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Insight, part of Special Feature on Adaptive Management

Resilience, Flexibility and Adaptive Management - - Antidotes for Spurious Certitude?

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ABSTRACT

In many cases, a predicate of adaptive environmental assessment and management (AEAM) has been a search for flexibility in management institutions, or for resilience in the ecological system prior to structuring actions that are designed for learning. Many of the observed impediments to AEAM occur when there is little or no resilience in the ecological components (e.g., when there is fear of an ecosystem shift to an unwanted stability domain), or when there is a lack of flexibility in the extant power relationships among stakeholders. In these cases, a pragmatic solution is to seek to restore resilience or flexibility rather than to pursue a course of broad-scale, active adaptive management. Restoration of resilience and flexibility may occur through novel assessments or small-scale experiments, or it may occur when an unforeseen policy crisis allows for reformation or restructuring of power relationships among stakeholders.

KEY WORDS: active learning, adaptive management, AEAM, ecological resilience, flexibility, Florida Everglades, policy crisis, restoration, stability domain, stakeholders, surprise, uncertainty.

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INTRODUCTION

Resource managers constantly grapple (explicitly and implicitly) with uncertainty. One approach is to assume most uncertainty away, as is seemingly the case indicated by current U.S. Secretary of the Interior Bruce Babbitt's recent promise of "no surprises" in resource policies for endangered species (Reichhardt 1997). Another approach is to seek spurious certitude, that is, to break the problem or issue into trivial questions spawning answers and policy actions that are unambiguously "correct," but, in the end, are either irrelevant or pathologic. Perhaps the most common solution is to replace the uncertainty of resource issues with the certainty of a process, whether that process is a legal vehicle -- such as a new policy, regulation, or lawsuit (Rodgers 1997)-- or a new institution -- such as a technical oversight committee or science advisory committee. Yet another solution is to confront the uncertainties, a central tenet of Adaptive Environmental Assessment and Management or AEAM.

Adaptive management has been promulgated as an integrated, multidisciplinary approach for confronting uncertainty in natural resources issues (Holling 1978, Walters 1986). It is adaptive because it acknowledges that managed resources will always change as a result of human intervention, that surprises are inevitable, and that new uncertainties will emerge. Active learning is the way in which the uncertainty is winnowed. Adaptive management acknowledges that policies must satisfy social objectives, but also must be continually modified and flexible for adaptation to these surprises. Adaptive management therefore views policy as hypotheses; that is, most policies are really questions masquerading as answers. Because policies are questions, then management actions become treatments, in an experimental sense. Although some learning occurs regardless of the management approach, adaptive management is structured to make that learning more efficient, although this is questioned by some authors (McLain and Lee 1996). Walters (1997) gives an excellent review of the lessons of AEAM, indicating successes in technical approaches and transformation of understanding, but he also outlines serious shortcomings in resource management institutions.

The central proposition of this paper is that the successes and failures of AEAM are intertwined with system properties of flexibility and resilience. In a nutshell, if there is no resilience in the ecological system, nor flexibility among stakeholders in the coupled social system, then one simply cannot manage adaptively. To develop this proposition, the remainder of this paper is structured in three parts. The first section presents some background on surprises and resilience, a central tenet of AEAM. The second contains an overview of lessons from applying the AEAM process in the Florida Everglades, United States, highlighting successes and failures. The final section highlights some obstacles and opportunities for future development of AEAM. First, I'll revisit some of the concepts that have been key ingredients in the gumbo of AEAM.

SURPRISE, RESILIENCE, AND FLEXIBILITY

In co-evolving systems of humans and nature, surprises are the rule, not the exception. Indeed, failures of policy and surprising ecosystem behavior characterized all of the case studies chronicled in Gunderson et al. (1995). A surprise in this context is a qualitative disagreement between observations and expectations, when an ecosystem behaves in an unexpected manner. In a weak typology, surprises can be characterized as local, cross-scale, and true novelty (Brooks 1986, Gunderson et al. 1997).

Local surprises are created by broader scale processes for which there is little or no previous local knowledge. These have been described as teleconnections, whereby spatially distant processes affect local dynamics. An ecological example of this is the connections between climatic fluctuations in the southeastern United States and the El Niño/Southern Oscillation (ENSO). When El Niño (actually a large mass of warm water in the Pacific Ocean), is active, the southeastern United States experiences warm, wet winters and fewer hurricanes during the summer. A local surprise can be resolved by a broader scale of observation, and an historical accumulation of knowledge.

Cross-scale surprises are similar to a local surprise, but differ in that the larger scale fluctuation intersects with slowly changing internal variables to create an alternative stable (local) system state. These are perhaps the most common and controversial types of surprises, and are often the source of policy crises (Gunderson et al. 1995). Two such southern Florida examples include the surprising vegetation shifts (from sawgrass to cattail) in the Everglades during the early 1980s, and the seagrass dieoffs and changes in water clarity in Florida Bay during this decade. Both examples include spatially contagious processes, such as fire, or seagrass dieoff, in which the process is an interaction between "fast" variables (ignition sources in fires, salinity variation in seagrass) and "slower" variables (fuel loads in fires, nutrient levels or biomass of seagrass beds). These types of interactions for qualitative shifts in stability domains of resource systems have been described by Walker et al. (1969), Scheffer et al. (1993), and Carpenter and Cottingham (1997).

The final type of surprise is genuine novelty -- that is, something truly unique, in which new variables and processes transform the system into a new state. In these surprises, little or no experience exists for either understanding the transformation or structuring management actions. In resource systems, examples of this type of surprise include invasions by exotic species such as Myrica faya in Hawaii (D'Antonio and Vitousek 1992) or Melaleuca quinquenervia in Florida (Myers 1983). Other examples include land use transformation, management structures (dams), or new technologies.

These surprises and corresponding policy crises are intertwined with the concept of ecological resilience. Resilience has been discussed at least two different ways in the ecological literature, each reflecting different assumptions of equilibria and dynamics. Holling (1973) first drew attention to these differences in outlining the tensions between efficiency and persistence, between constancy and change, and between predictability and unpredictability. The more commonly used definition of resilience assumes that ecological systems operate at or near a global equilibrium. Hence, resilience is the ability to return to an equilibrium following a perturbation; it is quantified in terms of return time (Pimm 1984, O'Neill et al. 1986, Tilman and Downing 1994). This definition focuses on efficiency, constancy, and predictability (Holling 1996). The other definition emphasizes conditions with more than one stable equilibrium, where instabilities can flip a system into another regime of behavior, i.e., to another stability domain (Holling 1973). In this case, resilience is measured by the magnitude of disturbance that can be absorbed before the system redefines its structure by changing the variables and processes that control behavior. The second definition has been used to describe the dynamics of multiple-equilibria behavior of a variety of ecosystems, including freshwater rivers (Fiering 1982), freshwater lakes (Scheffer et al. 1993, Carpenter and Cottingham 1997), forests (Ludwig et al. 1978), fisheries (Walters 1986), semiarid grasslands (Walker 1981), and interacting populations (Dublin et al. 1990, Sinclair et al. 1990).

The heart of these two different views of resilience lies in whether or not the existence of multistable states is assumed. If it is assumed that only one stable state exists or can be designed to exist, then the only possible definition and measures for resilience are near-equilibrium ones, such as characteristic return time. That is certainly consistent with the engineer's desires to make things work, not to intentionally make things that break down or suddenly shift their behavior. But nature is different.

Take the example of nutrient enrichment in the Florida Everglades. The Everglades is an oligotrophic wetland, limited primarily by phosphorus. For the past 5000 years or so, the ecosystem effectively self-organized around this low nutrient status, pulsed by annual wet/dry cycles and by nutrient recycling associated with fires that occurred on time scales of decades (Loveless 1959, Craighead 1971, Gunderson and Loftus 1994). The resulting landscape mosaic had small areas of enhanced nutrients or eutrophy in tree islands that were maintained by wading bird nesting, or in local refugia maintained by the cycles of flooding and drydowns that first collected diffuse energy and then concentrated it locally. The remainder of the landscape (sawgrass marshes and wet prairies) adapted to low nutrient thresholds (Steward and Ornes 1975).

In the late 1940s, a plan was put into effect that divided the Everglades into three designated land uses (Gunderson and Loftus 1994): agriculture (in the northern one-third of the historic Everglades), urban (the eastern one-fifth), and conservation of resources, including water (in the southern and central remaining one-half of the historic system). The latent effects of these land use designations were revealed in the late 1970s and early 1980s, when large-scale shifts in vegetation were noticed in the areas immediately south of the agricultural area. After years of research, the transition from a sawgrass to cattail-dominated marsh was attributed to an increase in water and soil phosphorus concentrations (Davis 1994). In most cases, a disturbance such as drought, freeze, or fire was followed by a shift in species dominance from sawgrass to cattail. Because the phosphorus was associated with runoff from agricultural fields, the resulting management options involved economic, human, and ecological variables. At the time of this writing, plans are underway to only allow clean water to reach the areas of the Everglades set aside for conservation, but little focus has been directed to management options for the areas where resilience has been exceeded and the vegetation community has changed from one stability domain to another.

When shifts occur between alternative states or conditions, they are usually signaled as a resource crisis. Using the previous typology of surprise, the nutrient crisis is a cross-scale surprise, in which slowly changing internal variables interact with externally driven variables, leading to a loss of resilience (sensu Holling 1973). In the freshwater Everglades, the external climate variation creates a set of disturbances (dry periods, freezes, or fire) that intersect with a slowly accumulating concentration of phosphorus (as one mechanism for the switch in stability domain). If these shifts in stability domains are viewed as a crisis, then understanding how and why people choose to react is key to managing for resilience.

When faced with shifting stability domains and corresponding crises, management options fall into one of three general classes of response. The first is to do nothing and wait to see if the system will return to some acceptable state, while sacrificing lost benefits of the undesirable state and often spending lots of money on piecemeal research. The second option is to actively manage the system and try to return it to a desirable stability domain. The third option is to admit that the system is irreversibly changed and, hence, that the only strategy is to adapt to the new, altered system. The resilience of the system provides the ability to cope or adapt in a world characterized by crises and shifting stability domains, and for managers to affordably fail and learn, as outlined in the following section on lessons gleaned from applying the AEAM process in south Florida.

AEAM IN THE EVERGLADES: ASSESSMENT AND NO MANAGEMENT

In the Everglades of Florida during the late 1980s, there was a growing sense from a small technical group that an integration of understanding was needed to help resolve chronic resource issues. The group had decades of experience as researchers or resource practitioners, and each understood various pieces of the system. The group hoped that a major synthesis of those disparate pieces of understanding would help to develop policies to reverse degradation of a variety of resource issues: declines in wading bird nesting populations, changes in vegetation patterns due to nutrients and water management, changes in aquatic communities, declines in fisheries, increases in populations of exotic organisms. At the time, the resource management agencies seemed more intent on directing lawsuits at one another than at serious consideration of ecosystem restoration. Discussions regarding ecosystem restoration emerged with the design of a symposium in 1989 to start integrating these various understandings.

Prior to the symposium, Carl Walters and Buzz Holling were invited to help integrate and synthesize pieces of the system. They applied the techniques of adaptive assessment and brought in a modeling team. Over a 2.5-yr period, a dozen workshops were held, involving about 50 technical professionals, mostly biologists and hydrologists. These workshops transformed the understanding of management for the system, a vision that persists to date. At the heart of developing that shared vision was a controversial computer model (Walters et al. 1992).

The Everglades AEA model was developed to simulate spatial and temporal dynamics of key ecosystem components. Submodels were developed for hydrologic dynamics, and a set of ecological interactions. Interactions among the hydrology and vegetation, aquatic organisms (fish and invertebrates), alligators, and wading birds were all modeled. The hydrology submodel became sufficiently credible because of its ability to recreate historical patterns and its application to a subregion, a Water Conservation Area. The ecological submodels were not credible, because the ecological processes that occur on a finer spatial and temporal scale could not be readily aggregated to the scale of the hydrologic model. The lessons from failures of the ecological submodels led to development of new models, based on aggregating individual dynamics (DeAngelis et al. 1998). However, the credibility and generalizability of the hydrology model led to its use in screening policies to identify a subset of policies that deserved a more searching evaluation in terms of feasibility and effectiveness, using other models and other analyses (Walters et al. 1992, Walters and Gunderson 1994).

The major conclusion of this informal, collaborative effort was that enough was known about the Everglades ecosystem to begin restoration and attempt a holistic resolution of chronic issues (Walters et al. 1992, Davis and Ogden 1994, Walters and Gunderson 1994). Most of the competing hypotheses regarding resource degradation (changes in vegetation, wading bird nesting, etc.) were linked to changes in either the quantity or quality of the hydrology (Walters et al. 1992). Therefore, the restoration assessment focused on new arrangements of the hydrology that would recreate historical patterns of flow, depth, and water quality. Those hydrological changes would provide the flexibility to test competing ecological hypotheses. The group found that tinkering with existing structures and operating policies (such as alteration of the regulation schedule within one management unit) would not be enough to insure restoration. Neither would singular, quick-fix structural solutions (such as removal of a single levee or insertion of a single weir). However, composite policies could be devised to meet restoration objectives and test hypotheses of resource declines. That is, integrated sets of structural and operational changes can be devised to satisfy restoration goals and provide alternative uses for water. Moreover, the group found more than one set of composite policies, so the region would not be dependent on one set of unforgiving policies. The understanding that was generated was instrumental in building a vision around which ecosystem restoration could begin. So, in a sense, the assessment phase of AEAM was dramatically successful, whereas the management phase never got off the ground.

A transforming assessment

In the Everglades, the AEA assessment transformed understanding of the system and created a new vision for ecosystem restoration (Light et al. 1995). That vision was developed by a core set of individuals, or camarilla (Holling and Chambers 1972). The group was made up of six people, each having technical roles in management agencies and academic institutions. All members were willing to look outside their institutional boundaries in a search for solutions. This small group had a very informal relationship, but used the interaction, along with their individual understanding of the system, to help build an integrated strategic overview. The camarilla took that integrated overview and developed a wider, shared vision in two stages, as described in the following paragraphs.

The first stage involved compressing and translating the technical understanding into a format understood by a broader audience. That translation was done in two formats. One was to produce a computer "movie" or animation of water dynamics in the Everglades system. That movie was made using output from the computer model mentioned previously, recreating a 28-yr period of seasonal, annual, and decadal fluctuations of water depths. The movie showed a dynamic complexity of hydrology under the current management regime, and how that complexity had changed when compared to a baseline or "natural" hydrology (how the hydrology would have looked without the current set of levees, canals, regulation schedules, etc.). The movie created a metaphor of the Everglades hydrology as a human "beating heart," indicating the rhythms created by multiple scales of rainfall inputs in an expanding and contracting pattern of wetting and drying. Another method used to capture and expand understanding was the creation of "fact" sheets: one-page documents discussing what is known and not known about a key issue. Such sheets were written for issues of water quantity, water quality, changes in landscape vegetation patterns, and wading bird nesting declines, among others. Each of these formats attempted to distill understanding for use in communicating options and opportunities to a wider audience.

Communicating that understanding to a wider audience was the second stage of transforming the AEA assessment. That communication was done in two rounds, first as individual meetings with board members of the South Florida Water Management District, and then in a workshop called the Everglades Restoration Colloquy. That workshop was attended by a wide set of stakeholders: federal, state, and county governmental management agencies, state and county executives, environmental organizations, farming interests, and academics. The colloquy provided the conceptual foundations for a set of formal planning activities, such as the Everglades Partnership, the Central and Southern Florida project Restudy, and the Governor's Commission for a Sustainable South Florida, all of which are still underway and, hopefully, will lead to restoring parts of the Everglades ecosystem. However, none of these processes is seeking active adaptive management.

Blinking at management trials

As of this writing, many adaptive policies have been recommended, but none has been incorporated. Workshops have been held to explicitly design alternative water management experiments that would help to provide information for dealing with resource issues. However, no direct experimentation has been adopted. The failure to pursue actively adaptive experiments is due to at least three reasons: no flexibility in the social system, little or no resilience in key components of the ecological system, and technical challenges with designing experiments.

The current arrangement among stakeholders and management agencies is not very flexible. Bureaucratic management agencies appear to be trapped by narrow interpretations of their legal mandates. One such example involved the endangered Snail Kite, when a potential jeopardy opinion by the U.S. Fish and Wildlife Service was issued on a set of proposed water management alternations (Orians et al. 1992). Stakeholders who benefit from the current management system are able to stalemate any implementation of alternative management regimes. The recent histories of numerous lawsuits (real and threatened) are indicative of little versatility in policies.

Another impediment is that there is not a lot of room to experiment with certain resource issues. In the oligotrophic Everglades, very small changes in nutrient concentrations result in dramatic shifts in vegetation stability domains. Other issues with seemingly little room for experiment include key populations of endangered species, such as the Florida panther or Cape Sable Sparrow. The natural system responds to very small changes in water quality and lacks any room for error in embracing adaptive approaches. As with the situation of endangered taxa in the Columbia River system (Volkman and McConnaha 1993), adaptive management cannot be applied when the risks of failure are socially and legally unacceptable. Fortunately, in the Everglades, there appears to be much more resilience in populations of some endangered species (Snail Kite, Wood Stork) when the issue is evaluated at larger scales (Orians et al. 1992, Bennetts et al. 1994).

The 9-yr-old AEA experience in the Everglades has been one of a dramatically successful assessment, followed by little or no active experimentation. The uncertainties of chronic resource issues appear to have been replaced by the certainty of a cumbersome planning process and a formalization of interactions among management agencies and stakeholders. However, the ideas spawned in the AEAM workshops seem to have taken root and are being incorporated into the ongoing planning processes mentioned earlier. Perhaps these ideas are creating a foundation upon which future learning can occur.

CAN WE MANAGE TO LEARN?

A central tenet of AEAM is learning, yet learning seems to be intertwined with cycles of policy success and failure (Westley 1995). If policies are working (or appear to be working), there is little or no emphasis on learning. It is when policy fails, either dramatically or chronically, that learning is deemed necessary and a priority. The challenge to develop a capacity for learning continues to be problematic among most resource institutions. Yet, when needed, that capacity seems to come by focusing on understanding (not efficiency) and by networking with those who practice learning.

Perhaps it is time to rethink the paradigms or foundations of resource management institutions, and to place more emphasis on development of sustaining foundations for dealing with complex resource issues. Learning is a long-term proposition that requires a ballast against short-term politics and objectives. Another shift will probably require a change from management, by objectives and determination of optimum policies, toward new ways to define, understand, and manage these systems in an ever-changing world. That focus should not be solely on variables of the moment (water levels, population numbers) and their correlative rates, but rather on more enduring system properties such as resilience, adaptive capacity, and renewal capability. This framework involves both the human components of the system (operations, rules, policies, and laws) and the biophysical components of the landscape and its ecosystems. The shift of focus to a learning basis is likely to require flexible linkages with a broader set of actors or network. Another way of saying this bluntly is that, until management institutions are capable and willing to embrace uncertainty and to systematically learn from their actions, adaptive management will not continue in its original context, but will be redefined in a weak context of "flexibility in decision making."

In cases of successful adaptive assessment and management, an informal network seems always to emerge. That network of participants places emphasis on political independence, out of the fray of regulation and implementation, places where formal networks and many planning processes fail. The informal, out of the fray, shadow groups seem to be where new ideas arise and flourish. It is these "skunkworks" who explore flexible opportunities for resolving resource issues, devise alternative designs and tests of policy, and create ways to foster social learning. How to develop and foster shadow networks is a challenge for most inwardly looking North American land management agencies.

Many of the observed impediments to AEAM occur when there is little or no resilience in the ecological components (e.g., there is a fear of an ecosystem shift to an unwanted stability domain), or there is a lack of flexibility in the extant power relationships among stakeholders. In these cases, a pragmatic solution is to seek to restore resilience or flexibility, rather than to pursue a course of active adaptive management. Lee (1993) suggests that social objectives such as management goals must be agreed upon before AEAM can be undertaken.

Understanding and diagnosis of ecological resilience and institutional flexibility are key roles that AEAM can perform. One of the reasons that the assessment in the Everglades was successful was that it uncovered where ecological resilience had been eroded (nutrient example) and where resilience was broad (in terms of alternative sources of water for restoration). That assessment led to a set of feasible alternatives for seeking restoration objectives. If that resilience is not defined during an assessment, then perhaps it can be discovered through a series of imaginative, smaller scale experiments, given the institutional space to conduct such explorations. Understanding institutional flexibility seems to be much more of a challenge and a key to unlocking a wider range of chronic management pathologies. Certainly, one way in which that institutional flexibility appears is when an unforeseen policy crisis allows for restructuring of power relationships among stakeholders (Gunderson et al. 1995). Perhaps another way is to seek opportunties for nurturing transient, independent institutions (much like a floating crap game) that recurrently evaluate activities and suggest new strategic approaches.

In spite of obstacles, AEAM still remains an antidote to current ecosystem management approaches that seek spurious certitude in science and social processes. AEAM has been shown to be effective in the resolution of multiple competing hypotheses around resource issues. It can change the ways in which management institutions assess resource issues, can nurture and test new theories, and can establish new ways of communicating among scientists, policy makers, and stakeholders. By helping to understand ecological resilience and seeking institutional flexibility, AEAM will continue as a useful approach to resolving complex resource issues into the next century.

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