Society and Natural Resources, 22:484–495
Copyright © 2009 Taylor & Francis Group, LLC
ISSN: 0894-1920 print/1521-0723 online
DOI: 10.1080/08941920902762321

Routledge
Taylor & Francis Group

Toward More Reflexive Use of Adaptive Management

C. JACOBSON

School of Integrative Systems, The University of Queensland, Gatton, Queensland, Australia

K. F. D. HUGHEY

Faculty of Environment, Society and Design, Lincoln University, Lincoln, New Zealand

W. J. ALLEN

Landcare Research, Lincoln, New Zealand

S. RIXECKER

Faculty of Environment, Society and Design, Lincoln University, Lincoln, New Zealand

R. W. CARTER

Faculty of Science, Health and Education, University of the Sunshine Coast, Maroochydore DC, Queensland, Australia

Adaptive management is commonly identified as a way to address situations where ecological and social uncertainty exists. Two discourses are common: a focus on experimentation, and a focus on collaboration. The roles of experimental and collaborative adaptive management in contemporary practice are reviewed to identify tools for bridging the discourses. Examples include broadening the scope of contributions during the buy-in and goal-setting stages, using conceptual models and decision support tools to include stakeholders in model development, experimentation using indicators of concern to stakeholders, an experimental focus that reflects the level of statistical confidence required by management, and the engagement of stakeholders in data interpretation so that those affected by management outcomes can learn and adapt accordingly. In this context, a framework of questions that managers can use to reflect on both ecological and social uncertainties as they relate to individual management contexts is proposed.

Keywords adaptive management, collaboration, epistemology, experimentation, reflection

Received 8 May 2007; accepted 16 April 2008.
Address correspondence to C. Jacobson, School of Integrative Systems, The University of Queensland, Gatton, Queensland 4343, Australia. E-mail: c.jacobson@uq.edu.au

Managing situations where uncertainty and complexity prevail is of increasing importance in addressing the goal of sustainable development. At the same time, environmental managers (individuals, public agencies, nongovernmental organizations [NGOs], and businesses) are faced with increasing demands for decision-making accountability. To address ecological uncertainties (e.g., what actions to take to improve outcomes), some academics have called for management that is underpinned by ecological science (e.g., Romesberg 1991; Steidl et al. 2000). However, social uncertainties also exist: for example, the consequences of actions on local livelihoods, differences in opinion about desirable outcomes, and the questioning of who has the knowledge and capacity to manage. In response, others have called for greater recognition of the role stakeholder groups can play in the success of management initiatives (e.g., Gunderson et al. 1995; Salafsky and Wollenberg, 2000). A commonly identified way to address situations in which ecological and social uncertainty exist is through adaptive management.

A plurality of adaptive management definitions and interpretations is evident in the literature (see MacDonald et al. 1997). Academic contributions to the practice of adaptive management have focused on addressing uncertainties. Examples include the use of large-scale experimentation to optimize management performance (Walters and Holling 1990), the use of models to refine knowledge about systems under management (Walters et al. 2000), and the development of multi-stakeholder processes to manage value conflict and increase the pool of contributions to potential management solutions (Walker et al. 2002). From the disciplinary tradition of expert knowledge, academic responses have resulted in a dichotomy of perspectives. Adaptive management has been used as a model for experimentation (adaptive experimental management or AEM) that focuses on "how" to manage (see Parkes et al. 2006), as well as a model for collaboration (adaptive collaborative management or ACM) that focuses on "what" to manage and "who" ought to manage (see Buck et al. 2001). These differences in interpretation may influence success in practice, as was evidenced in U.S. Pacific Northwest Forest management (Duncan 2001), and such differences have also been noted as problematic for progressing the practice of adaptive management (Parma et al. 1998; Wildhere 2002).

We posit that the disciplinary-based interpretations of adaptive management may constrain consideration of the range of ecological and social uncertainties that apply, and that improvement in the practice of adaptive management requires greater attention to uncertainties as they relate to the practice context, rather than epistemological interest. Whilst the relevance of context is clearly articulated in the policy design literature (e.g., Bobrow and Dryzek 1987; deLeon 1992), it has not been substantially considered within the literature on adaptive management. Rather than maintaining divergent development of epistemologies, a focus on context requires drawing from both (what we refer to as "bridging epistemologies"), and adapting appropriately to context (what we refer to as "bridging epistemologies in practice"). We propose a framework of questions, developed in conjunction with practitioners, to support reflection on practice and practice context. Inspiration for framework development drew on our observations of the effects of narrow interpretations of adaptive management in addition to observing others' apparent concerns about mispractice or misinterpretation of adaptive management (e.g., Duncan 2001; Hunter et al. 2003; Roe and Van Eeten 2001; Wildhere 2002).

Bridging Epistemologies

Adaptive management differs from traditional "trial and error" management in that it involves an explicit, formalized, and ongoing learning process that varies in degree of sophistication (Schreiber et al. 2004). A continuum of learning styles is practiced under the banner of adaptive management, ranging from passive to active approaches (see MacDonald et al. 1997). In addition, there may be limited to broad participation in the learning process. Learning under passive-adaptive management involves adapting management decisions, utilizing the monitoring of management actions to improve outcomes and to ensure management decision making and policy implementation are more defensible. In contrast, active-adaptive management distinguishes projects that build a quantitative system model to make predictions about the outcomes of management actions (e.g., Walkerden and Gilmour 1996). In such cases, policies act as hypotheses and management as an experiment to be implemented scientifically (Walters 1986). Multiple competing models and hypotheses may be tested simultaneously (i.e., using multiple experimental sites), increasing the rate of learning but also increasing the risk associated with potentially suboptimal management regimes at an individual location (McCarthy and Possingham 2007). Adaptive management, in any form, differs from basic science in that there is limited ability to "control" for all factors influencing the effectiveness of management actions, making causal relationships difficult to delineate. In addition, opportunities for replication are limited: Management areas utilized as replicates for particular management treatments may differ in land use history, ecological characteristics (e.g., flora and fauna), and locally associated values and constraints (e.g., localized funding and priorities). In some situations, management is non-replicable and there is no opportunity for testing multiple hypotheses—for example, where whole catchments represent management units (e.g., Allan and Curtis 2005), or when management units are unique (e.g., the Everglades).

AEM has emphasized the active-learning form of adaptive management. Due to the technical emphasis (especially that of quantitative modeling), AEM requires a leading agency capable of providing substantial financial commitment and attracting appropriate technical expertise. The technical emphasis results in funding that is often limited in duration. In this sense, adaptive management operates as a traditional model of information transfer where science is utilized to solve problems and increase certainty, challenging eco-theorist arguments (e.g., resilience theory—see Holling 1973; Gunderson and Holling 2001) that complexity and uncertainty are likely to persist irrespective of management. The nature of knowledge created in AEM privileges those with technical expertise and may therefore limit opportunities for ongoing learning by non-experts (Stankey and Shindler 1997). A focus on "how" to optimize a particular outcome assumes that there is agreement on the goal of management, that management effects have been adequately considered, and that there is agreement on the degree of certainty sufficient for management decision making.

Critics of experimental approaches to management (e.g., Endter-Wada et al. 1998; McLain and Lee 1996) question who should be involved in setting management goals and in deciding which uncertainties should be explored, and whose knowledge/policy "hypotheses" should be the basis for the experimentation. These criticisms are both ideological and pragmatic in nature (i.e., concerning rights to participate in decision making and improvement in outcomes). In response, proponents

of ACM have advocated the use of multi-stakeholder processes, such as facilitated workshops, that provide the opportunity to engage institutions and communities affected by management so that they might contribute to what is known about a management problem and what is uncertain, and identify probable impacts of management actions. Thus, ACM has emphasized so-called social and collaborative learning approaches (e.g., Keen et al. 2005). Further, Mendis-Millard and Reed (2007) argue that working collaboratively requires science to be willing to relinquish some control of the direction of adaptive management as project directions are adapted to local needs, interests, and circumstances. Slowed progress to management action or superficial participation may alienate some stakeholders and undermine long-term support for adaptive management, as identified in the Pacific Northwest forest areas (Duncan 2001). However, a solely collaborative emphasis may serve to reduce social uncertainty associated with the desirability of particular outcomes, and identify less privileged forms of knowledge (e.g., local and experiential knowledge), but may draw attention from the need for management decisions to be based on robust knowledge—the original concern of ecologists.

Instead of focusing on either experimentation or collaboration, opportunities exist for bridging these approaches. However, collaborative processes ought not to be seen as simply a "graft" in the early phases of AEM. Without stakeholder participation in data collection and interpretation, and training in the use of tools that enable knowledge models to be updated, AEM risks becoming detached from those who need to learn. Furthermore, any knowledge created may remain privileged. Thus, experts and managers need to consider both experimental and collaborative perspectives of adaptive management at each step of the learning process. That is, management experimentation can define management variables for testing and a framework for interpreting results so that causality can be appropriately apportioned so that managers have confidence in the management adaptations they might make. However, collaboration throughout the life of a project ensures that variables tested under management experimentation are identified from best available knowledge (i.e., local and indigenous knowledges triangulated with science) and that interest is maintained over a project's life so that those affected by management have the opportunity to sustain learning and adapt policy collaboratively.

Bridging Epistemologies in Practice

To avoid the shortcomings of AEM and ACM approaches, practitioners need to consider carefully the way in which they interpret and apply adaptive management. While there are different interpretations of adaptive management, there appears to be general (implicit) agreement on the steps involved. These include buy-in and goal setting, model development, action, monitoring, and feedback. Adaptive management is a learning process, and these steps are therefore not dissimilar to those of any other learning process (e.g., single- and double-loop learning [Argyris 1990], education [Moon 2004], or research and development [Ison et al. 2000]) wherein reflection on action leads to reconsideration of the course of action, the assumptions that support a particular course of action, and the goals of management.

The primary concern in this work was to review contemporary practice and present it in a logical and structured way that enabled practitioners to consider how insights from both experimental and collaborative perspectives of adaptive management might be relevant to their own practice. In doing so, we reviewed literature

(peer-reviewed and project reports) to identify criteria for adaptive management as they relate to each step of the learning process. The questions (Table 1) provide a framework for reflecting on the practice of adaptive management based on iterated refinement of these criteria. The remainder of this article details avenues for bridging epistemologies in practice. Incorporated are perspectives offered during interviews relating to process evaluations of another project in which the authors were involved.

Step 1: Buy-In and Goal Setting

Adaptive management is initially focused on collaboration, and involves the identification of and agreement on a management problem between stakeholders. Together, the stakeholders will define a joint depiction of the management situation (Salafsky et al. 2001) and will clarify needs and expectations of the process (Gilmour et al. 1999; Lee 1999). In this step, AEM perspectives emphasize consideration of the appropriate disciplinary mix of specialists who will make substantial contributions to model development and planning for management implementation (Walters 1986). Advocates of ACM broaden contributors to ensure the inclusion of those likely to be affected by resolution of the identified problem, including policymakers, managers, scientists, indigenous peoples, and interest groups (Meffe et al. 2002). During the refinement of the framework of research questions, project leaders identify the technical skill sets required. In our process evaluation, 11 of 20 non-expert participants commented that having participants with open minds and responsive to considering a range of perspectives (including scientists and project leaders) is equally important as having the appropriate mix of technical expertise. Conflict over value preferences can slow management (Schusler et al. 2003). To identify desirable and feasible actions in such cases, it may be necessary to apply problem structuring methodologies (e.g., Soft Systems Methodology [Checkland 1985] or Critical Systems Thinking [Mingers 2003]) that involve a critique of institutional and political factors affecting a management situation (Salafsky et al. 2001).

Step 2: Model Development

Model development involves transforming knowledge about a management situation into a model of it, with the purpose of exploring and clarifying assumptions, acknowledging uncertainty, and identifying knowledge gaps. The use of models ensures that upon review, new knowledge is incorporated and learning is made explicit. The model may be qualitative, mathematical, or both. Mathematical modeling received a strong focus in the early development of adaptive management (Walters 1986; Walters and Hilborn 1978), and subsequently in AEM where evidence is collected for competing models and incorporated using probability theorem (Hunter et al. 2003). Within ACM, emphasis is on the process of sharing knowledge under the premise that engagement can help to change individual perspectives of factors affecting and limiting management, thereby building capacity for adaptation (Pahl-Wostl 2002). Developments from ACM have supported stakeholder contributions beyond the step of problem framing through the use of conceptual modeling (e.g., Heemskerk et al. 2003; Lynam et al. 2002) and Bayesian modeling (Smith et al. 2007). These tools can link qualitative and mathematical models, as well as exploring the implications of different management scenarios (e.g., Salafsky and Wollenberg 2000).

Table 1. Questions to elicit reflection on adaptive management

Step 1: Buy in and goal setting
- Do you have a shared vision for your project and a set of goals to match?
- Are the ecological boundaries of management clearly defined? (temporally/spatially)
- Do goals consider ecological and social aspects of the management context?
- Are goals aimed at managing uncertainty?
- Have both social and ecological benchmarks for success been created?
- Have relevant stakeholders been identified and provision made to involve them?
- Have communication networks been identified and a process for communication been established?
- Do you have adequate capacity for your project? (people, resources, institutional support)

Step 2: Model building
- Has a model of the system being managed been developed?
- Have relevant sources of knowledge been identified and drawn together to use in the model?
- Have uncertainties in knowledge and assumptions in the model been acknowledged?
- Have issues associated with both temporal and spatial scales been considered (e.g., lag effects)?
- Is the model translatable for stakeholders and policymakers?

Step 3: Action
- Have management options been identified that meet goals, and are they stated as hypotheses?
- Have predictions been developed for each option?
- Have stakeholders been included in decision making?
- Have the risks and trade-offs between different management options been considered?
- Have ecological imperatives been considered equitably with economic and social imperatives?
- Have management actions been designed as experiments, and are they recognized as such?
- Have the limitations of methods been recognized?
- Has focus been given to biological significance?
- Have compromise and constraint been accepted?
- Has an appropriate running time been considered for experiments?

Step 4: Monitoring
- Is monitoring conducted systematically and in relation to hypotheses?
- Are short- and long-term responses monitored?
- Are appropriate criteria used in indicator selection?
- Have stakeholders been given an opportunity to be involved?
- Has data been collected so that management processes can be evaluated?

(*Continued*)

Table 1. Continued

Step 5: Feedback
• Is evaluation conducted systematically and in relation to goals?
• Are both process and experimental lessons documented?
• Is the management process transparent?
• Is the process iterative?
• Is evaluation completed in relation to the timing of ecological processes?
• Are failures and unexpected results treated as learning exercises?
• Are both social and ecological uncertainties evaluated?
• Has the appropriateness of goals been evaluated?
• Are management and learning processes evaluated?
• Are practitioners and organizations reflexive?

In our work, adaptive management project leaders stressed the significance of having a model that could be used to explain technical concepts to non-experts, and to ensure that findings were incorporated into management to support practice—for example, through a decision support tool. Collaborative approaches to system modeling are one means of doing so. In a study of fire management in protected areas, Smith et al. (2007) identified that processes used during model development can help to build capacity of staff to use and update models and decision support tools (such as Bayesian models) unaided, providing opportunity for continued learning beyond the term of specialist input.

Step 3: Action

This step involves a decision-making process between multiple management options. Early depictions of adaptive management and those of AEM emphasize that policies and management objectives are phrased as hypotheses and are implemented in an experimental manner (Lee 1993; Walters and Holling 1990). Experimentation provides managers with the ability to distinguish the effect of management actions by comparing outcomes in actively managed and nonmanaged areas, and provides adequate time to determine responses from temporal variability. Walters (1986) argues against incremental changes in management, suggesting that larger changes and the simultaneous testing of multiple hypotheses are more likely to reveal dynamic behaviors of systems being managed and maximize opportunities for learning. However, this is at odds with the typically precautionary nature of policy processes. McCarthy and Possingham (2007) identify that the simultaneous testing of management options may only be beneficial in situations where considerable uncertainty exists about the means of achieving success; in other cases, managers may actively avoid the risk of failure by removing elements at risk from experimentation. This is in line with Lindblom's (1979) observation that incremental changes in management are most likely to gain acceptance because they provide opportunity for social learning (what he refers to as partisan mutual adjustment) and may result in detailed analyses of a smaller selection of options rather than incomplete analysis of a larger selection.

A participant involved in framework testing revealed that local priorities resulted in the sacrifice of part of a spatially replicated adaptive management experiment to avoid risk to a locally significant species. Practitioners must recognize that

the relative success of adaptive management can be influenced by perceived risks and priorities at the smallest unit of management. It is therefore important to consider perspectives from all stakeholder groups (McLain and Lee 1996). Tools such as scenario modeling (e.g., Wollenberg et al. 2000) build on the use of models for knowledge sharing and contribute to further participation of a broad range of stakeholders. This emphasis in ACM offers the potential to improve relationships between public agencies and stakeholders through involvement in the management process; although this is not guaranteed. The potential for improved relationships with resource user groups was one reason agencies committed to one project in which we were involved. Process evaluation enabled the recording of improvements in relationships during this phase and of the factors that contributed to them (i.e., decision-making transparency and the ability to see individuals' ideas incorporated within project plans).

Step 4: Monitoring

Systematic and planned monitoring of management actions is an integral part of adaptive management, because of its learning focus. Monitoring is the key to ensuring rigor in knowledge about the effectiveness of management actions. Debate among ecologists about the appropriate use of indicators is therefore relevant (e.g., Ringold et al. 1996; Urban 2002). Within ACM, there are arguments for continued stakeholder involvement (e.g., Bosch et al. 1996). This may result in the broadening of ecological indicators to include socially and economically relevant ones. For example, stakeholders in one study in which we are involved suggested measuring the carbon costs and gains associated with forest management: something the scientists involved in the project had not considered.

More recently, the use of large-scale qualitative, rank-based assessment has been linked with adaptive management (Leverington et al. 2008). This provides a cost-efficient means of assessing the success of different management options and a way of engaging stakeholders in learning, although the reliability of such assessment remains to be tested. Monitoring of participatory processes may also be useful alongside each step in the management process. It ensures that changing ethical risks to participants (e.g., reputation effects from negative outcomes and interagency politics) are managed (Prokopy 2008), provides a means of assessing success from a sociological perspective, and enables processes to be adapted to the needs of those involved (see Mendis-Millard and Reed 2007). The process evaluations we conducted support this point. We identified that groups may respond differently to the same process and that processes may therefore need to be tailored to the needs of the individuals involved. For example, one group within our research sample was interested in increased science direction, explaining that it was inappropriate for non-experts to direct the process, while another was concerned about the technical level of discussion and asked for plain language and less direction from science.

Step 5: Feedback

Feedback involves the analysis and assessment of management experiments, assumptions, uncertainties, and knowledge gaps identified during model development. It also involves the analysis and assessment of goals and success benchmarks identified during goal setting and buy-in. Multiple levels of feedback accommodate multiple

temporal frames, and can be designed at multiple spatial frames (i.e., local, regional and national). Experimental perspectives on adaptive management highlight different tests that may be undertaken (Sit and Taylor 1998). New knowledge can then be incorporated into quantitative models, and likelihoods associated with different hypotheses can then be updated. In ACM, this step also focuses on the transmission of learning to stakeholders (and other interested parties) and on ensuring institutional memory of that learning (Dovers 2001). It bounds the "hard" knowledge gained within the "soft" social system of values, interpretations, and perspectives that contextualize that learning and give it relevance.

Participation in the analysis of the results may also provide a means of overcoming difference in opinion about the effects of management actions, provided participants can agree, at the outset, on what constitutes evidence for the model(s) applied. Although not seen in our experience, there may be a case for accepting significance levels other than $p < .05$ as a basis for change, given that the ability to detect a management effect at this level is resource dependent (i.e., limited by sample size). Approaches that focus on thresholds for management, as used in Kruger National Park (du Toit et al. 2003), ensure an adaptation response, or at least a trigger for transitioning between different styles of management (see Roe and Van Eeten 2001).

Concluding Comments

The framework of questions presented in Table 1 and discussed in this article allows managers to reflect on adaptive management practice by considering the advantages of both AEM and ACM. Our testing included managers at a range of different stages in adaptive management projects. For those in later stages, it provided an opportunity to reflect on the reasons behind their successes and failures. For those at earlier stages, it provided opportunity to consider their next steps. While testing was conducted with project leaders, there is no reason why such a framework could not be used to clarify differences in the interpretation of adaptive management between all involved. To bridge the epistemological dichotomy, policy and practice must be afforded opportunity to innovate as is appropriate to context. The questions are therefore not intended as a normative definition of adaptive management, but as a way to bridge academic positions and promote reflection on practice.

References

Allan, C. and A. Curtis. 2005. Nipped in the bud: Why regional scale adaptive management is not blooming. *Environ. Manage.* 36(3):414–425.

Argyris, C. 1990. *Overcoming organizational defences: Facilitating organizational learning.* Boston: Allyn and Bacon.

Bosch, O. J. H., W. J. Allen, J. M. Williams, and A. Ensor. 1996. An integrated system for maximising community knowledge: Integrating community-based monitoring into the adaptive management process in the New Zealand high country. *Rangeland J.* 18(1):23–32.

Buck, L. E., C. C. Geisler, J. Schellas, and E. Wollenberg. 2001. *Biological diversity: Balancing interests through adaptive collaborative management.* Boca Raton, FL: CRC Press.

Bobrow, D. B. and J. S. Dryzek. 1987. *Policy analysis by design.* Pittsburgh, PA: University of Pittsburgh Press.

Checkland, P. 1985. From optimizing to learning: A development of systems thinking for the 1990s. *J. Operation Res. Society* 36(9):757–767.

de Leon, P. 1992. The contextual burdens of policy design. *Policy Stud. J.* 17:297–309.
Dovers, S. 2001. Processes and institutions for resource and environmental management: Why and how to analyze. In *Processes and institutions for resource and environmental management: Australian experiences. Final report to Land and Water Australia*, eds. S. Wild Rivers and S. Dovers, 3–14. Canberra, Australia: Centre for Resource and Environmental Studies, Australian National University.
Duncan, S. 2001. Too early to tell, or too late to rescue? Adaptive management under scrutiny. *Science Findings* April(33):1–5. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.
du Toit, J. T., H. Biggs, and K. H. Rogers. 2003. *The Kruger experience: Ecology and management of savana heterogeneity*. New York: Island Press.
Endter-Wada, J., D. Blahna, R. Krannich, and M. Brunson. 1998. A framework for understanding social science contributions to ecosystem management. *Ecol. Applications* 8(3):891–904.
Gunderson, L. and C. S. Holling. 2001. *Panarchy; Understanding transformations in systems of humans and nature*. Washington, DC: Island Press.
Gunderson, L., C. S. Holling, and S. S. Light. 1995. *Barriers and bridges to the renewal of ecosystems and institutions*. New York: Columbia University Press.
Heemskerk, M., K. Wilson, and M. Pavao-Zuckerman. 2003. Conceptual models as tools for communication across disciplines. *Conserv. Ecol.* 7:3–8.
Holling, C. S. 1973. Resilience and stability of ecological systems. *Annu. Rev. Ecol. Systematics* 4:1–23.
Hunter, C. M., F. Johnson, W. L. Kendall, J. D. Nichols, H. Possingham, M. C. Runge, and B. K. Williams. 2003. A framework for adaptive management. Workshop at the 3rd International Wildlife Management Congress, Christchurch, New Zealand, 1–5 December.
Ison, R. L., C. High, C. P. Blackmore, and M. Cerf. 2000. Theoretical frameworks for learning-based approaches to change in industrialised-country agricultures. In *Cow up a tree: Knowing and learning for change in agriculture case studies from industrialised countries*, eds. M. Cerf, D. Gibbon, B. Hubert, R. L. Ison, J. Jiggins, M. Paine, J. Proost, and N. Roling, 31–54. Paris: Institut national de la recherche agronomique.
Keen, M., V. A. Brown, and R. Dyball. 2005. *Social learning in environmental management: Building a sustainable future*. London: Earthscan.
Lee, K. H. 1993. Greed, scale mismatch, and learning. *Ecol. Applications* 3(4):560–564.
Lee, K. H. 1999. Appraising adaptive management. *Conserv. Ecol.* 3(2):3.
Leverington, F., M. Hockings, and K. Lemos Costa. 2008. *Management effectiveness evaluation in protected areas—A global study*. Gatton, Australia: University of Queensland, IUCN WPCA, TNC, and WWF.
Lindblom, C. E. 1979. Still muddling, not yet through. *Public Admin. Rev.* 39(6):517–526.
Lynam, T., F. Bousquet, C. Le Page, P. d'Aquino, O. Barreteau, F. Chinembiri, and B. Mombeshora. 2002. Adaptive science to adaptive managers: Spidergrams, belief models, and multi-agent systems modelling. *Conserv. Ecol.* 5(2):24.
MacDonald, G. B., R. Arnup, and R. K. Jones. 1997. *Adaptive forest management in Ontario: A literature review and strategic analysis*. Forest Research Information Paper number 139. Ontario, Canada: Ministry of Natural Resources.
McCarthy, M. A. and H. P. Possingham. 2007. Active adaptive management for conservation. *Conserv. Biol.* 21:956–963.
McLain, R. J. and R. G. Lee. 1996. Adaptive management: Promises and pitfalls. *Environ. Manage.* 20(4):437–448.
Meffe, G. K., L. A. Nielsen, R. L. Knight, and D. A. Schenborn. 2002. *Ecosystem management: Adaptive, community-based conservation*. Washington, DC: Island Press.
Mendis-Millard, S. and M. G. Reed. 2007. Understanding community capacity using adaptive and reflexive research practices: Lessons from two Canadian biosphere reserves. *Society Nat. Resources* 20:543–559.

Mingers, J. C. 2003. Towards an appropriate social theory for applied systems thinking: Critical theory and soft systems methodology. In *Systems thinking volume IV: Critical systems thinking and systemic perspectives on ethics, power and pluralism*, ed. G. Midgley, 1–13. London: Sage.

Moon, J. A. 2004. *A handbook of reflective and experiential learning: Theory and practice.* London: Routledge-Falmer.

Pahl-Wostl, C. 2002. Towards sustainability in the water sector—The importance of human actors and processes of social learning. *Aquat. Sci.* 64:394–411.

Parkes, J., A. Robley, D. Forsyth, and D. Choquenot. 2006. Adaptive management experiments in vertebrate pest control in New Zealand and Australia. *Wildl. Society Bull.* 34(1):229–236.

Parma, A. M., P. Amarasekare, M. Mangel, J. L. Moore, W. W. Murdoch, E. Noonburg, M. Pascual, H. P. Possingham, K. Shea, C. Wilcox, and D. Yu. 1998. What can adaptive management do for our fish, forests, food, and biodiversity? *Integrat. Biol. Issues News Rev.* 1:16–26.

Prokopy, L. S. 2008. Ethical concerns in researching collaborative natural resource management. *Society Nat. Resources* 21:258–265.

Ringold, P. L., J. Algeria, R. L. Czaplewski, B. S. Mulder, T. Tolle, and K. Burnett. 1996. Adaptive monitoring design for ecosystem management. *Ecol. Applications* 6(3):745–747.

Roe, E. and N. Van Eeten. 2001. Threshold based resource management: A framework for comprehensive ecosystem management. *Environ. Manage.* 27(2):195–214.

Romesberg, C. H. 1991. On improving the natural resources and environmental sciences. *J. Wildl. Manage.* 55(4):744–756.

Salafsky, N. and E. Wollenberg. 2000. Linking livelihoods and conservation: A conceptual framework and scale for assessing the integration of human needs and biodiversity. *World Dev.* 28(8):1421–1438.

Salafsky, N., R. Margoluis, and K. Redford. 2001. *Adaptive management: A tool for conservation practitioners.* Washington, DC: The Biodiversity Support Program.

Schreiber, E. S .G., A. R. Bearlin, S. J. Nicol, and C. R. Todd. 2004. Adaptive management: A synthesis of current understanding and effective application. *Ecol. Manage. Restoration* 5(3):177–182.

Schusler, T. M., D. J. Decker, and M. J. Pfeffer. 2003. Social learning for collaborative natural resource management. *Society Nat. Resources* 15:309–326.

Sit, V. and B. Taylor. 1998. Statistical methods for adaptive management studies. Victoria, Canada: British Columbia Ministry of Forests Research Branch. Land Management Handbook 32.

Smith, C., L. Felderhof, and O. J. H. Bosch. 2007. Adaptive management: Making it happen through participatory systems analysis. *Syst. Res. Behav. Sci.* 24:567–587.

Stankey, G. H. and B. Shindler. 1997. *Adaptive management areas: Achieving the promise, avoiding the peril.* Portland, OR: U.S. Department of Agriculture Forest Service Pacific Northwest Research Station. PNW-GTR-394.

Steidl, R. J., S. DeStefano, and W. J. Matter. 2000. On increasing the quality, reliability, and rigor of wildlife science. *Wildl. Society Bull.* 28(3):518–521.

Urban, D. L. 2002. Tactical monitoring of landscapes. In *Integrating landscape ecology into natural resource management*, eds, J. Liu and W. W. Taylor, 294–311. Cambridge, UK: Cambridge University Press.

Walker, B., S. Carpenter, J. Anderies, N. Abel, G. Cumming, M. Janssen, L. Lebel, J. Norberg, G. Peterson, and R. Pritchard. 2002. Resilience management in socio-ecological systems: A working hypothesis for a participatory approach. *Conserv. Ecol.* 6(1):14.

Walkerden, G. and A. J. Gilmour. 1996. *Adaptive environmental assessment and management (AEAM) program for the Tuggerah Lakes system and associated catchment.* Final Report. Melbourne, Australia: Macquarie Research Ltd.

Walters, C., J. Korman, L. E. Stevens, and B. Gold. 2000. Ecosystem modeling for evaluation of adaptive management policies in the Grand Canyon. *Conserv. Ecol.* 4(2):1.

Walters, C. 1986. *Adaptive management of renewable resources*. New York: McMillan.

Walters, C. J. and R. Hilborn. 1978. Ecological optimization and adaptive management. *Annu. Rev. Ecol. Systematics* 9:157–188.

Walters, C. J. and C. S .Holling. 1990. Large-scale management experiments and learning by doing? *Ecology* 71(6):2060–2068.

Wildhere, G. F. 2002. Adaptive management in habitat conservation plans. *Conserv. Biol.* 16(1):20–29.

Wollenberg, E., D. Edmunds, and L. Buck. 2000. Using scenarios to make decisions about the future: anticipatory learning for the adaptive co-management of community forests. *Landscape Urban Plan.* 47:65–77.