Frontiers in Ecology and the Environment

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Front Ecol Environ 2008; 6, doi:10.1890/070089

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Building trust through collaboration, institutional development, and social learning enhances efforts to foster ecosystem management and resolve multi-scale society–environment dilemmas. One emerging approach aimed at addressing these dilemmas, is adaptive co-management. This method draws explicit attention to the learning (experiential and experimental) and collaboration (vertical and horizontal) functions necessary to improve our understanding of, and ability to respond to, complex social–ecological systems. Here, we identify and outline the core features of adaptive co-management, which include innovative institutional arrangements and incentives across spatiotemporal scales and levels, learning through complexity and change, monitoring and assessment of interventions, the role of power, and opportunities to link science with policy.

Front Ecol Environ 2008; 6, doi:10.1890/070089

Efforts to resolve multi-scale environment–society dilemmas require innovative governance approaches (Berkes *et al.* 2003; Dietz *et al.* 2003; Hughes *et al.* 2005). Adaptive and ecosystem-based forms of management have drawn attention to this need (Lee 1993, 1999; Grumbine 1994), yet much emphasis has been directed at the role of science, overcoming information gaps, and the construction of models. As a result, translating ecosystem management principles into practice has remained a challenge. Flexible social arrangements are necessary to develop the rules, institutions, and incentives (see Brown 2003; Ostrom 2005) that influence ecosystem management outcomes in a complex and uncertain world. While consensus on best management practices has been slow to evolve, there is evidence of progress.

In a nutshell:

- "Command-and-control" resource management is limited in a complex and changing world
- Innovative strategies that explicitly foster collaboration and learning are emerging, and contribute to trust building and the formation of social networks of researchers, communities, and policy makers
- One approach suited to conditions of uncertainty and conflict is adaptive co-management
- Adaptive co-management merges the principles and practices of co-management and adaptive management

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(continued on last page)

One emerging and interdisciplinary approach that holds promise for complex social–ecological systems is adaptive co-management. This approach explicitly links learning (experiential and experimental) and collaboration to facilitate effective governance, defined here as the public and private interactions undertaken to resolve societal challenges, and the institutions and principles which mediate those interactions (Kooiman and Bavinck 2005). In this paper, we identify and define the principal features of adaptive co-management and draw attention to its corollary ideas (see Panel 1): innovative institutional arrangements and incentives across spatiotemporal scales and levels (sensu Cash *et al.* 2006), learning through complexity and change, monitoring and assessment of interventions, the role of power, and opportunities to link science with policy. This review is intended to foster reflection and action on the societal processes and institutional arrangements appropriate in complex social–ecological systems, and to highlight their importance in moving ecosystem management forward.

Adaptive co-management

A reinvention of resource management is underway. Value and interest disputes, the cross-scale nature of environmental problems, and pervasive ecological and social uncertainty demand new strategies (Holling and Meffe 1996; Ravetz 2003; Waltner-Toews *et al.* 2003). The neglect of culture and the persistence of conventional assumptions about social and ecological stability, scientific certainty, and the place of experts in governance, all create challenging decision-making conditions. Centralized bureaucracies are often limited in their ability to respond to rapid social–ecological transformations (MA 2005) and to cope with uncertainty. Reductionism and disciplinary isolation restrict our

understanding of a world characterized by surprises and discontinuities (Levin 1999). These considerations reveal the limitations of yield-oriented, "command-and-control" governance.

In contrast, novel governance approaches emphasize group decision making that accommodates diverse views, shared learning, and the social sources of adaptability, renewal, and transformation (Folke *et al.* 2005; Campbell *et al.* 2006). While a considerable theoretical base has evolved for both co-management (eg Hanna 1994; Pinkerton 1994; Jentoft *et al.* 1998) and adaptive management (eg Holling 1978; Walters 1986), merging the two concepts engenders an approach that is distinct from either. The result is a flexible system of resource management, tailored to specific places and situations, supported by, and working in conjunction with, various organizations at different scales (Buck *et al.* 2001; Olsson *et al.* 2004; Colfer 2005). Ecological and social uncertainty is acknowledged as inherent to governance, and is best addressed with collaborative processes and recognition that multiple sources and types of knowledge are relevant to problem solving. As Olsson *et al.* (2004) suggest, the "self-organizing process of adaptive co-management development, facilitated by rules and incentives of higher levels, has the potential to make…social–ecological systems more robust to change".

Attention to management objectives and structures is necessary. However, an emphasis on trust building, institutional development, and social learning takes adaptive co-management into the realm of governance. Creating the social and institutional space for such interactions is a daunting task; most resources are contested by multiple stakeholders, while management institutions are often internally divided. Competing interests and values are the norm, and conflict is a frequent operating condition, while social relationships and rules regarding use and management are complex. New directions in research and practice are required to further support effective interventions under these challenging social conditions. We outline five thematic areas of adaptive co-management.

Panel 1. Glossary of selected terms

Cross-scale/multi-level linkages: Social, institutional, or ecological connections among individuals or organizations. Such connections may be horizontal (eg across geographical space) or vertical (eg across different levels of organization).

Governance: The public and private interactions undertaken to address challenges and create opportunities within society. Governance thus includes the development and application of the principles, rules, norms, and enabling institutions that guide public and private interactions.

Institutions: The formal (rules, laws, constitutions, organizational entities) and informal (norms of behavior, conventions, codes of conduct) practices that structure human interaction.

Memory: Accumulated experience and history of the system (both ecological and social), which provides the basis for self-organization.

Networks: The interconnections among people and organizations within a social–ecological system. Networks may structure themselves around resource use, administrative responsibility, and/or other functions, and may be connected to other networks within and outside of the system of interest.

Self-organization: In adaptive co-management, self-organization involves the emergence of formal and informal networks, working in a collaborative and creative process, often drawing on a range of knowledge sources and ideas, to resolve issues and move forward in response to disturbance.

Social capital: The social norms, networks of reciprocity and exchange, and relationships of trust that enable people to act collectively.

Social–ecological system: Integrated, coupled systems of people and environment.

Social learning: The collaborative or mutual development and sharing of knowledge by multiple stakeholders (both people and organizations) through learning-by-doing.

Institutions, incentives, and governance

The study of institutions has generated useful insights for governance in diverse resource contexts (Ostrom *et al.* 2002). Such factors as group size and levels of homogeneity, reciprocity and trust in social dilemmas, benefit and cost distribution mechanisms, the existence of monitoring systems, and clearly defined resource system boundaries are highlighted. However, these insights are largely derived from the study of self-organizing, community-based systems of management of the commons. Very few published papers about co-management have dealt with the complexities of multi-party and multi-scaled governance (Pinkerton 1994; Brown 2003). Recognition of the challenge of governance in multi-scale systems highlights additional priorities: deliberative processes among all stakeholders, redundant and layered institutions, and a mix of institutional types (Dietz *et al.* 2003). Adaptive co-management reflects these combined insights.

Responding to non-linear social–ecological feedback and cross-scale interplay requires multi-level governance arrangements that link social actors (vertically and horizontally) in the pursuit of shared learning (Young 2002; Ostrom 2005). Effective linkages will establish the basis for regularized flows of information, shared understanding, and problem articulation (Young 2002), and will move governance beyond simplified network perspectives. Figure 1 illustrates the potential multi-level institutional features of adaptive co-management, in which heterogeneous networks of actors are connected in a process of social learning. Using the case of narwhal management

in Nunavut, Canada, Figure 1 depicts horizontal and vertical linkages among local hunters' and trappers' organizations, regional wildlife organizations, and the Nunavut Wildlife Management Board. These entities are further linked to the national-level organizations (eg Fisheries and Oceans Canada) that are vested with authority for the management of narwhal. National-level entities also provide opportunities for transnational linkages and conflict resolution. In this narwhal management regime, local-level actors should have an increasingly central role in harvest decision making and enforcement, with support from higher level organizations and institutions (ie the Nunavut Final Agreement, a comprehensive land claim accord between the Inuit and the Canadian Government).

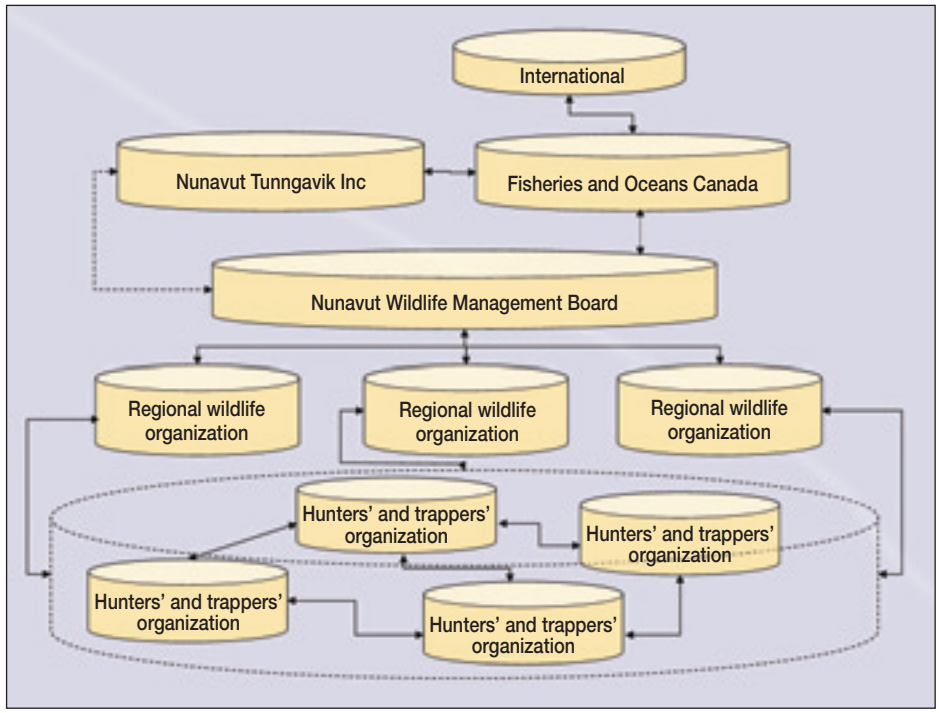

Figure 1. *Horizontal and vertical linkages among narwhal management organizations. Adapted from Armitage (2005).*

A number of factors have constrained learning among those participating in narwhal management, indicating a need to deepen our understanding of social networks (as in Figure 1). These factors include evolving motivations for resource harvesting as individuals and communities engage with the market economy, the formalized nature of interactions among local actors and government agencies, which can create barriers to Inuit participation in decision making, and the uncertainty about mobile and transboundary narwhal stocks. Despite many challenges, the linking and learning features of this innovative narwhal regime offer additional opportunities for the organizations involved to better collaborate and respond to change (Diduck *et al.* 2005).

While high levels of motivation and capacity may increase the rate at which successful institutional arrangements develop, more often such arrangements must be fostered for a long time. Experiences from earlier collaborative processes offer no recipe for trust building, but do reveal the need for repeated interaction among stakeholder groups and individuals, and a commitment to open communication. Thus, it may take a decade or more for these arrangements to mature to the point where levels of trust and social capital contribute to self-organizing systems of governance. Conversely, trust can be eroded very quickly, as a result of sudden shifts in harvest intensity by a particular group, unexpected regulations or restrictions on harvesting, or failure to meet a commitment. It is important to note, therefore, that the interactions associated with institutional arrangements for adaptive co-management are not necessarily fixed in time or space, and that institutional arrangements will vary with context. Institutional arrangements of adaptive co-management are likely to unfold in many hybrid forms.

Finally, it is valuable to recognize the importance of rights, responsibilities, and benefits within multi-level institutional arrangements, given the challenges of accountability, resource sharing, and knowledge transformation. To date, these concerns have been explored primarily with reference to the role of state and community-based entities, while that of non-governmental organizations and market incentives in adaptive, multi-level governance has not been fully explored (Ostrom *et al.* 2002). Careful analysis of institutional processes, structures, and incentives is vital, since the interactions of the various stakeholders are unlikely to be socially or politically neutral.

Learning through complexity

The struggle to learn from social–ecological feedback and to respond with appropriate strategies reflects a limitation of the conventional command-and-control paradigm (Gunderson and Holling 2002). Adaptive co-management takes learning as a necessary starting point, yet goes further and requires greater specificity with respect to learning objectives, approaches, outcomes, and risks. We highlight four issues in relation to learning.

First, systematic learning under conditions of complexity and uncertainty requires meaningful social interaction and a concerted effort to build trust. Technical expertise has a crucial yet restricted role in this regard (Waltner-Toews *et al.* 2003). Local and traditional knowledge also have a crucial (although similarly bounded) role (Figures

Courtesy of A Dale

Figure 2. *A hunting party traveling in uncertain sea ice conditions. Here, the knowledge and experience of local hunters is essential.*

2 and 3), and can support learning through dialogue and deliberation.

Second, the transition toward adaptive co-management signals a need to apply diverse learning strategies to understand social–ecological feedback. These learning strategies are intentional, whether experimental or experiential, and focus on the development of flexible institutional and organizational arrangements to encourage reflection and innovation (see Lee 1999; Cook *et al.* 2004). In this latter regard, scientists and decision makers must recognize that learning may often emerge from experience when individuals (and the organizations of which they are a part) pay attention to both their actions and the outcomes of their actions. Understanding the experiential dimension of learning draws attention to the importance of creating a shared understanding of the consequences of actions and behaviors, and the possibilities for positive change that can emerge as a result. In this sense, learning processes fit with the concepts of passive and active adaptive management in the resource management literature (see Walters 1986).

Third, careful attention to how learning is defined and conceptualized is critical, because learning theories are drawn from diverse disciplines and have various process and outcome implications (Parson and Clark 1995). What is apparent is that adaptive co-management requires a model of learning that accounts for social context (eg conflict and power imbalances), pluralism, critical reflection, adaptive capacity, systems thinking or interconnectedness, a diversity of approaches to adaptation, and paradigm shifts.

Fourth, careful attention to who is learning and the linkages among learners is required. Adaptive co-management involves more than individual learning; it also entails scaling up individual learning outcomes to various social levels, implying a certain sense of common purpose in the learning, and the capability of identifying, explaining, and ultimately facilitating effective cross-scale institutional arrangements (as outlined above). In the absence of clearly articulated learning objectives and strategies, definitive conclusions about individual or group learning outcomes will be slow to emerge. Similarly, learning is strongly related to the collective "memory" of groups engaged in deliberative governance and the cultural and collective historical experiences of those groups. Learning through complexity in the absence of collaboration and attention to social–ecological memory will undermine governance prospects.

Power asymmetries

With recognition of adaptive co-management as an evolutionary process, emphasis shifts toward the social processes that encourage flexibility and innovation – key ingredients of adaptive capacity. Trust building, conflict resolution, and social learning become governance requirements in a rapidly changing world, and highlight the role of power in adaptive co-management (Doubleday 2007). It is therefore necessary to examine the many sources and manifestations of power, how it emerges and persists (through control, resistance, and solidarity), and its influence – good and bad – on collaboration and learning. Different social entities continuously exert their power (eg through the use or misuse of information). Power is therefore linked to deliberation, learning (eg who defines what type of learning), the choice of indicators for measuring outcomes, and the sharing of risk – all key components of adaptive co-management.

With its greater emphasis on linking and learning, adaptive co-management provides a process for mediating conflict, where other approaches

Courtesy of A Dale

Figure 3. *Crossing a lead. Changing conditions can add an additional layer of uncertainty for local harvesters and may require the adoption of new technologies.*

may ignore, or discount as too complex, the dynamics of power inherent in novel institutional arrangements. Establishing such arrangements depends first on a thorough understanding of the social, economic, and other sources of power which influence regulatory bodies, and society more widely. Without an understanding of class, ethnicity, gender, and the other structuring dimensions of society, the social, bureaucratic, and scientific segmental tendencies that constrain flexibility and the sharing of governing authority will go unchallenged (Figure 4). These tendencies are exemplified in bureaucracies that fragment interests and values, responsibilities, and authority into separate, non-communicating departments, to partition information and engage in dysfunctional learning, to give preference to decisions targeting only short-term outcomes, and to compete rather than to cooperate within and between divisions and departments. Adaptive co-management can have a corrective effect on these inherent tendencies (Pinkerton 2007).


Courtesy of A Dale

Figure 4. *An Inuit hunter on the lookout. Less powerful groups require particular attention in co-management arrangements.*

Assessment: monitoring, indicators, and outcomes

Ongoing assessment and reflection are crucial within a complex adaptive systems worldview, which places a priority on responding to feedback (Holling 1978). Assessment is at the core of determining appropriate institutional responses to change, enabling an adaptive approach, and learning at multiple levels (Bellamy *et al.* 2001). Monitoring acts to position assessment, reflection, and learning in specific empirical contexts. Nevertheless, a number of challenges must be faced. First, while emerging experience points to the potential of adaptive co-management to encourage constructive interaction among stakeholders, contextual specificity makes it difficult to develop widely applicable blueprint solutions. Ostrom (2007) challenges the appropriateness of such panaceas for social–ecological systems and argues that researchers and practitioners considering outcomes must take into account contextual variables at multiple tiers in different domains (social and biophysical).

Second, the existing gap between theory and practice is further complicated by the shifting conditions of complex social–ecological systems, particularly in areas at the terrestrial–marine interface (Figure 5). Moving through the assessment process to the establishment of assessment parameters or indicators is particularly challenging. Useful parameters must draw attention to key slow and fast variables that structure most complex social–ecological systems (Gunderson and Holling 2002). Moreover, these parameters must provide the basis for context-appropriate indicator selection directed at ecosystem conditions, socioeconomic and livelihood outcomes, and process and institutional conditions (see Table 1). Matching indicators to the scale of the social–ecological system is particularly important, since, for example, indicators commonly used in large-scale systems may be inappropriate at the community level (Boyd and Charles 2006).

Third, assessment in adaptive co-management should take into account the specific context, uncertainties, and objectives prior to determining what outcomes will be monitored. This extends to the consideration of the role of different organizations in determining what questions to ask, what outcomes to encourage, and the choice of indicators used to assess outcomes (as previously noted), as well as the use of participatory processes for indicator development and monitoring (Prabhu *et al.* 2001; Garaway and Arthur 2004). Ultimately, to facilitate sys-


Courtesy of A Dale

Figure 5. *The terrestrial–marine interface deepens social–ecological complexity.*

Table 1. Broad assessment parameters

Domains	*Parameters*
Ecological system	Components (ecosystem types/habitats, species, and biophysical features); relationships between components (nutrients, biogeochemical cycles, trophic interactions); diversity and functional diversity; ecological memory and continuity
Socioeconomics and livelihoods	Increased well-being; decreased poverty; increased income; decreased vulnerability; increased food security; sustainable resource use
Institutions and process	Multiple interests, perspectives and linkages among institutions; communication and negotiation; transactive decision making; social learning.

Notes: Adapted from Plummer and Armitage (2007)

tematic assessment and learning across sites, consistent parameter and indicator selection is required.

Linking to policy

Adaptive co-management links scientists with resource users, government managers, and other stakeholders in collaborative problem-solving. To link the process of adaptive co-management with policy, two issues are of paramount importance. First, care must be taken when developing the policy conditions to enable adaptive co-management. Adaptive co-management processes are slow to develop, or will fail to develop at all, unless policy environments are supportive of multi-level learning networks, and unless scientists and managers are rewarded for participating in those networks (see Davidson-Hunt and O'Flaherty 2007).

Many of the conditions identified above highlight key policy directions. These include more attention to assessment, directing additional funds to building the social sources of learning and adaptation, fostering flexible institutions and bureaucracies designed to work in a rapidly changing world, using the full range of knowledge sources, and explicitly considering the role of power. Other requirements will emerge with additional experience and as a result of tests of adaptive co-management in a variety of social–ecological contexts. What is clear, however, is that an absence of the necessary ingredients for adaptive co-management can have strongly negative implications for the sustainability and resilience of the social–ecological system (Charles 2004, 2007).

Second, the incentives required to establish enabling policy conditions for adaptive co-management, over and above regular policy review and assessment, require further analysis. It is also important to consider the benefits policy makers expect from adaptive co-management processes, and how these expectations can best be met. Experience over several decades with conventional natural resource management has revealed a process that is often adversarial, pitting stakeholder groups against one another. Furthermore, given advances in our understanding of social–ecological feedback, those policies that seek to maximize yield and reduce uncertainty appear misdirected (Kates *et al.* 2001; Gunderson and Holling 2002). Optimism can be difficult to maintain. For policy makers and managers, there is merit in considering how adaptive co-management processes can encourage better outcomes, despite the apparent risks and higher transaction costs.

For instance, adaptive co-management will better enable learning over the mid- to long term as social networks are formed and trust accumulates, and will bear fruit, in the form of mutual respect and cooperative relationships (Hanna 1994). Transaction costs associated with this process-oriented approach may appear high in the short term, but long-term benefits associated with the development of policy and resource management decisions are likely to emerge (see Brown 2003; Waltner-Toews *et al.* 2003). In fact, where adaptive co-management emerges, both in structure and in spirit, there can be an important element of risk sharing (but not necessarily less risk) for policy makers and managers. Management experiments carry with them the possibility of failure, and risk sharing in collaborative partnerships is an important part of adaptive co-management processes. Thus, it is crucial to consider who bears both the transaction costs and the risks in adaptive co-management. If such concerns are suitably addressed, the enhanced capacity for adaptation, forged through collaboration, should help foster social and ecological sustainability.

Conclusions

Adaptive co-management is not a governance panacea, and will not be appropriate in all cases. On-the-ground examples and tools for successful adaptive co-management are still being developed, in what is a highly adaptive process of experimentation in many locations around the world. At the same time, researchers are seeking to synthesize these experiences to better understand the specific conditions under which this approach is most likely to succeed. To this end, Table 2 identifies ten key "conditions for success" in adaptive co-management. Based on case study evidence, we feel that these conditions must all be met to some extent in order to achieve a successful outcome, but there will certainly be variation depending on the system of interest.

Some resource management dilemmas (whether in rural or urban settings) will overwhelm novel institutional arrangements such as adaptive co-management. This may occur when it is difficult to identify a clear set of place-based entities linked to a defined resource stock,

Table 2. Ten conditions for successful adaptive co-management

Condition of success	*Explanation*
Well-defined resource system	Systems characterized by relatively immobile (as opposed to highly migratory and/or transboundary) resource stocks are likely to generate fewer institutional challenges and conflicts, while creating an enabling environment for learning.
Small-scale resource use contexts	Small-scale systems (eg management of a specific rangeland or local fishery) will reduce the number of competing interests, institutional complexities, and layers of organization. Larger-scale resource contexts (transboundary stocks, large watersheds) will exacerbate challenges.
Clear and identifiable set of social entities with shared interests	In situations where stakeholders have limited or no connection to "place", building linkages and trust will be problematic. In such situations, efforts by local/regional organizations to achieve better outcomes may be undermined by non-local economic and political forces.
Reasonably clear property rights to resources of concern (eg fisheries, forest)	Where rights or bundles of rights to resource use are reasonably clear (whether common property or individual), enhanced security of access and incentives may better facilitate governance innovation and learning over the long term. Such rights need to be associated with corresponding responsibilities (eg for conservation practices, participation in resource management).
Access to adaptable portfolio of management measures	Participants in an adaptive co-management process must have flexibility to test and apply a diversity of management measures or tools to achieve desired outcomes. These measures may include licensing and quota setting, regulations, technological adjustments (eg gear size), education schemes, and so on. In other words, economic, regulatory, and collaborative tools should all be available.
Commitment to support a long-term institution-building process	Success is more likely where stakeholders accept the long-term nature of the process, and recognize that a blueprint approach to institutions or management strategies is probably not advantageous. Commitments of this type can provide a degree of relative stability in the context of numerous changes and stresses from within and outside the system.
Provision of training, capacity building, and resources for local-, regional-, and national-level stakeholders	Few stakeholder groups will possess all the necessary resources in an adaptive co-management context. At the local level, resources that facilitate collaboration and effective sharing of decision-making power are required. Regional- and national-level entities must also be provided with the necessary resources.
Key leaders or individuals prepared to champion the process	Key individuals are needed to maintain a focus on collaboration and the creation of opportunities for reflection and learning. Ideally, these individuals will have a long-term connection to "place" and the resource, or, within a bureaucracy, to policy and its implementation. Such individuals will be viewed as effective mediators in resolving conflict.
Openness of participants to share and draw upon a plurality of knowledge systems and sources	Both expert and non-expert knowledge can play productive and essential roles in problem identification, framing, and analysis. The tendency in most resource management contexts is to emphasize differences in knowledge systems. However, there are substantial contributions to social–ecological understanding, trust building, and learning, where the complementarities between formal, expert knowledge and non-expert knowledge are recognized.
National and regional policy environment explicitly supportive of collaborative management efforts	Explicit support for collaborative processes and multi-stakeholder engagement will enhance success. This support can be articulated through federal or state/provincial legislation or land claim agreements, and the willingness to distribute functions across organizational levels. Additionally, consistent support across policy sectors will enhance the likelihood of success, and encourage clear objectives, provision of resources, and the devolution of real power to local actors and user groups.

or where there is little commitment or incentive among participants to encourage long-term learning around a shared goal (ie sustainability rather than rapid resource exploitation; see Berkes *et al.* 2006).

Adaptive co-management, however, is one potential tool in a suite of governance options to modify unsustainable social–ecological feedbacks. Conventional institutional responses, including strictly enforced regulations, the development of protected areas and set-asides, and other social and market incentives, are still needed. Within adaptive co-management, however, the ability to link adaptive and collaborative mechanisms offers the potential to produce deliberative processes (Stern 2005) that encourage reflection, observation, and opportunities for communication and persuasion among social groups, where uncertainties are high (Lee 1999). An adaptive co-management process can also help many such groups to articulate the full range of values and assumptions that will shape governance outcomes. Ultimately, this leads to several key attributes: (1) a greater recognition of different needs and an emphasis on distributive arrangements among stakeholders; (2) continued effort to build on culturally embedded, formal and informal rules and norms; (3) formation of horizontal and vertical linkages and net-

works to foster trust building and social learning; (4) a wide variety of types and sources of knowledge, and the shared development of such knowledge among stakeholders; and (5) enhanced capacity among resource management organizations to respond proactively to uncertainty.

Acknowledgements

This synthesis is one outcome of an expert Delphi process and a two-day workshop (at Wilfrid Laurier University, October, 2006). We thank all of the respondents of the Delphi process, and the participants of the workshop, whose insights have contributed to the ideas in this paper. The Adaptive Co-Management research group is supported by the Social Sciences and Humanities Research Council of Canada and the Ocean Management Research Network (www.omrn-rrgo.ca). Additional support has been provided by Brock University, the Canada Research Chair in Community Based Resource Management – Natural Resources Institute (University of Manitoba), and Wilfrid Laurier University (through the Cold Regions Research Centre).

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