22 WORKING PAPER

Adaptive Learning in Natural Resource Management: Three Approaches to Research

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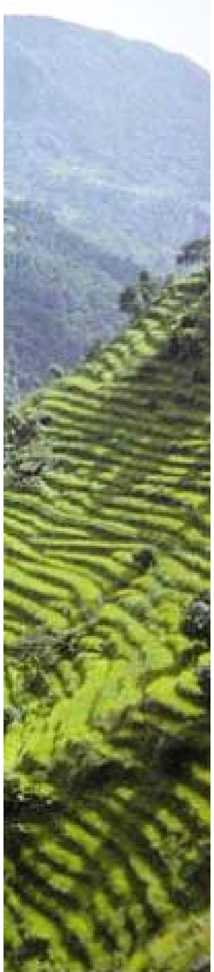

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Abstract

This paper explores different approaches to applied research in natural resource management that focus on adaptive learning as an element of the resource management challenge of continuous sustainable production. The research frameworks suggested by Adaptive Management (AM), social learning, and complex adaptive systems (resilience thinking) are considered. While AM typically emphasizes natural science and ecological systems, and social learning emphasizes human agency and interaction, resilience thinking addresses social-ecological systems as complex entities that behave in dynamic and cyclical fashion. All three frameworks offer insights into practices that support learning, adaptation, and sustainability. Some of the experience in the Canadian province of British Columbia is given in example. The emerging framework of adaptive co-management offers a promising approach to capturing relevant features of the other three. These four different conceptual approaches should not be seen as mutually exclusive alternatives but rather are characterized by overlapping features with different focal strengths. To date, experience with applying any of these frameworks in practice is limited and remains a big challenge. The conceptual frameworks considered here could underpin research into more effective adaptive learning in resource management.

Contents

Introduction

The livelihoods of hundreds of millions of farmers and fishers depend on effective management of the ecosystems on which they rely to produce food, fibre, and many other products. The well-being of the rest of us depends on whether these producers can continue to use these ecosystems without permanently degrading their productive capacities. With the world's population growing, pollution and urbanization increasing, climate changing, and food prices rising, the extent of this management challenge has been thrown into stark relief.

This paper explores different approaches to applied research in natural resource management (NRM) that focus on adaptive learning as an element of this resource management challenge. The paper is exploratory and synthetic. It describes some of the concepts and frameworks that have been proposed for systematically incorporating learning into ongoing management of natural resource systems. The intention is to provide a foundation both for programmatic discussion and for additional research on ways in which adaptive learning systems for resource management can be implemented more effectively. It is not a comprehensive review of the extensive literature in these fields but should provide a foundation (and references to key works and examples) that enables readers to explore details themselves as appropriate.

The focus here is not on particular resources or ecosystems and their management problems, nor on particular institutions for resource management and how to design these. The context of ecosystem management is rapidly changing in response to the social, economic, and ecological factors mentioned above. Any resource management interventions, at whatever scale, must be informed by such changes. For the many management actors involved at multiple scales, from farmers to local governments to non-governmental organizations (NGOs) to states, commercial enterprises, and global organizations, the margin for error in ecosystem management decisions is declining as the pressures on them mount. "Business as usual" is no longer an option for anybody: we must learn and adapt to the forces of change around us, or deal with the consequences as systems fail. So this paper explores two questions. What frameworks are used to help resource managers learn and adapt? How might we expand our knowledge of these adaptive learning approaches for NRM? Good practice in fostering learning for resource management is poorly understood, and many opportunities remain for pursuing pragmatic insights through sensitive research (Armitage et al. 2008).

The Nature of Resource Management Problems

In relation to international development, problems of NRM and poverty reduction are represented by the concept of ecosystem goods and services. The concept reminds us that human life depends on the healthy function of ecosystems to deliver food, clean water, and air, recycle materials and nutrients, as well as provide economically valued fibre, wood, and energy, and essential elements of human culture. There is now broad scientific consensus on the pace at which most global ecosystems are degrading, the threats this poses to human well-being, and the need for policy changes and management improvements to reduce the losses (MA 2005). While ecosystem degradation is often driven by market benefits, such as the value of timber, the non-market economic value of goods and services from preserved ecosystems, such as water quality, biodiversity, or carbon sequestration, typically exceed these benefits (MA 2005). At the same time, ecosystem degradation tends to further impoverish those people who are already most vulnerable (MA 2005; UNDP 2005). Strengthening ecosystems, especially to deliver non-market goods and services, is therefore consistent with poverty reduction generally but may constrain resource-based income in the short term. For resource-dependent communities, this transition poses a serious livelihood threat and a fundamental management challenge.

The recent report of the International Assessment of Agricultural Knowledge, Science and Technology for Development identified the importance of better NRM to sustainable agriculture, and to the livelihoods of marginalized rural women and men. It identified the challenge of maintaining the quality of cultural and environmental services from ecosystems while also ensuring sustainable production. And while highlighting the need to invest in research on resource management based on multidisciplinary approaches to complexity, it also emphasized the importance of strengthening two-way learning by better linking research to practitioners and to local knowledge through capacity building and networking in the public and private sectors (IAASTD 2008).

Thus, abundant evidence exists of the need for learning and adaptation in resource management. But the kind of learning needed is seldom critically assessed. Resource managers seek cause-effect knowledge so that they can reliably predict outcomes of their management interventions. Scientific and technical knowledge can provide better understanding of cause-effect relationships and so identify mistaken assumptions underlying management practices. However, many aspects of socio-ecological systems, such as emergent properties that arise from interaction of system variables, are not easily characterized by the type of cause-effect relationships revealed by positivist science (Berkes et al. 2003; Sayer 2003). Interactions in these complex systems can be iterative, dynamic, and discontinuous as external circumstances change and internal behaviour crosses systemic thresholds (Gunderson and Holling 2002). Successful practices based on cause-effect knowledge fail as system behaviour changes.

So we need to learn to update management practice by revising routines or guidelines. At the same time, new understandings of socio-ecological systems also lead us to recognize that the goals guiding the practices may themselves be inappropriate, leading to revision of policies and values. Finally, in some cases we may learn that the fundamental institutions and structures of governance that underlie management, policy-making and research / learning also need to be revised (for example, they may systematically exclude social groups whose perspectives and experience are crucial to resource management or knowledge). Note that while all three forms of learning may be necessary to address sustainability in complex socio-ecological systems, natural science research contributes mainly to the first one. To draw conclusions about values, goals or underlying institutions of governance not only requires new knowledge (based on social and natural science theories and evidence) but also communication, social interaction, and deliberative reflection. These distinctions are similar to the “single / double / triple-loop” learning framework synthesized from various sources in Armitage et. al. (2008). The original terminology derives from Argyris and Schon (1978).

The literature suggests that we have much to learn, in particular about appropriate institutions[*] for sustainable resource management. Institutions that deliver sustainable resource management are public goods: while it is in the collective interest of society to have conservation rules, individual resource users have little incentive to constrain their own behaviour. Despite their importance, experience with building and delivering such institutions is generally dismal. Whether at the private, government or community level, institutions for sustainable resource management are characterized more frequently by failure than success (Acheson 2006). In the absence of universal solutions, and with growing urgency to strengthen the delivery of both market and non-market ecosystem goods and services, the need for learning and contextual innovation at multiple levels for resource management becomes more compelling.

Research in NRM: How Best to Proceed?

We increasingly recognize that people have intervened to modify natural systems since before the dawn of agriculture. Natural science has played a huge role in economic development and industrialization over the past two centuries by enabling increased production of food, timber, and fibre through modifying natural systems. The power of science and engineering has been behind many of these gains, as scientists and practitioners have successfully controlled external sources of variability and improved productivity (MA 2005; Walker and Salt 2006). The approach has been to use specialized knowledge, technology, and chemical / physical inputs to drive ecosystems towards optimization for a narrow range of desirable outputs, taken to its extreme in the form of industrial agriculture. This instrumentalist approach to applied science underlies the original mandate for IDRC: to support the application of modern science in less developed countries as a means to speed their economic and social development.

Ecosystems have been harnessed to deliver an impressive range and quantity of goods and services with high commercial value. At the same time, industrial and population growth has placed a heavier burden on ecosystems to absorb wastes and recycle nutrients. Management has taken advantage of scientific knowledge to increase our

[*] "Institutions" is used here to mean the package of conventions, rules, and organizational practices that guide interaction of players making resource management decisions.

ability to manipulate ecosystems and reduce natural variability so that their outputs become more certain and more valuable.

Lately, however, this scientific knowledge has delivered bad news. Instead of reducing uncertainties around the delivery of ecosystem goods and services for human development, our interventions seem to be inadvertently *increasing* them. Climate change is an obvious example amongst many: the effects of pervasive agricultural chemicals, the decline of marine fisheries, diminishing supplies of fresh water resources, loss of forest biodiversity – all around us, management efforts seem to be yielding steadily diminishing, or at best ambiguous, ecological returns.

This leaves resource managers and decision-makers in a difficult position. Expert advice is not as helpful as it said to be (Prof. Fiket Berkes, personal communication, 2008). Conventional models of equilibrium in natural systems, which served as the foundations of analysis in most natural sciences for over a century, seem to be failing. While we now recognize the need for interdisciplinary approaches, and for the participation of users and other stakeholders in learning and technology choices (Sayer 2003), we are confronted by awkward new scientific findings in NRM. The problems of decision-making in the face of ecological uncertainty and institutional complexity can be summarized as: data are sparse, theory is limited and surprise is normal (Lee 1995). Not only are natural scientists challenged to predict system outcomes but also suspicion is increasing that conventional expert interventions directed at narrowly optimized solutions may make the problems worse. We obviously need more, or better, knowledge; but what is the best way to generate it?

Research Responses

One response to this research challenge is to invest more in applied natural sciences, to increase our understanding of these systems and to expand the range of system elements we can effectively manage. This is a big task but we know what it looks like. It is not exactly more of the same but more and better application of the tools of multi-disciplinary science, with better stakeholder involvement, in key strategic realms where we are facing urgent problems (Sayer 2003). Many worthy organizations are engaged in this kind of enterprise already (e.g., the Consultative Group on International Agricultural Research (CGIAR) Challenge Programs http://www.cgiar.org/impact/challenge/pilot.html, or the Alliance for a Green Revolution in Africa led by the Rockefeller and Bill and Melinda Gates Foundations http://www.agra-alliance.org/).

Another approach is to invest in research to build the adaptive capacity of organizations and groups on the front lines of NRM decision-making. The point of such an effort would be to develop better ways for resource managers and research users to identify knowledge requirements, and then to integrate new knowledge into their management decisions. These could include innovations to improve the availability and interpretation of science for local decision-making; to integrate scientific and local learning systems; to develop multi-scale institutions that foster creative, adaptive, and sustainable local responses, and that generate new research agendas and learning programs to meet local priorities. This is a smaller, more sparsely populated field of research, much more closely tied to practice. It is also a domain that IDRC's Rural Poverty and Environment Program has explored during its current programming cycle. In this domain, one area for research is how to become more effective at adaptation and learning in NRM.

Several conceptual frameworks might be used to address research on improving adaptation learning in NRM. This paper explores three frameworks for Adaptive Management (AM) research, drawing on literature and practice to elaborate their conceptual boundaries and describe key mechanisms and principles that might be used to guide applied research. It considers in turn the research frameworks suggested by AM, social learning, and complex adaptive systems (resilience thinking). The element of learning plays a central role in all these approaches, yet is seldom explicitly considered in assessing the effectiveness of AM strategies, so the paper also refers to learning issues before drawing conclusions.

Adaptive Management

While the basic concept of learning from experience is linked to most aspects of human development, AM has a more formal meaning in professional resource management practice, hence the capitalization. The key element of AM is that it specifies a formal design to test resource management interventions experimentally. The rationale for AM is that it permits managers to take action in managing complex ecosystems without waiting for all the scientific uncertainties around such action to be resolved. While most conceptual models of policy or planning include monitoring of outcomes, this approach treats management interventions or policies as "experiments" to be designed, implemented and monitored using scientific rigour to test hypotheses (Lee 1993).

Adaptive Management structures monitoring and research within a formal study design or hypothesis-testing framework. Typically, the design takes the shape of a model of resource ecosystem function. Key principles are that the model must simplify and limit complex ecosystems, represent best available scientific knowledge of the system and represent uncertainties in the system. In recognizing that part of what we "know" may be wrong, and that knowledge will never be adequate, the intent is to design management interventions and measure outcomes so as to address specific scientific uncertainties (Walters 1986). Key issues in AM include identifying appropriate indicators that are relevant to management objectives and for which data exist (or can be easily gathered), and defining research questions that are answerable through management interventions on selected natural systems that can be compared with controlled alternatives.

Adaptive Management links science to action in iterative cycles of experimental design and implementation, followed by critical appraisal of outcomes against theory and expectations. In order to test resource management policies they need to have clear hypotheses and structured control of extraneous factors. Management practitioners are expected to become experimental learners by systematically applying scientific knowledge and methods to their practices and, crucially, then revising their management practices based on these lessons (Stankey et al. 2005).

Adaptive Management requires attention to problem-framing processes, selection of questions for study, protocols for monitoring and documentation, and assessment and evaluation. Because multiple groups (with different interests) are typically involved in resource management decision-making, their input on problem (or model) specification and interpreting results is encouraged as a fundamental part of the approach. In this respect, the concept incorporates substantial elements of social interaction and discourse. Conceptually, AM recognizes the importance of political decision-making in sorting out public values in the face of contradictory expert opinion and evidence (Lee 1993). But the focus of attention has tended to be on the scientific research, and the process is typically driven by scientific experts (Stankey et al. 2005).

The great advantage of natural science is its explanatory power, and so results can be confidently replicated or extended to analogous situations. Managers are expected to re-create desired outcomes in new situations. They want replicable prescriptions. And many popular, widely-shared, and strongly argued explanations for resource outcomes are spurious (Lee 1993; Stankey et al. 2005). If managers are to be held accountable for their actions, all parties should recognize a scientifically valid explanation for the outcomes.

Usually, AM requires the integration of multidisciplinary scientific knowledge into formal dynamic models to predict decision outcomes. Models can include predictive aspects of indigenous knowledge as well as science. They are typically structured by experts in a stylized format (simulation model, mathematical formula, etc.). Structuring the model serves as a mechanism for engaging different knowledge holders, decision-makers (managers), and other stakeholders, and for assessing key knowledge gaps or uncertainties that weaken predictive strength. With the model specified, a management (action) experiment can be designed.

A number of practical issues are involved in implementing AM. Most important is that AM itself has little to say about policy goals, public values, and overall management objectives. These are best framed outside the AM framework itself. Yet this realm often poses the most intransigent challenges. Once all the stakeholders can agree on overall goals, objectives, and strategies, the monitoring of implementation or testing of strategy effectiveness is usually straightforward. Another issue is that AM is typically implemented within a pre-existing planning and management framework that may feature awkward and incompatible agency mandates or objectives. In large and complex regional ecosystems, it can be a challenge to set priorities among competing management studies across a range of linked issues (see under Babine Watershed Monitoring Trust for an example). In particular, when multiple interests are at stake, how can choices be made about research needs that would serve different interests?

Researchers have identified challenges involved with the application of AM, even in a North American context where professional skills are high and data relatively abundant (Stankey et al. 2005). These include problems with specifying models (linking small-scale, fast processes computationally with large-scale, slow processes), or of modelling large-scale ecosystems from small-scale data (large systems have emergent properties that are not manifest at smaller scales); and hence tendencies for modelling to become an all-absorbing end in itself, rather than a means for experimental hypothesis testing. Decision-makers also have practical concerns about how to manage the large expense and potential risks of large-scale ecological experiments, particularly when lessons are uncertain and only accrue in the longer term. A different concern is that the domination of scientific and technical models as tools for strengthening knowledge leads to an over-reliance on technical data collection and on framing problems as technical in nature when key management issues may be conflicts in institutions (rights, tenure) or values.

Examples of AM applied to NRM are numerous, particularly in North America's Pacific northwest region. Buzz Holling and Carl Walters pioneered and promoted the concepts and techniques at the University of British Columbia. The US Forest Service has used AM over a large area of national forests, and has also applied it to fisheries management in the Columbia River system. The implementation of AM has faced three main challenges. First, AM is typically interjected into organizations that already have histories, cultures, and policies of resource management, and professional norms that are hard to change and are often incompatible with AM. Second, when the process relies on annual public budgets, maintaining the long-term continuity required for learning about ecosystems is costly. Third, because of the way AM is designed, it can be difficult to facilitate shared learning. Many of the important issues may have to do with how the model is structured, and can be opaque to non-scientists.

Those cases where it has been successfully adopted usually involve simple jurisdictional situations with limited political or legal conflict and accepted scientific models (typically peer-reviewed) that are complex enough to be credible, but simple enough to be understood. They have involved relatively easy consensus on goals and objectives, along with strong institutional arrangements to facilitate negotiations. A few realistic options have been available for implementation as well as mechanisms for shared understanding on both the ecological and social side of the problem among key stakeholders represented in the process. And, most important, successful applications have required an organizational capacity to change and respond to learning (Stankey et al. 2005).

Proponents of AM have not generally envisioned it as applicable to socio-economic or institutional issues in resource management. In principle, the notion of social or institutional experiments (subject always to ethical constraints) is not inconceivable. One could, for example, design or compare different kinds of watershed management organizations or multi-stakeholder platforms in different watersheds (see, for example, Kemper et al. 2007). One can also use social science methods to test hypotheses about the different structures, using statistical tools. But controlling experimental alternatives in complex, open, social and institutional systems is much more difficult, as is discerning (much less measuring) the relative influence of key internal and external variables in order to draw replicable cause-effect conclusions.

Social Learning

The term "social learning" has been employed in a wide range of disciplines and theoretical perspectives, in studies focusing on individuals or on many different kinds of social groups, organizations, and societies, and lacks a shared definition. Its proponents may understand social learning to be learning by individuals as conditioned by social interaction; or learning by social aggregates such as organizations or communities (Parson and Clark 1995). "The key to social learning is not analytical method but organizational process…" (Korten 1981). By focusing on social learning in adaptation, we direct attention to processes of human interaction and shared experience. While natural science has an important role in contributing and validating information to these processes, the learning outcomes arise not from hypothesis testing but from deliberation (Korten 1981; Forester 1999; Schusler et al. 2003).

Social learning is an inherent part of AM, as elaborated in recent North American experience. While AM models are technically and scientifically specified, their design and framing is a social activity requiring deliberation and consensus-building (Lee 1993). Adaptive Management requires reaching agreement on what the problem is, what the key variables are, and on what we know already. It is this interaction around specification of the knowledge base and the desired outcomes that generates many of the benefits of the AM approach: it requires clarification of knowledge, values, goals, and management strategies. This process in complex NRM problems is inherently deliberative: it involves multiple interests, types of expertise and points of view. Even proponents of AM agree that testing experimental interventions often generates less valuable insights than the shared learning around specifying the problem and approach (Stankey et al. 2005). This suggests that big gains can often be made by focusing on improved social learning tools and approaches rather than on the science of modelling.

Social learning in the context of sustainable NRM is inherently conflict-ridden because of the divergent interests of different stakeholders and typically contradictory social and political values (e.g., economic growth/ ecological integrity/ social and cultural stability). Social learning is widely applicable in many fields and has been referenced both in adaptive resource management and in policy-making as a key tool for policy innovation, transferability, and influence (Stone 2001).

Social learning has strong roots in both social science theory and professional practice across a number of disciplines. The notion builds partly on the work of the iconic early 20th century American sociologist and educator, John Dewey, who viewed knowledge as a function of the interaction between cognitive humans and the material world. However, Dewey's political and epistemological approach generated a tension between the positive and normative dimensions of social learning. On the one hand, he encouraged the study of the role of individuals and society in the creation and validation of knowledge. On the other hand, he argued for the development and application of expert authority in decision-making, weakening the role of learning amongst a creative and deliberative public (Friedmann 1987).

In part, different perspectives on social learning depend on different theories of individual behaviour. In economics, philosophy, and political science, individual behaviour is seen as directly linked to cognition through rationality (Parson and Clark 1995). In order to choose, the rational actor must be able to predict consequences. Choice becomes a matter of acting to maximize preferences. In this model, the role of learning is either ignored (actor assumed to have all the relevant knowledge) or it is limited and instrumental. Action is always based on imperfect knowledge and a cost is associated with learning that may not be worthwhile to improve choices.

Alternative behaviourist models of the person have held appeal among some schools of psychology and sociology. These focus on stimulus/response patterns. Behaviours that are reinforced (rewarded) will be repeated more frequently. The social context of choice is reduced to the kinds of rewards and punishments that are delivered in response to behaviour. Cognitive structures are seen as more or less irrelevant to individual behaviour, so again the role of enhancing knowledge is minimal. These theoretical frameworks have been modified in application to reflect typical constraints of real world decision-making, such as bounded rationality or cybernetics, where pure rational analysis of choice is constrained by limitations of knowledge, cost, and convenience (Parson and Clark 1995).

While we understand that learning is an individual cognitive process driven in part by these individual motivations, clearly social interaction plays a big role in learning, particularly in groups that share a common purpose (e.g., organizations, professions, farmer groups). This occurs in two senses: individual learning may depend on the choices and learning of other members of the group where close teamwork is essential to successful performance (e.g., string quartet or rowing crew). Or individual learning may depend on processes requiring the participation of other group members (e.g., discourse, imitation, collaboration). We focus on the latter sense of social learning, which describes many of the learning practices not only of professionals in planning and management but also of scientists (Kuhn 1970; Argyris and Schon 1978).

In NRM, the social learning task has been described as moving from multiple cognition and agency of groups of individual actors towards “collective cognition” (Röling 2002). This is a process that requires fostering interaction, negotiation, and the construction of shared interests. The existence of a multi-stakeholder platform on which such interactions can develop is an important initial step but is far from being sufficient. Social learning requires building trust and legitimacy through incentives for engagement and careful ongoing facilitation. Note that these processes may already exist (e.g., farmer organizations in stable societies), or they may be supported through external intervention. The broader and more diverse the interests of the group involved in interaction, the more challenging it is to maintain over the long term (but even short-term engagement can be helpful).

Social learning in practice recognizes that interdependent social actors with interests in the same resources may have limited opportunities for positive interaction. The approach encourages sharing experience and knowledge through active membership in a group, through shared experimentation and through shared vision and planning. This process involves building relationships through networks, organizations, consultative bodies, monitoring processes and collective action, as much as it does generating new knowledge (Pinkerton 1989). Relationship leads to insight: building empathy, clarification of values and collaborative creation of new structures and processes of interaction. All of these are important sources of innovation and learning (Argyris and Schon 1978; Forester 1999; Armitage et al. 2008).

A key issue in a social learning approach is how to address the social distance between different groups. The processes of learning and social interaction are delicate and framed by social and political norms and expectations that often limit, rather than foster, effective communications. Participatory processes are plagued by persistent biases of organizers and power structures, and the perception of the problem shared by researchers may not match that of other actors (O'Hara 2006). But these tools are frequently advocated as a response to resource management approaches that have failed to acknowledge the roles of marginalized groups in solving problems (Chambers 1997). A central challenge of a social learning approach to AM is therefore the application of participatory methods and communications skills in the face of social and political power differences (Friedmann 1987; Beck and Fajber 2006; Armitage et al. 2008).

Deliberative processes form an essential element of social learning, and are marked by open exchange and the construction of trust and mutual confidence (Roberts 2004). They are difficult to manage but at their best can foster the emergence of shared identity and common values even in contested situations (Forester 1999; Delli Carpini et al. 2004). These tools are crucial elements of transparent and accountable governance, so they contribute to embedding democratic and egalitarian values and practices at multiple levels of society.

The practice of social learning should pay attention to subtle forms of coercion and conflict in the process of communication. The intent of coercion in communications and learning is usually to stifle, rather than foster, innovation. A key aspect of social learning is getting beyond natural resource conflicts and escaping the coercive aspects of communications, language, and learning, both within and between different groups involved in the process. Practitioners generally recognize it as an ideal goal but one that is inevitably compromised to varying degrees in messy reality. Still, there are limits to when this approach can be used. Under circumstances of intractable conflict, social learning cannot reasonably be pursued.

Social and natural scientists are important players in social learning but they should not *drive* the process. Their task is to validate and share various kinds of knowledge, expose assumptions, help structure experiments capable of generating useful new information, and apply data collection, management, and analysis tools in support of questions that arise from various players in the process.

The unique aspects of social learning foster innovation through deliberation, relationship building, better communications, and shared power; through greater empathy, recognition of mutual interest, and collaborative investigation. Deliberative processes are particularly helpful in learning about what others' concerns are, sharing and agreeing on facts, identifying a common purpose, and potential opportunity for action (Schusler et al. 2003). Over time, learning can include both innovations in NRM practice and innovations in roles, as users and managers become learners, and scientists become facilitators. Learning can be transformative, in the sense that it generates insight on cause-effect relations and tends to transform problem specification, leading to whole different classes of potential response, and creating new roles and responsibilities (Tyler 2006a).

The capacities and skills needed for effective social learning can be demanding. With large, heterogeneous or highly conflictual groups, the process can be time-consuming, particularly if employed throughout iterative cycles of problem diagnosis, intervention design, implementation, monitoring, reflection, and revision. Building capacity, modelling by example and transferring the skills needed for this approach are intrinsic elements of the process, so that first iterations are generally costly and slow. The process hinges on the effective use of superior communications skills, rather than on the application of research methods or analytical techniques. The approach is not deterministic, as social interaction is unpredictable and external conditions change, affecting the strategy, motivation and interests of participants. It is most successful with long-term commitment, iterative application, and skilled leadership.

These are some of the reasons why social learning, despite widespread familiarity and support for its principles, is seldom implemented effectively. Its incorporation into research and community projects has often been fragmentary, hasty, and ill conceived. Limited resources, time constraints, and the need of leaders to produce deliverables that have little or no value in contributing to the learning of the group itself (e.g., reports, academic articles, publications) inevitably detract from the value of the process. Systematic prioritization and critical, reflective implementation of social learning in processes of NRM innovation and adaptation does occur but is relatively unusual in practice (cf. field experiences reported in Tyler 2006b).

Complex Adaptive Systems (Resilience Thinking)

Concepts linked to ecosystem resilience derive from ecology and complex systems theory but its proponents believe this framework has broad applicability to policy-making for complex socio-economic and resource policy issues. Complex systems, in this framework, are self-organizing, driven by feedback loops that interact with system elements and condition their responses. Components of systems can perform independently but interact with each other. They include selection processes (e.g., competition, predation, decision-making) that lead to the success of some components and interactions, and the failure of others. The systems are dynamic, with internal processes that add variation and novelty independent of external factors (Gunderson and Holling 2002; Walker and Salt 2006). Change, not stability, is the central feature of complex adaptive systems. Learning consists of building response options through adjusting to disturbances. Resilient systems can return to prior levels of functionality and performance after disturbance but resilience typically requires features such as diversity, redundancy, and innovation.

While AM typically emphasizes natural science and ecological systems, and social learning emphasizes human agency and interaction, resilience thinking addresses social-ecological systems as complex entities that behave in dynamic and cyclical fashion. These complex systems comprise sub-systems that interact but are also capable of independent functions and self-organization in response to changing external conditions.

Feedback loops control how the system responds to these external conditions. Some variables change quickly (e.g., streamflow after heavy rain). Others change much more slowly (groundwater recharge or lake levels, fish population in the lake). Different system elements may be closely linked, loosely linked or only linked distantly if at all. In general, “slow variables” affect broad spatial scales and / or operate over long time periods. Typically, the crucial defining features of an ecological system (its species structure, its function, the kinds of goods and services it provides to humans) are sensitive to one or more of these slow variables but we may not know how.

Complex social-ecological systems operate within flexible “regimes”. Within one regime, the rules persist for how system feedback works, and the roles of different system elements are consistent. But at some threshold level of the defining slow variable, the driving forces within the ecosystem shift suddenly, like turning a switch on or off. While the outward characteristics of the system may not look much different, the feedback loops have changed, and the system no longer self-regulates in the same way. In the proximity of these thresholds, system changes are non-linear and often difficult to predict. The internal structure and interactions of the system now drive it in a new direction and produce a different set of ecosystem goods and services (generally inferior). Usually, you do not notice this is happening until it is too late. Threshold effects and regime change may or may not be reversible in practice.

Change is the normal state of complex systems, although sometimes it proceeds quickly and other times slowly. Systems proceed through four sequential phases that can be characterized as: growth (r) phase; conservation (K) phase; release (omega), and reorganization (alpha) (see Figure 1).

In this view, stability or equilibrium in natural systems are not long-term characteristics but contingent on the fluctuation of dynamic system variables. Resilience thinking argues that ecosystems are conditioned not by average conditions but by pulses of extreme events such as fire, flood or pests. Resilience is the ability of systems to respond and recover from extreme stress or combinations of stresses. Systems may appear stable and persistent only because we are not measuring the key driving variables. In fact, change is essential to system well-being. Change creates strength, opportunity, and learning.

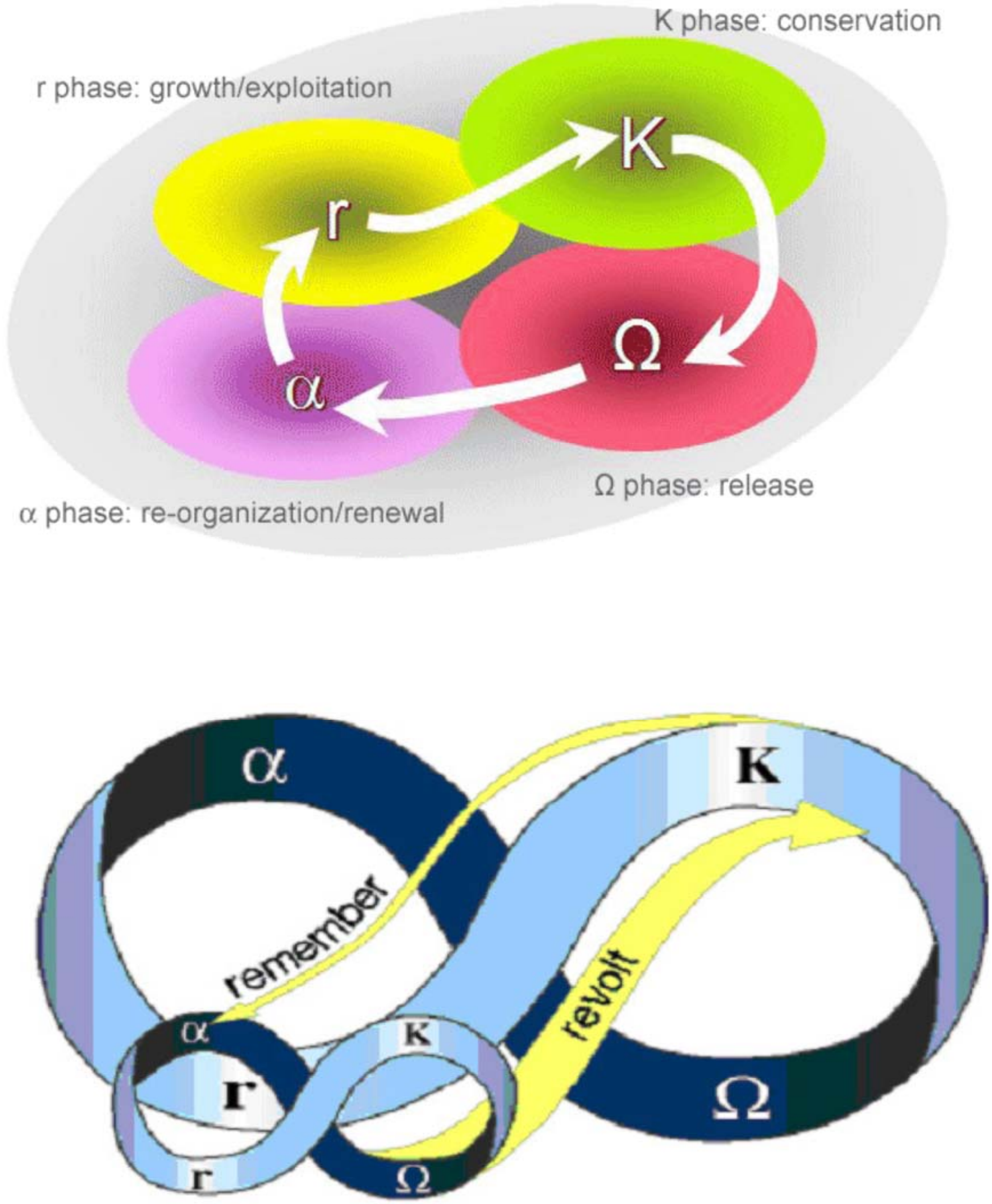

Figure 1: Cycles of change in complex, hierarchical systems (from Gunderson and Holling 2002)

A fundamental principle of complex systems is that they are nested in hierarchies across different scales. The whole picture of nested dynamic systems has been labelled "panarchy" (Gunderson and Holling 2002). For example, the feedback loops that regulate a wetlands ecosystem are dependent also on the inputs of water and nutrients from outside the system, and on the economic and political systems that influence human migration and agricultural colonization on the periphery of the wetlands. All of these systems at different scales operate on similar principles (growth, conservation, release, and reorganization) but often over much different timeframes. Proponents of this approach argue that it provides a useful framework for understanding how these nested systems interact and that disturbance at one scale has an influence on other scales ("remember" and "revolt"). For example, civil conflicts at the scale of the state can lead to "release" of the organizational capital invested in the social framework, leading to the destruction of homes and property and dislocation of refugees, some of whom may migrate to the agricultural frontier, drain wetlands and reorganize their society around new forms of agriculture that in turn lead to the collapse of the local wetlands ecosystem.

The resilience framework argues that contemporary NRM strategies are based on increasing resource productivity as measured in a limited number of dimensions ("maximum sustainable yield"). Managers focus on optimizing a small number of output parameters in these complex systems, such as increased food production, better water quality, faster growing trees and fatter pigs, because their objective is to use resources more efficiently in order to generate greater economic surplus. This approach to management relies on cause-effect models of ecosystems (adding input X leads to productivity gain Y). The effort to optimize a small number of ecological parameters leads to changes in other variables at different spatial or temporal scales and creates systems that are less able to recover from disturbances (Walker and Salt 2006).

The resilience argument is that every step we take to increase efficiency in a system reduces its adaptability. Ecosystem resilience (and adaptation) requires diversity of components, linkages, and flows. Redundancy is good. Optimization courts disaster, because it means the system has fewer alternative resources on which to reorganize when the inevitable release phase occurs. Managing for control and stability ironically pushes us faster towards turbulent and unpredictable change, after which we may not be able to return to a preferred system regime (i.e., one that provided desirable ecosystem goods and services). Prescriptions for system reorganization to improve adaptability carry a cost in terms of lost economic output, but this cost is argued to be small compared to the cost of system collapse and reorganization at much lower levels of capability (Walker and Salt 2006).

More recently, this approach has been extended to explore governance issues, particularly as they relate to social and political responses to crises, when systems are under the greatest stress and are facing abrupt reorganization. A preliminary conclusion from this work is that adaptive co-management, dependent on social capital, is one promising strategy to foster resilience. In this regard, a crucial role seems to be played by "bridging organizations" that can strengthen social capital (trust and collaboration) across multiple scales of organization (Berkes et al. 2003).

Managing in the "back-loop" of system behaviour requires social organization and collective practices that evoke change, practices that survive change and that nurture sources of reorganization following change. Learning is an important element of these practices and is a key part of building "portfolios" of responses to support resilience. Institutions that foster effective transformation of systems should have several characteristics (Walker and Salt 2006). They should be able to identify when change is needed, and help lead change and restructuring at an appropriate scale to avoid massive system disruption. They should emphasize learning from broad and diverse experience, in order to have access when needed to a portfolio of response options. They should be able to mobilize resources at multiple scales towards shared goals, and to engage other organizations collaboratively across sectors and levels of organization. Characteristics such as these are referred to as "emergent" because you cannot measure them from a static snapshot of independent system components. Nor are these the kind of inputs that you can add in, like fertilizer, to create desirable outcomes. These kinds of features emerge from the operational dynamics of the system itself and reflect not only the capacities of individual system components but perhaps more importantly the nature of system interaction, linkages, and learning between them. These kinds of features are not easily created by external measures such as policy or regulatory changes (Ruitenbeek and Cartier 2001).

In summary, thinking about resource management in terms of resilience of socio-ecological systems is more challenging than a conventional productivity or sustainability approach because:

- Usually there is no long-term stable equilibrium, so the notion of some desired “outcome state” or carrying capacity is not meaningful without extensive qualification.
- It can be difficult to tell if a system is resilient, even with careful observation, because there are not yet clear criteria, and even if there were, the slow processes that control systems can be hard to identify.
- Conventional “state” indicators and measures are usually inappropriate as guides to desirable ecosystem features: overall system characteristics and emergent properties (i.e., things you cannot yet see) are more important.
- Resilient systems respond well to small-scale disturbance because these generate renewal and opportunity while creating “memory” of adaptive response to broaden response repertoire. But most management organizations have a hard time seeing the need to “generate disturbance” (typically managers see their role as increasing predictability and avoiding disturbance).

One potential approach is to develop surrogate measures for resilience, such as capacity to live with uncertainty and change, nurture diversity, combine different kinds of knowledge, and foster learning. A key factor supporting resilience in practice appears to be cross-scale, deliberative, learning-oriented forms of governance, which can deal with different epistemologies (Berkes et al. 2003). The attention accorded to indigenous knowledge in a socio-ecological systems perspective is of particular relevance to the learning aspects of adaptation. Indigenous knowledge is valued because it is based on long-term observation and on feedback from practice, but it is typically linked to a system of culture and beliefs as ways of validation and so not easily integrated with scientific knowledge.

From a learning perspective, the most helpful aspect of resilience thinking is that adaptive learning is not an add-on to resource management to make it more effective. Rather, in the face of continual cycles of disturbance and change, management **IS** adaptive learning. There is no equilibrium, no long-term target, no maximum sustainable yield, and no ideal: only a series of disturbances, short-term functional objectives, learning, and managed change.

Learning and Resource Management: Some Observations

The shared emphasis on learning in all three frameworks belies the limited critical attention that learning has received in the resource management literature (Armitage et al. 2008). While the objective of resource management research is to foster learning, there is typically very little reflection on what needs to be learned, by whom, and how this might best be accomplished. This section of the paper introduces some general considerations about learning in relation to NRM.

Learning can be aided and motivated by a tension between what is needed and what is known. One can imagine this motivation inspired by competition, by urgency, by greed, or by collaboration and social support. A great deal of learning, especially among adults, arises from making mistakes. Learning is not merely the acquisition of facts or even understanding. In the context of its use here, learning implies a link between knowledge (cognition) and informed action (behaviour). Learning is inferential: you cannot tell if it happens unless you observe changed behaviour. This poses a dilemma: human cognition is essentially individual and unique but behaviour is inevitably social and contextual. We cannot separate these dual aspects of learning and adaptation in resource management (or anywhere else) but the implications are profound. Despite improved understanding of resource management, there are a host of socially sensible reasons why resource users' behaviour might not change.

Because learning usually involves behavioural change and/ or making mistakes, we face another dilemma in the social context of organizations through which we act. The purpose of most organizational structures and social institutions is to reduce risk by creating stability, predictability, and continuity (i.e., to mitigate buffeting by dynamic external forces). In other words, organizations are often designed to resist change and avoid experimentation (Stankey et al. 2005).

Learning is a process that needs facilitators, not managers. People process information and learn in different ways but can be aided in this task by institutional and organizational factors, by socio-cultural factors (values, beliefs), and by emotional and psychological factors (degree of risk tolerance). Most adult learning comes not from the accumulation of new facts but from sudden insights – perceiving familiar situations in new ways, often as a result of critical reflection and challenging of assumptions. Note that scientific theories also change in this way: not from incremental accumulation of experimental evidence but from contested ideas and sudden paradigm shifts (Kuhn 1970). Learning is not a smooth, linear, incremental process. Crises ("back loops") are often good opportunities for learning, but the learning involved in a linear problem (making practice conform more closely with desired goals through cause-effect relations) is very different from the learning involved when organizational objectives, structures, and processes are inconsistent with the problem set (e.g., system reorganization in the panarchy cycle).

This relates to the earlier distinction between single-loop learning (error correction by changing implementation instructions), double-loop learning (error correction by changing goals or strategies), and triple-loop learning (error correction by re-thinking institutional frameworks and governance of the whole management and research process). Each of these kinds of learning requires different forms of interrogation and may engage different learners. These are fundamentally different enterprises, requiring increasing engagement of organizational effort and time to accomplish what can amount to complete shifts in paradigm.

Conventional approaches to scientific learning, such as inductive approaches to generating knowledge by generalizing from extensive collection of data, or deductive approaches to explanation by building on theories and observations of scientific predecessors, are time consuming. This is acceptable when the decision environment and the ecosystem are both relatively stable and it permits detailed investigation and reductionist analysis of component elements. But when conditions are changing rapidly, the data collection and analysis methods of conventional scientific inquiry may be less helpful than improving our capacity to figure out what we need to learn. By the time we have carefully specified the problem, it may have changed or the context and priorities have evolved, and the data we collect are no longer relevant.

This suggests that alternative research methods might include iterative cuts at the same problem, rapid surveys, simpler monitoring, learning systems, and feedback loops, integrated with risk management decisions. And, because scientists are in short supply, we may want to consider building research and learning skills among other actors.

Finally, this leads to the question of who needs to learn what about NRM for purposes of adaptation. The identification of partners and their motivations will inevitably lead to differentiation of learning needs, styles, and thematic emphasis in adaptive processes. Not everybody needs to learn everything. Adaptive learning mechanisms should respond to the learning needs and priorities of different actors in order to be effective.

Resource users and managers are forced to adjust by changes in markets, policies, ecosystems or institutions. Change may be inevitable but it can also be painful. The objective of strengthening learning mechanisms is to reduce the costs of adaptation and to enable adjustment measures to be more effective, perhaps even anticipatory. Learning is not the only prerequisite to effective adaptive resource management (Schusler et al. 2003). Communities or resource managers must be able to act on the knowledge gained to influence their own destinies. They need to have the capacity to take decisions; mobilize other assets such as information, technology, capital or political influence; adopt innovations; and pursue long-term strategic objectives. For resource dependent communities, these capacities seem to require leadership, good governance, networks for support and information exchange, enabling policies, and high levels of motivation (Fabricius et al. 2007). Learning is a necessary but not sufficient condition for effective adaptation.

Applying Adaptive Management Approaches

All three frameworks offer insights into practices that support learning, adaptation, and sustainability. All three have attracted a substantial academic literature and numerous case studies that give rise to critical interpretations of practice, both in the developed and developing world. Despite this, all three frameworks remain outside the mainstream of conventional resource management training and practice. There are many international examples of how these tools are beginning to be used (e.g., Berkes et al. 2003; Sayer 2003; Tyler 2006a,b). But what can we learn from a “best case scenario”: the application of these innovative adaptive resource management practices in a highly developed, technically literate and prosperous country with strong democratic institutions?

This section highlights some of the experience in the Canadian province of British Columbia (B.C.), which has an economy based largely on natural resources, but is facing the challenges of ecosystem degradation and public conflict over contradictory resource uses.

There has probably been the most experience, and critical review, with the social learning approach. The tools of social learning and closely related public deliberation have been widely applied as a way to deal with increasing conflicts over resource use. There has been broad recognition that various methods of engaging multiple interests in resource management decision-making are essential to reversing deadlock and degradation (Buckles 1999). Many examples are documented of gains in terms of reduced conflict and more sustainable management from engagement of multiple resource interests in local learning in research projects (Tyler 2006b). However, many examples are also seen where multi-stakeholder planning and information-sharing fails to resolve disputes, or fails to come up with workable management rules and mechanisms to enforce them, or is systematically undermined by more powerful interests (Acheson 2006). In many cases, failure is attributed to political intransigence or entrenched power differentials that cannot be overcome by shared learning mechanisms. In others, shared learning has provided a mechanism for building trust and commitment.

Land and Resource Management Plans (LRMPs)

Over about a decade, beginning in the mid-1990s, B.C. undertook a unique, province-wide effort to address broad resource and land management conflicts through multi-stakeholder planning processes. These LRMP processes employed many of the features of social learning, including extensive preparation and training in dispute resolution and consensus-based decision-making. An assessment of 17 completed LRMPs concluded that they had been largely successful in terms of generating consensus and changing land use designations (Frame et al. 2004). Among other points, the processes made a key contribution to regional and provincial decisions to more than double the area of the province protected from development. The processes also generated considerable learning, both about the nature of consensus-based multi-stakeholder planning as a process and about the particular local details of land-based knowledge, positions of different interests and shared values. The process led to improved relationships and networks among stakeholders.

Despite these successes, there were also frustrations with a process that became very costly and took enormous amounts of professional and volunteer time over many years. Participant assessment of the process was dominated by perceptions of its legitimacy; measured in terms of fair and effective representation, appropriate resources, and the achievement of real consensus (Mascarenhas and Scarce 2004). In some cases, the LRMP tables were unable to reach consensus. Processes for implementation were left largely to provincial agencies, which retained exclusive management authority, and in most cases there are no provisions for updating the plans. Many conflicts persisted even after plans were approved. Most of the LRMPs proceeded without the engagement of First Nations, who argued their unextinguished rights and resource interests could only be resolved in a government-to-government forum. This model proved too cumbersome to maintain as an adaptive learning mechanism, both in terms of scale and cost.

Babine Watershed Monitoring Trust

The Babine watershed involved two LRMPs and several other plans. The development of an ongoing mechanism for adaptive learning and management proved to be a key tool to achieve consensus and contribute to plan implementation. The Babine Watershed

Monitoring Trust provides an innovative example of the application of a science-based AM model.

The Babine watershed in north-central B.C. is a sub-basin of the Skeena River, and the home of the largest sockeye salmon run in northern B.C. Primarily for this reason, it is an essential portion of the traditional territories of the Gitxsan and Ned'u'ten First Nations. It is also a prime wilderness recreation area, with a handful of world-class fly-in fishing lodges that rely on the pristine steelhead and salmon habitat along with abundant wildlife viewing opportunities. But the watershed is also heavily logged by several commercial timber companies who jointly contribute millions of dollars every year to provincial revenues in the form of stumpage, taxes, and cutting fees. A multi-stakeholder land use planning process was unable to reach consensus after several years of deliberation because each party suspected that the proposed plan would not achieve its own objectives of highest priority. Consensus was finally reached on condition that the objectives would be monitored and the plan revised if their achievement was at risk. A monitoring and adaptive management framework was therefore implemented as a way to reach consensus, not as a learning or research mechanism. The framework's design was premised on three criteria, that it should (i) allow the diverse and conflicting interests to participate and share information, ensuring that no single one could control monitoring decision-making or results; (ii) ensure that selection of the monitoring projects be impartial, reliable, and transparent, with results freely available; and (iii) apply scarce monitoring resources to those plan objectives most at risk.

The parties agreed on a Trust structure to oversee the monitoring, because it provided the greatest certainty that the political interests of any individual group could not influence the course of decision-making. Essentially, the rules of the Trust established the processes for decision-making and prioritization of monitoring investments, and trustees were then obliged to follow them. Three kinds of monitoring were proposed: (i) implementation indicators (levels of key system parameters specifically targeted in management strategies); (ii) effectiveness indicators (to detect whether strategies were actually contributing to objectives); and (iii) measures to improve knowledge and reduce uncertainty. These are essentially three types of research to inform managers.

To determine the priority for investment of limited funds, the monitoring framework assesses risk based on the probability that any particular management strategy will fail to achieve the desired objective. This risk depends on the level of the indicator value chosen (based on best available knowledge). For example, the more that actual forest seral stage in a particular stand or zone diverges from the natural distribution of forest stages over that landscape, the greater the risk of failing to preserve natural levels of biodiversity. This risk level is always uncertain because of both accuracy of information and confidence in the knowledge base. This uncertainty can be approximated as high, medium or low. By evaluating the levels of risk and uncertainty across multiple strategies, the process categorizes monitoring and research issues accordingly. For a given objective, monitoring investments focus first on obtaining or estimating implementation indicators because without knowledge of current indicator levels, no risk assessment can be made. Well-designed management strategies based on good knowledge should not create high risks of failure. The prioritization process reviews both current and future risk and uncertainty (based on the land use plan), and assesses the costs of undertaking a study for all three types of monitoring prioritized according to risk and uncertainty. Monitoring studies and research proposals are categorized into high, medium, and low priorities, and the limited research budget (or opportunistic external funds) allocated accordingly. Scientists or technical consultants conduct studies. Results are shared with all parties but either forest managers or tourism operators would implement changes to management strategies or objectives that result, as appropriate.

The system provides for neutral investment in management knowledge. In the 4 years of its operation, no changes have so far been made to management strategies but trust and collaboration have significantly increased through shared learning between the parties using the watershed (Sources: D. Daust, personal communication, 2008; Price et al. 2005; Overstall 2007).

The rigour and neutrality of formally represented scientific knowledge as a basis for determining risk to ecosystem management objectives, and for prioritizing adaptive management research investments, proved crucial to enabling buy-in of interest groups in an atmosphere of suspicion and latent conflict. However, the biggest gains for collaborative management came not from the scientific research itself, but from the processes of assessment and learning. These have provided a simple framework for building trust, sharing knowledge, and structuring productive ongoing interaction between interest groups to guide plan implementation (D. Daust, personal communication, 2008).

Forest and Range Evaluation Program (FREP)

Adaptive management has also been mainstreamed in the B.C. Ministry of Forests and Range but in a different way. The Ministry's FREP is a new, long-term commitment to continuous improvement in forest management policies and practices across the province. The FREP involves a partnership between field and headquarters staff across several divisions of the Ministry including its Research Branch, as well as with the Ministry of Environment. The emphasis of the program is on high scientific standards of monitoring implementation and effectiveness of the province's Forest and Range Practices Act (FRPA) and associated regulations (Ministry of Forests and Range 2007). The Act emphasizes sustainable management of the province's forest resources through results-based practices and industry reporting.

The purpose of FREP is to determine whether forest management practices under FRPA are meeting the intent of stated policy objectives and whether the policies and legislation are meeting broader goals of sustainability. The program determines priority evaluation / research questions, then designs and implements monitoring studies to address them with the aid of technical services and operational staff. It has developed indicators and monitoring protocols for data collection in priority research areas, and has set objectives of high scientific quality for all its studies, whose results are to be peer-reviewed. The program has also committed to high standards of communications and transparency to ensure that its products meet the needs of policy-makers, senior managers, operational staff, and external stakeholders. The FREP focuses on learning through the promotion of, and communication with, communities of practice, chiefly based in district forest offices and comprising operational personnel of the Ministry.

Other Small-Scale Examples

Many other small-scale examples of AM are related to forestry and fisheries in B.C., in both the public and private sectors, where this approach has been used to perform research studies on experimental forest management strategies (mostly at the stand or sometimes landscape scale). In most of these examples, academics or professional scientists undertake the research. Scientific peers validate the conclusions, which are often published, but are then digested and used to inform the operational practices of the forest industry or the regulatory practices and planning requirements of the provincial Ministry of Forest and Range, particularly at its district level. These experiences have conveyed the clear impression to the professional community that AM is mainly a matter of applied research on topics relevant to managers. However, approaches are substantially diverse, particularly in terms of how decisions about research priorities are made, how research is funded, how learning and management changes are expected to occur. Most of the focus is on monitoring implementation of forest management strategies, and to some extent on assessing the effectiveness of practices. However, AM does not address issues of institutional structure, roles and responsibilities for resource management, or resource governance at any scale in any of these models. These omissions seem particularly noteworthy In B.C., where dozens of treaty negotiations and interim resource management and revenue-sharing agreements with First Nations are in the process of completely revising resource governance and institutional structures. Current variants of AM do not apply this tool to management of human well-being, even when sustainable livelihoods are the ultimate rationale for resource policies.

Another example of adaptive learning comes from the rapidly growing literature on climate change adaptation. In many parts of the world, these problems receive greatly increased attention. Most of this work starts from climate prediction and proceeds to analyze local vulnerability. This body of research has evolved from an overwhelming focus on the scientific and technical issues of modelling and ecological performance to an increased recognition of the importance of institutional responses and human behaviour (Füssel and Klein 2006). This work increasingly engages concepts of adaptive capacity, resilience, and learning but conclusions applicable to adaptive learning in practice are only beginning to emerge.

Many efforts are made to put science into the hands of both community-level and policy-level decision-makers. However, little systematic effort is made to reform resource management organizations and users so as to encourage them to manage complex socio-ecological systems as learners rather than as recipients of knowledge generated elsewhere. Nor do we see systematic efforts at managing / collecting / storing / retrieving information for shared experimentation and learning to build portfolios of responses for resilience, or efforts at constructing innovative cross-scale institutions to respond to nested hierarchies of resource management interaction.

The Fraser Basin Council (FBC) is one example of an attempt at cross-scale management in B.C. As a multi-stakeholder, multi-level organization covering a large part of the province, including the densely-populated lower mainland, it has pioneered a number of processes for social learning, monitoring, and development of shared insights, but has no authority for implementation and must rely on local governments and provincial agencies to implement lessons (Kemper et al. 2007). Ongoing adaptive learning is represented only in the FBC's bi-annual State of the Basin indicators, which have limited decision-making value because resource and policy decisions are not made at a basin level anyway (see http://www.fraserbasin.bc.ca/publications/indicators.html).

Experience with implementing a resilience approach in practice remains limited. While structuring learning and intervention in NRM has obvious implications, it remains unclear how these can best be operationalized or what practical outcomes accrue, for whom, when they are attempted. While the framework seems so broad as to risk generating "paralysis by analysis", its proponents insist on the centrality of iterative action and learning to the concept. So while this is a framework intended to guide action, much work remains to test how such guidance might be expressed.

Comparing the Three Adaptive Learning Frameworks

Adaptive Management, social learning, and resilience thinking are increasingly finding their way into the curricula of planning and professional schools but they are far from becoming routine for technocratic resource management agencies. Guidelines for implementation and practice in these areas are relatively rare, in part because it can be difficult to generalize across different resource, cultural, and governance contexts, in part because experience has been limited and practical success elusive. The principles of adaptive learning in resource management are gaining wider adherence, however, and in the face of increasing environmental change, there are new opportunities for exploring good practices. The three frameworks presented above have many areas of overlap. Yet they represent significantly different perspectives on the adaptive learning issue.

First, we can see that all these frameworks emphasize research approaches where learning is shared not only among scientists but also natural resource decision-makers and often other stakeholders. They are all interdisciplinary and integrative, even though they build on and incorporate instrumental knowledge from scientific inquiry. They all emphasize the application of results to support long-term livelihoods of resource users and sustainable provision of multiple ecosystem goods and services. They also are often oriented specifically to policy decision-making but the approach to policy varies substantially. The formal AM framework sees management interventions as experiments to be monitored and modified based on scientific appraisal of structured outcomes. Social learning sees policy as responding to the lessons that emerge from engaging the practical experience of marginal groups in decision frameworks through deliberation. The resilience approach treats senior government policy as an enabling framework for local or multi-level action and learning, and local policies as interim propositions that will need to be adapted as conditions change.

These approaches share other common features. They use iterative learning and action in the face of uncertainty and risk. They are capable of engaging multiple sources of knowledge, although this is less true of formal AM, where the emphasis is on scientific rigour as the main criterion for legitimizing contested knowledge. Their ecological and social-institutional components dynamically interact. The approaches integrate and pay attention to history (pathways of historical change and evolution of both social and ecological systems have management consequences). They are all critical and cumulative processes: in different ways, they share and expose new knowledge for critical assessment and validation, documenting and accumulating it for continuing learning. And finally, they all require leadership and long-term commitment to a learning process that is fraught with uncertainty.

Note that all these approaches use formal research as a tool for learning (although in some cases, not the only one). They are all concerned about the rigour of research results, and appropriate scientific attention to published theoretical and methodological antecedents as a foundation to their work. All could employ peer review processes for quality control. Despite the similarities among these conceptual approaches, problems and research issues will be framed differently depending on the approach taken.

Adaptive Management tends to focus on the ecological questions and emphasizes the predictive power of natural science in providing managers with tools to assess and improve resource extraction practices so that they better approach sustainability goals. Questions that tend to preoccupy AM include the quality and availability of data (particularly indicators linked to implementation of management strategies relative to desired targets, the spatial and temporal scale of experimentation (or modelling) needed to test the effectiveness of management strategies, or the procedure for allocating scarce resources between competing monitoring and research options. This approach appeals to technocratic managers because it reinforces reliance on expert-driven processes of knowledge generation. However, when the key issues concern the political legitimacy of the resource management agency itself in a contested resource context, this approach must hand over greater decision-making responsibility to non-government interests.

Social learning focuses much more on the questions of who is engaged in learning, and the processes by which their engagement legitimizes learning outcomes, thereby reinforcing behavioural (management) changes. This approach specifically brings in critical perspectives on power and marginalization and the way that these processes exclude experiential and local knowledge in learning. Social learning would tend to focus on questions of communication, of process, of legitimacy, of bridging cultural and social barriers to learning as means to strengthen adaptation and management effectiveness.

Resilience focuses on dynamics of change and on the ecological drivers of change, as well as on the social and institutional processes of change management.

Learning is fundamental to all of these frameworks but the process of learning is seldom critically assessed. The different approaches assume respectively that learning occurs from the generation of new knowledge (research); or that learning occurs from structured interaction around contested issues; or that learning is an emergent feature of the behaviour of complex socio-ecological systems. These are all fragmentary views of a process that is central to the success of AM and a process that has received remarkably little critical attention by NRM researchers (Armitage et al. 2008).

Adaptive Co-management: An Emerging Paradigm

The notion of adaptive co-management has gradually attracted adherents and clarity over the past decade. This framework combines some of the features of all three of the others and so offers a new perspective on the resource management puzzle. Adaptive co-management builds on the collaborative and collective management approaches of resource co-management but introduces greater attention to learning-by-doing and dynamic improvement in resource practices (Ruitenbeek and Cartier 2001; Berkes et al. 2003; Armitage et al. 2007). The approach is characterized by an emphasis on long-term, collaborative institutional arrangements through which stakeholders share learning and resource management tasks across multiple scales. Some features that characterize adaptive co-management are: a shared vision, goal and/or problem definition to provide a common focus among actors and interests; a high degree of dialogue, interaction, and collaboration among multi-scaled actors; distributed or joint control across multiple levels, with shared responsibility for action and decision-making. A degree of autonomy for different actors at multiple levels is also required, along with commitment to the pluralistic generation and sharing of knowledge, and a flexible and negotiated learning orientation with an inherent recognition of uncertainty (Armitage et al. 2007).

The approach specifically emphasizes the application of complex adaptive systems theoretical concepts (e.g., scale, non-linearity, multiple epistemologies, and self-organization), to the practice of co-management, in which resource management institutions and relationships evolve through iterative and ongoing interaction. The approach recognizes the importance of interactive linkages across scales between communities and various agencies and levels of government, in their roles as collaborative resource managers. A central feature of this concept is the need for systematic social learning in structuring change and management interventions. While this approach covers a lot of territory, it specifically directs attention to the role of innovations in governance to support ongoing adaptation (distinguishing it from the more constrained AM or social learning approaches described above).

By adopting many of the conceptual tools of complex adaptive systems theory, adaptive co-management focuses attention on the feedback and learning processes that are central to resilience thinking (see above). However, it pays special attention to the practical and institutional challenges of implementing co-management across multiple scales of organization and government. This is a particular challenge because of the contradictions between the formality and rigidity imposed by legislative and sectoral mandates of government agencies, and the flexibility and modification implied by iterative feedback and social learning processes as part of the implementation of co-management (Armitage et al. 2007). Unlike classic bureaucratic function, where success is measured in terms of accurate prediction and control, success in adaptive co-management is measured in terms of learning, change and flexibility in response to dynamic uncertainty.

This approach directs special attention to the institutions of resource management as the focus of adaptation efforts. The development and operation of flexible institutions for resource management and learning is the central thrust of adaptive co-management. A particular feature of the approach is that while we usually think of institutions as operating at particular scales (local, national, or intermediate), adaptive co-management emphasizes institutions that operate *across* scales of governance. The emerging framework of adaptive co-management therefore offers a promising approach to capturing relevant features of all three of the other frameworks: the power of scientific methods for addressing uncertainty and replicability, along with the capacity to engage multiple epistemologies and interests through institutions for equitable deliberation and learning, using systems of feedback and dynamic adjustment across different scales of ecosystems and institutions.

Conclusions

This paper has explored conceptual frameworks that could underpin research into more effective adaptive learning in resource management. This kind of research would be a kind of “meta-research”, i.e., developing institutional forms and practices that more effectively engage research and learning as tools for better resource management practice. This review has explored the application of three different frameworks to the practice of adaptive learning in resource management and considered their different implications for framing research issues. I have also introduced a fourth framework, with which there is even less practical experience, as an area of potential for addressing some of the weaknesses and gaps in the other three. These four different conceptual approaches should not be seen as mutually exclusive alternatives but rather are characterized by overlapping features with different focal strengths, as discussed above.

Selection of a particular conceptual framework implies the selection of a particular research context and set of tools. Relevant theory and conceptual tools vary for different approaches to adaptive learning and management. Their prescriptions also vary but each tends to be fragmentary. For example, AM generates ecological research suggestions and hypotheses to be tested through management actions. However, it does not address contradictory interests and values in management, and while it employs social mechanisms it does so without explicit attention to the theory and practice of social learning.

Adaptive approaches to management have become perhaps the most widely recognized for dealing with the challenges of managing complex socio-ecological systems in which applied learning is a central element. But the notion of learning and change as criteria for successful resource management are only slowly gaining traction in practice.

Most attention has been given to ecological research and to AM as a framework for managing scientific uncertainty and risk, especially in relation to ecosystem protection.

Yet the resolution of practical management problems when resource use is contested usually has not been due to better science but to institutional reforms to increase collaboration, build trust, transparency, and joint engagement in learning processes. These reforms do not happen easily and their implementation in practice benefits from the theoretical insights and practical guidance of social learning.

A greater emphasis on social learning would thus appear to augment the scientific explanatory power of AM. However, there are problems here too. Social learning mechanisms are ill defined, and conditioned by power relations, interest and agency. They are often costly and time consuming. As a result, outcomes are uncertain and difficult to replicate. Enabling conditions are specified in theory but frequently ignored in practice, even if they are not particularly onerous. Social learning is always a work in progress but there seem to be opportunities here for improving practice.

Resilience thinking focuses on change as unavoidable, and adaptive learning not as an “add-on” to the management system but as the central and most crucial element. In resilience thinking, management **is** learning to adapt. Planning, or optimizing, for average conditions is risky because it will likely lead to failure under inevitable stress.

A resilience approach directs scientific attention away from equilibrium or “undisturbed” states and towards processes of ecosystem recovery and rebuilding of productivity. Management responses to resilience thinking would likely favour greater diversity, redundancy and variation, building on existing feedback mechanisms. Management attention would be directed towards protecting key functions, ecological keystones, and ecosystem drivers, and would recognize that risks are probably higher than anticipated because ecosystem response to cumulative stress is non-linear and irreversibility thresholds unpredictable. But it is not clear under this framework, with its dynamic cycles and unpredictable disturbances, what the objectives of managers should be and how they might intervene to achieve them without causing further ecological stress.

The emerging framework of adaptive co-management combines some of the appealing and effective features of the other three approaches. Good practice has not been well defined yet but recent collections of cases and syntheses of lessons across different streams of the literature provide helpful insights for both practice and applied research.

While the problems of resource management are widely recognized, as is the need for adaptive learning, so far experience with applying any of these frameworks in practice is limited. This remains a big challenge. Resource management issues are both scientifically complex and almost always socially complex and politically contentious. Practitioners are unlikely to please all the stakeholders in any particular resource management context regardless of what they suggest. Any interventions to extract ecosystem products for human use risk further stress to ecosystems already degrading, and there are often equivalent risks of aggravating political and social tensions.

Research into these emerging approaches to adaptive learning should be designed to simultaneously build knowledge and theory to underpin them and to build practical experience for their delivery. The point of AM is that research and practice are not independent and should not be addressed separately. Management action cannot await further research, but innovative practice can provide researchers with crucial insights to better understand complex social-ecological systems and to strengthen theory and methods.

The lessons from limited experience suggest a few areas of potential investment. Any management action must be based on prediction, which requires an effective mechanism to compile and share existing knowledge as a basis for identifying uncertainties. Yet knowledge remains fragmentary, difficult to retrieve, and different kinds of knowledge are generally difficult to compare. This should be one focus for innovation and improved effectiveness.

Once uncertainties have been identified and complexities approximated, they need to be addressed. How big are they? How important are they to system performance? How likely are they to impact management objectives if we guess wrong? Tools that help managers to make uncertainty explicit, and then deal with it in the context of risk, will be valuable in prioritizing investment in costly monitoring and research to generate new knowledge.

The importance of preserving system resilience in the face of mounting ecological stress from multiple sources suggests the need to redirect management attention to ecological processes rather than target levels or states. Instead of aiming to replace or manage components of ecosystems, managers could consider strengthening processes of feedback, change, and recovery. Similar conclusions apply to institutions through which management takes effect (e.g., tenure, resource rights, consultation, policy analysis, incentives, markets). Processes of feedback, learning, and integration of multiple sources of knowledge, adjustment, cross-scale coordination, and implementation all provide opportunities for innovation.

Naturally, many challenges are posed by each of the conceptual frameworks that could be studied through critical assessment of comparative cases or innovative practices. For example, one of the challenges of AM is how to better integrate costly, difficult, and long-term ecological experiments into resource management so that managers have an incentive to support them and change practices based on the lessons they generate. For social learning, practitioners need tools and confidence to be able to implement core processes more quickly and effectively. Critical studies of practice could be helpful in demonstrating whether problems are due to poor training, gaps in knowledge, or to inherent weaknesses in the approach.

The key innovations needed in adaptive learning for resource management lie in the linkage between learning and practice. The traditional process of scientific research leading to new knowledge that is gradually transferred through training and extension to practitioners is simply too slow for AM. In order to respond to urgent pressure on ecosystem goods and services, managers and researchers need to develop new institutions to deliver practical and effective learning, while building capacity and confidence to reform management practices in response.

Acronyms & Abbreviations

AM	Adaptive Management
B.C.	British Columbia, Canada
CCAA	Climate Change Adaptation in Africa Program
CGIAR	Consultative Group on International Agricultural Research
FBC	Fraser Basin Council, British Columbia
FREP	Forest and Range Evaluation Program of the British Columbian Ministry of Forests and Range
FRPA	Forest and Range Practices Act
IAASTD	International Assessment of Agricultural Knowledge, Science and Technology for Development
LRMP	Land and Resource Management Plan
MA	Millennium Ecosystem Assessment
NGO	non-governmental organization
NRM	natural resource management
RPE	Rural Poverty and Environment Program of the International Development Research Centre

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