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Article *in* Human Ecology · October 2006

DOI: 10.1007/s10745-006-9008-2

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Human Ecology, Vol. 34, No. 4, August 2006 (© 2006)
DOI: 10.1007/s10745-006-9008-2

Knowledge, Learning and the Evolution of Conservation Practice for Social-Ecological System Resilience

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Published online: 11 April 2006

There are two broadly conceptualized ways in which conservation knowledge may evolve: the depletion crisis model and the ecological understanding model. The first one argues that developing conservation thought and practice depends on learning that resources are depletable. Such learning typically follows a resource crisis. The second mechanism emphasizes the development of conservation practices following the incremental elaboration of environmental knowledge by a group of people. These mechanisms may work together. Following a perturbation, a society can self-organize, learn and adapt. The self-organizing process, facilitated by knowledge development and learning, has the potential to increase the resilience (capability to absorb disturbance and reorganize while undergoing change) of resource use systems. Hence, conservation knowledge can develop through a combination of long-term ecological understanding and learning from crises and mistakes. It has survival value, as it increases the resilience of integrated social–ecological systems to deal with change in ways that continue to sustain both peoples and their environments.

KEY WORDS: resource management; conservation; indigenous knowledge; traditional ecological knowledge; resilience; adaptive learning; common property; institutions.

INTRODUCTION

There has been a resurgence of interest in community-based conservation and resource management systems using customary practices and local

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knowledge in many parts of the world, including Oceania (Johannes, 1998), New Zealand (Taiepa *et al.*, 1997), Indonesia (Alcorn *et al.*, 2003), Alaska (Hunn *et al.*, 2003), the Amazon (Holt, 2005), and elsewhere (see the other papers in this issue). Considerable attention has been focused on the role of local and traditional knowledge in conservation. But we know little about how conservation knowledge develops among indigenous groups and small-scale rural communities. The question of the creation and development of knowledge is important in regard to the nature of community-based conservation and resource management. A debate has developed between two schools of thought on the question of whether local management is in fact conservation.

On one side of the debate, there are detailed descriptions of a great many indigenous knowledge and conservation systems (Berkes, 1999; Blackburn and Anderson, 1993; Boyd, 1999; Deur and Turner, 2005; Turner *et al.*, 2003). There is an increasingly comprehensive appreciation of traditional ecological knowledge and ethnoecology as systems of local and indigenous conservation (Ford and Martinez, 2000; Turner *et al.*, 2000). In many cases, knowledge is developed by feedback learning, as in adaptive management (Lee, 1993). Also available is a large literature base analyzing the conditions under which the 'tragedy of the commons' is avoided and local common property institutions may develop for resource management (Ostrom, 1990; Ostrom *et al.*, 2002).

On the other side of the debate, a number of authors have questioned whether these systems could be considered to represent 'conservation' and, by extension, whether users of customary resources can be entrusted with management. In particular, some see conservation as an incidental by-product of what might be optimal foraging strategies (Alvard, 1993; Aswani, 1998). For example, Smith and Wishnie (2000) argue that the evidence on the effectiveness of indigenous conservation is weak if conservation is defined in terms of the two criteria of effect and design. That is, any action or practice 'should (a) prevent or mitigate resource depletion, species extirpation, or habitat degradation, and (b) be designed to do so' (Smith and Wishnie, 2000, p. 501).

Using similar criteria of effect and design, Johannes (2002) observed that some groups have conservation practices and some do not, but generalizations are difficult to make, and space and time considerations are important. A group that may have conservation practices for a particular area or resource may not have these for another resource or area. A society that conserved resources at one stage in their history may not have done so at another stage. It is significant that much of the evidence cited by the critics of indigenous conservation is archaeological or ethnohistoric in nature

(Krech, 1999; Smith and Wishnie, 2000). This suggests that the evolutionary aspects of conservation knowledge should be examined.

The debate is important also with respect to discussions over the necessity of developing place-based, participatory models to approach the question of sustainability of social–ecological systems, or integrated systems of societies and their environment (Berkes and Folke, 1998). For example, Folke *et al.* (2002) suggest that many of our environmental problems are in fact complex systems problems that are not easily dealt with using conventional science and management. Rather, they require alternative approaches, such as adaptive management and resilience thinking. They see comanagement (or the sharing of management power and responsibility between governments and local people) as necessary to produce flexible, multilevel governance systems in which institutional arrangements and ecological knowledge are tested and revised in an ongoing process of trial and error. This arrangement has been referred to as adaptive comanagement (Folke *et al.*, 2002; Olsson *et al.*, 2004) and it is relevant to the question of building resilience (shock-absorbing capability) towards sustainability in a world of uncertainty and transformations.

All of these considerations indicate that it is important to understand the nature of traditional knowledge as a basis of conservation in indigenous societies and other local resource-dependent groups. Thus, this paper addresses the question of how new knowledge relevant to conservation may be created, how it may develop or evolve, and how it may be incorporated into local rules-in-use.

We start by reviewing two broadly conceptualized mechanisms for the development of conservation knowledge, what may be called the *depletion crisis model* and the *ecological understanding model.* The next section turns to the notion of adaptive comanagement as a way to integrate these two models of knowledge development. The last section explores the interrelationships among knowledge, self-organization, disturbance, and diversity for building adaptive capacity and resilience in institutions for conservation.

TWO MODELS FOR THE DEVELOPMENT OF CONSERVATION KNOWLEDGE

How does conservation and management knowledge develop? One position represented in the literature is that the development of conservation depends, first and foremost, on learning that resources are limited and depletable. Various authors have pointed out that the concept and practice of conservation can arise only from an experience of resource limitations (Hill, 1996; Holt, 2005). Such learning typically follows a resource crisis (Johannes, 2002). We term this mechanism the *depletion crisis model.* The

second position puts relatively more weight on the elaboration of environmental knowledge by a group, leading to increasingly more sophisticated understanding of the ecosystem in which they dwell. We term this mechanism the *ecological understanding model.* In this paper, we highlight the *depletion crisis model*; the companion paper by Turner and Berkes (this issue) elaborates on the *ecological understanding model.*

It is said that people living on islands discover their environmental limits more easily than do continental peoples. Johannes (2002) argues that this is only because they exceeded those limits more easily. An effective way to discover the limits, such as of the sustainable yield of a resource, is by exceeding these limits. This thought has a long history in the adaptive management literature. One of the central tenets of adaptive management is to structure management probes for learning, that is, the deliberate creation of perturbations, such as pulses of heavy exploitation that can give back signals (Carpenter and Gunderson, 2001).

There is indirect evidence that some island peoples have learned conservation by first depleting their resources. Johannes points out that almost all the basic marine conservation measures devised in the Western world in recent times (e.g., closed fishing areas, closed seasons, allowing escapement, bans on harvesting immature individuals) were already in use in the tropical Pacific centuries ago (Johannes, 1978, 2002). These rules were socially enforced as reef and lagoon tenure systems and taboos (Wilson *et al.*, 1994). In Johannes' (2002) assessment, these measures not only prevented depletion, but were also *designed* to do so. But how did they emerge? "For the Pacific islanders to have devised and employed deliberate conservation measures, first they had to learn that their natural resources were limited. They could have only done so by depleting them" (Johannes, 2002, p. 3).

The actual depletion events or crises are not easy to identify or record. It is of course possible to deplete various shallow water marine species, such as abalone, in specific areas (Hilborn *et al.*, 2005). However, unlike some terrestrial resources (McGovern *et al.*, 1988), it is very difficult to exterminate them. Marine fish and invertebrates produce many larvae, and currents distribute them over thousands of square kilometers. Hence, Oceania provides an ideal setting to learn from multiple depletion events. Many marine resources are depletable, and recovery periods may be on the order of a year to a decade or more, depending on the species and habitat, leading to a rich mix of depletion and recovery cycles and adaptive management-like learning.

However, some Pacific Island societies never learned (until historic times), that their resources were depletable. The original Easter Islanders are the iconic example of a society that evidently never learned to conserve (Bahn and Flenley, 1992). Elsewhere, some groups lived in areas where marine resources always exceeded their ability or capacity to overharvest

them. Johannes (2002) gives the example of Torres Strait islanders, a population of less than 5,000 people (until recent years) surrounded by 30,000 km^2 of shallow, productive marine waters. Their marine resources were effectively "unlimited" and the islanders showed little evidence of having possessed a traditional marine conservation ethic (Johannes and MacFarlane, 1991). For a contrary view, see Kwan (2005) who argues that contemporary dugong hunters in Torres Strait islands *are* concerned with sustainability. But it is difficult to determine when or how attitudes may have changed. The point is that under conditions of resource abundance or a high degree of hunter mobility that allows resource regeneration, a group may never develop the concept of conservation, another case in point being the Ache people of Paraguay (Hill, 1996).

There are two recorded wildlife resource crisis events from the Hudson Bay area of the Canadian North, and they provide telling lessons regarding the development of conservation and management knowledge. The first concerns the depletion of caribou in the Quebec-Ungava peninsula, and the other the local extinction of caribou in the Belcher Islands.

According to narratives by Chisasibi Cree elders in the 1980s, a disaster occurred in 1910 at Limestone Falls, near the center of the Quebec-Ungava peninsula (Berkes, 1999, chapter 6). Equipped with repeating rifles that had just become available, hunters abandoned their hunting restraints and conventional ethics of respect for the animals, and slaughtered large numbers of caribou at the river crossing point. The caribou had already been in decline along the Hudson Bay coast. Following the event at Limestone Falls, the herd disappeared altogether from the lands hunted by the Cree and did not reappear until the 1980s. The Cree believe that all changes occur in cycles, and the elders at that time had predicted that the caribou would return one day.

In the winter of 1982/1983, large numbers of caribou appeared for the first time in the lands of the Chisasibi Cree, validating elders' predictions in 1910. The first large caribou hunt of the century took place in the following winter, but the result (according to Chisasibi elders) was disastrous. Large numbers were taken, not necessarily a bad thing, but many hunters were shooting wildly and without restraint, killing more than they could carry, wounding animals, and leaving a mess behind, instead of disposing of wastes properly. According to the Cree worldview, hunters and animals have a reciprocal relationship based on respect (Tanner, 1979) and Chisasibi elders were worried that hunters' behavior signaled a lack of respect for the caribou.

In following winter, there were very few caribou and many hunters were left empty-handed. Meetings were called and two of the most respected elders stepped forward and told the story of the disastrous hunt in Limestone Falls, refreshing oral history. The caribou had disappeared for

generations because the hunters had shown no respect. Now that the caribou were back, as their grandfathers had predicted, the hunters had better take good care of them if the caribou were to stay. By violating traditional ethics, they were about to lose the caribou once again. The elders' words had a profound effect on the younger hunters, and the following winter's hunt was a very different affair. Monitored by the senior hunters, the hunt was carried out in a controlled and responsible way, in accordance with traditional standards. There was little waste and no wild shooting; the harvest was carried away efficiently and wastes were cleaned up promptly. In the subsequent years, caribou kept coming. Hunters' observations of tracks indicated that by 1990, the caribou had reoccupied most of their former range along Hudson and James Bays (Berkes, 1999).

A number of interesting points come out of this story. Note that the convincing point is oral history and Cree ethics, not government regulations and penalties. Government managers, much to their credit, did not try to penalize the hunters and left it to the Cree to deal with the situation under their comanagement agreement (Drolet *et al.*, 1987). Elders play the key role in the story. They are the holders of the knowledge and the keepers of the ethics and span the generations to provide feedback. They are not creating new knowledge. Rather, they are adapting existing knowledge to the current circumstance of hunting with overly efficient (and potentially destructive) technology, and providing culturally relevant meaning for the Cree to continue to live with their resources.

The second story also concerns caribou and the setting is Belcher Islands, eastern Hudson Bay, home of the Inuit of Sanikiluaq. The Belcher Island Inuit are unique as the only Canadian Inuit group to wear bird skin parkas. The traditional material for parkas in Belcher Islands, as elsewhere in the Arctic, used to be caribou skin. Caribou were plentiful in the area until about 1880 when freezing rain glazed the islands with ice, causing the starvation of caribou (Nakashima, 1991, p. 108). There is some controversy over the date but not over the cause of caribou disappearance; caribou die-offs following freezing rain events have been known from various areas in the Arctic. The Belcher Island Inuit started making inner and outer coats of eider duck skin and pants of seal skin. They developed an elaborate knowledge of the use of the skin and feathers of the eider duck (*Somateria molissima*), a large-sized species that does not migrate south but actually over-winters in Hudson Bay. Eiders provided the material to produce light, warm and waterproof (but not very durable) parkas that replaced caribou skin garments (Nakashima, 1991). The fact that caribou were scarce along the Hudson Bay coast for much of a century meant that caribou did not recolonize Belcher Islands, nor were caribou skins available in large numbers by trade from nearby Inuit or Cree groups.

The obvious question is whether the Belcher Island Inuit knew how to make eider skin parkas before the caribou crisis, or whether it was the crisis itself that forced the creation of new knowledge to make this unusual kind of winter clothing. Nakashima (1991) is silent on this question, but (pers. comm.) offers that the knowledge of bird skin processing and uses, such as bags made of loon skin, is common across the Arctic. Even though there is no evidence that the Belcher Island Inuit ever used eider skin parkas before the caribou crisis, it is likely that considerable knowledge of the eiders and other birds did exist among them. When the crisis struck, they likely built upon their existing knowledge, showing ingenious adaptation to turn eider duck parka-making into a very fine art that persisted well into the middle of 20 century (Nakashima, 1991).

Returning to the question of how new knowledge relevant to management is created, and how existing knowledge develops or evolves, the first case provides evidence that a resource crisis is important. The crisis becomes a trigger point regarding the redesign of the conservation system. For the Cree of Chisasibi, the disappearance of the caribou in 1910 was linked to the last big, wasteful hunt. The lesson of the transgression, once learned, survived for generations in Cree oral history, and it was revived precisely at the right time to redesign the hunting system when the caribou returned in the 1980s. The lesson delivered by the elders (do not kill too many; do not waste) followed the validation of the elders' prediction of the return of the caribou, and it was too powerful to take lightly, even by the most skeptical young hunter.

The second case has little to do with conservation but is relevant to the question of knowledge creation. As far as we know, the Inuit did not make bird skin parkas before the caribou crisis, but they certainly knew something about bird skin processing and use. The loss of the caribou resource and thus the unavailability of skins for clothing must have been a shock. The shock must have triggered an intense period of experimenting and rapid learning, and the Inuit probably did not have more than 2 or 3 years before the available stock of caribou skins ran out. Emerging out of that learning process was an elaborate system of eider duck skin parka-making, unparalleled in the circumpolar Arctic, refined by building layers upon layers of knowledge.

ADAPTIVE COMANAGEMENT: INTEGRATING THE TWO MODELS

There are compelling reasons to think that much conservation-oriented knowledge accrues through ecological understanding over time,

and there are many possible mechanisms for such understanding to develop (Turner and Berkes, this issue). Hence, we are not making the claim that depletion is a *necessary* condition for the emergence of learning for conservation. Neither do we argue that is a *sufficient* condition; see for example the Easter Island case (Bahn and Flenley, 1992). Even though the creation of conservation knowledge does not necessarily depend on crises and depletions, such catastrophic learning probably does have a role to play in many situations. It may help speed up knowledge creation and promote the adaptation of existing knowledge, as in the eider parka case, and may be important in how well lessons may be learned and remembered, as in the Cree caribou case. The two models of knowledge creation probably work together, and hence it may be useful to think of a way in which these two mechanisms (the depletion crisis model and the ecological understanding model) may be integrated.

The concept of adaptive comanagement may be useful for such an integration. It may be defined as a process by which institutional arrangements and ecological knowledge are tested and revised in a dynamic, ongoing, self-organized process of learning-by-doing (Folke *et al.*, 2002, p. 20). Adaptive comanagement combines the *dynamic learning* characteristic of adaptive management with the *linkage* characteristic of cooperative management. The concept is similar to what Norgaard (1994) has called the coevolution of people with their environment. The key point has to do with feedback learning: there has to be some kind of perturbation to produce a change from which people can learn (Carpenter and Gunderson, 2001).

Conservation does not come naturally; it has to be learned. As Vickers (1994, p. 331) puts it "...'conservation' is not a state of being. It is a response to a people's perceptions about the state of their environment and its resources, and a willingness to modify their behaviors to adjust to new realities." One practical significance of this observation is that people's learning opportunities should not be stifled in pursuit of top-down ("internationalized") conservation (Holt, 2005). Another implication is that analyses of conservation, or lack thereof, should be sensitive to local history. For example, judging by the contrasting conclusions of Johannes and MacFarlane (1991) and Kwan (2005), it is possible that Torres Strait islanders may have changed their attitudes in recent years regarding dugong conservation.

As Dasmann (1988), among others, has pointed out, a distinction must be made between invaders and natives. When humans invade a new and unfamiliar ecosystem, their initial impact may be huge, as with ancient Polynesians (Steadman, 1995). But this initial relationship may change as the people develop a knowledge base, learn from their mistakes, and come to terms with the limits of their new environment. Long-settled natives

tend to coevolve with their environment, often achieving a certain level of symbiosis. But this does not happen with all societies; nor does it happen over short periods; nor is it a permanent state.

Each major environmental or social perturbation alters the human–environment relationship, and a new balance develops. This is the basic argument of the resilience approach (Gunderson and Holling, 2002), and is consistent with various studies of the development of environmental knowledge following perturbations (Berkes and Folke, 2002). Thus, integrated systems of people and environment, or social-ecological systems, are seen as multiequilibrium systems, and social-ecological relationships as dynamic and cyclical. Institutions governing human–environment relationships are the result of aggregate decision-making processes and actions of the people (actors). Environmental knowledge of these people seems to develop by feedback learning or adaptive management. The elaboration of knowledge may take a long time to develop, and practices based on such knowledge even longer (Turner and Berkes, this issue, for examples). Practices, in turn, will be grounded in institutions, as in land and marine tenure systems (Chapman, 1985; Johannes, 1978), so that knowledge–practice–institutions make an interconnected set.

Such an approach, using thinking from resilience, adaptive management, and multiequilibrium systems, leads to the view that indigenous resource management systems are not mere traditions but adaptive responses that have evolved over time. These adaptations may involve the evolution of similar systems in diverse areas and cultures, as in the case of shifting agriculture found in virtually all tropical forest areas of the world. Or they may involve the elaboration of one basic model of management into a diversity of variations, as one finds, for example, in the reef and lagoon tenure systems of Oceania (Johannes, 1978; Ruddle, 1994). They may involve the combination of traditional approaches and contemporary commercial pressures, into a new synthesis, as in contemporary marine conservation systems in Vanuatu (Johannes, 1998) or biodiverse agroforestry systems in Mexico (Beaucage *et al.*, 1997; Castillo and Toledo, 2001).They may involve a major transformation of the landscape from one production system to another, as in the evolution of irrigated rice systems in Southeast Asia. Over some 400 years, irrigated rice culture developed from less intensive to more intensive modes of agriculture, and productivity increased through the building of dikes, terraces, and canals. This technology was developed in a two-way feedback relationship between the new production system and social institutions (Geertz, 1963). Some of these social institutions show remarkable adaptations to the characteristics of the local social-ecological systems such as the water temple system in Bali that can be modelled formally (Lansing, 1991). These various papers in the present issue of *Human*

Ecology in fact illustrate a range of possibilities of how new knowledge systems may emerge out of previous arrangements.

KNOWLEDGE, SELF-ORGANIZATION, DISTURBANCE, AND DIVERSITY

Many resource conservation problems require approaches suitable for dealing with complex systems. Folke *et al.* (2002) argue for flexible, multilevel governance systems, that is, systems in which decision-making is not top-down but shared among a number of levels, from the local to the international, as appropriate to the situation. Such multilevel governance may be structured in the form of networks and partnerships (Olsson *et al.*, 2004); it could also take the form of polycentric systems with multiple overlapping centers of authority, each contributing to the solution of one aspect of a complex problem (McGinnis, 2000).

Multilevel governance systems are said to be adaptive if institutional arrangements and ecological knowledge are tested and revised in an ongoing process of trial-and-error (Folke *et al.*, 2002). Such governance systems, and the process of learning and testing knowledge iteratively, are seen as important for building resilience towards sustainability in an unpredictable and changing world. The concept of resilience has developed out of the effort to study ecological change and nonequilibrium systems (Gunderson and Holling, 2002). Resilience, as the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks (Walker *et al.*, 2004), is about a system's flexibility in the face of change. This capacity, in turn, depends on the degree to which the system can self-organize and build its capacity for adapting. In human systems, self-organization and adapting is not something that happens by itself or mechanistically. Rather, it depends on a complex of people's decisions and actions, as in the development of conservation thought and practice, based on perceptions of the status of a resource or group of resources and a societal willingness to modify practices to adjust to new realities (Vickers, 1994).

The process of adaptive comanagement involves iterative knowledge development, contributing to self-organization and learning. Thus, it has the potential to increase the ability of communities and societies to deal with shocks and stresses, making them more robust to change. The capacity to elaborate knowledge about ecosystems and resources, and to learn from management mistakes, provides a buffer that guards against the failure of subsequent management actions based on incomplete knowledge and understanding. Institutional responses can and do vary. Human societies may

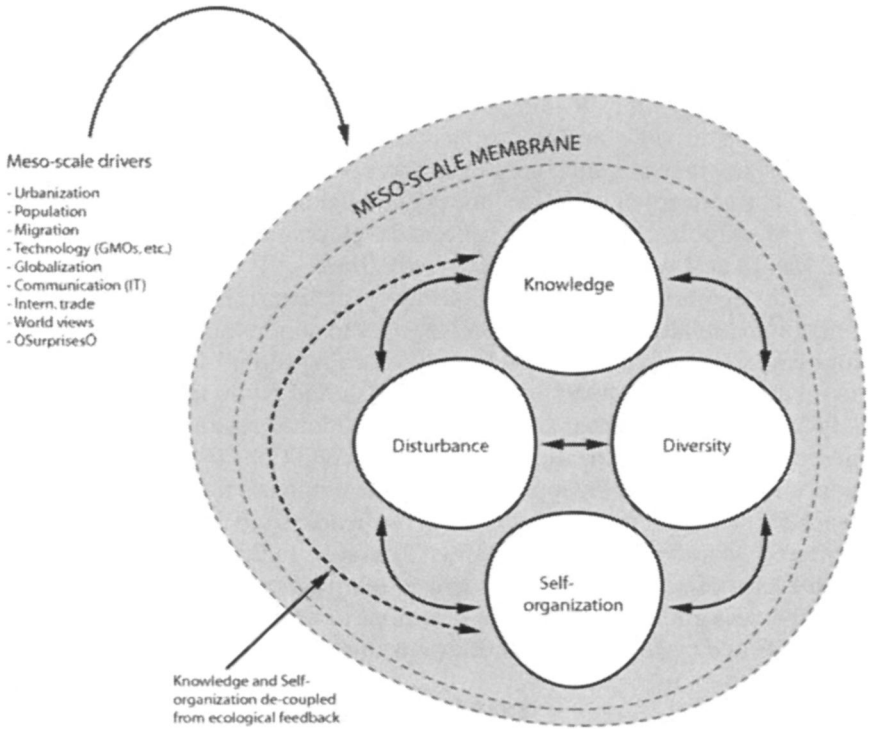

Fig. 1. The interplay between disturbance and diversity, and their relationship to knowledge systems and self-organization. Source: Adapted from Folke *et al.* (2003).

respond to a crisis by ignoring it, by responding "according to the book," or by allowing considerable autonomy at multiple levels of decision-making to respond differentially and learn from experience (Berkes and Folke, 2002). Hence, the process of responding to a crisis, or to smaller perturbations, needs to be considered in terms of the learning that is generated. To analyze the crucial role of knowledge development, one may consider the interrelationships of disturbance, diversity, self-organization, and knowledge (Fig. 1). Starting with one of the key considerations of adaptive management, we assume that disturbance and change are ever-present, both in the ecological system and the social system (Folke *et al.*, 2003; Gunderson and Holling, 2002). Periods of change caused by disturbance or crisis events are followed by periods of renewal and reorganization.

Disturbance is what initiates cycles of adaptive renewal. This renewal is based on a diversity of information in the system, both social and ecological, referred to as memory. Renewal is also in part based on innovation and

novelty, made possible by taking advantage of the opportunities created by change (Holling, 2001). Resilience thinking treats perturbation and change not necessarily as a negative factors but as opportunity. Disturbance triggers new observations leading to knowledge creation. Thus, the interplay between disturbance and the capacity to respond to and shape change is what makes renewal and reorganization possible in the adaptive renewal cycle. The concept of adaptive renewal highlights the idea that societies can learn to adapt to natural disturbances, developing a knowledge base along the way to deal with change (Folke *et al.*, 2003).

The significance of the relationships sketched in Fig. 1 is that it is not only futile but also counterproductive to try to eliminate disturbance events and crises impacting a system. Instead of trying to find technological fixes to environmental problems, the emphasis should be on maintaining diversity (biological/ecological and cultural/institutional), as the raw material or memory for self-organization, and creating conditions that facilitate or enhance learning. Such an approach shifts the emphasis from efficiency goals (such as maximum sustained yields) to resilience; from a static, equilibrium-centered worldview to one that is dynamic, multiequilibrial, and rich with cycles of renewal, creating diverse learning opportunities. The latter worldview is not far from ancient traditions of wisdom that see sacred relationships and cycles in all manifestations of nature.

CONCLUSIONS

Learning and adapting based on an accumulation of ecological knowledge, often following a perturbation such as a resource crisis, and the ability to reorganize or self-organize seem to be the major ingredients of developing conservation-oriented practices. The optimum foraging approach to conservation is blind to the fact that people and societies are capable of learning from experience, modifying their decisions and rule sets, and passing their knowledge on to others. The narrow logic of optimum foraging does not allow the generation of conservation solutions except in the most unusual circumstances (see discussion in Hunn *et al.*, 2003). There is no fixed "human nature." Conservation practices can develop over time because there are institutions, such as common property institutions (Ostrom, 1990; Ostrom *et al.*, 2002) that mediate the logical outcomes of optimum foraging calculus. These institutions, in turn, develop out of the accumulation of knowledge and the elaboration of resource management practices of a group of people capable of making decisions to alter their actions through learning.

We hypothesize that the relationships indicated in Fig. 1 are the ingredients that confer resilience for the long-term survival of common property

systems and other social-ecological systems. Such a view of the development of conservation is consistent with historical evidence, and provides insights on the question of how new knowledge relevant to conservation is created, and how existing knowledge develops or evolves.

One key insight of such an evolutionary approach is the distinction between 'invaders' and 'natives.' The initial impact of the invaders' excessive exploitation can trigger learning, and the initial human-environment relationship may change as a society develops knowledge, practices, and institutions, coming to collective terms with the limits of their new environment. Some such sequence of events may have occurred in the case of New Zealand (Moller *et al.*, 2004; Taiepa *et al.*, 1997), the Torres Strait islands, and parts of Oceania (Johannes, 2002). It may explain the observed sequence of knowledge development in groups that are new to an area, as in the case of the Brazilian Amazon (Muchagata and Brown, 2000) and salal harvesters of Washington State (Ballard, this issue). Such considerations supplement common property analysis by providing a historical and developmental context.

A similar model of knowledge development may also apply to groups undergoing social or technological transformation, as in the 1910 caribou depletion case when the repeating rifle came into use. The dynamics of such cases may be thought of as adaptive comanagement, or the coevolution of social groups with their environment, as in Geertz' (1963) rice farmers and Lansing's (1991) priests who control the water temple system in Balinese traditional rice production. Such transformations are not likely to happen over short periods, and feedback learning often requires learning from mistakes and other experiences. A communal knowledge base takes a long time to develop, and practices based on such knowledge even longer. Practices, in turn, come to be grounded in institutions, and self-interest is brought into check by a variety of social norms and institutions.

ACKNOWLEDGMENTS

An earlier version of this paper was presented at the panel, "Knowledge for the development of adaptive co-management," N.J. Turner and F. Berkes (session organizers) International Association for the Study of Common Property, IASCP '04, Oaxaca, Mexico. For the development of the ideas presented here, we thank our many colleagues in the IASCP session and Douglas Nakashima, UNESCO, Paris. This paper is dedicated to the memory of Bob Johannes, an original thinker on the meaning of conservation and its relationship to traditional ecological knowledge. Berkes' work was supported by the Social Sciences and Humanities Research

Council (SSHRC) and the Canada Research Chairs program; Turner's work was supported by SSHRC.

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