# Knowledge, Learning and the Resilience of Social-Ecological Systems

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**Abstract**

There are two broadly conceptualized ways in which conservation knowledge may evolve: the *depletion crisis model* and the *ecological understanding model*. Regarding the first one, R.E. Johannes argues that developing conservation thought and practice depends on learning that resources are depletable. Before they could develop conservation practice, points out Johannes, fishers of the Pacific islands first had to learn that their natural resources were limited -- but "they could only have done so by depleting them." Thus, such learning typically follows a resource crisis, as also seen in the James Bay caribou case and others. Regarding the second mechanism, there is large amount of evidence that suggests that the development of conservation practice often follows the elaboration of environmental knowledge by a group of people, leading to increasingly more sophisticated understanding of the ecosystem in which they dwell.

The adaptive co-management concept may be useful in suggesting a way in which these two mechanisms may be integrated. Adaptive co-management 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. Adaptive co-management combines the *dynamic learning* characteristic of adaptive management with the *linkage* characteristic of cooperative management. Local groups can self-organize, learn and adapt through social networks. This self-organizing process of adaptive co-management, facilitated by knowledge development and learning, has the potential to increase the resilience (shock-absorbing capability) of common property systems. Hence, it can be concluded that conservation and management knowledge develops 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.

## 1. Introduction

There has been a resurgence of interest in community-based conservation and resource management systems, using customary practices and local knowledge, in many parts of the world, including Oceanea (Johannes 1998), New Zealand (Taiepa et al. 1997), Indonesia (Alcorn et al. 2003), Alaska (Hunn et al. 2003) and elsewhere. Considerable attention has focused on the role of local and traditional knowledge in conservation. But we know little about how conservation knowledge develops among indigenous groups and other rural communities. The question on 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 the one hand, we have available detailed descriptions of great many indigenous knowledge and conservation systems (Berkes 1999; Turner et al. 2003; Blackburn and Anderson 1993; Boyd 1999; Deur and Turner, in press). There is an increasingly comprehensive appreciation of traditional ecological knowledge and ethnoecology, as systems of local and indigenous conservation (Berkes et al. 2000; Turner et al. 2000). Also available is a large literature base analyzing the conditions under which the 'tragedy of the commons' may be avoided, and local common property institutions may develop for resource management (Ostrom 1990; Ostrom et al. 1999).

On the other hand, many authors have questioned whether these systems could be considered to represent 'conservation' and 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). 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: 501).

Using these 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 become important. A group that may have

conservation practice for a particular area or resource may not have this 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.

Also relevant to the debate are discussions over the necessity of developing place-based, participatory models to approach sustainability. For example, Folke et al. (2002) suggest that many of our environmental problems are in fact complex systems problems that may require alternative approaches, such as adaptive management and resilience thinking. They see co-management (or the sharing of management power and responsibility between governments and local people) as necessary to produce flexible, multi-level governance systems in which institutional arrangements and ecological knowledge are tested and revised in an ongoing process of trial and error. Folke et al. (2002) call this arrangement adaptive co-management, an important policy measure for 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 the basis of conservation in indigenous societies and other resource-dependent groups. More specifically, this paper addresses the question of how how new knowledge relevant to conservation is created, and how existing knowledge develops or evolves.

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

## 2. Two Models for the Evolution 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 depletable. Various outhors have pointed out that the concept and practice of conservation can arise only from an experience of resource limitation (Hill 1996). 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 will expand on the *depletion crisis model*, as Turner has already elaborated on the *ecological understanding model* (see IASCP '04 paper by Nancy Turner).

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. Perhaps the best way to discover the limits, such as the sustainable yield of a resource, is by exceeding them. In fact, one of the central tenets of adaptive management is to structure management probes for learning, that is, to create perturbations that can give back signals (Carpenter and Gunderson 2001).

Johannes points out that almost all the basic marine conservation measures devised in the West in the 1900s (e.g., closed fishing areas, closed seasons, allowing escapement, ban on harvesting immature individuals…) were in use in the tropical Pacific centuries ago (Johannes 1978; Johannes 2002). "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: 3).

The actual depletion events or crises are not easy to record. It is possible to deplete various shallow water marine species in specific areas, but unlike some terrestrial resources, it is very difficult, if not impossible, to exterminate them. Marine fish and invertebrates produce many larvae, and currents distribute them over thousands of square kilometers. Some Pacific island societies did not learn until historic times that their resources were depletable. Some groups lived in areas where marine resources always exceeded their ability to harvest 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 sq km of shallow, productive marine waters. Their marine resources were effectively "unlimited", and the islanders show no evidence of having possessed a traditional marine conservation ethic (Johannes and MacFarlane 1991). Similarly, Hill's (1996) study shows 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, the case in point being the Ache people of Paraguay.

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

According to narratives by Chisasibi Cree elders in the 1980s, a disaster occurred in 1910s at Limestone Falls, near the centre 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 on a 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 re-appear 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 1982/83, large numbers of caribou appeared for the first time in the lands of the Chisasibi Cree, validating elders' predictions in the 1910s. 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 wastes properly. According to the Cree worldview, hunters and animals have a reciprocal relationship based on respect, and Chisasibi elders were worried that hunters' behaviour signaled a lack of respect for the caribou.

The 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 its 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, stayed out of trying to regulate the hunt and left it to the Cree to deal with the situation under their co-management 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 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: 108). There is some controversy over

the date but not over the cause of caribou disappearance; caribou dieoffs 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 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 (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 to ask 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 Nakashima (pers. comm.) offers that the knowledge of bird skin implements, 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$^{th}$ 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 the 1910s 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 (don't kill too many; don't 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 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 two or three years before the available 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.

**3. Adaptive Co-management: Integrating the Two Models**

There are compelling reasons to think that much of conservation-oriented knowledge accrues through ecological understanding over time, and there are many possible mechanisms for such understanding to develop (see IASCP '04 paper by Nancy Turner). The creation of conservation knowledge does not necessarily depend on crises and depletions, but such catastrophic learning probably does have a role to play. It may help speed up knowledge creation and 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 co-management may be useful for such an integration. Adaptive co-management 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: 20). Adaptive co-management 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 co-evolution 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 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. 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 co-evolve with their environment, often achieving a certain level of symbiosis. This does not happen over short periods, nor is it a permanent state. Each major environmental or social perturbation alters the balance, and a new relationship with the environmental develops based on learning-by-doing, or adaptive management. The necessary base of knowledge may take a long time to develop, and practices based on such knowledge even longer. Practices will be grounded in institutions, as in land and marine tenure systems (Johannes 1978).

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). They may involve the combination of traditional approaches and contemporary commercial pressures, into a new synthesis (Beaucage et al. 1997; Johannes 1998).

They may involve the 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; productivity increased through the building of dikes, terraces and canals; and this technology was developed in a two-way feedback relationship between the new production system and social institutions (Geertz 1963).

**4. Knowledge, Self-organization, Disturbance and Diversity**

Many resource conservation problems require approaches suitable for dealing with complex systems, such as adaptive management and resilience thinking. Folke et al.

(2002) argue for flexible, multi-level governance systems in which institutional arrangements and ecological knowledge are tested and revised in an ongoing process of trial-and-error. Such governance systems and the process of learning and testing knowledge iteratively are seen as important for building resilience towards sustainability in a world of uncertainty and transformations.

The concept of resilience has developed out of the effort to study ecological change and non-equilibrium systems in general (Gunderson and Holling 2002). Resilience is a measure of the amount of change the system can undergo and still retain the same controls on function and structure, that is, a system's shock-absorbing capability. This capability, in turn, depends on the degree to which the system is capable of self-organization, and the ability to build and increase the capacity for learning and adapting.

The process of adaptive co-management involves iterative knowledge development, contributing to self-organization and learning. Thus, it has the potential to increase the shock-absorbing capability of common property systems (and other integrated social-ecological systems), making them more robust to change. The capacity to elaborate ecosystem knowledge and to learn from management mistakes provides a buffer that protects the system from the failure of subsequent management actions based on incomplete knowledge and understanding.

To analyze the crucial role of knowledge development, one may consider the interrelationships of disturbance, diversity, self-organization and knowledge (Figure 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 in the social system (Holling 2001; 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 (Figure 2). Renewal is also in part based on innovation and novelty, made possible by taking advantage of the opportunities created by change (Holling 2001; Gunderson and Holling 2002). 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 cycle implies that people learn to adapt to natural disturbances, developing a knowledge base to deal with change.

## 5. 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. These are exactly the same 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 regarding the debate on indigenous conservation is that a distinction should be made between "invaders" and "natives". When humans invade a new and unfamiliar ecosystem, their initial impact on the environment may be substantial. 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. This may be the case in New Zealand (Taiepa et al. 1997; Moller et al. 2004) and part 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). Such considerations supplement common property analysis by enriching the historical and political context of the commons case.

A similar model of knowledge development may also apply to groups undergoing a social or technological transformation, as in the 1910s caribou depletion case when the repeating rifle came into use. The dynamics of such cases may be thought of as adaptive co-management, or the co-evolution of social groups with their environment, as in Geertz' (1963) rice farmers. Such transformations are not likely to happen over short periods, and feedback learning often requires learning from mistakes. A 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.

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Figure 1. The interplay between disturbance and diversity, and their relationship to knowledge systems and self-organization. Source: Folke, Colding and Berkes (2003).

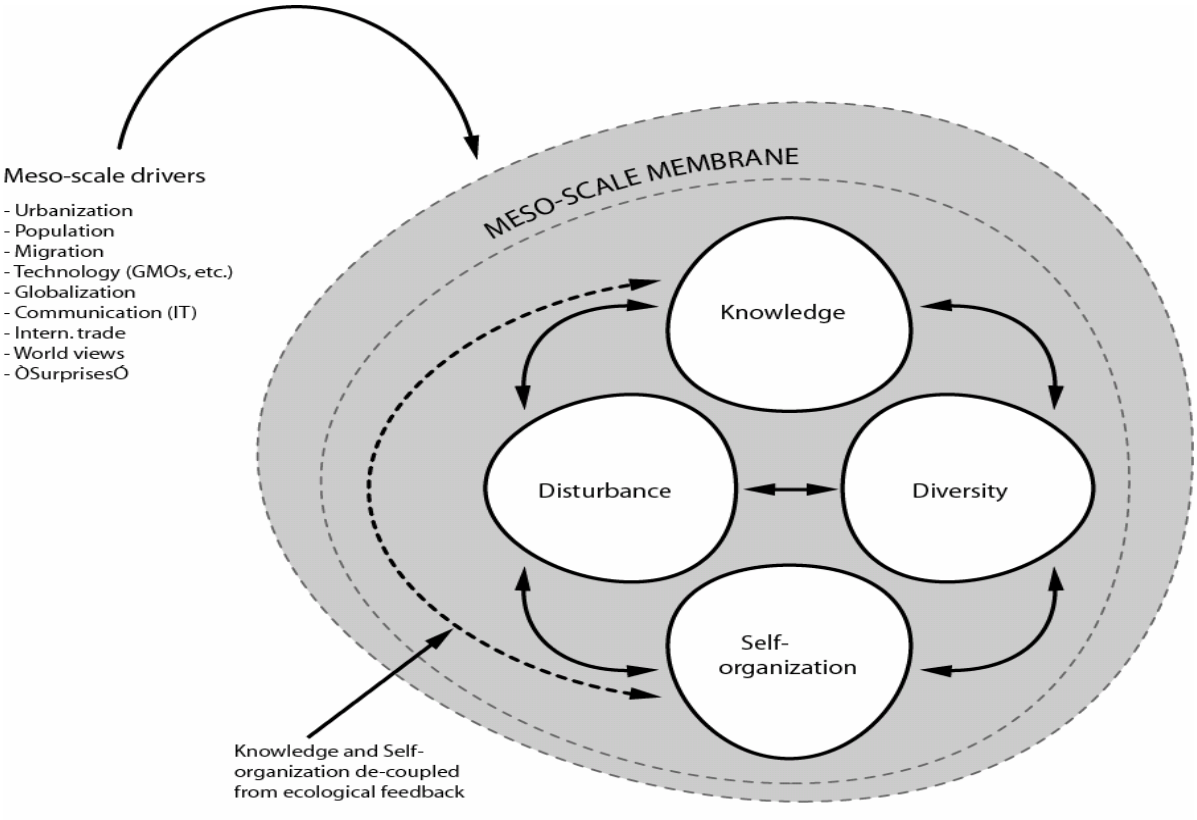

Figure 2. Components of memory for the reorganization phase of the adaptive renewal cycle. Source: Folke, Colding and Berkes (2003).