



Contents lists available at [ScienceDirect](http://www.sciencedirect.com)

Global Environmental Change

journal homepage: www.elsevier.com/locate/gloenvcha



Institutional dynamics: Resilience, vulnerability and adaptation in environmental and resource regimes

Oran R. Young

Donald Bren School of Environmental Science and Management, University of California at Santa Barbara, Donald Bren Hall 4518, Santa Barbara, CA 93106-5131, United States

ARTICLE INFO

Article history:

Received 20 May 2009

Received in revised form 18 September 2009

Accepted 2 October 2009

Keywords:

Regimes

Governance

Resilience

Adaptation

Vulnerability

Global environmental change

Institutions

Complexity

ABSTRACT

Like all social institutions, governance systems that address human–environment relations – commonly know as environmental or resource regimes – are dynamic. Although analysts have examined institutional change from a variety of perspectives, a particularly puzzling feature of institutional dynamics arises from the fact that some regimes linger on relatively unchanged even after they have become ineffective, while others experience state changes or even collapse in the wake of seemingly modest trigger events. This article employs the framework developed to study resilience, vulnerability, and adaptation in socio-ecological systems (the SES framework) in an effort to illuminate the conditions leading to state changes in environmental and resource regimes. Following a discussion of several conceptual issues, it examines institutional stresses, stress management mechanisms, and the changes that occur when interactive and cumulative stresses overwhelm these mechanisms. An important conclusion concerns the desirability of thinking systematically about institutional reform in a timely manner, in order to be prepared for brief windows of opportunity to make planned changes in environmental regimes when state changes occur.

© 2009 Elsevier Ltd. All rights reserved.

1. Introduction

Like all social institutions, governance systems that address human–environment relations – commonly known as environmental or resource regimes – are dynamic. Once established, they change continually in a variety of ways. Some changes, such as the addition of significant amendments to an existing law, treaty or other constitutive agreement, are developmental in character. They put additional flesh on the bones of the regimes in question. Others are better understood as responses to events occurring in the biophysical and socioeconomic settings in which regimes operate. Some changes are gradual and incremental in nature; they unfold step-by-step over relatively long periods of time and often take the form of informal adjustments in the practices that grow up around specific regimes. But others are more abrupt and far-reaching. They feature non-linear and irreversible developments that precipitate state changes; they can lead to wholesale restructurings of existing constitutive agreements. In one form or another institutional change is pervasive. The need to understand change and its consequences for efforts to address problems arising in socio-ecological systems therefore looms large as a challenge for those who study environmental and resource regimes.

There is a sizable literature on institutional change in other settings (Breit et al., 2003). Those interested in economic systems have been particularly active in thinking about change (North, 1990; Campbell, 2004; Hall and Thelen, 2007). But our knowledge of the institutional dynamics of environmental and resource regimes is comparatively underdeveloped (Young, 1999, Ch. 6). A particularly intriguing puzzle centers on the common alternation between long periods of institutional stickiness in which even ineffective regimes remain in place and shorter bursts of change that can lead to the emergence of new or substantially reformed institutions in short order.

This article takes some tentative steps toward coming to grips with change in environmental and resource regimes and especially with change that is non-linear and abrupt in character. My strategy is to employ the analytic lens developed in the recent literature on resilience, vulnerability, and adaptation in socio-ecological systems (Berkes and Folke, 1998; Gunderson and Holling, 2002; Adger, 2006; Folke, 2006; Walker and Salt, 2006). I ask whether this analytic framework (hereafter the SES framework) can yield insights that will advance our understanding of state changes in environmental and resource regimes. The central argument is straightforward. With the passage of time, environmental and resource regimes become increasingly entrenched. Often, they fall prey to rigidification and suffer from what observers have called institutional arthritis (Olson, 1982). The effect of this is to sap their resilience and to increase their vulnerability to various types of stress. Stresses, on the other hand, exhibit a tendency to proliferate

E-mail addresses: young@bren.ucsb.edu, oran.young@gmail.com.

0959-3780/\$ – see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.gloenvcha.2009.10.001

Please cite this article in press as: Young, O.R., Institutional dynamics: Resilience, vulnerability and adaptation in environmental and resource regimes. *Global Environ. Change* (2009), doi:10.1016/j.gloenvcha.2009.10.001

and to become interactive and cumulative over time. The longer institutions remain in place, the more brittle and crisis prone they apt to become. Sooner or later, stresses will overcome the stress management capacity of regimes, paving the way toward the occurrence of changes that are non-linear and often abrupt.

This line of analysis helps to resolve a familiar paradox. Institutions are sticky; they often remain in place long after mismatches between regimes and the biophysical and socio-economic settings with which they interact become severe and widely understood, at least among specialists. Yet, arrangements that are brittle are also prone to dramatic changes or even sudden collapse. Once a tipping point is reached, seemingly entrenched arrangements can come down like a house of cards. The resultant crises are not necessarily bad; they can provide opportunities for making needed adjustments in institutional arrangements that are simply out of the question during normal times. This process can and often does give rise to a pattern in which long periods of institutional stasis are punctuated by shorter periods or bursts of far-reaching and dramatic change.

This reasoning offers a perspective with direct links to several of the central threads of this special issue. Environmental and resource regimes are themselves complex and dynamic systems. It is important to understand that the governance systems we create to steer human–environment relations can be and often are just as complex and dynamic as the socio-ecological systems they are created to steer. This makes it relevant to ask questions about the resilience and vulnerability of regimes in the face of changes occurring in large coupled human–environment systems like the Earth's climate system, large marine ecosystems, and their terrestrial counterparts. A question of particular interest in this connection centers on the extent to which complexity in the relevant socio-ecological systems poses special challenges with regard to resilience and vulnerability in environmental and resources regimes.

To explore these issues, I proceed as follows. The first substantive section focuses on analytic matters. It discusses the application of the SES framework to the analysis of environmental and resource regimes treated as complex and dynamic systems. The next section distinguishes a number of types of stress that affect these governance systems and introduces several key ideas relating to the processes through which stresses affect individual regimes. This is followed by a section that focuses on mechanisms for managing stress that are particularly relevant to environmental and resource regimes. The final substantive section then asks what happens when stress management fails; can we discern patterns of change in this realm, such as the “adaptive cycle” that figures prominently in many discussions of resilience in biophysical systems? An important conclusion is that we should think ahead in order to have well-designed options in hand when state changes open up windows of opportunity for introducing major changes in prevailing institutional arrangements.

In the following sections, I turn repeatedly to regimes dealing with marine systems as a source of illustrations. The issues under consideration here are generic; they affect environmental and resource regimes dealing with a wide range of issues at all levels of social organization. But regimes relating to marine systems have experienced dramatic changes in recent decades; more changes are likely to occur in the foreseeable future (Ebbin et al., 2005). This issue area offers a particularly rich source of illustrations relevant to the institutional dynamics I explore in this article.

2. Analytic matters

The point of departure for the SES framework is the proposition that it is both feasible and helpful to approach the phenomena in question as systems. The resultant studies address ecosystems, social systems, and, increasingly, socio-ecological systems.

Although the reasoning is less familiar to those who study institutions, it is straightforward to apply the same conceptual lens to governance systems. Environmental and resource regimes – from the local level to the global level – consist of systems in the sense of interconnected elements (e.g. assemblages of rights, rules, and decision-making procedures) that are organized around functions or purposes (e.g. managing human activities affecting large marine ecosystems or LMEs for sustainability) and that are differentiable from their environments (which may include other institutions) (Meadows, 2008). As is the case with ecosystems, the specification of spatial boundaries separating specific institutions from their environments requires judgment on the part of the analyst. Regimes operating at any given scale or level in the dimension of jurisdiction are nested into institutional arrangements operating at higher levels that affect their performance. The various regional seas regimes as well as many regional fisheries regimes, for example, all fit into the overarching regime for marine systems articulated in the 1982 UN Convention on the Law of the Sea (UNCLOS) (Stokke, 2001).

Resilience, on this account, refers to the “... capacity of a system to experience disturbance and still maintain its ongoing functions and controls” (Holling and Gunderson, 2002, p. 50). Sometimes labeled “ecosystem resilience,” this perspective emphasizes the ability to handle stress in an adaptive manner and focuses on issues of adaptation to exogenous stresses along with the maintenance of key elements in contrast to the idea of “engineering resilience” which starts from the concept of equilibrium and directs attention to the derivation of stability conditions that specify how far a system can be displaced from a fixed point of equilibrium and still return to that equilibrium once the disturbance has passed. Although engineering resilience is more familiar – not to mention easier to model – adopting the idea of ecosystem resilience as a point of departure makes sense for studies of institutional dynamics as well as the dynamics of socio-ecological systems (Holling and Gunderson, 2002, pp. 27–30).

There is nothing static about this conception of institutional dynamics. Instead of returning to some prior equilibrium (e.g. a specified temperature in a thermostatically controlled heating system or a fixed speed in a car equipped with a governor), institutions often develop in the sense that they move toward realizing their potential or make adjustments needed to maintain their compatibility with changing biophysical or socioeconomic circumstances. The law of the sea as set forth in UNCLOS, for instance, has evolved significantly through the addition of the straddling stocks agreement, new rules pertaining to marine transport, regional seas arrangements dealing with pollution, the growing influence of ecosystem-based management (EBM), and so forth. But no one would claim that these developmental processes have transformed the law of the sea as articulated in the 1982 convention or, to use a common ecological phrase, triggered a state change regarding the character of the institutional arrangements governing human uses of marine resources.

Although there is some lack of consensus in the literature, vulnerability is a closely related concept (Adger, 2006). Simply put, vulnerability rises as stresses begin to overwhelm an institution's robustness (i.e. its capacity to cope with stress without adapting) and resilience (i.e. its capacity to deal with stress through adjustments that stop short of transformative change).¹ While robustness and resilience refer to an institution's capacity to cope with stress, vulnerability is a matter of its sensitivity to disturbances, stresses, and threats of one sort or another. A regime that is highly robust or resilient will be relatively invulnerable in

¹ For a discussion of the distinction between robustness or the ability to withstand stress without adapting and resilience or the capacity to withstand stress through various types of adaptation see Anderies et al. (2004).

the sense that it can cope with many disturbances. But there is no reason to assume that a regime's robustness, resilience, and vulnerability will be uniform either across the full range of actual or potential stresses or from one time period to another. A regime may be resilient in the sense that it is more or less immune to the impact of most stresses and yet have an Achilles heel in the sense that it is highly vulnerable to one or more specific types of stress. The sudden introduction of new technologies (e.g. high endurance stern trawlers in commercial fisheries), for instance, can quickly undermine a management system that has produced tolerable results over an extended period of time. This is one reason why regimes that seem solidly entrenched to most observers can disintegrate quite suddenly and in a manner generally unanticipated by participating actors and outside observers alike. The sources of stress may be internal, external, or both. Management regimes for fisheries may lack the procedures needed to restrict harvest levels in a manner compatible with the sustainable use of the resources. Exogenous biophysical forces, such as ENSO events, changes in water temperatures, or ocean acidification, affecting the relevant systems may generate stresses on a regime over and above problems arising from the operation of the regime itself. There is nothing mutually exclusive about stresses of this sort. A common occurrence is the emergence of multiple stresses that can and often do interact with one another in such a way as to challenge the capacity of an institutional arrangement to cope with stress.

From this perspective, it is important to consider the mechanisms – spontaneous or intentionally created – that environmental or resource regimes develop to cope with stress. Like other institutions, regimes vary in terms of their ability to create and implement mechanisms to cope with stress as the need arises. Regimes that are rigid in the sense that they are difficult to amend formally or to adjust informally run the risk of falling prey to rapid changes in either biophysical or socioeconomic conditions. Yet regimes that are too easy to alter in response to pressures will be ineffective in terms of influencing the behavior of those whose actions have given rise to the relevant problems. A fisheries regime that is unable to act in a timely manner to lower quotas when key stocks decline, for instance, cannot play an effective role in promoting sustainable uses of these resources. But such a regime that changes quotas at the least sign of stress cannot be effective in guiding the behavior of those subject to its provisions. The problem of striking a balance between extreme rigidity and excessive flexibility looms large in any effort to understand the nature of institutional dynamics.

Major changes occur when stresses overwhelm the capacity of an institution's stress management mechanisms to cope with these pressures. Individual regimes vary enormously in these terms. Some experience high stress but also develop effective mechanisms to manage stress. Others are low-stress systems that do not need a highly developed capacity to manage stress. Real-world arrangements are often more complex than these generalizations seem to suggest. Fisheries regimes that are generally robust can collapse in short order in the wake of seemingly small changes in biophysical conditions (e.g. slight variations in water temperatures or patterns of upwelling). Arrangements that are crisis prone in the sense that they have a limited capacity to cope with day-to-day stresses (e.g. the need to reduce total allowable catches in light of fluctuations in the condition of fish stocks) can emerge as effective arrangements once the occurrence of a crisis is acknowledged (e.g. the need to respond quickly and effectively to signs of a state change in an LME). An important issue facing those responsible for operating specific regimes concerns the allocation of attention between anticipatory measures or, in other words, efforts to build capacity to cope with stress before it occurs and adaptive measures or, in other words, actions that are considered seriously only after the pressures associated with stress become severe.

Not all changes occurring once pressures arising from stress overwhelm the capacity of stress management mechanisms are the same. Some changes are confined largely to well-defined institutional components; others ripple through whole institutions and ultimately give rise to systemic state changes. While some changes unfold slowly, others are fast and may accelerate as they spread through an institution, spiral out of control, and produce cascades of change. Needless to say, managers will be particularly concerned to avoid or at least to anticipate the occurrence of changes that course through a regime at a rapid pace and trigger full-blown crises. Given the fact that conscious efforts to adjust institutional arrangements to come to terms with new pressures (e.g. the introduction of powerful new harvesting technologies in the fisheries) are typically cumbersome and slow, changes that spread rapidly and accelerate as a function of time can easily spiral out of control before managers are able to mobilize the material and political resources needed to make the adjustments required to come to terms with the problem.

3. Forms of institutional stress

Stresses that challenge the resilience of environmental and resource regimes come in a variety of forms. Moreover, individual stressors regularly interact with one another producing pressures that are cumulative and become chronic over the course of time. To understand the role of stressors in institutional dynamics, it is helpful first to develop a clear understanding of the processes at work with regard to individual stressors and then to turn to the dynamics of multiple, interactive stressors.

3.1. Individual stressors

Although there is no standard taxonomy of stresses affecting institutional arrangements, we can take some initial steps toward differentiating major categories of stressors. There is an important distinction between stresses arising from internal or endogenous processes in contrast to environmental or exogenous pressures. Classic examples of internal stresses arise in cases where regimes are sluggish and unable to cut quotas in the face of unambiguous evidence regarding stock depletions, are poor at devising effective methods of dealing with new entrants, or are insensitive to far-reaching changes in the marine ecosystems in which stocks of commercially valuable fish are embedded. The need to take action to avoid or mitigate these endogenous stresses may seem obvious. Yet planned adjustments of regimes once they turn into entrenched social practices are always difficult to accomplish; the onset of institutional arthritis makes such efforts more difficult to carry out successfully with the passage of time (Olson, 1982).

It is equally important to recognize the critical role of exogenous stresses or pressures arising from forces outside a regime that can call into question its ability to manage the human–environment interactions in question effectively. Perhaps the most obvious cases in point arise from biophysical changes that lower harvestable surpluses or degrade the ability of stocks of fish or marine mammals to rebound from severe depletions. Cutting total allowable catches to take into account these biophysical changes is always difficult. With regard to marine systems, this challenge is particularly severe both because the relevant problems often are not fully diagnosed until they become extreme and because knowledge of the dynamics of complex marine ecosystems remains sketchy (Norse and Crowder, 2005). As the case of the cod stocks of the Northwest Atlantic makes clear, regimes that have operated over long periods of time can be left in ruins as a result of such depletions, while managers and other observers debate whether the changes in question constitute long-term trends or temporary fluctuations (Harris, 1998).

Socioeconomic developments not attributable to the operation of a regime per se may also be a source of more or less severe stress. Consider the effects of technological innovations or the arrival of new entrants in important fisheries as cases in point. Regimes that do reasonably well in ensuring sustainable yields in one technological setting can prove wholly inadequate to prevent severe stock depletions, rising by-catches, and largescale damage to the relevant ecosystems when new technologies come on stream. A dramatic example involves the introduction of large, high endurance stern trawlers deploying increasingly powerful gear in many fisheries during the 1960s and 1970s (Warner, 1983). Similar problems emerge when changes in some other arenas displace fishers from customary fishing grounds who then flock to fisheries in which they had not previously participated. Many examples of this phenomenon occurred during the 1970s and 1980s as the creation of Exclusive Economic Zones (EEZs) by coastal states displaced distant-water fishers from many familiar fishing grounds (Ebbin et al., 2005). Although the source of the resultant problems was plainly exogenous, regimes governing fisheries that remained open to new entrants soon found themselves experiencing more or less severe stress attributable to institutional changes in a different sphere.

Beyond this, regimes can and often do come under pressures due to changes in relevant intellectual capital or shifts in the way key actors define the problem to be solved. Striking and easily understandable conclusions like the proposition that 90% of the original stocks of large fishes in the sea are gone (Pauly et al., 1998) can generate crises of understanding in which regimes governing the use of marine resources that have seemed rock solid for years suddenly lose their cognitive credibility and legitimacy and, as a result, become susceptible to major restructuring. Similarly, the rise of the discourse of ecosystem-based management has called into question the appropriateness of institutional arrangements based on the goal of achieving maximum sustainable yields from individual fish stocks without reference to the impacts on the encompassing ecosystems (Larkin, 1977). Shifts in a dominant discourse do not produce fundamental changes over night. But new perspectives regarding the nature of the problem can permeate the system over time. There is unmistakable evidence that a development of this sort is unfolding at the present time with regard to marine systems; it is highly likely to generate major changes in ocean governance over the next 5–10 years (Norse and Crowder, 2005; Crowder et al., 2006; Young et al., 2007).

Changes in overarching political and legal arrangements and in broader socioeconomic systems also can prove stressful to issue-specific environmental and resource regimes. While the genesis of these changes may have little or nothing to do with individual regimes, their impact on the operation of these arrangements can be profound. The creation of EEZs during the 1970s and 1980s, for instance, disestablished some regimes entirely and forced major changes in others. A drastic restructuring of the international regime governing fisheries in the Northwest Atlantic, for instance, became necessary following the establishment of the American and Canadian EEZs in the 1970s (Stokke, 2001). Similar remarks are in order regarding the effects of changes in overarching economic and political systems. The problem of saving the Aral Sea, for instance, has become far more complex in the aftermath of the breakup of the Soviet Union, since its basin now encompasses areas under the jurisdiction of six independent countries rather than being under the jurisdiction of a single country (Kasperson et al., 1995).

3.2. Multiple stressors

Although it is helpful to differentiate among distinct types of stress for purposes of analysis, it is equally important to recognize

that regimes can and regularly do experience stress from two or more sources at the same time. The simplest case involves the simultaneous occurrence of several stressors whose origins are unrelated (e.g. internal problems impeding efforts to set appropriate harvest levels and external pressures arising from climate-related changes in water temperatures). Although the sources of these stresses may be unrelated, there will often be significant linkages between or among them when it comes to problems of stress management. An institutional arrangement that is experiencing difficulties in coping with pressure generated by interest groups to set allowable harvest levels too high, for example, may have little capacity to come to grips with the consequences of biophysical changes unfolding during the same time period.

Individual stressors often interact with one another, either reducing or intensifying the challenge of maintaining resilience. The growth of aquaculture in many areas depends on the availability of large quantities of fish meal. But the production of fish meal not only affects stocks of species used in the production of fish meal (e.g. anchovies, herring, menhaden); it also affects the condition of stocks of other fish that prey on fish used in the production of fish meal (e.g. cod). And increases in the cost of fish meal will lead those involved in aquaculture either to find substitutes for fish meal or to promote efforts to target new and different stocks of marine living organisms in order to meet the growing demand for the food needed to sustain the aquaculture industry. This is a comparatively simple example. But it should suffice to demonstrate the importance of interactive stressors as determinants of resilience and vulnerability in environmental and resource regimes. Faced with such challenges, regimes may find their coping capacity stretched to the limit. Even worse, they will often encounter situations in which actions taken to mitigate one type of stress make the system more vulnerable to the impacts of other stressors.

To this increasingly complex picture we must add the phenomenon of cumulative stress. The basic idea here is that stresses can accumulate, becoming in the aggregate more severe over time. Partly, this is a matter of the diffusion and intensification of biophysical effects. As stocks of commercially valuable species in the central Bering Sea have come under increased pressure, for instance, the biomass of jellyfish, which have no commercial value, has increased tenfold (NRC, 1996, 2003). In part, it is a matter of shifts in the behavior of human actors subject to the provisions of regimes. Fishers may move from one stock to another, for instance, as individual stocks become severely depleted. This strategy can work so long as there are new stocks to exploit. But with the passage of time, it is likely to trigger state changes in the overall ecosystem as well as growing economic pressure on fishers who experience steady declines in their catch per unit of effort (CPUE) and who must therefore work harder to continue to make mortgage payments on their boats and provide for their families. Such processes give rise to vicious circles that generate cascades of stresses from the perspective of the relevant regimes. Stock depletions lower CPUEs leading fishers to increase their efforts and upgrade the fishing power of their boats/gear which intensifies pressure on key stocks and so forth. Quite often, a major casualty of such a negative spiral is the relevant regime which is seen as lacking the teeth needed to come to terms with the emerging crisis.

In thinking about the resilience of environmental and resource regimes, therefore, it is essential to move beyond an analysis of individual stressors to an examination of both interactive and cumulative stresses. Given the fact that many institutional arrangements experience rigidification with the passage of time, the occurrence of a spiral of interactive and cumulative stresses can easily overwhelm the capacity of regimes to respond effectively. What emerges in such cases is a mismatch between relatively fast and often accelerating disturbances and a fixed or

even declining capacity on the part of the relevant institutions to respond swiftly and decisively. When this happens, the stage is set for the onset of crisis, an occurrence that may be triggered by an event that seems relatively unimportant or even trivial when looked at in isolation but that can touch off processes that quickly overcome the stress management mechanisms that are on hand to cope with such pressures. When this happens, substantial reforms become necessary in order to avoid institutional disintegration.

4. Managing stress

Some institutional arrangements have spontaneous or self-generating mechanisms that serve to alleviate the impacts of stress in the absence of conscious initiatives on the part of administrators or policymakers (Hayek, 1973). Properly functioning markets are often cited as the paradigmatic example of such processes. When demand for a good exceeds supply, the price will rise, new entrants are likely to conclude that there are opportunities to make a profit by acting to increase supplies of the good in question, and consumers may find that it makes sense to turn to alternative products. Similarly, persistent imbalances of trade should lower the value of the debtor's currency, thereby making imports dearer and increasing the competitiveness of the debtor's products from the perspective of consumers in other countries. Whatever the merits of this logic with regard to well-functioning markets, however, there is little reason to expect such self-correcting processes to suffice to maintain the resilience of environmental and resource regimes, especially in the face of cumulative stress. Those responsible for administering individual regimes – not to mention those interested in constructing generalizations about the performance of these arrangements – are increasingly concerned with the prospects for creating and using stress management mechanisms on an intentional or planned basis.

Even in cases involving regimes thought to be highly resilient, there is a need to establish monitoring and reporting systems capable of providing early warning concerning the onset of conditions known to generate more or less severe stress. In the simplest cases, this is a matter of monitoring biophysical processes to keep track of natural forces that can impose stresses on the relevant regimes. For many marine systems, however, this is easier said than done both because the dynamics of these systems are poorly understood and because state changes in the relevant biophysical systems can occur suddenly and with little advance warning. In addition, monitoring should take into account anthropogenic forces that can generate pressures on individual regimes. Those charged with administering specific regimes will want to know whether and when important technological advances are likely to occur or major shifts in overarching political or legal arrangements will take effect. Naturally, early warning is not sufficient to avoid or mitigate stress; there are numerous examples of regimes that turn out to be incapable of adjusting to severe stresses even when the existence of growing threats becomes common knowledge. But in the absence of spontaneous mechanisms that can be counted on to deal with stress, early warning is necessary for success in managing stress.

Turning to more pro-active options, the ideas of adaptive management and social learning come into focus (Lee, 1993; Haas and Haas, 1995; Social Learning Group, 2001). There is no clearcut consensus regarding where adaptive management ends and social learning begins. Here, I start with some comments on policy instruments and institutional levers available to a regime prior to the onset of stress. Conventional fisheries regimes are normally authorized to alter allowable harvest levels or to use gear restrictions and open and closed seasons as measures to adjust human activities to accommodate fluctuations in the condition of stocks or to control externalities (e.g. the unintentional killing of

marine mammals, the effects of by-catches) associated with commercial fishing. There is nothing automatic about the operation of these procedures. Fishers can and often do resist the imposition of reduced quotas; they may respond to shortened seasons by increasing the fishing power of their vessels and gear leading in extreme cases to what are known as “fishing derbies” (Dobbs, 2000). What is more, such measures are typically more effective at changing or redirecting the behavior of human users at the margin than at coming to terms with situations calling for more drastic measures. This is not to find fault with mechanisms featuring adaptive management in the narrow sense as elements in the stress management toolkit. But it would be a mistake to set too much store by adaptive management as a general response to the problem of managing institutional stresses.

When adaptive management in this sense is insufficient to come to terms with rising stress, it makes sense to move on to a consideration of institutional learning. Learning, in this context, refers to the adoption and implementation of instruments that are not included in a regime as initially established but that can be added without triggering a wholesale shift in the basic character of the arrangement (Haas and Haas, 1995). In regimes dealing with marine resources, for instance, it is possible to introduce individual transferable quotas (ITQs), dedicated access privileges (DAPs), or procedures for creating marine protected areas that place certain areas off-limits to commercial fishers without altering the fundamental character of these regimes as arrangements designed to achieve sustainable yields from living marine resources (Iudicello et al., 1999; NRC, 1999; Costello et al., 2008). It would be naïve to suppose that institutional learning is easy to promote or that it can occur quickly enough to cope with – much less to head off – the onset of many severe stresses. By its nature, however, learning of this type is more open-ended than adaptive management in the narrow sense. Whereas adaptive management is confined to adjusting instruments already in place, there is no limit to the range of new policies and measures that can become foci of institutional learning. Learning, on this account, emerges as an important source of ecosystem resilience in a variety of settings.

Another strategy that can prove effective – especially in combating institutional arthritis – features the use of programmed review procedures. In their most familiar forms, such measures mandate the reauthorization of environmental and resource regimes at regular intervals. In the extreme, they can take the form of sunset provisions terminating institutional arrangements after a certain number of years, making it possible to start over with arrangements that may be better suited to biophysical or socioeconomic circumstances as they evolve over time. Reauthorization amounts to a mandated opportunity to reassess major features of a regime at regular intervals. The US Fishery Conservation and Management Act (FCMA), which was enacted initially in 1976 and remains the major source of management arrangements for marine fisheries under the jurisdiction of the federal government, goes through a reauthorization process at roughly 5-year intervals (Young, 1982; NRC, 1999). It would be naïve to expect too much from such processes. The course of least resistance is certainly to renew the mandate of any given regime with little change; it takes political will to achieve more significant changes in institutional arrangements. Even so, reauthorization can provide an opportunity to alter institutional arrangements to improve their ability to avoid or overcome major stresses. The FCMA illustrates both points. Congress has reauthorized this legislation with few changes on a number of occasions, but it has used the opportunity afforded by the process of reauthorization to make substantial changes on other occasions (e.g. the provisions of the Sustainable Fisheries Act of 1999).

Environmental and resource regimes often include procedures allowing for amendments or what some observers call secondary

rules (Hart, 1961). Such rules may be more or less precise and more or less stringent. In contrast to the rules governing amendments to international conventions or treaties, secondary rules embedded in domestic arrangements may assign authority to adjust the provisions of issue-specific regimes to an overarching legislative body (Ostrom, 2005). Even in such settings, however, it is helpful to draw a distinction between formal amendment procedures and informal processes leading to de facto changes in the operation of regimes treated as social practices (Young, 2002). In principle, such processes can help to manage stress by making changes in institutional arrangements needed to ameliorate endogenous stresses or to strengthen the capacity of these arrangements to cope with exogenous forces. But the usefulness of this approach to stress management is often severely limited, especially under conditions involving interactive stressors that can spiral out of control quickly. Not only is the amendment process typically slow; it can also open a Pandora's box of issues that many wish to avoid, even when this means failing to come to grips with the need to strengthen existing stress management mechanisms. This mechanism for managing stress may go unused, even when pressures for change become intense.

5. When stress management fails

Significant changes occur when cumulative stresses overwhelm a regime's capacity to cope with stress. The resultant changes may range from marginal adjustments involving specific regulatory measures to state changes in which constitutive provisions are restructured.² Similarly, changes may arise from conscious efforts on the part of stakeholders to alter specific components of an existing arrangement or take the form of unplanned or de facto alterations. Changes may occur slowly and incrementally or surface as sudden eruptions that get out of hand with little warning. Change sometimes begins as a gradual process that seems relatively benign from the standpoint of management but then picks up speed and spirals out of control once some critical threshold or tipping point is crossed.

Given the variability of specific changes, can we discern patterns of institutional change that recur on a regular basis and in many issue areas? Those who have pioneered in the development of the SES framework for understanding socio-ecological systems typically address this question via the analysis of ecosystems and direct attention to what they call the "adaptive cycle" (Gunderson and Holling, 2002). This cycle consists of four distinct stages designated in the literature on ecological resilience as exploitation, conservation, release, and reorganization. The basic idea is that processes of interest (e.g. growth in the population of a key predator) rise rapidly before leveling off, collapsing, and in due course reorganizing to start the cycle over again.

It is comparatively easy to see how the adaptive cycle plays out in simple ecosystems. Predators may exhaust the supply of prey, as in the lynx/rabbit cycle; herbivores may decimate the food supply, as in the case of lemmings and (probably) anchovies. But is there a plausible analogue in the case of environmental and resource regimes? While some analysts have made use of the metaphor of the lifecycle in thinking about the behavior of individual regimes, it is difficult to map institutional dynamics on to the stages of the adaptive cycle. Some regimes are slow starters, gaining steam only after a fairly prolonged period of incubation. Others remain robust or resilient indefinitely, showing little or no tendency to collapse.

² In the extreme, a regime may simply disappear to be replaced in due course by some fundamentally different arrangement. A prominent example is the collapse and disappearance of the international regime for northern fur seals during 1984–1985.

Still others work their way out of a role in the sense that the problems they are created to address are solved in a manner that is sufficiently decisive to make these arrangements superfluous.

Whatever the merits of the adaptive cycle as a lens for organizing analysis about institutional dynamics, it would be a mistake to infer that institutional dynamics lack distinct patterns. Two basic patterns seem worthy of differentiation and separate treatment in this context. Incremental change that centers on adjustments to the regulatory provisions of regimes happens all the time and may even be invisible to the ordinary observer. Debates over gear restrictions, the length of openings, and the treatment of by-catches in marine fisheries exemplify this class of changes. Such processes can easily become politicized; fishers may voice strong opposition to alterations that will make their harvesting activities more difficult or costly in the short run (Dobbs, 2000). Still, many changes of this sort can be introduced and implemented largely at a technical level. While they are not immune to the impacts of rent-seeking behavior, much less general bureaucratic sluggishness or inefficiencies, they do not trigger the intense battles associated with more far-reaching or constitutive changes.

On the other hand, some changes are constitutive in the sense that they involve institutional state changes in contrast to adjustments in existing policy instruments. Although the idea of constitutive change is complex, it is relatively easy to identify such changes in specific cases. The establishment of EEZs, formalized in the 1982 UN Convention on the Law of the Sea, is a case in point (Ebbin et al., 2005). The transition from regimes based on the concept of maximum sustainable yield to arrangements based on the idea of ecosystem-based management is another (Larkin, 1977; Norse and Crowder, 2005). A shift from efforts based on the idea of conservation to the alternative goal of preservation is a third (Friedheim, 2001). These changes not only generate far-reaching revisions in the operating rules governing the activities of key stakeholders; they can also draw in new stakeholders or reallocate bargaining strength among the stakeholders active in an issue area.

In thinking about changes in constitutive provisions and especially about those that give rise to state changes, there is much to be said for the proposition that such occurrences produce patterns of punctuated equilibrium (Speth and Repetto, 2008). Most regimes are sufficiently robust or resilient to remain intact for some time even as pressures mount and their deficiencies as problem-solving arrangements become increasingly well-known to those involved in the relevant issue area. Examples include a variety of regimes for marine fisheries that are based on ecologically arbitrary jurisdictional boundaries and that (in many cases) continue to emphasize maximizing sustainable yields, despite the growing consensus regarding drastic declines in populations of large fish as well as the disruptive impacts of industrial fishing on marine ecosystems. As those concerned with these issues know well, it is hard to dislodge entrenched institutional arrangements that have achieved the status of standard operating procedures among both those subject to their provisions and those responsible for administering the relevant rules, regulations, and decision-making procedures on a day-to-day basis.

Yet processes that eventuate in far-reaching and often abrupt changes do occur from time to time. How is this possible? Here is where the convergence of cumulative stress and the growth of institutional arthritis becomes relevant. As stress rises and institutional rigidity increases, regimes become increasingly brittle or less and less capable of coping with disturbances or threats, whether they are the result of endogenous processes (e.g. an inability or unwillingness to reduce catch quotas), exogenous forces (e.g. overarching jurisdictional conflicts), or – most often – some combination of the two. Once a threshold is reached,

seemingly small events can become triggers unleashing processes of change that spread rapidly throughout an institution and lead to a dramatic and seemingly sudden collapse. Something of this sort happened in the 1960s and 1970s as severe depletions associated with distant-water fishing in the waters adjacent to coastal states fueled the movement to create fishery-conservation zones and then full-fledged Exclusive Economic Zones or EEZs in the context of the law of the sea negotiations (Hoel, 2000; Ebbin et al., 2005). We may be approaching another threshold of this sort as evidence mounts that industrial fishing not only decimates fish stocks but also causes irreversible damage to larger marine ecosystems.

The resultant crises are anxiety producing for those responsible for the administration of existing regimes, not to mention individual actors subject to their authority. But this does not mean that the ultimate consequences will be negative, either from the point of view of sustainability or from the perspective of some broader criterion of social welfare. Institutional crises present opportunities to introduce far-reaching changes in existing regimes, alterations that are unimaginable during normal periods. We know that state changes arising from periods of crisis are irregular but not infrequent occurrences. For the most part, however, we are poorly equipped to understand what triggers these fundamental changes and therefore to anticipate the eruption of crises. This means that it is not easy to take advantage of the resultant opportunities to alter prevailing institutions, especially in the absence of advance planning. There is a strong case, under the circumstances, for devoting time and energy to the systematic examination of institutional alternatives, even when existing arrangements seem unlikely to change significantly – much less to disintegrate – during the foreseeable future. Windows of opportunity that open as by-products of crises are typically of short duration. Whether or not individual stakeholders are prepared to introduce carefully crafted alternatives when a window opens, some new institutional arrangements will emerge in fairly short order to fill the vacuum caused by the disruption of an existing order. There are always individuals or groups ready to prescribe preconceived and typically simplistic remedies (e.g. privatization coupled with the creation of free and unregulated markets) in situations of this sort. A necessary condition for avoiding such traps is to engage in rigorous analyses of the relevant alternatives before the onset of crisis makes it impossible to consider the relative merits of these options properly.

6. Concluding thoughts

Environmental and resource regimes change continuously. Sometimes the resultant changes are non-linear and more or less abrupt, giving rise to what systems analysts think of as state changes. Social scientists have developed a variety of approaches to understanding institutional change. While these approaches have produced insights, we remain puzzled by the facts that ill-adapted institutions can remain in place over long periods of time and that far-reaching institutional changes sometimes occur abruptly and in response to seemingly small triggers. This article draws on the SES framework, a mode of analysis that has helped to illuminate the dynamics of socio-ecological systems, in search of insights that will help us to understand this puzzle with particular reference to environmental and resource regimes.

Environmental and resource regimes have difficulty responding promptly and appropriately to socio-ecological changes that are non-linear and abrupt, even when the growing mismatch between prevailing institutions and the changing character of biophysical and socioeconomic systems becomes a matter of common knowledge. The stress management mechanisms that regimes develop are able to control the resultant pressures up to a point. At some point, however, mismatches are apt to cross a threshold or

reach a tipping point, generating crises in prevailing institutional arrangements. Like crises in other realms, the resultant institutional crises present opportunities as well as threats for all parties concerned. There is much to be said, under the circumstances, for thinking systematically about institutional options in advance, so that well-crafted options are available when crises open up windows of opportunity for the introduction of substantial institutional changes.

References

- Adger, W.N., 2006. Vulnerability. *Global Environmental Change* 16, 268–281.
- Anderies, J.M., Janssen, M.A., Ostrom, E., 2004. A framework to analyze the robustness of social-ecological systems from an institutional perspective. *Ecology and Society* 19 Art. 18.
- Berkes, F., Folke, C. (Eds.), 1998. *Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience*. Cambridge University Press, Cambridge.
- Breit, H., Engels, A., Moss, T., Troja, M. (Eds.), 2003. *How Institutions Change*. Leske and Budrich, Opladen.
- Campbell, J.A., 2004. *Institutional Change and Globalization*. Princeton University Press, Princeton.
- Costello, C., Gaines, S.D., Lynham, J., 2008. Can catch shares prevent fisheries collapse? *Science* 321 (September), 1678–1681.
- Crowder, L., et al., 2006. Resolving mismatches in U.S. Ocean Governance. *Science* 313 (August), 617–618.
- Dobbs, D., 2000. *The Great Gulf: Fishermen, Scientists and the Struggle to Restore the World's Greatest Fishery*. Island Press, Washington, D.C..
- Ebbin, S., Hoel, A.H., Sydnes, A. (Eds.), 2005. *A Sea Change: The Exclusive Economic Zone and Governance Institutions for Living Marine Resources*. Springer Verlag, Dordrecht.
- Folke, C., 2006. Resilience: the emergence of a perspective for social-ecological systems analyses. *Global Environmental Change* 16, 253–267.
- Friedheim, R.L. (Ed.), 2001. *Toward a Sustainable Whaling Regime*. University of Washington Press, Seattle.
- Gunderson, L.H., Holling, C.S. (Eds.), 2002. *Panarchy: Understanding Transformation in Human and Natural Systems*. Island Press, Washington, D.C..
- Haas, P.M., Haas, E.B., 1995. Learning to learn: international governance. *Global Governance* 1, 255–284.
- Hall, P., Thelen, K., 2007. *Institutional Change in Varieties of Capitalism*, unpublished paper.
- Harris, M., 1998. *Lament for an Ocean: The Collapse of the Atlantic Cod Fishery*. McClelland and Stewart, Toronto.
- Hart, H.L.A., 1961. *The Concept of Law*. Clarendon Press, Oxford.
- Hayek, F., 1973. *Rules and Order*, vol. 1 of *Law, Legislation, and Liberty*. University of Chicago Press, Chicago.
- Hoel, A.H. with contributions from Andreeva, E., Reichelt, R., Walsh, V., Young, O.R., 2000. Performance of Exclusive Economic Zones, IDGEC Scoping Report No. 2.
- Holling, C.S., Gunderson, L.H., 2002. Resilience and adaptive cycles. In: Gunderson, L.H., Holling, C.S. (Eds.), *Panarchy: Understanding Transformation in Human and Natural Systems*. Island Press, Washington, D.C., pp. 25–62.
- Iudicello, S., Webber, M., Wieland, R., 1999. *Fish, Markets, and Fishermen: The Economics of Overfishing*. Island Press, Washington, D.C..
- Kasperson, J.X., Kasperson, R.E., Turner, II, B.J. (Eds.), 1995. *Regions at Risk: Comparisons of Threatened Environments*. UNU Press, Tokyo.
- Larkin, P.A., 1977. An epitaph for the concept of maximum sustainable yield. *Transactions of the American Fisheries Society* 106, 1–11.
- Lee, K., 1993. *Compass and Gyroscope*. Island Press, Washington, D.C..
- Meadows, D., 2008. *Thinking in Systems: A Primer*. Chelsea Green, White River.
- National Research Council (NRC), 1996. *The Bering Sea Ecosystem*. National Academy Press, Washington, D.C..
- National Research Council (NRC), 1999. *Sharing the Fish: Toward a National Policy on Individual Fishing Quotas*. National Academy Press, Washington, D.C..
- National Research Council (NRC), 2003. *Decline of the Steller Sea Lion in Alaskan Waters: Untangling Food Webs and Fishing Nets*. National Academy Press, Washington, D.C..
- Norse, E., Crowder, L.B. (Eds.), 2005. *Marine Conservation Biology: The Science of Maintaining the Sea's Biodiversity*. Island Press, Washington, DC.
- North, D.C., 1990. *Institutions, Institutional Change, and Economic Performance*. Cambridge University Press, Cambridge.
- Olson Jr., M., 1982. *The Rise and Decline of Nations*. Yale University Press, New Haven.
- Ostrom, E., 2005. *Understanding Institutional Diversity*. Princeton University Press, Princeton.
- Pauly, D., Christensen, V., Dalsgaard, J., Froese, R., Torres Jr., F., 1998. Fishing down marine food webs. *Science* 279, 860–863.
- Social Learning Group, 2001. *Learning to Manage Global Environmental Risks: A Comparative History of Social Responses to Climate Change, Ozone Depletion, and Acid Rain*. MIT Press, Cambridge.
- Speth, J.G., Repetto, R. (Eds.), 2008. *Punctuated Equilibrium and the Dynamics of US Environmental Policy*. Yale University Press, New Haven.
- Stokke, O.S. (Ed.), 2001. *Governing High Seas Fisheries: The Interplay of Global and Regional Regimes*. Oxford University Press, Oxford.

Walker, B., Salt, D., 2006. Resilience Thinking: Sustainable Ecosystems and People in a Changing World. Island Press, Washington, DC.
Warner, W., 1983. Distant Water: The Fate of the North Atlantic Fisherman. Little, Brown, Boston.
Young, O.R., 1982. Resource Regimes: Natural Resources and Social Institutions. University of California Press, Berkeley.

Young, O.R., 1999. Governance in World Affairs. Cornell University Press, Ithaca.
Young, O.R., 2002. The Institutional Dimensions of Environmental Change: Fit, Interplay, and Scale. MIT Press, Cambridge.
Young, O.R., et al., 2007. Solving the crisis in ocean governance: place-based management of marine ecosystems. *Environment* 49 (May), 20–32.