Shifting perspectives on resource management:
Resilience and the Reconceptualization of 'Natural Resources' and 'Management'

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Abstract Conventional notions of 'natural resources' and 'management' are problematic because of their history, and they need to be reconceptualised. The term 'resource' carries a sense of 'free goods', human-centric use and commodification of nature; it can be revised to include the protection of ecosystem services for human well-being. The term 'management' implies domination of nature, efficiency, simplification, and expert-knows-best, command-and-control approaches. It similarly needs a makeover to emphasize stewardship, pluralism, collaboration, partnerships and adaptive governance, balancing efficiency objectives against ecological and social objectives. Resilience is a recurring theme in discussions of shifting perspectives in resource management, and I argue that it can be used as the basis of such a reconceptualization. The main elements of the resilience approach include attention to drivers and change processes, treating social-ecological systems as complex adaptive systems characterized by cycles and uncertainty, and social systems and ecosystems as coupled and co-evolving. It is a good fit for contemporary resource management highlighting property rights, participation, interaction of institutions at multiple levels, and experimentation as in adaptive management and interactive governance.

Introduction

Living with uncertainty and adapting to change require some major shifts in the ways in which we consider human interactions with the sea, and the ways in which we perceive and practice 'resource management'. Such an inquiry is timely because we live in an age of rapid change, in part related to the 'double exposure' of globalization and global environmental change (Leichenko and O'Brien 2008). Rapid change creates a threat to existing human interactions with the sea (such as small-scale fisher livelihoods and ways of life), but at the same time it also creates an opportunity to re-appraise these interactions and the ways in which we seek to understand them.

The argument in this paper is that the conventional concepts of 'natural resources' and 'management' are problematic, if not obsolete, because of their history or the 'baggage' they carry. These two terms can be replaced or, perhaps more reasonably, be redefined in view of new perspectives and changing paradigms. Resilience thinking (resilience theory) provides an entry point into the process of change, and is a recurring theme in the discussion of shifting perspectives in resource management. Hence, resilience can be used as the conceptual basis of such a redefinition.

To develop the argument, I start by reviewing the context within which some major shifts of perspective are taking place in resource management. In the subsequent sections, I discuss the historic background and provide the rationale, both social and ecological, for redefining 'natural resources' and 'management'. Next, I shift the focus to resilience to explore some of the insights provided by this approach, with examples, for developing a more holistic and complete account of human relationships with the sea.

Changing Theory and Practice of Resource Management: The Context

The current theory and practice of fishery management evolved over the past century or so in response to a major restructuring of the relationship of humans with the environment. The history of the notion of 'natural resource management' is closely associated with the emergence of several ideas in political economy and environmental philosophy. These include the following: 1) the separation of humans from the environment, 2) the commodification of nature, 3) the separation of the resource user from the manager and the rise of the managerial class, 4) the evolution of a tradition of positivistic science that assumes that the world is predictable and controllable, and 5) the predominant use of reductionism in science (Worster 1977; Bateson 1979; Callicott 2003).

However, over the last few decades, many of the basic approaches and assumptions that underpin the science of management in general, and classic fisheries management in particular, have in fact been abandoned one by one. Instead of the separation of humans from the environment, or the separation of mind and nature in Bateson's (1979) terminology, we are seeking ways to restore unity. This includes the recognition that the social and ecological aspects of the management of fisheries and other coastal resources are closely associated; these systems can be considered integrated social-ecological systems (Berkes and Folke 1998; Glaser 2006; Berkes 2010). Instead of production-oriented management objectives for fish-as-commodity, we are learning to appreciate the need to foster healthy fishing communities (Jentoft 2000) and healthy fish habitats and ecosystem processes as the basis for the fishery (MA 2005; Francis *et al*. 2007). Instead of entrusting resource decision-making to managers and experts, we speak of user participation, public-private partnerships, governance (Kooiman *et al*. 2005), co-management (Wilson *et al*. 2003), and fisher knowledge (Haggan *et al*. 2006). Instead of positivistic science that assumes that the world is predictable and controllable, we are emphasizing living with uncertainty (Charles 2001; Gunderson and Holling 2002). Instead of reductionism that seeks to model, for example, individual fish species and fishing fleets separately, we emphasize holistic approaches that consider fisher-fish-environment together (Cochrane and Garcia 2009) and complexity (Levin 1999, Lansing 2002).

Some of the elements of the shifting perspectives and assumptions in human-environment relations are summarized in Table 1.

Table 1. Some elements of the shifting perspectives in human-environment relations.

	Conventional resourcist view	**Emerging view**	**References**
Human interactions with the environment	Human-environment (or mind-nature) dualism	Restoring unity of humans and environment	Bateson 1979
Use of the environment	Commodification of nature	Nature as providing ecosystem services and human well-being	MA 2005
Role of expertise	Scientists and managers as independent, objective experts	Recognizing limitations of technical expertise; pluralism in management	Ludwig 2001
Uncertainty and the control of nature	Positivistic science that assumes the world is predictable and controllable	Recognizing intrinsic uncertainty of nature and the necessity to live with it	Charles 2001
Mode of analysis	Reductionistic science that treats individual species and fishing fleets separately	Holistic approaches that consider fish, fisher and environment together	See Table 2

What is labelled as the conventional resourcist view in Table 1 is a mix of Enlightenment Age or even older wisdom (for example human-environment dualism) and twentieth century science. The shift to emerging views has occurred largely in the 1990s, along with decentralization and public participation trends. But they are also a mix and difficult to characterize in terms of the extent to which they have been incorporated into contemporary practice. Many examples exist of attempts to develop an integrated interdisciplinary science of humans and environment (or fish and fishers, or coastal peoples and coastal environments). It is instructive to examine a set of these initiatives to see what such an integrative approach might look like, the shifts in perspective they may illustrate, and the theory base they employ.

Several disciplines, such as geography, anthropology and development studies, and interdisciplinary areas such as ecological economics and political ecology, have developed a number of conceptualizations of integrated social-ecological systems or human-environment systems (Glaser 2006).

The five examples in Table 2 are selected here because they represent a deliberate mixing of social science and natural science, two of them specifically about fish and fishers, and the other three more broadly about humans and environment. McEvoy's (1986; 1996) conceptualization is based on a legal and historical study of California fisheries. He uses systems thinking to point out the feedback relations between the environment that sustains the fish stocks, the economy (including the social organization of user groups), and management (including regulation and more broadly the legal system).

Francis and colleagues (2007) consider that a paradigm shift is underway toward ecosystem-based management, and they seek to establish a set of principles to help accelerate the shift. Although the emphasis is on the natural science of fisheries (with principles regarding population and spatial structure of fish stocks, conservation of habitat and critical food web connections), they point out the need to integrate natural and social sciences. In addition to an eclectic mix of ecological theory, they use systems theory, complexity and resilience in the way they conceive the relationship of the ecological system and the social system.

Table 2. Some examples of interdisciplinary attempts for integrating human-environment systems.

	Reference
The fishery consists of three interacting spheres: nature, the economy and the legal system. A systematic, mutually reinforcing relation exists between the social and cultural organization of harvester groups and the ecology of their target stocks. What we can manage for and sustain is the long-term health of the interaction among the three spheres.	McEvoy 1986, 1996
To accelerate the ongoing paradigm shift in fisheries science towards ecosystem-based approaches, the authors offer ten principles ('commandments') for a holistic extension of conventional approaches that grapples with the complexity of social-ecological systems and incomplete knowledge.	Francis *et al.* 2007
The concept of integrated social-ecological systems emphasizes the futility of dealing with the ecological or the social system separately, when the two subsystems are interactive and interdependent in resource management.	Berkes and Folke 1998; Berkes *et al.* 2003
Sustainability science is a field that seeks to understand the fundamental character of interactions between nature and society. This is done through problem-driven interdisciplinary research, focusing on the interaction of global processes with the ecological and social characteristics of particular places.	Kates *et al.* 2001; Turner *et al.* 2003
Millennium Ecosystem Assessment sought to assess the consequences of ecosystem change, and informed various international conventions dealing with the environment. It focused on linkages between ecosystems and human well-being, and in particular on ecosystem services.	MA 2005

Resilience thinking and commons theory are the starting points for a team project reported in Berkes and Folke (1998). They develop the idea that the integrated social-ecological system must be the key analytical unit. This is because there is mutual feedback between the social subsystem and the ecological subsystem in any resource and environmental management situation. The key links between the two subsystems are ecological knowledge people hold, and the various kinds of management institutions, both formal and informal, that establish the rules and norms by which humans interact with the environment. Berkes *et al.* (2003) further identify complex adaptive systems as the setting (with its characteristics of scale, uncertainty, non-linearity and self-organization), and resilience as the approach to deal with complexity and change.

Sustainability science (Kates *et al.* 2001; Turner *et al.* 2003) starts from the need to establish a methodology and principles to guide the sustainable development concept that emerged in the 1980s (Norton 2005). The sustainability science group is large and interdisciplinary, with expertise in various areas of social science, earth systems science, climate change, and international scientific programs. The theory base is not explicitly given but leans toward complex systems, vulnerability, and resilience. Key processes in nature-society systems are studied across a range of scales from local to global. Research methodology emphasizes cases located in specific times and places, how they respond to stress, self-organizational phenomena, and different ways of knowing and learning.

An even larger team project with over a thousand scientists involved globally, the Millennium Ecosystem Assessment sought to evaluate the health of earth's ecosystems and their ability to sustain human well-being (MA 2005). Current conditions and trends in ecosystem services were assessed using various ecological theories and ecological economics. The MA (2005) brought into the global environmental discourse a vocabulary of drivers, policy responses, and scenario planning. It expanded the scope of the interdisciplinary treatment of global environmental problems, and the methods by which national and international level policies could be put into place.

These five attempts to develop an integrated science of people and environment help us visualize what such approaches entail. They are all interdisciplinary, combining social science with natural science concepts and approaches. They may involve a single scholar (McEvoy 1986), a small group (Francis *et al.* 2007), or a large international team (MA 2005). Each may emphasize a small-scale or a large-scale nature-society system, and many of them deal with multiple scales. They all use variations of systems approaches and emphasize feedback relations. Many of them use interdisciplinary fields as their theory base, such as commons, ecological economics, vulnerability and resilience. They pay attention to property rights, 'including the familiar domain of privatized property, the still poorly charted territory of commonly held property, and the mythical terrain of no property or open access' (McCay 2008:7). It is notable that resilience appears in four of these five examples, McEvoy's case being the sole exception. All five provide illustrations of the use of the suite of 'emerging views' in Table 1. In particular, all five deal with 'natural resources' not in the sense of commodification of nature but in the sense of nature as providing ecosystem services and human well-being.

The Intellectual Baggage of 'Natural Resources' and 'Management'

Natural resources are assets for the creation of human satisfaction or utility. According to the classical view, they are not desirable in themselves but rather they are a means to an end. They are of value only to the extent that they can be used to create goods and services – fishery resources to create human food and a fishing industry, for example, or coastal resources to satisfy human need for recreation. This view of resources is still found in most textbook and dictionary definitions. The idea of human-defined value is conveniently summarized by Zimmerman's (1951) dictum that 'resources are not, they become'. Not only is natural resource a socially constructed concept, it is also culturally defined. For example, European settlers in Atlantic Canada in the 1700s used lobsters as fertilizer in their fields; by contrast, in the 2000s lobster was the most valuable species in the small-scale fishery (Wiber *et al.* 2009).

Traditionally economists identified three broad categories of resources: natural resources, human resources, and capital resources. Natural resources were called 'free gifts of nature' by the early economists, with the assumption that they were wholly replenished without cost after our use or consumption of them. The water we remove from a lake could be fully replaced by river flow and precipitation; the fish stocks we harvest could be fully renewed by the growth and reproduction. As part of the 'freedom of the seas' concept, Hugo Grotius argued around 1600 that the fish in the sea cannot be exhausted. The concept persisted more or less into the twentieth century. In fact, it was widely believed as late as 1930s that fish in the sea could not be overfished (Eckert 1979).

Even though the idea that the environment is created for the use of humans, and the idea of human-environment dualism in general, goes back to the emergence of monotheistic religions, the early Industrial Age played a major role in the full development of these concepts. In pursuing individual wealth, people were taught to regard land, resources and their own labour as commodities for the market. '... Natural resources were other-ized and objectified. They lost their identities as individuals, even as species, and became but raw material for human transformation into humanly useful commodities' (Callicott 2003:245). Breaking human-environment bonds and separating people from nature allowed people to enjoy the fruits of industrialization without any undue obligations and concern for nature. Worster (1988:11) points out that this marked a shift in world view so that everyone would treat the earth, as well as each other, with a 'frank, energetic self-assertiveness, unembarrassed by too many moral or aesthetic sentiments'. Such commodification of nature as 'natural resources' is strongly linked to the development of 'resource management' in which the use of reductionism, positivistic assumptions, and the emergence of scientists and managers as independent, objective experts figures prominently.

In the history of American environmental philosophy, Callicott (2003) distinguishes between preservationism and resourcism. The first chief of the US Forest Service, Gifford Pinchot, who had been educated as a forester in Europe, articulated the elements of a resourcist philosophy that renewability required taking only the surplus, or the 'interest'. The concept of 'nature' of preservationists Thoreau and Muir became Pinchot's 'natural resources'. In case one missed the point about nature existing solely for human use, Pinchot declared that 'there are just two things on this material earth – people and natural resources' (as quoted by Callicott 2003:244). Pinchot brought resourcism into the then mainstream utilitarian ethic of John Stuart Mills and others.

Efficiency was the hallmark of utilitarianism. The problem with the way that hunters, fishers, farmers and loggers used natural resources was that such uses were inefficient and destructive from the resourcist point of view. Renewable natural resources such as trees and fish could be consumed without depleting them, but one could not depend on loggers and fishers to do this. Technical expertise was necessary to carry out such tasks as doing an inventory of the resource, finding out the growth rates of useful species, the age at which growth slowed down, and the age and size at reproduction, so that the harvestable surplus could be calculated. The idea of only skimming the interest off the natural resource capital required the development of various applied sciences, such as forestry, wildlife management and fishery management, and the development of government agencies dedicated to the task of making natural resources yield productively and efficiently.

The 'master narrative' of resource managment, as Bocking (2004) puts it, with nature as the source of raw materials, requires natural resource professionals as arbiters of human-environment relations, pursuing its efficient harvest. Efficiency could be achieved by making the resource not only productive but also more predictable. Resource management is often said to be engaged in a quest for certainty, with precise predictions of the future state of the resource, often involving the simplification of the ecosystem (monoculture farming being an extreme example). Variation is to be eliminated where possible in the quest for factory-like harvesting, processing and marketing of these commodities. Such an objective of efficiency was based on the best science available, using reductionistic approaches and positivistic assumptions.

Since the seventeenth century, science has been dominated by positivism, also called logical positivism or rationalism. It assumes the existence of a reality driven by immutable laws based on universal truths. The role of science is to discover these truths, and put them to use for predicting and controlling nature. Science is assumed to be value-neutral and the scientists themselves operating in a value-free environment (Norton 2005). The use of reductionism is closely associated with positivism. It involves breaking a system into discrete components, analyzing the components, and making predictions. Generalizations and synthesis are made possible by such an approach, independent of the context of space and time. This is mechanistic science in which nature is seen as clockwork in which the pieces can be assembled and disassembled.

Such a summary of positivism and reductionism is no doubt simplistic, and many contemporary natural resource scientists do not subscribe to all the assumptions in the summary. But it is also true that the positivist-reductionist paradigm has historically dominated resource management science (along with most other sciences) and still remains influential (Worster 1977; Norton 2005). For example, most fisheries biology, economics and resource management throughout the world still uses positivist-reductionist assumptions and methods, and aims to calculate, species by species, the harvestable surplus in a predictable world. However, the ground is shifting on many of these assumptions, necessitating a re-appraisal of our conceptualizations of resources are and management.

An Ecological Critique of Conventional Management

For several decades now, the science of ecology has been shifting from a balance-of-nature paradigm to a dynamic ecosystem paradigm, with major advances in the understanding of biodiversity, complexity, and uncertainty. The shift was more or less complete in the field of ecology by 1980 or so, and applied ecology disciplines such as fisheries management were beginning to grapple with the implications of the paradigm change. I will discuss three aspects of this change and their implications: biodiversity and species interactions; complexity and the understanding of ecosystems as complex adaptive systems; and uncertainty and the significance of natural variability.

Regarding the first point, suffice to point out that the term biodiversity was coined only in the 1980s (the terms species diversity and genetic diversity did exist prior to 1980). Under the conventional positivist-reductionist methodologies, it is implicitly assumed that the productivity and harvesting of a target species can be understood in isolation of other species, and non-economic species and other components of the ecosystem conveniently ignored. Such a focus on species of immediate economic interest works only if these resources were indeed 'free gifts of nature' disconnected from their ecological roles. But in reality, species are connected to one another through relationships such as predation, competition, and symbiosis. Stocks are not discrete commodities in space and time. Therefore, harvesting one species has ecological implications for the rest of the ecosystem. The area of fisheries management is replete with examples of mismanagement through ignorance of ecological relationships (Francis *et al.* 2007)Regarding the second point, the management quest for certainty and simplification came into critical focus as ecologists developed a more sophisticated view of ecosystem complexity. An understanding of ecosystems as complex adaptive systems (Levin 1999) stimulated attention to feedback relations, a hallmark of systems thinking. It also stimulated more attention to the various characteristics of complex adaptive systems such as scale, self-organization, emergent properties, non-linearity, uncertainty, and irreversibility (or path dependence). A few comments and examples can be offered, without going through each of these systematically (Berkes *et al.* 2003).

The importance of scale is well known in geography. Self-organizational ability is seen by Levin (1999) to be a key attribute of complex systems. Emergent properties are those properties of a system that cannot be deduced from the analysis of the parts but can only be understood from the analysis of the system as a whole; resilience is an example. Uncertainty is discussed below. The related concept, non-linearity, is often observed through threshold effects. For example, on many coral reefs the depletion of herbivorous parrotfish beyond a certain threshold can result in a phase shift in which macroalgae growth replaces corals (Hughes *et al.* 2005). Irreversibility (path dependence) means that the corals may not come back, just as the depleted Newfoundland cod has not recovered despite twenty years of fishing controls. To give a social science example, co-management seems to be path-dependent; its outcome is strongly influenced by the context and history of each case (Chuenpagdee and Jentoft 2007).

Regarding the third point, ecosystems are seen as being in a state of continuous change, as opposed to hovering around an equilibrium point. Accepting unpredictable system change as a fact of life has resulted in the development of multi-equilibrium thinking or the rejection of equilibrium thinking altogether (Holling 1973; Gunderson and Holling 2002). Some of this change is related to uncertainty, thought to be intrinsic to the system and essentially irreducable (Charles 2001; Gunderson and Holling 2002). Assuming away uncertainty has created public policy problems. For example, salmon fisheries in British Colombia, Canada, consist of many stocks of several species of salmon per river, and management agencies issue forecasts of the size of the larger stocks. In 1994, a major controversy broke out among the major user-groups (recreational, commercial and native) over the 'missing' salmon in the Fraser River, as if the stock forecast was some sort of a guarantee of actual numbers. Every few years, problems of missing salmon trigger newspaper headlines and sometimes even judicial inquiries, for example, in 2009/10 for Fraser River sockeye.

Unpredictability and change are part of natural variation. Holling and Meffe (1996) argue that natural variation is important for ecosystem resilience. Given the variability in such parameters as the temperature and salinity in the physical environment, the diversity and variability in plant and animal populations provides the capacity to respond and adjust to change. Management that results in diminished genetic variation in hatchery fish, or major reductions in the population size of ecologically important species, erodes the resilience of the ecosystem. Conventional resource management that aims to reduce variation and increase predictability, damages the very process that maintains resilience in a system, leaving it more susceptible to crises and less able to renew itself and self-organize in response to natural perturbations (Holling and Meffe 1996).

The implications of these three points for the conventional concepts of natural resources management are quite serious, in fact fatal. Commodification of single species abstracted from the ecosystem and the conventional reductionist methodologies do not work, at least not for long-term sustainability. Likewise, resource management that does not take into account complexity principles will be in trouble in due time. For example, management that uses linear thinking performs poorly in a world characterized by non-linear processes and phase shifts, such as algae replacing corals and benthic invertebrates replacing cod. The uncertainty inherent in complex systems directly contradicts the positivist assumption that the world is predictable and therefore controllable. Most natural and social scientists know that the Enlightenment Age analogy of a clockwork nature (or for that matter, a clockwork human body) has to be rejected. Nevertheless, mechanistic approaches are still common, and results of computer models still presented as 'predictions'.

Similarly, few contemporary ecologists would speak of the 'balance of nature', and yet the equilibrium-based concepts are still in use in ecology and resource management science. For example, the idea of maximum sustained yield (MSY) is still used in fisheries management, disguised as Total Allowable Catch (TAC) targets. In the short term, quantitative targets may be appropriate for efficient resource exploitation. But in the long run, fixed quantitative targets work against the maintenance of healthy and resilient social-ecological systems because they ignore interactions within the system and because they reduce the natural variability of the system, including the ability of fishers to switch species flexibly.

A Social Critique of Conventional Management

Social and ecological critiques of conventional management are becoming, or could become, more aligned. For example, political ecology can help reveal the challenges in putting new ecology into practice and the contextual forces that make top-down management resistant to change (Armitage 2008). Historically, centralized government agencies have played a key role in carrying out the master narrative of resource management for a good reason. Making ecosystems more productive, predictable, controllable, and economically efficient is a task for centralized institutions and command-and-control resource management. In the United States, resourcism developed with the task of opening up the land taken away from indigenous peoples and establishing a whole new economic order – internal colonization (Cronon 1983).

In the industrialized world in general, centralized command-and-control resource management developed in the service of colonization and industrialization and was imposed on colonized lands (Gadgil and Guha 1992). It is therefore not surprising that long-term sustainability of local resources was never an overriding concern for conventional management, nor was equity and local livelihoods. Resource management, developed under a mechanistic worldview and inspired by the utilitarian ethics of John Stuart Mills, 'had more to say about the human mission to extract rather than to conserve' (Worster 1977:53). Such resource management was not geared for sustainability and social justice, but rather for efficiency and profit.

However, both then and now, resource management agencies frequently invoke the 'public interest' for their decisions. Gifford Pinchot is often credited with the classical formulation of the public interest in resource management: resources should be used for the common good, and not just for private gain. Pinchot's 'the greatest good for the greatest number for the longest time,' appears to be a rewording of John Stuart Mill's maxim, 'the greatest happiness for the greatest number' (cited in Callicott 2003:245).

In the case of resource management, the reference to 'the greatest number' seems to be code for the government takeover of locally controlled or commonly held resources, for the benefit of society at large, with state agencies acting on behalf of the citizenry. It is the age-old distinction between *Gesellschaft* and *Gemeinschaft* of the German sociologist Ferdinand Tönnies writing in the 1880s. *Gesellschaft* (society in an urban and capitalist setting) grabs control of rights of *Gemeinschaft* (the local society or community). As James Scott (1998) might put it, such a takeover not only generates revenues for the state, but also replaces the obscure local system with standardized scientific management that is transparent or intelligible to government.

Resource management by public agencies has continued to be justified in the name of such public interest, by the use of objective, rational science and decision-making. But the image of a public-minded resource management is often met with skepticism. Critics note that, far from pursuing an idealistic notion of public interest, centralized resource management often privileges the interests of the resource industry, in both colonial and neo-colonial resource extraction situations (Bocking 2004). This includes, for example, joint-venture fisheries common in Africa and elsewhere, that provide some revenue for the central government but often at the cost of damaging local, near-shore small-scale fisheries.

The disempowerment of the community and the erosion of local control is one of the more serious consequences of contemporary resource management with its standardized science and command-and-control practice. Prior to contemporary management, communities and tribal groups in many parts of the world managed their own resources. We have some idea about how these systems worked – mostly through locally designed commons rules (Wilson *et al*. 1994), such as reef and lagoon tenure systems (Johannes 1998). Command-and-control management did not fill a gap in the absence of management but rather replaced previously existing systems. Resource controversies in many parts of the world, for example in India, can be traced to centralized government management, loss of equitable access to resources, and damage to the livelihood systems of local people (Bavinck 2001).

Contrary to the assumptions of some, the national government's takeover of resources did not necessarily restore order or the rule of law, but often created open-access conditions that facilitated efficient exploitation, industrial-scale extraction and liberal trade. Johannes' (1978) review from Oceania provides detailed documentation of the demise of local management in the face of colonial pressures, the commodification of a whole range of species for export trade, and the subsequent decline of resources. The breakdown of indigenous commons controls and their replacement by government-backed free-for-all have been documented from the US Pacific Northwest, British Columbia and Alaska as well. The area was overrun by the canned salmon stampede between 1878 to the turn of the century and replaced by an open-access system before government controls were eventually instituted (Rogers 1979).

The contestation of expertise is the other political aspect of resource takeover by government. Just as there is tension between government regulations and local commons rules, there is also tension between government technical expertise and local/indigenous knowledge (Berkes 2008). The government scientists and managers in charge of the new management systems were not only the technicians who knew how to calculate the harvestable surplus but also the high priests of the positivist-reductionist paradigm. They rejected local and traditional knowledge because it did not fit the paradigm and it was not transparent to the state, and perhaps also because they did not want to share the legitimacy of expertise.

The role of expertise in management and the politics of legitimate knowledge is a large topic (Berkes 2008); suffice it to say that fisher knowledge has a potentially important role to play in fishery management (Neis and Felt 2000; Haggan *et al*. 2006; Lutz and Neis 2008). The ongoing acrimonious relationships between indigenous groups and the government, and between fishers and fishery managers, not only in a few spots but in many parts of the world, can be ultimately linked to the disempowerment of the local (Bavington 2002). Rather than offering their knowledge and skills freely to assist government management, local and indigenous experts have generally been content to stay away from managers and scientists. One exception was the (unsuccessful) efforts of Labrador inshore fishers to warn managers of the impending collapse of the Newfoundland cod. In the Labrador community of Makkovik, only three codfish were caught in the entire summer of 1990 (two years before the 'official' cod collapse and fishing closure) but fishers were unable to make themselves heard (Chantraine 1993).

The only indigenous groups (that I know) that have seriously taken up scientific management and created their own tribal fishery management agencies were those forced to do so by law, the example being the establishment of tribal management agencies as a condition for salmon co-management under the Boldt decision in the US Pacific Northwest (Singleton 1998). For the most part, indigenous peoples' rejection of government management is not merely politics; it also has to do with their worldview. The notion of the separation of user from manager, and the idea that a remote agency knows best what to do with a local group's resources just does not make sense to most local and indigenous knowledge holders (Berkes 2008).

Interestingly, Ludwig (2001) comes to a similar conclusion about environmental managers and the limits to their expertise, but for somewhat different reasons. Noting that the really important environmental problems of our time, such as climate change and biodiversity conservation, cannot be solved by conventional management, he calls for a radical change in approaches. Since 'there are no experts on these problems, nor can there be,' Ludwig (2001:763) invites a re-appraisal of our unquestioned acceptance of economism (placing inordinate emphasis on economic values versus other), scientism (belief that science is inherently capable of solving almost all problems), and technocracy (achieving policy solutions by recourse to technological innovation).

In seeking a new role for experts and for management, Ludwig (2001) seeks to expand the range of values to be taken into account, and the range of knowledge used, including local and indigenous knowledge. Given that many of our complex environmental problems are 'wicked problems' that have no definitive formulation, no stopping rule and no test for a solution, he suggests that era of [conventional] management is over. Since the really important issues are in the realm of ethics and environmental justice, he suggests that these considerations be moved to the forefront, and a new kind of management style based on learning be adopted.

Ludwig (2001) is one of many observers calling for partnerships, learning, and problem-solving through a flexible, iterative adaptive management process (Kates *et al.* 2001; Kooiman *et al.* 2005; Armitage *et al.* 2007). A number of possibilities has been suggested on how such approaches can be designed. One of these is adaptive management, originally developed to deal with uncertainty, and related to complexity and resilience thinking. Such an approach shifts resource management philosophy from reacting to observed changes to proactive governance that shapes change (Chapin *et al.* 2009).

Relevance of Resilience Thinking

Resilience concepts appear in many interdisciplinary attempts for integrating human-environment systems (Table 2), in understanding the processes of change (Berkes *et al.* 2003), and in the critique of the conventional notions of natural resources and management. This makes resilience a likely source of insights for developing a more holistic and complete account of human relationships with the sea, and a natural candidate for the theoretical basis in redefining 'natural resources' and 'management'.

Resilience thinking originates from systems approaches and complexity. It is a post-positivistic approach closely related to adaptive management (learning-by-doing) as a way of dealing with uncertainty (Gunderson and Holling 2002). In its narrower context, it is an ecological concept, based on Holling's observations of the dynamics of the boreal forest ecosystem, its uncertainties and its renewal cycles (Holling 1973). Recognizing that ecosystems often exhibit multiple stable states, Holling sought to characterize the capacity of a system to maintain itself in the face of disturbance. Resilience theory envisions ecosystems as constantly changing, and focuses on renewal and reorganization processes rather than on stable states. It focuses on scale, non-linear effects and thresholds. In its broader context, resilience is about managing ecosystems and people together, under the assumptions that there is no 'balance of nature' but multi-equilibrium, complex, unpredictable social-ecological systems subject to continuous change, cycles, renewal and threshold effects (Berkes and Folke 1998; Berkes *et al*. 2003).

There are competing notions of resilience and many definitions. The Holling definition of resilience is 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). There are other definitions of resilience, including one in psychology that focuses on the ability of individuals to recover from adversity, and one in ecology that focuses on 'bouncing back' to a reference state after a disturbance. These other definitions are less useful for discussion of uncertainty since there often is no such fixed reference state in social-ecological systems to bounce back to. The reference state itself is also subject to uncertainty.

Resilience is significant for the discussion of living with uncertainty and adapting to change for three reasons. First, resilience deals with coupled human-environment systems and contributes to an understanding of coastal resource use systems by avoiding the artificial disciplinary divide between the study of people and the environment.

Second, resilience puts the emphasis on the ability of a system to deal with change. It allows for the multiple ways in which a response may occur, including the ability of the system to buffer or absorb the disturbance, or to learn from it and to adapt to it, and to reorganize following an impact. These processes are often occurring simultaneously, across scale, in subsystems nested in larger subsystems, referred to as panarchy (Holling 2001; Gunderson and Holling 2002).

Third, because it deals with the dynamics of response to change, resilience is forward-looking and helps explore policy options for dealing with uncertainty and change. Resilience building is an effective way to cope with social-ecological change characterized by future surprises or unknowable risks. Resilience provides a way for thinking about policies for the future, an important consideration in a world characterized by unprecedented environmental change (Chapin *et al*. 2009; O'Brien *et al*. 2009).

In living with uncertainty, we need to know when a perturbation or change might lead to a non-linear response, a response that is out of proportion to the size of the perturbation. Such responses, called threshold effects, are breakpoints or abrupt changes (Lyytimäki and Hildén 2007) that occur in systems with multiple stable states. In resilience terminology, the shift from one stable state to another is a regime shift or a flip. Such a regime shift occurs when the threshold level of a controlling variable is exceeded, such that the nature of feedbacks changes, resulting in a change of trajectory of the system itself (Walker and Meyers 2004). Threshold effects are pervasive in both biophysical systems (for example the breaching of a seawall) and social systems (for example a society dissolving into chaos after a civil war). Figure 1 illustrates non-linear response and threshold effect in the Canadian Atlantic cod fishery.

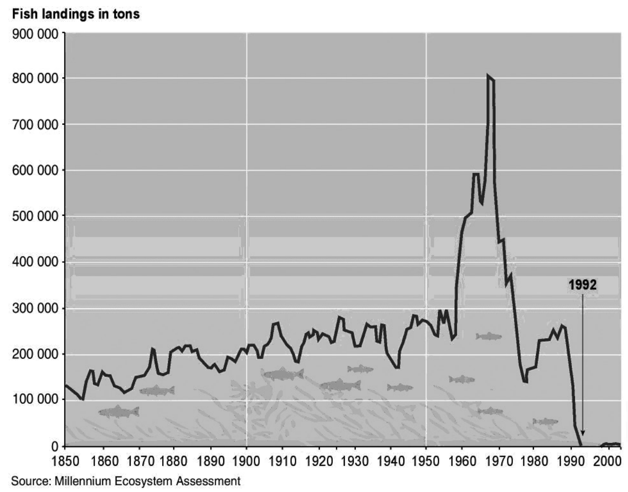

Figure 1. Example of non-linear change used by MA *(2005) shows the growth and eventual collapse of the Newfoundland cod fishery.*

Box 1. The Canadian Atlantic cod fishery

Often known as the Newfoundland cod fishery in reference to the dominant stock, the Canadian Atlantic cod fishery, once one of the largest fisheries in the world, collapsed in 1992, forcing the closure of the fishery. It has not recovered even though the closure has been maintained, except for some local use and sampling for monitoring. The case offers an illustration of the failures of conventional management and application of some concepts used in resilience analysis (Charles 2007). MA (2005) uses the Newfoundland cod case as an example of non-linear response and threshold effects, and the fact that depleted stocks may take many years to recover or not recover at all.

Until the late 1950s, the Newfoundland cod was used by inshore small-scale fishers and migratory seasonal fleets from Europe. In the late 1950s, offshore trawlers began exploiting deeper waters, and catches increased sharply with the entry of offshore fleets into the fishery in the 1960s. Harvests reached a peak in the late 1960s, leading to internationally agreed quotas in the early 1970s. Despite quota management, however, catches declined sharply in the 1970s, followed by Canada's unilateral declaration of a 200 mile Exclusive Fishing Zone in 1977, ahead of the 1982 UN agreement on the Law of the Sea. This measure initially halted the decline, and the fishery seemed to be recovering in the late 1980s. Even though it was under a national quota system, using the best of conventional resource management, the fishery collapsed in 1992 (Chantraine 1993; Walters 2007). What actually did happen to the fishery, and why it has not recovered have been hotly debated ever since.

Regarding linearity and threshold effects, the verdict is fairly clear. In the 1960s, the sharp increases in harvest were in fact proportional to the increasing fishing effort. However, the sharp declines in the 1970s and the final collapse look like non-linear effects. The prevailing level of fishing effort exceeded the threshold level of some controlling variable, resulting in stock collapse. Resilience theory would predict a regime shift from one stable state to another, and this is in fact what we find. Cod has collapsed and the stable state characterized by groundfish has flipped into a different stable state. The new state is characterized by an invertebrate fauna of crab, shrimp and lobsters. These have increased, presumably because the predation pressure on them by the previously dominant groundfish has been lifted.

The aggregate value of the catch in Atlantic Canada, in fact, has not declined since the cod collapse. The increased value from the invertebrates has made up for the loss of groundfish -- the real tragedy is a social one. The inshore groundfish fishers are the losers in this flip because they do not have the capital to enter the offshore, deep-water fisheries for valuable invertebrates. They do have access to lobster and to some extent crab, and these maintain the inshore fishery (Wiber *et al*. 2009). Both alternative states (groundfish vs. bottom invertebrates) are stable in the sense that small perturbations cannot flip them. Now that the invertebrates dominate, the system is resilient and will not easily flip back to a cod-dominated state.

Box 1 tells the story of the cod fishery and explains why the collapse can be considered a shift in alternative stable states. We can speculate on some of the elements of the failure of conventional management in the cod collapse. First, positivistic assumptions have a role in the failure. The Atlantic cod social-ecological system has been neither predictable nor controllable. Fishing technology changed and fishing pressure increased over several decades. The social subsystem has been subject to drivers such as international markets; the ecological subsystem has been subject to drivers such as climate change. Second, reductionistic science seems to be at fault. Ames *et al.* (2000) have argued that conventional management models that approach overfishing with a single variable (fishing mortality), at a single spatial scale (range of the stock), and at a single temporal scale (one year) are not likely to work. This is because such models are omitting multiple-scale factors and complexity such as the presence of multiple discrete stocks. Third, conventional management has been ignoring knowledge and observations that do not seem to fit the model, thus throwing out fisher knowledge and other useful information on trends (Chantraine 1993). This can have serious consequences. Walters (2007:306) has commented that the cod collapse can be attributed 'more or less directly to misinterpretation of inadequate monitoring data on trends in stock size'.

The recognition of the pervasiveness of non-linear responses and threshold effects are part of the revolution in the current science of ecology. The notions of stability and other positivistic assumptions that have guided ecosystem management for almost a century have given way to the idea of non-equilibrium systems, multiple steady states and surprises, necessitating management for resilience (Scheffer and Carpenter 2003; Holling 2001). But further, many of the elements of uncertainty and surprise are social, economic and political, necessitating that resilience theory incorporate fully the social subsystem of the social-ecological system (Berkes *et al.* 2003; O'Brien *et al.* 2009).

Originally developed as an ecological concept, the full application of resilience to integrated social-ecological systems is a work in progress. The ecological part of the theory is much better developed than the social part. Most of the current work in resilience acknowledges two-way interactions between social systems and ecological systems. But progress has been slow in developing the intellectual tools in restoring the unity of humans and environment; the application of these ideas to marine and coastal management has been equally slow.

The extension of resilience theory to the social realm has led to the consideration of the key ideas of adaptive capacity and the ability of social systems (such as institutions) to learn and adapt in response to change (Folke *et al.* 2005). Learning theory is being extended to organizations and institutions, even though in conventional educational theories, learning is about individuals. However, learning in the resilience sense refers to social and institutional learning, as in adaptive management (Lee 1993). Such learning is a crucial element in the dynamics of participatory management (Armitage *et al.* 2007), interactive governance (Kooiman *et al.* 2005; Jentoft 2007), and adaptive governance (Chapin *et al.* 2009). For purposes of living with uncertainty, key issues include institutional learning that emerges out of society's response to previous crises, and the institutions and people that provide social memory (McIntosh 2000; Adger *et al.* 2005). In many indigenous and traditional societies, the elders are the holders of social memory; in urban and industrial societies, this role is much less clear.

Applying Resilience Thinking

Resilience thinking provides an entry point for the study of uncertainty and change, and it is useful to examine some examples. There is a large literature, for example, on resilience and thresholds, but most of the cases deal with biophysical systems, only a few with social-ecological systems (Walker and Meyers 2004). Many resilience applications are commonsense and follow from the basic definition of the concept. For example, in the 2004 Asian tsunami, coastal devastation in Sri Lanka, Thailand and some other countries was explained in part as related to loss of mangroves and their buffering capacity (Adger *et al.* 2005). Following this line of thinking, the resilience approach also made it possible to link tsunami devastation to coastal clearing for the expansion of shrimp aquaculture for global markets, and the increasing vulnerability of coastal populations to cyclones and storm-surges partly as a result of globalized shrimp markets.

Some resilience applications help emphasize the importance of flexible and locally controlled management. For example, *padu* systems in southern India provide rules for the conduct of caste-specific, gear-specific, species-specific coastal and lagoon fisheries. They randomize fishing success through the assigning of fishing sites to members by lottery, and seem to be resilient or robust systems because they have persisted over time despite increases in fisher numbers and declines in catch per unit effort (Coulthard 2008). These *padu* systems are important for managing resources as well as people; they help reduce conflict and provide social identity for members of the fishing caste. *Padu* rules are flexible, for example, based on local observations of environmental change, allowing adjustments to deal with siltation and periodically redefining fishing sites to be allocated (Lobe and Berkes 2004). At the same time, note that *padu* itself is based on an institution (the Indian caste system) which has persisted despite laws against it – thus showing that resilience is not always positive.

Resilient management systems may be found in some traditional fisheries and contemporary fisheries. Box 2 is a description of the First Salmon Ceremony in the traditional indigenous fisheries of the US Pacific Northwest.

Box 2. The First Salmon Ceremony of the Indigenous Peoples of the Pacific

The First Salmon Ceremony was practiced by many indigenous groups in the Pacific Northwest of North America, from northern California to Alaska. When the migrating salmon appeared in the river, the people of these tribes were not free to fish. They had to wait for the First Salmon ceremony and the permission of elders (Swezey and Heizer 1977). There were many variations of the system. In some tribes, the ceremony relied on families who were the designated salmon watchers, and on runners who would communicate up the river the news about the approaching salmon. The system hinged upon a tribal ritual leader who would make the decision about the timing of the ceremony which then marked the opening of salmon fishing.

As a part of indigenous culture, the First Salmon ceremony is important in its own right. But it also seems to have served a resource management function. It is known that an experienced observer could make a qualitative assessment of the strength of a particular salmon run. This is similar to what contemporary biologists do, with population models and counting fences in salmon rivers, to establish daily harvest quotas and to allow sufficient escapement, a term that refers to making sure that a portion of the reproducing stock is able to get by the fishery and reach spawning grounds.

It is also known that ritual leaders in the First Salmon Ceremony were able to adjust the timing of the ceremony to allow for a portion of the run to escape upstream before declaring the fishery open. For example, if a particularly strong run was coming, the leader might wait only three days before opening the fishery. But is the run was weak, he might delay the opening for ten days. The leader did not use a resource management discourse; he supervised a ritual consistent with cultural values encoded in stories about respecting salmon, allowing them to reproduce, and not interfering with the migration leaders (Swezey and Heizer 1977; Williams and Hunn 1982).

The First Salmon Ceremony has been superseded by biological management in many areas, even where indigenous tribes manage their own salmon fisheries. In Oregon and Washington State, for example, the tribes are obliged under their co-management treaties to use scientific management (Singleton 1998). But many tribal biologists still know the traditional system, and a few places still practice it – for example, the Karuk people on Klamath River in northwestern California. The Klamath has sites where the river narrows and the migrating salmon can be visually assessed by experienced harvesters. The Karuk people have traditional fishing sites where the salmon and some other species are harvested, consistent with historic practice.

It may be judged as resilient because it does not aim for harvest efficiency, or maximizing the catch, but rather for ensuring that the salmon stock perpetuates itself. Since there are year-to-year variations in the strength of the salmon run, the indigenous system makes adjustments for this variation by delaying the opening of the fishery in bad years. This allows for a sufficient number of individuals to escape upstream and spawn. It is based on making good observations of the fish, an accurate judgement of the strength of the run, an ability to set the opening date flexibly, and social enforcement of the management rule.

But how did the system really work? Can an indigenous leader, with an understanding of the natural history of salmon but without the science behind it, produce results similar to those achieved by biological management – without the research infrastructure and quantitative data? According to tribal biologists in Oregon, an experienced observer can in fact do a pretty good qualitative visual assessment of the strength of a salmon run moving upstream. Contemporary scientific management does something very similar but uses more intrusive techniques to force salmon through a counting fence. Without the quantitative data at his disposal, the ritual leader presumably makes a qualitative assessment, analogous to the use of fuzzy logic, of the strength of the run and of the number of spawners that should be allowed to escape upstream before the fishery is declared open and the event marked by a ceremony (Berkes 2008).

In contemporary fisheries, the more striking examples to illustrate resilience concepts are often negative stories, as in the Newfoundland cod case. One intriguing story concerns the Gulf of Maine where a number of factors have come together to result in a highly successful lobster fishery. In contrast to declining stocks in many parts of the world, the Maine lobster fishery is more successful than ever in its history. But it resembles a shellfish farm. Lobster predators, large bottom feeding fish such as cod, have become locally extinct. Fishers feed the lobsters with herring used as bait in traps, and have devised management methods to maximize the number of large reproductive individuals by placing them under permanent protection (Box 3).

Box 3. The Gulf of Maine as a lobster pond: monocultures and resilience

The commercial fishery of the Gulf of Maine relies very heavily on lobsters; in fact, some eighty to ninety percent of the value of the entire Gulf comes from this one species, *Homarus americanus*. It was not always like this. In the late 1800s cod was the most valuable fishery. Archival photos show that extremely large codfish were captured. During the 1930s, the fishery developed the ability to target spawning aggregations of coastal cod and haddock; by 1949, these stocks were declared 'depleted' by the State Government of Maine (Steneck *et al*. 2009). Oral history from retired captains indicate that these were distinct stocks of cod and haddock, many of them identified by name and location by the fishers (Ames *et al*. 2000). The harvest of more distant stocks of cod continued from the 1950s to the 1970s, and new fisheries for species such as monkfish, squid, and sea urchins developed, increasing the diversity of the fishery for a few years.

By the 2000s, however, the Gulf of Maine had become 'a highly simplified and domesticated ecosystem similar to many agricultural and aquacultural systems' (Steneck *et al*. 2009). In many respects, the Maine lobster fishery does not look like a wild fishery but shares many of the characteristics of aquaculture: control of predators (groundfish have been removed); provision of food (herring, the second most abundant species in the Gulf, is used for bait in lobster traps); and a greatly simplified food web. The population density of lobsters at twenty meter and less is one to two lobsters per square meter over hundreds of kilometers of coastline, higher than anywhere else in the world (Steneck *et al*. 2009). In some places, lobster traps are set so close together that the floats of the traps look like mooring buoys in a small-craft harbour.

Success of Maine lobster fishery is in a major may due to effective management, partly designed and largely enforced by lobster fishers themselves. By law, fishers return undersized lobsters and egg-bearing individuals to the sea. But perhaps even more important, they have developed a technique called the v-notch, whereby 'berried' (egg-bearing) lobsters are marked with a 'v' cut into the tail. This marks these individuals as proven reproductive stock, and such v-notched lobsters cannot be landed or sold even when they are not carrying eggs. As well, fishers have developed their own rules of conduct, including territoriality in some areas (Acheson 2003). By all conventional resource management measures, this is a very successful fishery. But is it resilient and sustainable?

However, from a resilience perspective, the Maine lobster fishery is notable as a 'gilded trap', one in which the current state delivers lucrative short-term economic returns, but at increasing risks of collapse and loss of resilience (Steneck *et al*. 2009). The problem is that, as with monocultures everywhere, the unnaturally high density of lobsters in the Gulf of Maine increases their susceptibility to disease. There is no disease now in the Gulf. But only about 200 kilometres south of the area, in eastern Long Island Sound, shell disease lethal to some three-quarters of lobsters was recorded in the unusually warm summer of 1998. Hence, Steneck *et al*. (2009) surmise that similar events can occur in the Gulf as sea-water temperatures continue to rise.

Some of the fishers themselves see the risk but few want to return to the alternative stable state, a fishery that is ecologically and economically diverse, with cod and other groundfish predators of lobster. Many fishers carry high debt loads, and see themselves as stuck in a social trap, the current stable state characterized by high profitability but lacking the economic and biological diversity required for long-term sustainability. Some, in fact, seem to be ready for a system transformation – out of the fishery and into a recreation and tourism economy in which the Gulf becomes a playground. They are investing in guesthouses and other tourist amenities, towards an economy in which commercial fishery is not a major player.

Conclusion: Reconceptualizing 'Natural Resources' and 'Management'

The First Salmon Ceremony and the Gulf of Maine examples, along with some of the other examples in this paper, can be used to generate some lessons from resilience thinking (Table 3).

Table 3. Learning from resilience: some lessons for the management of marine and coastal resources (Gunderson and Holling 2002; Berkes et al. 2003; Chapin et al. 2009).

Management goals should not be framed in terms of stability but rather resilience	Social-ecological systems are rarely stable. Rather, they are non-equilibrium systems or systems characterized by multiple stable states, as in the Newfoundland cod and Gulf of Maine examples. Hence, stability, simplification and control are not realistic goals. Instead, maintaining variation, diversity, ecosystem processes, and renewal make more sense.
Management should aim to retain and restore critical types and ranges of natural and social variation	Natural variation includes species and genetic variation, habitats and ecosystems. Different practices and methods of fishing also add to diversity, and the ability to switch species and gears. Also important are the different livelihood strategies developed by different groups of fishers.
Accommodate change, allowing for innovation and adaptation through windows of opportunity	Resilience theory focuses on systems characterized by cycles and constant change. Innovation and adaptation in these changing systems requires diversity as raw material and system memory as the source of renewal. Timing is important to initiate change; for example, policy change can often benefit from timing to 'windows of opportunity'.
Emphasize the importance of responding with flexibility and keeping options open	First and foremost, resilience is about flexibility and keeping options open. For example, the First Salmon Ceremony provides a flexible solution for dealing with environmental uncertainty and year-to-year fluctuations. The lobster monoculture in the Gulf of Maine is vulnerable to disease, and needs diversification to keep fishery options open.
Eliminate the various dichotomies that characterize conventional resource management	Eliminate distinction between 1) the social system and the natural system; focus on integrated social-ecological systems; 2) science and management, as done in adaptive management; 3) user and decision-maker, as becoming common in participatory management; and 4) different kinds of knowledge.
Create learning institutions to provide flexible, multi-level governance	Learning-by-doing is important because there are no set recipes or blueprints for management in the face of uncertainty. Adaptive co-management, interactive governance, and adaptive governance are some of the terms that capture related ideas of flexible management based on institutional learning and experimentation.

The main elements of this approach include treating social-ecological systems as complex adaptive systems characterized by cycles and uncertainty, and social systems and ecosystems as coupled and co-evolving. If the Gulf of Maine lobster fishery collapses and cod fishery is not an option, then the system may be transformed out of a fishery and into a recreational economy. Here, not only the species or technology would change, but also the economics of the region and the social/cultural makeup of former fishing communities, that is, the whole social-ecological system.

Production objectives reduce natural variability, eroding resilience and leaving systems vulnerable in the face of change. Therefore, resources and environment can be managed for resilience (instead of production) by protecting diversity, working with natural variation, and maintaining memory to enable self-organization. Resilience obliterates the distinction between science and management, and is open to users participating in management and the recognition and use of their knowledge.

Coming out of the ecological literature, resilience has not done as well dealing with the social. For example, adaptability is mainly a function of the social component of the integrated system, and adaptation is not a mechanistic or predetermined outcome. Human agency, including the role of individuals, leaders and institutions, influences outcomes. This collective capacity to manage resilience determines whether thresholds can be successfully avoided. As well, issues around power and conflict are important, as they explain the persistence of top-down management and shape the ways in which partnerships and collaboration may take place (Armitage 2008).

These considerations are in support of shifting perspectives on resource management in which many of the assumptions of conventional management have been abandoned, or are in the process of being abandoned (Table 1). The emerging views, however, need work, as does resilience. Resilience-based stewardship of natural resources is still struggling to move from theory to practice (Chapin *et al.* 2009). One of the major challenges here is that the resilience approach embraces uncertainty, and in doing so, rejects 'management' in its deterministic sense: a manager operating by a fixed set of rules, measuring outcome in some quantitative way ('you can't manage what you can't measure'), and exercising control over the system. Does this mean 'the era of management is over' (Ludwig 2001)? Or can we redefine management?

It may make more sense to redefine management than to abandon it altogether, given that many of the elements of such a redefinition are in fact in place. First, we need to reformulate the term 'resource', which carries a sense of 'free goods', economism, strict human-centric use, and commodification of nature. The notion of resource can be revised to include objectives to protect ecosystem services for human well-being (MA 2005), while maintaining diversity and social-ecological system resilience. Resources are needed and used by humans, but cod fish and other species need their resources too, as the ecosystem-based approach reminds us. On the social side, de-emphasizing the market economy of resources would make us more sensitive to the political economy of resources. Some resources with little market value, or global market demand, may nevertheless be crucially important for local livelihoods, food security, and local culture.

The term 'management', which carries implications of domination of nature, efficiency, social and ecological simplification, and expert-knows-best, command-and-control approaches, similarly needs a makeover. It can be updated to emphasize stewardship in place of domination and control of nature, a silly objective in view of paradigm changes in ecology. Efficiency objectives need to be balanced against ecological (for example biodiversity) and social (for example equity) objectives; resource management for multiple objectives is an emerging trend (Cochrane and Garcia 2009). Management needs to move from reductionism to dealing with complex adaptive systems, with all the complications that such a shift entails, such as attention to scale, self-organization, non-linear interactions and threshold effects, as in the Newfoundland cod case.

Attention to drivers and change processes are key considerations (MA 2005; Leichenko and O'Brien 2008). Contemporary resource management highlights property rights (McCay 2008), participation, institutions at multiple levels and their interactions (Armitage *et al*. 2007) and experimentation, both in adaptive management sense (Lee 1993) and interactive governance sense (Kooiman *et al*. 2005). It needs to address social relationships, community (Jentoft 2000), social and institutional learning, and adaptation. Resource management, as redefined, takes us in the direction of learning-by-doing, pluralism, collaboration, partnerships and adaptive governance, and creates new opportunities for bridging social and natural sciences towards a more holistic understanding of human interactions with the sea.

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