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Social institutions in ecosystem management and biodiversity conservation

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Abstract: This synthesis addresses local institutions and associated management practices related to natural resources and ecosystem dynamics, with an emphasis on traditional ecological knowledge systems. Traditional practices for ecosystem management include multiple species management, resource rotation, ecological monitoring, succession management, landscape patchiness management and practices of responding to and managing pulses and ecological surprises. There exist practices that seem to reduce social-ecological crises in the events of large-scale natural disturbance such as creating small-scale ecosystem renewal cycles, spreading risks and nurturing sources of ecosystem reorganization and renewal. Ecological knowledge and monitoring among local groups appears to be a key element in the development of many of the practices. The practices are linked to social mechanisms such as flexible user rights and land tenure; adaptations for the generation, accumulation and transmission of ecological knowledge; dynamics of institutions; mechanisms for cultural internalization of traditional practices; and associated worldviews and cultural values. We dive deeper into the role of informal social institutions in resource management, such as many taboo systems. We find that taboos may contribute to the conservation of habitats, local subsistence resources and 'threatened', 'endemic' and 'keystone' species, although some may run contrary to conservation and notions of sustainability. It is asserted that under certain circumstances, informal institutions may offer advantages relative to formal measures of conservation. These benefits include non-costly, voluntary compliance features. Since management of ecosystems is associated with uncertainty about their spatial and temporal dynamics and due to incomplete knowledge about such dynamics, local management practices and associated institutions may provide useful 'rules of thumb' for resource management with an ability to confer resilience and tighten environmental feedbacks of resource exploitation to local levels.

Resumen: Esta síntesis aborda el tema de las instituciones locales y las prácticas de manejo asociadas relacionadas con los recursos naturales y la dinámica de los ecosistemas, enfatizando a los sistemas tradicionales de conocimiento ecológico. Las prácticas agrícolas para el manejo ecosistémico incluye el manejo de muchas especies, la rotación de recursos, el monitoreo ecológico, el manejo de la sucesión, el manejo de la heterogeneidad del paisaje, prácticas de respuesta, el manejo de pulsos y los imprevistos ecológicas. Algunas prácticas pueden reducir la crisis socioecológica ante la eventualidad de disturbios naturales de gran escala, como los que crean ciclos de renovación ecosistémica de pequeña escala, dispersando los riesgos y alimentando a las fuentes que nutren la reorganización y la renovación de los ecosistemas. El conocimiento ecológico y el monitoreo realizado por grupos locales son elementos clave en el desarrollo de muchas prácticas. Las prácticas están ligadas a mecanismos sociales tales como los derechos flexibles de los usuarios y la tenencia de la tierra; las adaptaciones para la generación, acumulación y transmisión de conocimiento ecológico; las dinámicas institucionales; los mecanismos de internalización cultural de las prácticas tradicionales; y las distintas visiones del mundo y valores culturales asociados. Nosotros exploramos a profundidad el papel de las instituciones sociales informales en el manejo de recursos, como es el caso de muchos sistemas de tabúes, los cuales pueden contribuir a la conservación de hábitats, de recursos locales de subsistencia y de especies 'amenazadas', 'endémicas' y 'clave', si bien algunos llegan a ir en contra de la conservación y las nociones de sostenibilidad. Se afirma que bajo ciertas circunstancias, las instituciones informales pueden ofrecer ventajas relativas sobre las medidas formales de conservación. Estos beneficios incluyen rasgos no costosos de conformidad voluntaria. Dado que el manejo de ecosistemas está asociado a la incertidumbre sobre la dinámica espacial y temporal, y debido a que el conocimiento de tal dinámica es incompleto, las prácticas locales de manejo y las instituciones asociadas pueden brindar reglas empíricas útiles para el manejo de los recursos, capaces de conferir resiliencia y fortalecer las retroalimentaciones ambientales de la explotación de los recursos a niveles locales.

Resumo: Esta síntese aborda as instituições locais e práticas de gestão associadas aos recursos naturais e às dinámicas dos ecosistemas, com ênfase nos sistemas de conhecimento ecológico tradicional. As práticas tradicionais para a gestão dos ecosistemas incluem a gestão de espécies múltiplas, rotação de recursos, monitorização ecológica, gestão da sucesão, gestão da malha da paisagem, e práticas de resposta a impulso de e a surpresas ecológicas. Existem práticas que parecem reduzir as crises sócio-económicas face a disturbios naturais de grande dimensão tais como criando ciclos renováveis de ecosistemas de pequena dimensão, distribuindo os riscos e a criação de fontes de reorganização e renovação dos ecosistemas. O conhecimento ecológico e a monitorização entre grupos locais parecem ser o elemento chave no desenvolvimento de muitas das práticas. As práticas estão ligadas a mecanismos sociais tais como a direitos de uso flexíveis e o direito de posse da terra; adaptações para a geração, acumulação e transmissão do conhecimento ecológico; dinámicas das instituições; mecanismos para a internalização das práticas tradicionais; e associação com pontos de vista mundiais e valores culturais. Na gestão dos recursos mergulha-se fundo no papel das instituições sociais informais tal como em muitos temas tabu. Encontrou-se que os tabus podem contribuir para a conservação de habitats, recursos locais de subsistencia, e "ameaçados", "endémicos" e espécies "alicerce", se bem que alguns podem funcionar de forma contrária à conservação e às noções de sustentabilidade. Foi determinado que sob certas circunstancias, as instituições informais podem oferecer vantagens comparativas em relação às medidas formais de conservação. Estes beneficios incluem medidas baratas voluntariamente aceites. Dado que a gestão do ecosistema está associada com a incerteza àcerca da sua dinámica espacial e temporal, e devido ao conhecimento incompleto àcerca daquela dinámica, as práticas locais de gestão e instituições associadas podem proporcionar regras básicas para a gestão dos recursos com uma aptidão susceptivel de conferir resiliência e apertada retroacção ambiental da exploração de recursos aos níveis locais.

Key words: Biodiversity conservation, cultural ecology, natural resource management, traditional ecological knowledge.

Introduction

In recent years there has been increasing interest to address the role of local communities and institutions[1] in the management of natural resources and ecosystems. Examples include Ostrom (1990) on institutions and collective action; Bromley (1991) and Hanna *et al.* (1996) on property rights; Baland & Platteau (1996) on community-based resource management; Lee (1993) and Gunderson *et al.* (1995) on institutional learning and resource management; Berkes & Folke (1998) and

Berkes *et al.* (2002) on linked social-ecological systems.

There has also been increasing interest in incorporating traditional ecological knowledge[2] in natural resource management. Such interests are noticeable in agricultural research (Muchagata & Brown 2000), pharmacology (Cox 2001), biodiversity conservation (Gadgil *et al.* 1993; Horowitz 1998; Johannes 1998a; Nabhan 2000; Ramakrishnan *et al.* 1998), in the management of ecological processes (Alcorn & Toledo 1998), complex ecological systems (Turner *et al.* 2000) and for practice of sustainable resource use in general (Berkes 1999; Schmink *et al.* 1992). Also, indigenous rights to traditional ecological knowledge and the legal recognition of indigenous and local communities in national legislation are subject to important policy issues (Mauro & Hardison 2000).

Traditional ecological knowledge (TEK) refers to "a cumulative body of knowledge, practice and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment" (Berkes & Folke 1998; Gadgil *et al.* 1993). This definition draws on previous analyses of TEK-systems, showing that there is a component of local observational *knowledge* of species and other environmental phenomena, a component of *practice* in the way people carry out their resource use activities, and a component of *belief* regarding how people relate to resources and ecosystems. This type of knowledge can include both taxonomic knowledge and knowledge about ecosystem processes (Minnis & Elisens 2000; Nabhan *et al.* 1991). Such knowledge may be common, or vested in experts, such as resource management stewards, elders or chiefs. It may be expressed in indigenous taxonomies (Nabhan 2000), local institutions and management practices (Berkes *et al.* 2000; Colding *et al.* 2003). Alternatively, such knowledge may be incorporated in local myths, and oral stories (Turner *et al.* 2000).

There are a number of ways in which local institutions and resource management practices related to TEK can be studied. Here we address the role of TEK in management practices and social mechanisms for conservation of biological diversity. In particular we focus on the management of diversity to secure a flow of resources and ecological services on which the local social-ecological system depends. Many of the practices and social mechanisms described here relate to the potential to confer resilience in local resource management systems.

The focus on TEK systems partly derives from the recognition that conventional resource management in many places has failed to manage biological resources and diversity in a sustainable fashion (Holling & Meffe 1996). The studying of local communities with long-term success of management of common pool (property) resources may provide clues on how to improve resource management and conservation. It may serve as a complement to other approaches of biological conservation.

We begin with the theoretical framework of the paper through a brief description of the concept of ecosystem resilience and the adaptive renewal cycle (Holling 1986, 2001). This section is followed by the identification of some key characteristics of conventional resource management (CRM) in relation to resilience and sustainability. In the next section local social institutions and associated natural resource management practices, with an emphasis on TEK systems, contrast CRM. We then focus on social taboo systems (referred to as 'resource and habitat taboos' (RHTs)) in relation to natural resource management and biological conservation. Some RHTs may be understood in the context of the adaptive renewal cycle, thus increasing understanding about their role in contributing to ecological resilience as a prerequisite for sustainable development. Recommendations for improved ecosystem management are presented in the conclusion section.

1 Rules and conventions of society that facilitate coordination among people regarding their behavior (North 1990). Institutions are made up of formal constraints (rules, laws, constitutions), informal constraints (norms of behavior, conventions and self-imposed codes of conduct) and their enforcement characteristics; thus they shape incentives in human exchange, whether political, social or economic. Environmentally oriented scholars define institutions simply as *working-rules*, or *rules-in-use*, meaning "the set of rules actually used by a set of individuals to organize repetitive activities" (Ostrom 1992) or alternatively as: "codes of conduct that define practices, assign roles and guide interactions; the set of rules actually used" (Berkes 1995).

2 Others term this type of knowledge 'indigenous knowledge' (Warren 1995), folk knowledge (Ruddle 1994), tribal knowledge, or 'ethnoecological knowledge' (Bodley 1994).

Theoretical framework - ecosystem resilience and the adaptive renewal cycle

Since Connell (1978) launched the 'intermediate disturbance hypothesis', empirical evidence suggests that moderate frequencies or intensities of disturbance foster a high level of species richness in some ecosystems (Hobbs & Huenneke 1996). Disturbance[3] is key for ecosystem renewal and thereby for the maintenance of biological diversity and ecosystem resilience (Clark 1996; Holling 1986). How a disturbance regime - a bundle of disturbances at different temporal and spatial scales - affect ecosystem resilience seems among other factors contingent on the size and frequency of the disturbances and on the ecological characteristics of a particular ecosystem (Gunderson & Pritchard 2002). Disturbances are a natural part of the development of many ecosystems and their renewal capacity depends on disturbance. If disturbances are not allowed to enter the ecosystem, it may become over-connected and brittle and thereby even larger perturbations will be invited with the risk of massive and widespread impacts. Human activities may alter natural disturbance regimes by transforming pulse events into persistent disturbance or even chronic stress, by introducing new disturbance, or by suppressing or removing disturbance (Nyström *et al.* 2000; Paine *et al.* 1998).

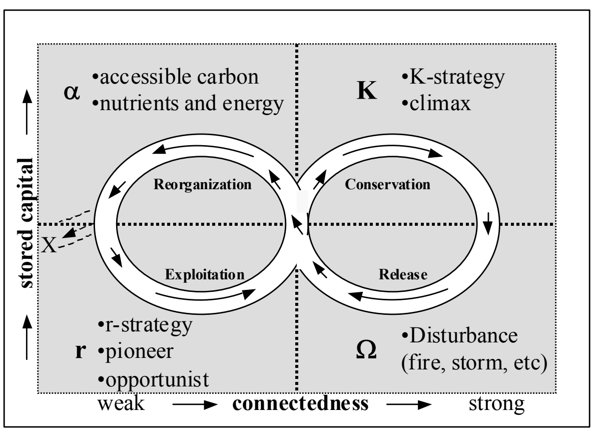

Fig. 1. The four ecosystem functions of the Adaptive Renewal Cycle (r, K, Ω, α) and the flow of events among them (Source: Holling 1986).

Holling (1986) argues that badly adopted nature-society interdependencies lead to increasingly brittle ecosystems that over time lose the capacity to buffer and incorporate natural disturbances. *Ecological resilience* (Holling 1973), or *ecosystem resilience* (Holling & Meffe 1996), is the ability of the system to buffer change and to reorganize and renew following change; or the magnitude of disturbance that can be absorbed before a system changes its structure by changing the variables and processes that control behavior (Holling 1973, 2001). Even though ecosystems are perturbed they usually remain within a stability domain due to their resilience (Levin 1999). For example, a fire can devastate parts of a forest. However, over time the disturbed parts of the forest tend to recover. The biota has adapted over long time periods to a certain disturbance regime to absorb its effects.

Hence, disturbance is a key component of the Adaptive Renewal Cycle (Fig. 1), a heuristic model that describes ecosystem dynamics and development (Holling 1986). It consists of the dynamic interaction among four basic functions: *exploitation, conservation, release* and *reorganization* (Holling 1986, 2001). The first two, the r- and K-stages, are similar to ecological succession. The next function is the *release* phase, the omega-phase (Ω). It takes place when the conservation phase has built elaborate and tightly bound structures that have become "over-connected", so that a rapid change is triggered. The system has become brittle. The stored biomass is then suddenly released and the tight organization lost. The abrupt destruction is created internally but caused by an external disturbance (i.e., fire, disease or grazing pressure). This process of change both destroys and releases opportunity for the fourth stage, *reorganization*. In this phase, called the alpha-phase (α), released materials are mobilized to become available for the next exploitation phase (Holling 2001 or Gunderson & Holling 2002 for a comprehensive elaboration of the adaptive renewal cycle).

An ecological system is not a fixed stock that generates a flow of renewable resources infinitely or in a linear fashion. The stock is a changing phe-

3 Disturbance may be defined as "any relatively discrete event in time that disrupts ecosystem community or population structure and changes resources, substrate availability or the physical environment" (White & Pickett 1985). Natural disturbances include abiotic, such as fire, storms and floods; and biotic, such as insect outbreaks and herbivore grazing (Gunderson *et al.* 1995).

nomenon and it is the resilience that determines its capacity to respond to perturbations imposed by exploitation or pollution (Mäler 2000). Ecological resilience acknowledges the fact that complex adaptive ecosystems tend to have multiple stable states (Levin 1999), or stability domains, towards which they progress and organize around (Ludwig *et al.* 1997). An ecosystem can be pushed from one domain to another. Such shifts of stability domains involve passing a threshold, as illustrated for lakes, savannas, coral reefs and oceans (Scheffer *et al.* 2001). These flips may occur in nature but tend to be exacerbated by human activities that simplify ecosystems and often cause loss of biological diversity and ecosystem services (Nyström *et al.* 2000). Hence, human induced disturbance, such as exploitation and pollution, may flip an ecosystem to a less desirable functional state from a human perspective (Baskerville 1995; Holling *et al.* 1995) or to more or less irreversible states (Lugo 1995; van der Leeuw 2000). In degraded ecosystems (i.e., with reduced resilience), a natural disturbance that earlier could be absorbed may instead shift the system from one stability domain into another (Schaffer *et al.* 2001). Disturbance edits ecosystems and contributes to ecosystem reorganization and builds adaptive capacity. But to sustain the positive effects of disturbance there has to be ecosystem resilience. Otherwise reorganization and renewal of a disturbed ecosystem will be hampered, and the likelihood of phase shifts increases (Folke *et al.* 2003).

Conventional natural resource management

Conventional resource management is here defined as "resource management based on Newtonian science and on the expertise of government managers" (Berkes *et al.* 2000). Having a strong sector-based focus, conventional resource management often aims at managing a few target resources, e.g., timber, monoculture crops, fish species and livestock. These resources are primarily managed for economic output by way of rules and regulations made by technical experts often of centralized management and disconnected from local resource and ecosystem dynamics (Gunderson *et al.* 1995). The emphasis of management is generally on securing steady flows of certain environmental goods and the maintenance of predictable yields, such as maximum sustained yields by way of quota and bag limits (Carpenter & Gunderson 2001). Controlling environmental variability and natural disturbance becomes key in such systems, since fluctuations impose problems to meet predicted production goals (Holling & Meffe 1996). Thus, managers seek to command and control these processes in an attempt to stabilize ecosystem outputs (Carpenter & Gunderson 2001).

Preventing natural disturbances at the local level may lead to accumulation of disturbance at regional scales and cause alterations in ecosystem functioning (Gunderson & Holling 2002). Also, conventional resource management may be slow in adapting and responding to ecological change and variability. For example, rather than responding to early signs of declines in resource stocks and adapting to environmental change, incentives for industrial fisheries are often to invest in more sophisticated technologies and larger fishing vessels to maintain a steady supply of fish. Since the fishery provides employment to people, managing agencies often favor socioeconomic development prior to environmental concern. Their interdependence is not recognized. By ignoring environmental feedbacks and the failure to take into account structures and functions of the ecosystem on which fish stocks depend, there is a risk that the ecosystem gradually looses capacity to support commercial fish population (Jackson *et al.* 2001; Pauly *et al.* 1998). In the end, the impoverishment of ecosystem capacity can no longer support a viable industry (Finlayson & McCay 1998).

Because of dynamic changes in many ecosystems, economic policies that apply fixed rules for achieving constant yields, e.g., fixed carrying capacity of cattle or wildlife, or fixed sustainable yield of wood, may lead to ecological systems that increasingly lack resilience and cause consequent losses in human welfare (Mäler 2000). Holling & Meffe (1996) refer to this as the "pathology of natural resource management". It is, therefore, important to devise management systems with tighter feedback loops, a key element in maintaining resiliency in any system (Levin 1999). Tighter feedback loop management allows for small-scale natural disturbances to enter the management system to be dealt with locally (Berkes & Folke 1998).

In the next section we will address tighter feedback loop management through analyzing:

1. How local social systems have developed management practices based on ecological knowledge for dealing with the dynamics of the ecosystems in which they are located; and
2. Social mechanisms behind these management practices.

Traditional knowledge systems in practice

There are a rich variety of traditional and local resource management practices for dealing with local ecosystem dynamics (e.g. Berkes & Folke 1998). Practices exist for managing specific resources and responding to ecosystem dynamics and managing environmental variability (including disturbances) to secure a flow of biological resources. Also, there exist deliberate disturbance practices. Furthermore, in virtually all the cases looked into by Folke *et al.* (1998) there exist local practices for monitoring resource abundance and change in ecosystems.

Most of these practices are embedded in or linked to a number of social mechanisms that constitute cultural capital (Berkes & Folke 1994). These mechanisms have been sequentially organized, ranging from mechanisms for the generation, accumulation and transmission of ecological knowledge; the existence of a diverse set of dynamic institutions; mechanisms for cultural internalization; and the underlying world view and cultural values of the local community. Management practices and social mechanisms identified in Folke *et al.* (1998) are summarized in Table 1 and also described in Berkes *et al.* (2000). These practices relate to different systems of management, ranging from agroforestry systems, pastoral systems, forests to watersheds.

Traditional management practices in the S-phase

Fig. 2 presents examples of traditional management practices that may be interpreted as being located in the *exploitation* and *conservation* phases of the adaptive renewal cycle (Fig. 1). These practices include succession management, resource rotation and multiple species management. Examples of such practices are polycultures of local communities in Samoa and among Bangla-

Table 1. Social-ecological practices and mechanisms in traditional knowledge and practice (adapted from Folke *et al.* 1998).

1.	Management practices based on ecological knowledge
(A)	*Practices found both in conventional resource management and in some local and traditional societies*
	Monitoring resource abundance and change in ecosystems
	Total protection of certain species
	Protection of vulnerable life history stages
	Protection of specific habitats
	Temporal restrictions of harvest
(B)	*Practices largely abandoned by conventional resource management but still found in some local and traditional societies*
	Multiple species management
	Maintaining ecosystem structure and function
	Resource rotation
	Succession management
(C)	*Practices related to the dynamics of complex systems, seldom found in conventional resource management but found in some traditional societies*
	Management of landscape patchiness
	Watershed-based management
	Managing ecological processes at multiple scales
	Responding to and managing pulses and surprises
	Nurturing sources of ecosystem renewal
2.	Social mechanisms behind management practices
(A)	*Generation, accumulation and transmission of local ecological knowledge*
	Reinterpreting signals for learning
	Revival of local knowledge
	Folklore and knowledge carriers
	Integration of knowledge
	Intergenerational transmission of knowledge
	Geographical diffusion of knowledge
(B)	*Structure and dynamics of institutions*
	Role of stewards/wise people
	Cross-scale institutions
	Community assessments
	Taboos and regulations
	Social and religious sanctions
(C)	*Mechanisms for cultural internalization*
	Rituals, ceremonies and other traditions
	Cultural frameworks for resource management
(D)	*World view and cultural values*
	A world view that provides appropriate environmental ethics
	Cultural values of respect, sharing, reciprocity, humility and other

deshi char-dwellers. Other examples include integrating farming and aquaculture. While common in traditional societies, such practices have largely been abandoned in conventional resource management (Berkes *et al.* 2000).

Another practice of key importance in the succession phases is monitoring of resource abundance and change in ecosystems. Monitoring often leads to the acquisition of ecological knowledge and is, therefore, a key attribute in sustainable ecosystem management. Monitoring may provide information about location and timing of target resources (i.e., resource procurement) and provides the basis for spatial and temporal regulations for resource use in many local communities (Folke & Colding 2001). Thus, various social response mechanisms may evolve as a result of ecological monitoring, such as some of the taboo systems described below.

For example, the widespread use of temporal taboos in Oceania is based on observations about the spawning periods of key fish species and prohibits fishing during such periods. At aggregation sites, fishers monitor yearly changes of fish stock size and composition and reduce their fishing effort when stocks are low (Hviding 1989; Johannes 1978). Due to the proximity of local resource users to their resource base, many local communities provide for day-to-day monitoring (Jodha 1995). In some local communities, ecological monitoring is compulsory for community members (Alcorn & Toledo 1998). In others, monitoring is the responsibility of particular individuals, such as resource stewards, elders or shamans (Folke & Colding 2001).

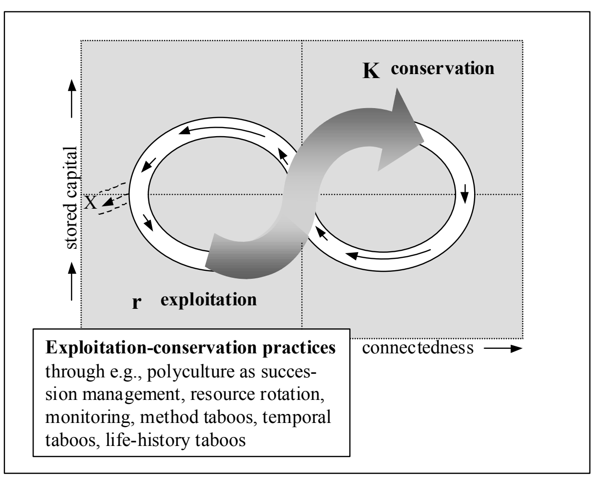

Fig. 2. Traditional management practices located in the *exploitation* and *conservation* phases (i.e., the 'S-phase') of the adaptive renewal cycle (modified from Berkes & Folke 2002).

Traditional management practices in the backloop

Fig. 3 describes traditional resource management practices that are located in the *release* and *reorganization* phases, referred to as 'backloop management' in the context of the adaptive renewal cycle. Management of natural resources with the aim to confer ecosystem resilience need carefully consider these two phases, so that undesirable shifts in stability domains is avoided. Avenues toward such potential 'shifts' are marked with the letter X in Figs. 1 to 3.

There are resource management practices that evoke *small-scale disturbances* in ecosystems (Berkes & Folke 2002). Such practices trigger small-scale release and create smaller renewal cycles in the local ecosystem. Such practices may reduce the impact of large-scale natural disturbances in ecosystems (Holling *et al.* 1998). Examples include shifting cultivation and fire management for habitat improvement. These practices provide for the regeneration of important subsistence resources by creating habitat heterogeneity in local ecosystems (Orejuela 1992), and may en-

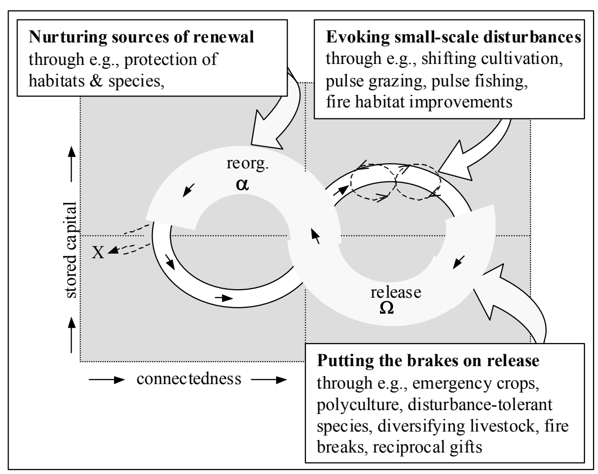

Fig. 3. Traditional resource management practices (evoking small-scale disturbance, putting the brakes on release and nurturing sources of renewal) located in the *release* and *reorganization* phases (the 'backloop management') of the adaptive renewal cycle (modified from Berkes & Folke 2002).

hance the capacity of certain ecosystems to provide local subsistence resources. Pulse fishing, employed by the James Bay Cree and pulse grazing, employed by some African pastoralists represent examples of such a practice (Berkes *et al.* 2000).

Furthermore, there exist traditional resource management practices that may be important in the *release phase*, because they may 'put the brakes on release' following natural disturbance (Fig. 3). In this way, a local community may reduce the likelihood of large-scale impact from disturbances (Berkes & Folke 2002).

Polyculture of Samoa represents an example of such a practice. A minor food crop, yams, became the most important food for an extended period of time following a large-scale cyclone. Polyculture and 'multiple-disturbance tolerant' species among the char-dwellers in Bangladesh serve the same function by reducing the potential impacts of flooding or droughts (Colding *et al.* 2003). Diversification of livestock species among many pastoral groups in the African Sahel may reduce the effects of various disturbance regimes such as disease outbreaks and droughts.

A number of social mechanisms, such as flexible user rights, dispersed land ownership and values based on reciprocity, help local communities survive periods of crisis. For example, among pastoralists of the African Sahel, rights to use territories belonging to other tribes are exercised when tribes know that in the future they can return the favor (Niamir -Fuller 1998). Similarly among the Huastec, members of one family have the right to ask another family to borrow land or harvest forest products to meet their subsistence needs (Alcorn & Toledo 1998). Such mechanisms of reciprocity may exist in many local societies exposed to frequent natural disturbances. Also, locally protected habitats (often framed by taboos) may serve important functions by 'putting the brakes on release' (Colding *et al.* 2003).

Table 2. Resource and habitat taboos (RHTs) and their nature conservation and resource management functions (Source: Colding & Folke 2001).

Category	Function
Segment taboos	Regulate resource withdrawal
Temporal taboos	Regulate access to resources in time
Method taboos	Regulate methods of withdrawal
Life history taboos	Regulate withdrawal of vulnerable life history stages of species
Specific-species taboos	Total protection to species in time and space
Habitat taboos	Restrict access and use of resources in time and space

Locally protected ecosystems, such as sacred groves, buffer zone areas and range reserves, may also be important for the *reorganization* of ecosystems. Such areas may provide dispersal and migration of animals and plants into disturbed ecosystems. Such habitats may contribute to building resilience in the local landscape. Locally protected species, such as keystone species may also turn out to be functional in this phase (Colding & Folke 1997, 2001). Even taboos imposed on population of common species may have critical functions in the reorganization phase - especially those imposed on mobile link species (Elmqvist *et al.* 2001).

Ecological functions of social taboos

The specific role of social taboos in the context of resource and ecosystem management, what we refer to as resource and habitat taboos (RHTs), will be synthesized below. The synthesis is based on Colding & Folke 1997, 2000, 2001. The taboos are grouped into six major categories in relation to their conservation and resource management functions (Table 2). The last two categories of RHTs in Table 2 can be referred to as *non-use taboos*, because they do not allow for human use of biological resources. The other four categories may be referred to as *use-taboos* since the taboos permit restrictive use of resources (Colding & Folke 2001).

Segment taboos apply when a cultural group bans the utilization of particular species for specific time periods for human individuals of a particular age, sex or social status. Thus, certain segments of a human population may be temporarily proscribed from the gathering and/or consumption of species. This group of taboos exists in a number of traditional societies. In the literature, cases predominantly stem from Africa and South America. Cultural perceptions, customs and superstitious beliefs of human health risks are frequently associated with such taboos. Some literature sources indicate that segment taboos serve as strategic responses to avoid game depletion among

South American groups since they depress rates of species withdrawal.

Temporal taboos may be imposed *sporadically*, *daily* or on a *weekly* to *seasonal* basis. Cases recorded in the literature derive from Oceania and India. Such taboos are imposed on both aquatic and terrestrial resources. In an ecological context, they function to reduce harvesting pressure on particular subsistence resources and are closely related to the dynamic change of resource stocks. Hence, they follow the same principle as traditional fallow systems.

Method taboos are imposed on certain gear types and extraction methods that may easily reduce or deplete the stock of a resource. Method taboos are common in SouthEast Asia and are often fishing-related. This category of RHTs may also have the institutional function of providing equal access to a resource.

Life history taboos apply when a cultural group bans the use of certain vulnerable stages of a species' life history based on its age, size, sex or reproductive status. Such taboos may be imposed on reproducing and nesting species and species particularly susceptible to over harvesting, such as slow moving or sessile, marine species. Hence, they often have resource management functions. Examples of such taboos derive mainly from India and Oceania.

Specific-species taboos prohibit any use of particular species and their population. This category of RHTs was analyzed in depth in Colding & Folke (1997), where a comparison was made between taboos imposed on species and species recognized by ecologists to be threatened, endemic and keystone. Based on the literature review of 70 specific-species taboos, about 30% of them were set on species that are recognized as "threatened" by the International Union for the Conservation of Nature (IUCN), predominantly on threatened reptiles and mammals. Notably, the largest class imposed by specific-species taboos was mammals (34 taboos), followed by birds and reptiles (11 taboos each). It was estimated that out of the 34 mammals avoided, 44% were listed as threatened by IUCN. Out of the 70 identified species avoided by taboo, five out of eight reptiles were threatened, four were endemic and five were keystone species. The threatened species in this category of RHTs are confined to tropical and subtropical regions, mainly in Central and South America, Africa and India.

The reasons for the existence of specific-species taboos vary, ranging from beliefs in species being toxic, serving as religious symbols, representing reincarnated humans and species being avoided due to their behavioral and physical appearance. Such reasons constitute strong sentiments behind self-enforcement of taboos due to beliefs in "automatic sanctions" (Colding & Folke 2001).

Habitat taboos are often imposed on terrestrial habitats, river stretches, ponds and coastal reefs. Examples of such 'socially fenced' ecosystem types (Colding *et al.* 2003) include 'sacred groves' of India and Africa, 'spirit sanctuaries' of South America, *waahi tapu* and *ahupua'a* in the South Pacific and *hima* of Saudi Arabia. Habitat taboos provide for the protection of a number of ecological services on which a local community may depend. These services include the maintenance of biodiversity, regulation of local hydrological cycles, prevention of soil erosion, pollination of crops, preservation of locally adapted crop varieties, habitat for threatened species and predators on noxious insect and pest species of crops and serving as wind and fire brakes.

As results also indicate, some RHTs may work against conservation. For example, some specific-species taboos set on common species may increase harvesting pressure on less abundant ones (Harris 1979; Johannes 1994). In some settings this category of taboos may also lead to too low use of potential food resources (Ntiamoa-Baidu 1991). Segment taboos may also lead to malnutrition and run contrary to notions of sustainable development (Wilson 1980). Hence, not all RHTs may be desirable in biological conservation designs. They need to be understood in their specific social, ecological and cultural contexts.

Institutional results of resource and habitat taboos (RHTs)

Results of the institutional analysis of RHTs of Colding & Folke (2000, 2001) indicate that they fit neatly in the class of informal institutions, in congruence with the discussion by North (1990). Table 3 represents a crude attempt to distinguish among informal and formal institutions, following the reasoning of North (1990, 1994) and Knight (1992).

It is important to recognize that institutions are subject to historical change, and that traditions, conventions and norms in any society may over time turn into formalized rules and be enforced through formal laws. Hence, there exist a certain degree of overlap between formal and informal institutions in many societies.

Formal institutions largely represent consciously designed, written-down legal rules that often are third-party monitored and enforced. Third-party enforcement entails use of a regulatory agency that often must hire its own monitors (e.g., police, coast guards and forest wardens) and mediators (e.g., lawyers). Informal institutions represent unwritten codes of conduct, norms of behavior and conventions. In many settings informal institutions are self-enforced and self-monitored by individuals in smaller groups or communities (Baland & Platteau 1996) or due to beliefs in 'automatic sanctions' or cosmological and religious beliefs held by individuals (Colding & Folke 1997, 2000). Hence, the economic costs for third-party enforcement and monitoring of formal institutions tend to be higher relative to the costs of enforcement and monitoring of informal institutions (North 1990). Norms are generally hard to change in a given society and may gradually weaken over time (Ensminger 1996). Many formal institutions, such as constitutions, may be extremely resistant to change. However, cultural traditions and mechanisms that have been developed as adaptations to the environment over tens or hundreds of generations may quickly be cast aside when a local community comes in contact with new technologies and outside influences (McNeely 2001).

Table 3. Characteristics of formal and informal institutions (Source: Colding & Folke 2001).

Characteristics	Formal	Informal
Laws	+	
Conventions or norms		+
Written	+	
Consciously designed	+	
Self-imposed		+
Self-monitored		+
Third-party enforced	+	
Costly to enforce	+	
Hard to change		+

Following from this analysis, RHTs may be viewed as norms, defined as "a social rule that does not depend on government for either promulgation or enforcement" (Posner & Rasmusen 1999). In the context of law, RHTs are congruent with 'ethical-rules', which are not legally binding and do not prescribe judicially imposed sanctions for violations. This does not mean that sanctions are lacking against violators of RHTs. There exist sanctions that range from beliefs in various supernatural sanctions, material punishments of different kinds, gossiping and even community exclusions.

When people comply with self-enforced norms, economic transaction costs may be low relative to formal enforcement measures. During such conditions, informal institutions, like RHTs, may provide for (1) low monitoring costs, (2) low enforcement costs, and in many cases (3) low sanctioning costs (Colding & Folke 2001).

Significance of resource and habitat taboos

As the results of the synthesis of RHTs indicate, both use-taboos and non-use taboos may contribute to the conservation of local subsistence resources, habitats and even ecologically critical species, such as threatened, endemic and keystone species, and their related ecological services. However, there is no doubt that there exist traditional informal institutions (including taboos) that lead to unsustainable resource management practices (Baland & Platteau 1996). Not all RHTs have conservation outcomes. Some may be associated with the underutilization of potential food resources while others may lead to malnutrition among practitioners that abstain from food resources over a long time-period (Colding & Folke 2001). Not all RHTs may qualify as traditional ecological knowledge systems, i.e. 'knowledge-belief-practice complexes'. As Douglas (1966 [1996]) notes, ideas such as 'destiny', 'witchcraft', 'mana' and 'magic' represent institutions. These institutions "are all compounded part of belief and part of practice" and "they would not have been recorded in the ethnography if there were no practices attached to them". In this sense, RHTs represent examples of belief-practice complexes, but not necessarily knowledge-belief-practice complexes. On the other hand, most use-taboos of RHTs appear to be based on ecological knowledge and understanding and may represent dynamic response mechanisms for managing subsistence resources in the context of traditional ecological knowledge systems.

How representative RHTs are as informal institutions cannot be determined based on this synthesis of RHTs. If taboos are to be considered as 'prohibition rules', they represent but a subset of informal institutions. Using the typology of Ostrom *et al.* (1994), rules are prescriptions that define what actions (or outcomes) are *required*, *prohibited* or *permitted* and sanctions are authorized when rules are not followed. Accordingly, "rules provide information about the actions an actor "must" perform (obligation), "must not" perform (prohibition), or "may" perform (permission) if the actor is to avoid the possibility of sanctions being imposed". Potentially, in local communities there also exist a number of informally based obligation and permission rules. For example, obligation rules in the form of community forest care, patrol and decision making are undertaken as part of *faena* - required work for community benefit - in operating *ejidos* and *comunidades* in Mexico (Alcorn & Toledo 1998). Furthermore, among the same communities, if a household stops making *milpa*, it is cut out of reciprocity networks that can be relied upon for other types of assistance. Permission rules are of course abundant in local communities and probably pertain to most practices referred to (Berkes *et al.* 2000). Few, if any scholars have studied taboos systematically from an institutional context. In fact, Bennet (1990) argues that early anthropologists did not believe institutions existed in traditional societies.

Formal measures, such as setting aside legally protected areas and other legislative measures for biodiversity conservation do not automatically lead to conservation. Crude analysis reveals that the amount of state funding devoted to protected area management varies highly among countries, with a critical dividing line separating developed from less developed nations (Groombridge 1992). Several studies indicate that strictly protected areas function poorly in developing countries and are associated with many problems (e.g., Gadgil 1998; Jordan 1995; Murphree 1994). Also, third-party monitoring of regulations in conservation designs is often financially costly (Berkes 1996; Horowitz 1998). Finally, the recognition that most biodiversity exists outside of protected areas (Murphree 1994; Nabhan 2000) indicates a need to protect biota through other complementary conservation approaches (Cox & Elmqvist 1991).

There is a risk that RHTs and possibly other types of informal institutions that work for conservation are ignored in biological conservation schemes. This may partly be due to narrow definitions of what constitutes conservation. Using a broader framework of analysis that includes TEK as cultural capital may highlight informal measures that are largely "invisible" in conventional analyses (Berkes 1996). This is a major reason why an institutional analysis of this kind may be fruitful. The recognition of the role of informal institutions in sustainable resource and ecosystem management is apparently on the rise. For example, partnership conservation designs based on informal institutions are emerging (Gadgil *et al.* 2000; Horowitz 1998; Western & Wright 1994). This may even entail protection of species not previously protected by taboos (Johannes 1998b). Also, there are local communities currently reviving religious practices with an explicit understanding that they serve secular functions (Gadgil *et al.* 1998; Zerner 1994). Hence, there is a potential to combine scientific knowledge related to conservation with local and traditional knowledge systems for enhancing the possibility of successful conservation of the capacity of life-support systems to sustain social and economic development.

Conclusions and future challenges

This synthesis of local institutions and management practices, related to TEK systems, may provide clues for improving natural resource management in many settings of the world. Ecological knowledge and understanding, provided for by way of environmental monitoring, appear to be a key element in the development of many of the traditional and local resource management practices referred to here. Management practices in local communities do not exist in a vacuum but are framed by a social context. Hence, they tend to be coupled to and embedded in informal institutions and other types of social mechanisms, that are supported by a worldview and cultural values that do not de-couple people from their dependence on natural systems (Berkes *et al.* 2003).

Successful resource management systems require flexible social mechanisms for continual adjustments to environmental dynamics. Thus, institutional structures are needed to take environmental variability and ecological feedbacks into account and with a capacity of responding to such dynamics. There exist an extensive array of practices in local communities with a capacity to confer resilience in ecological systems. There also exist informal institutions with a capacity to adjust to ecological feedbacks and a capacity to conserve critical biota.

Furthermore, and as illustrated using the framework of the adaptive renewal cycle, there exist practices and linked social mechanisms that may play a critical role for buffering the effects of natural disturbances and practices that contribute to the renewal of ecosystems. Such practices, relating to the backloop part of the adaptive renewal cycle, may reduce the likelihood of an ecosystem being pushed from one stability domain of functioning to another. From a human perspective, unintended 'flips' of stability domain is often associated with social and economic strife (Holling & Meffe 1996). Hence, sustainable natural resource management needs to draw on practices and institutions with a capacity of reducing the potential of such undesirable shifts of stability domain.

Many of the practices may be viewed as rules of thumb for resource management. Since management of complex ecosystems for resource exploitation is associated with uncertainty about their spatial and temporal dynamics and due to incomplete knowledge about such dynamics, rules of thumb for management of natural resource systems appear to be critical. The protection of specific habitats and species, temporal restrictions of harvest, resource rotation, multiple species and integrated management represent such rules of thumb. Rules of thumb practices allow for change in natural resource management systems and provide for ecosystem renewal capacity that often contribute to the maintenance of biological diversity over wider spatial and temporal scales (Folke *et al.* 2003).

A growing number of researchers emphasize the importance of local institutions for improved management of the world's natural resources and ecosystems (Alcorn & Toledo 1998; Berkes & Folke 1998; Costanza *et al.* 1998; Johannes 1998b; Nabhan 2000; Ostrom 1990; Turner *et al.* 2000). As often recognized, local institutions are better able to adjust to feedback dynamics due to that people living near the resource base and ecosystems may faster detect ecological change, the tight coupling argument of Levin (1999). Hence, ecological monitoring may often be better provided for at the local level (Baland & Platteau 1996). As the institutional analysis of RHTs indicates, during certain conditions local institutions may also reduce transaction costs for institutional monitoring. Self-monitoring organized by users themselves is likely to be significantly less costly than control exercised through formal administrative agencies (Baland & Platteau 1996).

However, there are good reasons to believe that local institutions alone cannot carry out the function of regional or national institutions (Baland & Platteau 1996; Colding & Folke 2000; Young 1995). It is, therefore, essential to link local institutions that work for conservation with institutions existing at other hierarchical levels and across scales, e.g., at the regional and national levels (Alcorn & Toledo 1998; Folke *et al.* 2003; Hanna 1998). Such cross-scale linkages are referred to as nested institutions, or nested enterprises. The simplest kind of cross-scale institutional linkage is the one that connects local-level management with governmental-level management in partnerships, e.g., co-management (Berkes 2000; Pomeroy 1995; Pomeroy & Berkes 1997). Resource management organized around partnership arrangements should ideally focus at regional levels, for example, at the level of a watershed in order to monitor impacts of uncoordinated sector-based management. In such arrangements it is essential to establish institutional links between decision-makers, scientists, and local users. Cash (2000) refers to such links as 'polycentric networks'. Fig. 4 describes how polycentric networks may function in the context of co-management. Such an arrangement holds potential of combining traditional or local ecological knowledge and scientific knowledge in a dynamic on-going process (Olsson & Folke 2001).

Many traditional resource management practices share characteristics advocated in 'adaptive management' (Gunderson *et al.* 1995; Lee 1995) by taking uncertainty into account and by emphasiz-

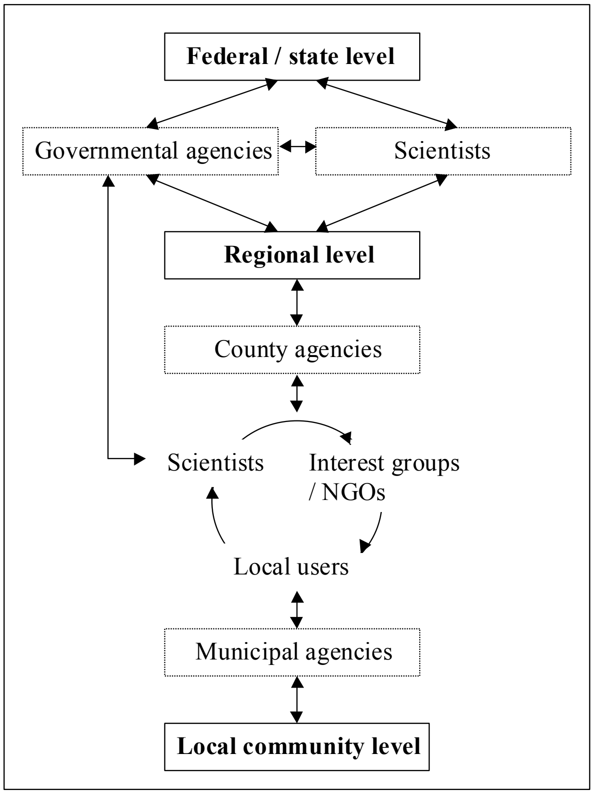

Fig. 4. An example of a polycentric co-management arrangement. At the local level, (e.g., a local community) scientists, local users and various interest groups, such as botanical groups and ornithologists, form multiple-level communication networks where ecological knowledge is shared and capitalized on. Knowledge is also exchanged among municipal agencies, multiple-level communication networks and county agencies for improved resource management. At the regional and sate levels, scientists and central decision-makers at governmental levels form the same kind of networks, where scientists inform about environmental characteristics at both the local and regional levels.

ing resource management practices that confer resilience. The concept of resilience in the framework of the adaptive renewal cycle may instructively provide deeper understanding about dynamic nature and may reveal insights in the development of practices based on rules of thumb with a capacity to confer resilience in resource management systems and ecosystems.

The major lessons of this synthesis paper can be summarized as follows:

- Make use of informal institutions that work for ecosystem management and conservation in cross-scale partnership designs.
- Strive for partnership designs that build on local cooperation and public support.
- Management of natural resources in partnership designs should consider the functioning of ecosystems at a regional scale and build on notions of ecosystem resilience and adaptive management.
- Because of the complex dynamics of ecological systems, resource management should be based on rules of thumb with increased focus on ‘backloop’ management.
- Devise management systems that tighten feedback loops between applied management practices and environmental effects. Such management should strive to allow small-scale natural disturbances to enter the resource management system and be dealt with locally.
- Sustainable resource management needs to be embedded in a social context. There must be social mechanisms in a society by which information from the environment can be perceived, processed and interpreted in order to confer resilience in ecological systems and their linked social systems.
- Combine qualitative and quantitative management approaches for increased likelihood of ecosystem management success.
- Combine traditional or local ecological knowledge with scientific knowledge to speed up the process of adaptive management.

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