Gunderson, L. H., S. R. Carpenter, C. Folke, P. Olsson, and G. D. Peterson. 2006. Water RATs (resilience, adaptability, and transformability) in lake and wetland social-ecological systems. *Ecology and Society* **11** (1): 16. [online] URL:http://www.ecologyandsociety.org/vol11/iss1/art16/

Insight, part of a Special Feature on Exploring Resilience in Social-Ecological Systems

Water RATs (Resilience, Adaptability, and Transformability) in Lake and Wetland Social-Ecological Systems

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ABSTRACT. The lakes in the northern highlands of Wisconsin, USA, the lakes and wetlands of Kristianstads Vattenrike in southern Sweden, and the Everglades of Florida, USA, provide cases that can be used to compare the linkages between ecological resilience and social dynamics. The erosion of ecological resilience in aquatic and wetland ecosystems is often a result of past management actions and is manifest as a real or perceived ecological crisis. Learning is a key ingredient in response to the loss of ecological resilience. Learning is facilitated through networks that operate in distinct arenas and are structured for dialogue, synthesis, and imaginative solutions to chart alternative futures. The networks also help counter maladaptive processes such as information control or manipulation, bureaucratic inertia, or corruption. The networks help create institutional arrangements that provide for more learning and flexibility and for the ability to change. Trust and leadership appear to be key elements for adaptability and transformability.

Key Words: *resilience, management, social networks, learning; wetlands; lakes; Wisconsin; Everglades; Florida; Sweden;*

INTRODUCTION

Aquatic and wetland ecosystems are among the most productive systems in the world (Daily 1997). They provide services of habitat and water quality improvement as well as goods in the form of fish and fiber. Currently they are also considered important for their recreational and aesthetic values. Continued production of these values is compromised by the loss of ecological resilience.

Ecological resilience in aquatic and wetland systems is defined as the amount of disturbance that the system can absorb without a change in structure and composition (Holling 1973, Carpenter et al. 2001). Ecological resilience is related to slowly changing variables such as soil or substrate nutrient levels, habitat structures, trophic relationships, sea level, and other longer-term climatic factors. This resilience is tested by recurring disturbances in the form of drought/flood cycles, sedimentation, and grazing, among others. The erosion of resilience is a result of human interventions that stabilize ecosystem processes, such as the mitigation of floods and droughts or fires (Gunderson and Pritchard 2002), changes in trophic level interactions (Carpenter 2003), or nutrient enrichment (Gunderson 2001, Scheffer et al. 2001, Beisner et al. 2003, Carpenter 2003).

State changes in ecological components of aquatic and wetland systems have been well documented (Scheffer et al. 2001, Gunderson and Pritchard 2002, Carpenter 2003, Folke et al. 2004). Algae blooms in lakes and certain changes in wetland plant communities are signals of a change in their ecological state and are often perceived as ecological crises (Gunderson et al. 1995, Folke et al. 2004). How the social components of these social-ecological systems have responded in the past to documented state changes or will respond to perceived future changes is a central theme of this paper. Changes in the social components are described as adaptability and transformability (Walker et al. 2004) and are briefly discussed in the following sections.

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Adaptability, transformability, and learning

Adaptability and transformability are related terms that contrast degrees of change in social-ecological systems. Adaptability is the capacity of the social components in a system to manage ecological resilience (Walker et al. 2004, 2006). Human actions influence resilience, either intentionally or unintentionally (Berkes et al. 2003, Scheffer et al. 2003), and can focus on maintaining a system within a desired regime that provides necessary ecosystem goods and services or restoring the system from an undesirable regime into a desired one. Transformability is the capacity to create a fundamentally new system configuration (Walker et al. 2004). Social-ecological systems can be transformed in response to the recognition of the failure of past policies and actions, signaled by a resource crisis or driven by shifts in social values (Gunderson et al. 1995, Olsson et al. 2004)

Social adaptability and transformability are complex self-organizing processes that involve interactions among key actors in the system, knowledge and understanding of the system, and the provision of conditions or opportunities for change (Folke et al. 2002). At least four components appear necessary for adaptability and transformational change. One of these components is the development and maintenance of open and flexible epistemic networks (Gunderson et al. 1995, Berkes and Folke 1998, Olsson et al. 2004, Folke et al. 2005). Another component is the roles of different types of learning, through the development of either scientific activities or other forms of social learning (Walters 1997, Fazey et al. 2005). The third component is an arena for discourse, suggesting that, although networks and learning are critical components, no changes will occur unless the network participants have a place to meet and foster learning. The final component is the fostering of trust through leadership.

Objectives

The goals of this paper are modest. Our first goal is to compare how three ecologically similar water-based social-ecological systems have responded to declines in ecological resilience. These three systems are the lakes in the northern highlands of Wisconsin, USA; the lakes and wetlands of Kristianstads Vattenrike in southern Sweden; and the Everglades of Florida, USA. Some systems may not respond to losses of resilience at all because of ignorance, including the inability to detect such losses, or a perceived lack of consequences. In this comparison, we focus on systems that have responded, and on the learning component of those responses in particular. This is an exploratory comparison, and as such is not a rigorous testing of hypotheses. Rather, it is an attempt to compare and contrast these systems in terms of differences in social structures and dynamics. We focus on a few key elements, such as the shape and form of epistemic networks (Haas 1992) and the role networks and key actors play in fostering different types of learning in adaptations and transformations. These correspond roughly to Propositions 11 and 12 in Walker et al. (2006).

The social-ecological systems are described more fully in Walker et al. (2006). We will not reiterate the basic components in this paper, but refer the reader to this reference for more information. A brief synopsis of the current status of these systems is summarized in Appendix 1. These systems have ecologically similar characteristics but very different social arrangements, as described in the next section.

CASE CONTRASTS

All three of the systems currently provide a variety of ecosystem goods and services around which social systems have organized with concomitant sets of expectations. In Wisconsin's Northern Highland Lakes District, the ecosystem provides clean water, water renewal, food, forest products, carbon sequestration, hunting, fishing, many other forms of recreation, and cultural values related to aesthetics, education, and spiritual renewal. Similar services are provided by the Everglades, with an emphasis on recreation and ecotourism. In Sweden's Kristianstads Vattenrike, eco-tourism, recreation, water quality improvement, and flood control are services provided by the wetland, and goods of hay and cattle are produced and harvested as well.

The social systems in the three cases are very different with respect to their components, complexities, and degrees of connectedness. Details appear in Walker et al. (2006), and key contrasts are developed in the following sections of this paper.

THEMATIC COMPARISONS AMONG THE SOCIAL-ECOLOGICAL SYSTEMS

Social-ecological networks

In this paper, we use the term "social-ecological network" to describe the set of actors or network nodes, and we use their linkages or ties to describe the structure of the groups engaged in resource management, borrowing from Wasserman (1994) and Schusler et al. (2003). The actors may be governmental agencies, stakeholders, associations, or private interests, all of whom either directly influence or execute polices that influence the ecological state of the system. Many metrics, such as structural or functional diversity or complexity, can be used to describe aspects of social networks. Although these aspects are important, we suggest that other characteristics may be more important to managing for ecological resilience. At least two key characteristics of networks provide ecological resilience: (1) openness and (2) formality of institutions. Openness is the degree of connection with groups outside of the region of the managed system. Formality reflects the degree of flexibility in the extant institutions such as organizations, rules, and norms. These characteristics of each case are discussed next.

The management network in Kristianstads Vattenrike (KV) is characterized as a flexible organization (Olsson et al. 2004). This flexibility involves creating interactions among actors, including cross-scale linkages to deal with change and emerging challenges. This dynamic process forms ad hoc organizations that are in place only as long as the problem exists (Hahn et al., *in press*). The Ecomuseum Kristianstads Vattenrike (EKV), a bridging organization (Folke et al. 2005), orchestrates this process, with different clusters of actors taking on different decision-making roles. It is a process that can be envisioned as pulsing collaboration in active responses to change.

The Everglades network is a large, complex network composed of government agencies at the federal, state, and local levels as well as nongovernmental agencies that represent environmental and agricultural interests. The Everglades network has a high institutional diversity both numerically and functionally. The network is dominated by government agencies and formal policies. As such, it has developed into a formal, closed network in spite of infrequent efforts to create more openness, including the creation of the Everglades Coalition in 1984 and the Everglades adaptive environmental assessment process in the early 1990s. After each of these attempts to create a more open system, the system became even more insular and self-sealing. Because of the number of components in the network, it has a very complex management structure. Associated with the complex network are high transaction costs because of the number of components; in addition, extensive coordination is required, and there is a high degree of inertia. All of this leads to strong pressures to maintain the status quo (Light et al. 1995). In spite of the cross-scale structure of the network, a large amount of filtering of information and compartmentalization of communication occurs.

The social networks in the NHLD can be characterized as sparsely populated and very open. Few or no formal connections exist among stakeholders, public agencies, and other private commercial and conservation interests. The network has lots of centers or nodes, with little coordination and only sporadic connections or ties. Only one institution, the Wisconsin Department of Natural Resources (WDNR), can be characterized as closed. Its role is diminishing because of budget and staff cuts. Few formal channels exist among state and federal agencies or individuals. No strong cross-scale institutional connections exist as such. Because the system is open, new dialogues (Peterson et al. 2003) can easily be conducted.

These three systems cover a range of network types. The Everglades represents a formal, closed system. The network is in a rigidity trap, in that it creates large, explicit rules and regulations about who is in the network and how the members interact. The KV network is much more flexible, with a combination of formal and informal relationships. As such, it seems to be more adaptive to resource and governance issues. The NHLD is an open, informal network. It may be close to a poverty trap, too underconnected to evaluate and disseminate information and innovations. Each of these types of networks influences learning in different ways, as described in the next section.

Learning and adaptability

Panarchy theory (Gunderson et al. 1995, Gunderson and Holling 2002) was proposed as a theory of cross-scale dynamics in coupled ecological and social

systems, and it describes categories of change in social components responding to ecological changes. These categories include gradual change, e.g., human responses to ecological changes that do not involve a regime shift; adaptive change, i.e., the ability of social components to respond to shifts in ecological regimes; and transformative change of both social and ecological components into new regimes. Each of these categories suggests different forms of learning (Yorque et al. 2002)

We broadly define learning as the process of proposing conceptual models, then testing those models through empirical observation. This model of learning has been mapped or translated to resource management. Policies are created from conceptual or mental models, tested through management actions, and evaluated through monitoring and study, a process described as adaptive management by Holling (1978) and Walters (1986). Experience with adaptive management (Gunderson et al. 1995) shows that at least three types of learning occur in social-ecological systems: incremental, lurching, and transformational.

Incremental learning occurs as plans, models, and policies are implemented and evaluated. Models or schemas are assumed to be correct, and learning is characterized by collecting data or information to update those models. In bureaucratically dominated resource systems, the learning is carried out largely by self-referential professionals or technocrats, who view dealing with this type of change and learning mainly as problem solving (Westley 2002). Passive forms of adaptive management promise this type of learning.

Episodic learning is discontinuous in time and space. It can be generated by ecological regime shifts that reveal the inadequacies of the underlying models or policies. This type of learning occurs after environmental crises in which policy failure is undeniable (Gunderson et al. 1995). In this case, the learning is described as double-loop, in which the underlying model or schema is questioned and rejected (Argyris 1977). This is also characterized as problem reformation. In bureaucratic resource systems, this type of learning is facilitated by outside groups or charismatic integrators (Blann et al. 2003).

Transformational learning is the most profound form of learning. Cross-scale surprises or the emergence of novelty characterize this type of change. In these cases, learning requires the reframing of problem domains (Westley 2002). Transformational learning involves several levels in a social-ecological panarchy, not simply one level of a social system responding to ecological surprises.

This typology of learning in the context of resource management has similar constructs from other disciplines. Argyris (1977) describes incremental and adaptive learning as single-loop learning, in which existing schema or mental models are updated by observation and experience. He refers to transformational learning as the confrontation of underlying assumptions, norms, and objectives and to subsequent changes in mental models and meaning as double-loop, a model that was applied by Blann et al. (2003) to ecosystem management. Olsson et al. (2004) illustrate how knowledge about ecosystem management in southern Sweden, generated through local innovation and practice as well as through external experiences and contacts, can lead to adaptive and transformational learning. Parson and Clark (1995) describe transformational learning as evolutionary learning, with new species of ideas emerging from the failure of other ideas.

In the following paragraphs, we describe how this typology corresponds with the patterns of learning in the study cases.

All of the research and monitoring in the Everglades is funded by government management agencies. Consequently, the focus of the research is on understanding key ecosystem processes and improving management efficiency. A lot of monitoring of the system has occurred, which has resulted in a slow accumulation of knowledge about how the system operates. Although lots of money has gone into studies of the system by scientists over the past five decades, social learning seems to occur only during periods of policy crisis. One reason why learning is slow is because the science does not pursue novel, unknown areas that could objectively evaluate policy effects. Instead, the agencies filter the type of work done through funding schemes that do not foster the development of the sort of broad, integrative studies that might bring their policies into question but instead channel the available funding into studies that reinforce existing dogma. The Everglades is a system that funds merely the

accumulation of information, not the generation of understanding and knowledge that is characteristic of learning.

The Everglades provides a good example of the difference between learning and monitoring. The mangers, primarily the South Florida Water Management District, have an impressive state-of-the-art monitoring system that can determine water levels throughout the system in almost real time. This monitoring information is used to make short-term decisions about moving water around the landscape to compensate for too much or too little rainfall. Nevertheless, the history of the system indicates that major changes occur only when environmental crises allow for the unlocking of political relationships (Light et al. 1995). Moreover, active experimentation is suppressed, partly because of latent and unresolved power relationships among stakeholders (Gunderson 1999). So, in spite of large fiscal resources and a coordinated management framework, the management system focuses on short-term monitoring and only reluctantly goes through long-term learning cycles when external variability intersects with internal vulnerabilities.

Although the Everglades system appears to discount active learning through experimentation, the NHLD has a lot of structured learning. Many groups, from the WDNR to university consortia and local tribes, actively engage in experimentation. This includes whole-lake manipulations, experimental management regimes, comparisons of contrasting systems selected from among the regions 7600 lakes, and long-term federally sponsored research. These provide spatially scattered but plentiful loci for learning about complex ecological dynamics and a diverse set of stakeholders who are actively engaged in learning. It is within such a distributed framework that many discussions about a wide range of alternative futures can be generated (Peterson et al. 2003)

The EKV continuously conducts inventories to increase ecosystem knowledge and fine-tune management practices and associated institutional and organizational structures to the dynamics of the ecosystem. The EKV also provides an arena for collaboration and learning. The EKV was created by a key individual who believed that the complexity of the issues of managing the wetland ecosystems of the lower Helgeå River catchment required a coordinated effort involving a range of stakeholders at different levels of society and representing a variety of interests. Regular meetings of a reference group established within the nature conservancy section of the EKV are meant to forestall conflict and in this way produce mechanisms for conflict management. Depending on the type of problem arising in Kristianstads Vattenrike, the relevant stakeholders are gathered by the EKV to be part of the process of solving the problem and building experience (Hahn et al., *in press*). The EKV acts as a facilitator in this arena. The stakeholders are part of the planning, implementation, monitoring, and evaluation phases of the learning process, and management practices emerge and are revised through this process.

In all three areas, active learning while carrying out ecosystem-based management involves coordinating information flows, initiating collaborative processes, and pursuing knowledge and understanding. In two systems, the Everglades and the EKV, adaptive learning was initiated with the recognition of ecological crises that signaled the loss of resilience. In the NHLD, much small-scale experimentation has occurred, preparing the way for transformational learning. Transformational learning occurs when new ideas, concepts, and paradigms are sufficiently tested and adopted to create new management activities. These new ideas are usually generated from new visions, scenario building, questioning of existing assumptions, mental models, and integrative syntheses of existing ideas. In all places, however, a crucible is needed to propose, test, and communicate these ideas. Such arenas are described in the next section.

Arenas for discourse

Arenas provide for collaboration on the generation and testing of new ideas. The case studies provide a stark contrast in how arenas for discourse are created and used. The Everglades has tried to formalize these arenas throughout the years, as shown by the creation of the Soil and Crop Society in the 1940s, the Everglades Research Center in the 1970s, the Everglades Coalition in the 1980s, and the National Academy of Science Panel in the 1990s. Although these formal arrangements provide a structure for communication and collaboration, they rarely seem to lead to transformational learning. In the Everglades, transformational learning was led by individuals such as Marjorie Stoneman Douglas, Art Marshall, and Buzz Holling

at key points in time following ecological crises. In contrast, the NHLD is open and diffuse, which allows for unfettered and wide-ranging discussions among scientists and stakeholders. The KV has an ongoing program of adaptive co-management and provides the arena for integrating science, policy, and management actions.

Universities such as Stockholm University in the Swedish case, the University of Wisconsin in the NHLD, and the University of Florida in the Everglades have and continue to play a key role in providing arenas for discourse and structured learning. In Sweden, this new arena was the creation of the EKV, established to expand management structures to meet the new challenges of matching social and ecological dynamics. This type of expansion is needed when prevailing management structures became insufficient to address functional links in the landscape, e.g., between sandy grasslands and wet grasslands. Although the aim was to manage the lower Helgeå River catchment, much of the focus has been on the Ramsar Convention Site. The next step in expanding management is the establishment of a Man and Biosphere (MAB) Reserve that could provide an opportunity to address social-ecological dynamics at other scales. The preparations for implementing a MAB area started with knowledge accumulation thorough inventories of, for example, the sandy grasslands. In the Everglades and the NHLD, years of funded research through universities helped increase knowledge about the dynamics of their respective ecosystems. Universities are also key arenas for the integration of that knowledge into existing institutional and organizational management structures and processes for ecosystem management.

Although arenas are required for adaptability and transformability, by themselves they are not enough. A key element of adaptability and transformability is the emergence of leaders, as described in the next section.

Trust and leadership

Trust and leadership were found in two of the case studies to be key ingredients of adaptive capacity and transformational learning. Trust is needed to keep information flowing, to adapt to changing circumstances and knowledge, and to provide the social capacity for confronting unknowns in these complex systems. One of the key functions of leadership is to foster and maintain trust in the social network. It is the oil that keeps the network lubricated. Another key function of leadership is to integrate social and ecological understanding. Leadership is decentralized in the NHLD. If leadership were to emerge at the scale of the district, e.g., through a coalition of lake associations with tribal governance, it could have a catalytic impact on change in the region. Examples of region-wide leadership, through the actions of an individual or a small group who developed trust and integrative understanding, were present in Kristianstad and the Everglades.

In Kristianstad, one individual played a particularly significant role in creating and shaping the organizational change by forming the EKV (Olsson et al. 2004). He started a dialogue with other concerned individuals and groups and initiated a social network as a response to ecosystem change. He compiled existing ecosystem knowledge and experience found within the network into a project proposal and linked people and ongoing projects in the area. He also provided overall goals and vision in a holistic approach to wetland management and used a window of opportunity to convince political decision makers of the need for a new organization and improved management of the wetlands. This steward coined the term Kristianstads Vattenrike (the rich wetlands of Kristianstad) and developed and realized the idea of the EKV of which he is also the director (Olsson et al. 2004).

The social-ecological memory resides in the individuals who are part of the epistemic or policy communities that have formed around KV projects. These networks represent not only knowledge but also an infrastructure of social norms and a memory of conflict resolution. Historical archives are important sources of social-ecological memory, and the EKV uses them to give meaning to present-day ecosystem management. Several local individuals, representing different organizations, observed a continuing decline in natural and cultural values despite the fact that the wetlands of the lower Helgeå River had become a Ramsar Convention Site. In particular, they observed declining bird populations, eutrophication and overgrowth of lakes, and a decrease in the use of wet grasslands for haymaking and grazing.

Leaders in KV have initiated processes that are essential for ecosystem management. These individual actors serve as key players in institution

building and organizational change in relation to ecosystem dynamics and facilitate horizontal and vertical linkages in an adaptive co-management process (Olsson et al. 2004). The work of the director of the EKV in linking people and activities was part of the strategy to create social networks that draw on several sources of knowledge, solve complex problems, and stimulate engagement in adaptive co-management of the wetland ecosystems. This strategy involved writing proposals and initiating a trust-building process that was important for mobilizing the people in these networks and creating vertical and horizontal linkages.

In the Everglades, leaders have emerged following ecological crises to resolve the crisis and restore trust. In 1971, the state governor convened a symposium in response to a drought that threatened the capacity of the water management system to provide enough water. John DeGrove led the symposium, which integrated understanding and successfully led the implementation of a plan to create a new management agency, the South Florida Water Management District (Light et al. 1995). In 1992, the Everglades management network was in the middle of a protracted lawsuit related to a loss of ecological resilience that was associated with nutrient enrichment. The federal government had sued the state government over its failure to enforce water quality standards, which resulted in a degradation of federal resources (John 1994). The lawsuit indicated a loss of trust among management agencies. Timer Powers, the director of the South Florida Water Management District, brought together the embattled stakeholders and resolved the lawsuit. The key to settlement was the adoption of an ecosystem restoration plan, which originated in the epistemic network organized to synthesize understanding (Davis and Ogden 1994).

The capacity to deal with the interactive dynamics of social and ecological systems requires an entire network of interacting individuals and organizations at different levels that create timely links around relevant issues (Westley 2002). The social networks in KV are fundamental to managing ecosystems and dealing with uncertainty and change; the key individuals in these networks establish functional links within and between organizational levels in times of change and facilitate the flow of information and knowledge applied in the context of local ecosystem management. Key individuals also play an important role in making sense of and managing knowledge, synthesizing a variety of data into a coherent collective narrative (Westley 2002, Folke et al. 2005).

CONCLUSIONS

Learning appears to be a key ingredient for adaptive and transformative capacity in social-ecological systems. Transformational learning is fostered by open social networks that link ecosystem understanding across social and ecological scales. Transformations rely on social-ecological memory and understanding and are limited by social legacies and key vulnerabilities that determine ecological resilience. Open institutional arrangements, both within a system and to linkages outside the system, provide for more flexibility and learning. To learn and innovate, systems must be open and tolerant of failure. Every failure is full of learning successes. The key to transformational learning is to know what to keep, e.g., memory, experience, and wisdom, and what to discard. Closed institutional systems such as the Everglades appear to change only when forced to by social or ecological crises, because their primary focus is on insulating themselves, filtering information, and maintaining existing theories and paradigms. Open flexible systems such as the Northern Highlands Lake District and Kristianstads Vattenrike show tremendous capacity for learning despite much more limited resources. They appear to be willing to take risks and to tolerate and learn from mistakes, and they know that they must focus on learning to maximize the use of their meager resources.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/vol11/iss1/art16/responses/

Acknowledgments:

We thank all of our colleagues at the Kristianstads meeting of the Resilience Alliance for their thoughtful input. This work was supported by the Resilience Alliance and the Emory University Institute for Comparative International Studies, which provided travel grants to the two workshops that produced this work.

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Appendix 1. Potential Futures--Vulnerabilities, Trajectories, Transformations

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