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PROFILE

Can We Manage for Resilience? The Integration of Resilience Thinking into Natural Resource Management in the United States

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Abstract The concept of resilience is now frequently invoked by natural resource agencies in the US. This reflects growing trends within ecology, conservation biology, and other disciplines acknowledging that social–ecological systems require management approaches recognizing their complexity. In this paper, we examine the concept of resilience and the manner in which some legal and regulatory frameworks governing federal natural resource agencies have difficulty accommodating it. We then use the U.S. Forest Service's employment of resilience as an illustration of the challenges ahead.

Keywords Resilience · Social–ecological systems · Natural resource management · Environmental management · Governance · Agencies

Introduction

Resilience is quickly emerging as a buzzword among natural resource managers. It is important to examine the implications of this development. If resilience is an emergent property of social–ecological systems that should be incorporated into natural resources decision-making, what are the implications for federal natural resource management? By questioning what it might mean to manage for resilience and how the concept interfaces with existing institutional frameworks and management goals, there is an opportunity for more explicit engagement of this important theory within natural resources management. The concept of resilience is an important one. Resilience theory moves society away from previously held assumptions of equilibrium and toward approaches that embrace the complexities of social–ecological systems. Within academia, resilience thinking has been the subject of discussion and research for decades (Holling 1973; Walker and others 2002; Folke and others 2004; Gunderson and others 2010). Natural resource managers are catching up and are beginning to invoke the concept of resilience (see Table 1). This article examines the challenges involved in moving from theory to practice and the ways in which current legal and institutional frameworks in the US will struggle to effectively incorporate resilience thinking. It concludes with a few observations regarding what is needed in order to successfully integrate resilience as a management concept within federal agencies, using the U.S. Forest Service as an example.

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Managing for Resilience

Resilience is an emergent property of complex adaptive systems (Gunderson and Holling 2002). Brand and Jax (2007) have acknowledged differing definitions of resilience and point to the need for increased conceptual clarity in order to maintain the practical relevance of this concept. There are two definitions of "resilience" commonly referred to in the ecological literature. One definition, originally forwarded by Pimm (1991), refers to the ability of a system to return to "balance" in the face of perturbations. Pimm's definition implies that ecological systems

Table 1 Recent examples of natural resource managers invoking the concept of resilience within federal agencies

Federal agency and document source	Management objectives that use the concept of resilience
USDA Forest Service, Interim Directive in Forest Service Manual: Ecological Restoration and Resilience (2009)	The aim [of this directive is to reestablish and retain ecological resilience of National Forest System lands and associated resources to achieve sustainable management and provide a broad range of ecosystem services. Healthy, resilient landscapes will have greater capacity to survive natural disturbances and large scale threats to sustainability, especially under changing and uncertain future environmental conditions, such as those driven by climate change and increasing human uses
US Department of Interior, Fish and Wildlife Service, Strategic Plan for Responding to Accelerating Climate Change for the National Wildlife Refuge System, Draft Vision (2010a)	The protection and management of wildlife refuge lands and waters to maintain biological integrity, diversity and environmental health are critically important to support ecological resilience and facilitate adaptation of fish, wildlife and plants to climate change at landscape scales…. Critical conservation delivery strategies to enhance ecological resilience include maintaining or restoring the ecological integrity of existing conservation units, enhancing linkages and connectivity among units, buffering core areas, identifying and protecting climate refugia, and ensuring adequate representation of our nation's ecological communities in the collective conservation estate. The Service's strategic plan for responding to climate change recognizes that adaptation strategies can be anticipatory or reactive. Anticipatory adaptation manages towards a new climate change-induced equilibrium; reactive adaptation abates the impact by trying to maintain the current condition despite climate change
US Department of Interior, Bureau of Reclamation's Landscape Conservation Cooperatives (2010)	The LCCs will facilitate the development of applied science on climate change and other regional scale stressors. The LCCs will help provide information to resource managers regarding potential impacts of climate change as the partners develop resilience and adaptation strategies (e.g., Reclamation West-Wide Climate Risk Assessments (WWCRA) and Service Priority Species Conservation) for resources in the geographic location. The LCCs will facilitate an on-going dialog between scientists and resource managers to create a mechanism for informed conservation planning, effective conservation delivery, and adaptive monitoring to evaluate the effects of management actions
US Department of Commerce Nation Marine, Fisheries Service, National Oceanic and Atmospheric Administration, NOAA's Next Generation Strategic Plan (2010)	NOAA's vision of the future is one of healthy ecosystems, communities, and economies that are resilient in the face of change. Resilient ecosystems, communities, and economies can maintain and improve their health and vitality over time by anticipating, absorbing, and diffusing change—whether sudden or prolonged. This vision of resilience will guide NOAA and its partners in our collective effort to reduce the vulnerability of communities and ecological systems in the short term, while helping society avoid or adapt to long-term environmental, social, and economic changes. To this end, NOAA will focus on four long-term outcomes within its primary mission

are characterized by one regime, and are thus highly predictable. The alternative definition of resilience, and the one we use for this manuscript, was originally offered by Holling (1973). Resilience (Holling 1973) is the capacity of an ecological system to absorb internal and/or external change while exhibiting a similar set of structures and processes (i.e., remaining within a regime). If an ecological system's resilience is "eroded" the system becomes vulnerable to regime shifts, which involves the system shifting from one regime to another regime characterized by a different set of structures and processes. Regime shifts are indicative of non-linear dynamics, and the weight of the evidence suggests that ecological, and other complex systems exhibit multiple regimes (Garmestani and others 2009a).

The distinction in the two definitions of resilience, and the one which now reflects the state-of-the-art with respect to our understanding of system dynamics (Holling 1973), has very clear implications for natural resource management. Given the increasingly accepted characterization of ecological systems as defined by multiple regimes, sound environmental management is ideally focused upon proactive, rather than reactive actions. By this, we mean that environmental management should seek to characterize the aspects of a system that contribute to the resilience of that system via a suite of methods, rather than relying on simple predictive models that are useful for single-regime systems characterized by linear change. The best evidence indicates that resilience is a self-organizing property in ecological systems that have a diversity of ecological functions, as well as a redundancy of those ecological functions within and across scales (Allen and others 2005). In this sense, resilience provides a way of thinking about what has been described as the "no-analog future" wrought by global climate change (Ruhl 2008). Resilience thinking acknowledges the potential for regime shifts while also

providing a framework for building adaptive capacity within social–ecological systems (Gunderson and others 2010).

Managing for resilience focuses on specific attributes or drivers of complex systems and crafts guiding principles for human intervention to improve long term performance of the systems (Zellmer and Gunderson 2009). Emphasis is increasingly being placed on the resilience of ecological systems as the primary basis for sustainability (Walker and others 2002; Chapin 2009). Particularly within the context of environmental change, natural resource managers are now invoking the concept of resilience as a management goal (see Table 1). For example, when the U.S. Forest Service announced plans to revise its land management planning rule in 2009, it specifically asked for comments on how the agency "could address the need for restoration and conservation to enhance the resilience of ecosystems to a variety of threats," and listed climate change as chief among those threats (U.S. Forest Service 2009).

Before detailing the institutional challenges associated with integrating resilience thinking into management, there are a few observations that need to be made. The first observation is that within the discussion regarding how to build resilience, there is often a privileging of current system states. In other words, there is a tendency to assume that regime shifts are to be avoided. Articulations of resilience require "parsing our systems into the elements that we subjectively consider essential to identity" (Cumming and Collier 2005). In the context of biodiversity, for example, the United Nation's Millennium Ecosystem Assessment (Millennium Ecosystem Assessment, 2005; Altaweel and others 2009) informs us that humans have increased the species extinction rate by as much as 1,000 times over background rates typical over the planet's history and that 10–30% of mammal, bird, and amphibian species are currently threatened with extinction. Resilience thinking recognizes that anthropogenically caused ecological change has negative consequences for the provisioning of ecosystem services and seeks to maintain biodiversity and the self-organizing capacities it embodies. In this sense, environmental management efforts such as the Endangered Species Act (ESA) are in fact statements about specific ecological states. Embedded within those statements is the assumption that we want things to stay the way they are. As will be discussed, the management challenges associated with the privileging of current system states can lead to a problematic "restoration" focus that may be unrealistic given climate change and projected rates of biodiversity loss.

The second observation relates to the importance of acknowledging the critical role of both temporal and spatial scales. The questions "resilience of what and to what" (Carpenter and others 2001) require explicit recognition of the system state being considered and the perturbations of interest. One of the main obstacles to dealing with these questions involves the cross-scale nature of the challenges facing most social–ecological systems (Cash and others 2006). Climate change is a relevant example. As a global phenomenon, it manifests challenges on many spatial scales. From a contribution standpoint, climate change is clearly global in the sense that greenhouse gases created anywhere in the world have impacts everywhere. From an adaptation and mitigation perspective, however, more refined scales are needed to provide meaningful assessment and response. These cross-scale dynamics make it difficult to establish notions of resilience in any tidy way. While the related social–ecological system theory of panarchy contributes to our understanding of cross-scale dynamics (Gunderson and Holling 2002; Garmestani and others 2009a), the challenges of mounting appropriately scaled societal responses for fostering resilience remain (Benson 2010).

Finally, it must be recognized that, from a social and institutional standpoint, resilience is not always associated with functionality or overall system health. An example can be found in the Comprehensive Everglades Restoration Plan (CERP) for the Florida Everglades. Led primarily by the U.S. Army Corps of Engineers, the CERP is one of the largest and most ambitious adaptive management efforts in the US and involves 16 counties over an 18,000-square-mile area of southern Florida. Describing some systems of governance as "pathologically resilient," Gunderson and Light (2006, p. 324) argue that adaptive management and sustainability efforts in the Florida Everglades are failing because the institutions operating within the social system are "pathologically resilient" in the sense that "the management system is trapped in a structure that is not only resistant to change but unable to withstand change." The principles of adaptive management were developed as a vehicle for achieving the integration of resilience into natural resources decision-making (Holling 1978). Adaptive management incorporates the inevitability of scientific uncertainty into management actions involving natural systems. The National Research Council provides the following definition:

> Adaptive management [is a decision process that] promotes flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood. Careful monitoring of these outcomes both advances scientific understanding and help adjust policies or operations as part of an iterative learning process. Adaptive management also recognizes the importance of natural variability in contributing to ecological resilience and productivity. It is not a "trial and error" process, but rather

> emphasizes learning while doing. Adaptive management does not represent an end in itself, but rather a means to more effective decisions and enhanced benefits. Its true measure is in how well it helps meet environmental, social and economic goals, increases scientific knowledge, and reduces tension among stakeholders (Williams and others 2009, p. 4).

An adaptive management approach recognizes that our understanding of natural systems is constantly evolving and reflects a willingness to test our assumptions about the natural environment in order to adapt and learn (Lee 1989, 1993). Successful adaptive management efforts will require that institutions have sufficient space and support for learning and experimentation (Gunderson and Light 2006). As will now be discussed, the current legal and institutional structures for natural resource management often make it difficult to create this space.

Conclusions: Resilience Thinking Within Existing Legal and Institutional Frameworks

Management's Assumptions of Ecological Equilibrium

The integration of resilience theory into natural resource management faces several challenges. First, and perhaps foremost, natural resources laws and regulations in the US currently tend to ignore ecological complexity and instead tend to embody a "preservation paradigm, generally through a focus on minimizing or mitigating destructive human change to ecosystems and species" (Craig 2010). Many of these legal mandates date back to the 1970s and reflect notions of ecological equilibrium that are at odds with a resilience approach (Thrower 2006; Glicksman 2009). In another paper, we discuss the National Environmental Policy Act (NEPA) as a primary example of this problem (Benson and Garmestani 2011). Passed in 1970, NEPA requires all federal agencies to take a "hard look" at the environmental consequences of their actions. The process of taking this hard look has embedded within it the assumption that ecological complexity and social action can be captured through a single, linear process of examination. It also assumes a single, well-defined "agency action" that either does or does not have a significant environmental impact. For this reason, NEPA has been described as a "front end approach" that unrealistically assumes that natural resource managers have both (1) a serviceable knowledge of the ecological system of interest and (2) the capacity to predict the environmental impact of a proposed action before any activity occurs (Ruhl 2005). Without a substantial reconfiguration, NEPA and other management structures will struggle to accommodate resilience (see Benson and Garmestani 2011 for a proposed restructuring).

The ESA provides another example. Passed into law in 1973, the ESA has the stated purpose of providing "a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved" (16 U.S.C. § 1531). It takes the position that extinction is to be avoided at all costs. Management of listed species under ESA results in a preservation focus on achieving the persistence of individual species rather than integrity of ecological systems. As ecological systems change, the diminished capacity of certain listed species to function can create situations in which listed species are "conservation-reliant" in the sense that without ongoing management, the ecological systems cannot sustain them (Scott and others 2005).

These environmental laws drive much of the natural resource decision-making of federal agencies, and the concept of resilience is being thrown like a blanket on top of these and other existing legal mandates. Noting the core assumptions of our environmental laws is important because, while managers might want to embrace resilience on a conceptual level, management directives will inevitably default to the core statutory and regulatory requirements (Benson and Garmestani 2011; Ruhl and Fischman 2010; Benson 2009). Without a more explicit recognition of how resilience thinking challenges many of the assumptions underlying our current legal mandates, the concept will remain on the surface and will fail to actually transform management practices.

Resilience of Both Social and Ecological Systems

The second observation is that, in their discussions on resilience, agencies refer to social resilience and ecological resilience, but rarely both at the same time. In general, there are few explorations of social resilience, particularly by natural resource agencies. While this is understandable, we argue that a willingness to look at both social and ecological resilience together is critical, particularly in the context of formulating responses to environmental change. The social aspect of resilience refers to the capacity of "society" to learn and adapt to change, such as the loss of ecological resilience. Social–ecological resilience then, is the capacity of linked social and ecological systems to absorb as well as adapt to change (Adger and others 2005). Environmental change is already creating and will continue to create stresses on both social and ecological systems (Garmestani and others 2009b). In New Mexico, for example, estimates are that 93% of New Mexico's watersheds have become drier and the timing of the runoff peak is an average of one week earlier than in the mid-twentieth century (U.S. Fish and Wildlife Service 2010), and current

projections indicate these trends will continue. Stanton and Ackerman (2011) predict climate change could increase by 25% the total shortfall of water in the American Southwest over the next century. There will be consequences, both socially and ecologically, related to these shifting patterns. Social resilience will require a reassessment of land use and water consumption strategies. Ecological resilience will include a reassessment of the efficacy of current conservation strategies for imperiled species, including the Rio Grande Silvery Minnow (U.S. Fish and Wildlife Service 2010).

In general, the integration of resilience thinking to date tends to reflect a willingness to manipulate ecological systems, but not social ones. This trend reflects the fact that management takes place within existing legal and institutional frameworks, which tend to bifurcate decision-making between issues that are "social" and those that are "ecological." These parameters are comprised of multiple and often competing authorities and requirements. The operation of Glen Canyon dam provides a relevant example. Interstate water compact obligations, the ESA, and flood control requirements form a complex web of intertwined and often conflicting legal and institutional mandates (Zellmer and Gunderson 2009; Susskind and others 2010). Despite evidence that high flow experiments benefited the endangered humpback chub, ongoing dam operations at Glen Canyon have not been formally changed to incorporate the benefits of these releases due to social implications (Susskind and others 2010). Because many aspects of the social system (i.e., water allocation decision-making) often fall outside of the control of federal agencies, it is difficult to address both the social and ecological aspects of resilience. As a result, it is often ecological systems that have to "give" when manipulation of social systems is outside the jurisdiction of a particular agency.

The Role of Monitoring

The next observation concerns the role of monitoring. As Carpenter and others (2001) note: "a resilient monitoring program needs to invest part of its endowment in a set of indicators that seem likely to be relevant for the foreseeable future and the remainder in explorations of system function that lead to new indicators that may become important under new configurations of the social–ecological system." While some monitoring occurs under current programs, almost all of it falls under the first category (i.e., indicator of obvious and/or immediate relevance) rather than also playing the important role of monitoring for new indicators that will guide the creation of new conceptual models. It is also important to define emergent properties of response variables that are sensitive to resilience (or lack thereof) and then develop a list of those variables that can be monitored efficiently and cost-effectively, as has been noted in coral reef management (Hughes and others 2010). This may be easier to describe than to implement; scholars in other contexts have often lamented the lack of adequate commitment to monitoring (Moir and Block 2001; Karkkainen 2002).

Adaptive management as the application of resilience theory requires monitoring for implementation (Allen and others 2011). In particular, adaptive management identifies uncertainty in potential environmental management policies, and attempts to test and ameliorate that uncertainty via an iterative process that incorporates information from the system of interest via monitoring (Allen and others 2011). By incorporating monitoring data in a structured manner, adaptive management allows for improved understanding, and therefore management of social–ecological systems (Benson and Garmestani 2011). Undoubtedly, new and more institutionalized investments in monitoring are necessary for adaptive management and therefore resilience.

Enforceable Standards

This leads to the fifth observation, which relates to the lack of clearly articulated and enforceable standards for managing for resilience. A tension exists between the need for flexibility and experimentation on the one hand and the need for some specific legal and regulatory grounding on the other. This tension has been explored by others, particularly within the realm of adaptive management (Ruhl and Fischman 2010). There seems to be a general view, particularly within agencies, that informal agency guidance is sufficient to incorporate new management concepts like adaptive management and resilience. But experience tells us otherwise. It is often either litigation or the threat of litigation that places these innovative management strategies on the table in the first place. Without the ESA, the Clean Water Act, and the citizen suits that place rivers, streams, and species under their protection, most of the environmental protections efforts currently under way would not even exist (Nie 2008). Furthermore, litigation is often necessary to create meaningful requirements out of lofty management goals. An example is the "multiple use-sustained yield" standard for forest management. Under this standard, the Forest Service clear-cut 61% of Western forests and 50% of Eastern forests by 1969 (Zaslowsky and Watkins 1994). It took the powerful combination of a university-based scientific report and a legal challenge to give actual meaning to the "multiple use-sustained yield" requirement. Grounding resilience approaches within enforceable regulatory frameworks is likely necessary in order to allow for enforcement actions that would maintain the integrity of the approach (see Benson and Garmestani 2011; Flournoy and Driesen 2010).

Resilience in a No-Analog Future

Our final observation regarding the integration of resilience into federal natural resource management regards the need to more explicitly acknowledge the "no analog future" we face with global climate change (Ruhl 2008). The challenges associated with successfully negotiating social–ecological systems are exacerbated by the realities of environmental change, which will require a willingness to assess what adaptation strategies are capable of in terms of maintaining the integrity of many ecological and social systems. Craig (2010) argues for new management approaches based on "principled flexibility." Unfortunately, many of the current discussions regarding resilience within federal agencies (even those that take on climate change like the new forest planning rule) fail to fully acknowledge that this will require not only attempts to maintain the resilience of existing ecological systems but will also require engagement in what Betancourt (2010) calls the necessity of "managing the products of succession in the context of a changing climate." Emerging scholarship in this arena can guide agencies as they take on these challenges (Tompkins and Adger 2004; West and others 2009; Bardsley and Sweeney 2001; Hansen and others 2010; Lawler and others 2010). But without a more serious and explicit acknowledgement of a no analog future, resilience thinking cannot play its proper role in formulating social–ecological approaches to environmental change.

Example: U.S. Forest Service and Resilience

Perhaps no other federal agency has been more intentional about its integration of resilience thinking than the U.S. Forest Service. Building off of early efforts dating back to 2008, Forest Service Chief Kimbell issued an interim directive for a new title to the Forest Service Manual on "Ecological Restoration and Resilience" in March of 2010. The stated objective of this foundational policy is to "reestablish and retain ecological resilience of National Forest System lands and associated resources to achieve sustainable management and provide a broad range of ecosystem services" (U.S. Forest Service 2010). Ecological restoration is defined by the agency as "the process of assisting the recovery of resilience and adaptive capacity of ecosystems that have been degraded, damaged, or destroyed." In turn, resilience is defined as "the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks." As noted earlier, the agency's recent announcement of a NEPA analysis for its new planning rule reflects this commitment to resilience (U.S. Forest Service 2009).

The Forest Service's approach to managing for resilience illustrates many of the observations made in this article. While the agency embraces the concept of resilience, it ignores the nature in which its primary management authorities—including the Multiple Use-Sustained Yield Act of 1960 and the National Forest Management Act 1976—reflect assumptions of ecological equilibrium and create mandates that direct the agency to "multiple-use, sustained yield" and assume stable ecological systems. While the new directive explicitly acknowledges the fifteen laws and five executive orders that govern the Forest Service, it does not address how those mandates interface with this new management goal. And while the agency does provide an explicit definition of resilience, the incorporation of restoration into that definition is problematic. Restoration tends to reflect a focus on historical conditions and is generally thought of as the attempt to return a system back to some prior "original" state, while resilience is focused on current feedbacks and conditions, and on building adaptive capacity to maintain those processes. Also missing from the Forest Service's discussion is the need to assess social and ecological systems simultaneously. The Forest Service's policy addresses ecological processes almost exclusively, ignoring the related social processes that are within the Forest Service's scope of influence (e.g., grazing permits timber sale contracts, etc.). Nor does the policy address the need for substantial new investments in monitoring and other resources that would be required when managing for resilience. Finally, while the new policy discusses climate change as an important driver for managing for resilience, it does so within the overarching goal of restoration, which may be unrealistic. Climate-induced regime shifts are occurring and will continue to occur, and managing for resilience must include a willingness to explicitly address how management actions will guide the inevitable trade-offs that will occur (Walther 2010).

The intent here is not to single out the Forest Service but rather to highlight the challenges involved with taking on resilience as a management objective. Both the challenges and opportunities associated with managing for resilience are significant. Emerging theories on resilience are providing new ways of thinking about social–ecological systems that not only acknowledge their complexity but also provide a basis for increasing our capacity for learning and adaptation. As federal agencies begin to incorporate this important concept, careful attention should be paid to what managing for resilience will require in terms of institutional reconfigurations and resource investment in order to make it successful. By outlining the limitations inherent in current management configurations and existing legal mandates, we hope to generate a more explicit discussion regarding the implications of integrating resilience thinking into natural resource management.

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