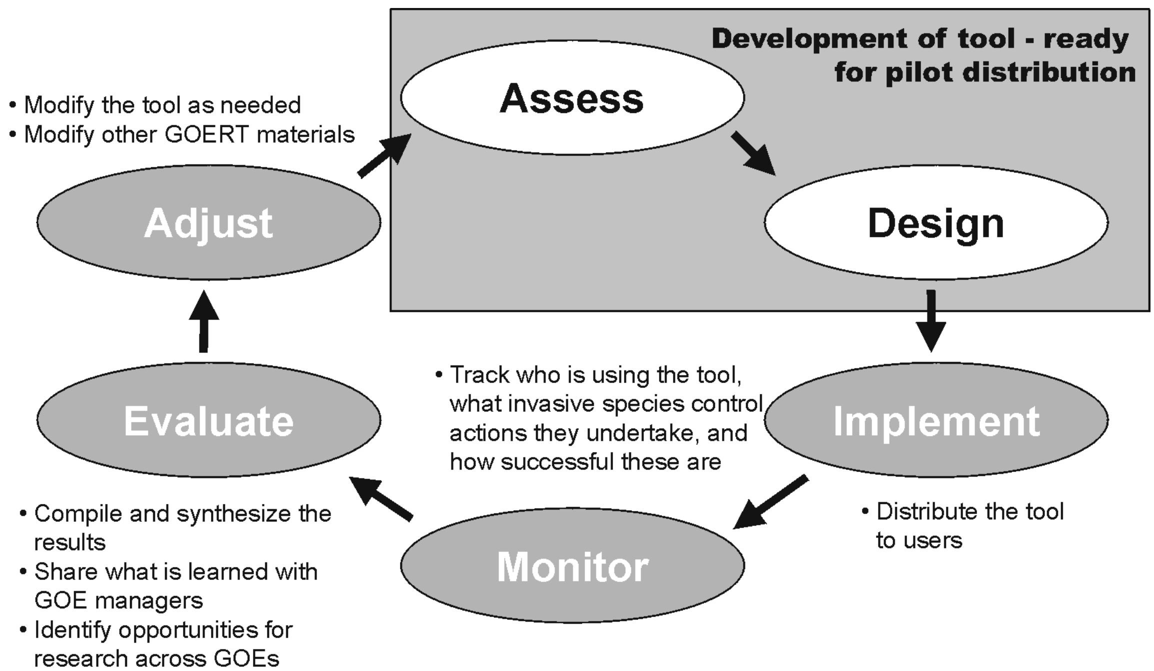

Figure 4. Strategic application of the adaptive management cycle. (Source: modified from (17))

5. AN ADAPTIVE MANAGEMENT ATTITUDE

Adaptive management is not just a set of steps or tasks; it is also an attitude: a way of looking at problems and a curiosity to resolve them. Salafsky et al. (18) understand this and have developed principles for applying adaptive management to conservation that include promoting institutional curiosity and innovation; valuing failures and learning from mistakes; expecting surprises and capitalizing on crises; and encouraging personal and organizational growth by hiring people who are committed to learning.

An adaptive management attitude can be fostered by starting with small successes: applying the approach to relatively simple problems in relatively small areas that can be resolved in a reasonably short time frame. This will build confidence and experience which can be applied to gradually larger problems. The challenge for organizations is to create a culture that embraces change, admits uncertainty, and questions the status quo; treat unexpected events as catalysts to rethink past approaches; and rewards members that embark on adaptive management.

Often one hears of multi-agency struggles to come to consensus on long-term management policies. Consensus on long-term decisions is impossible when major uncertainties exist regarding the effects of those decisions. However, it **is** possible to develop consensus on adaptive management experiments which could resolve, or at least reduce, these uncertainties. As such management experiments are implemented it will build trust among the participants and reduce management uncertainty.

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