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ORIGINAL ARTICLE

Adaptive management and adaptive governance in the everglades ecosystem

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Abstract The Everglades is an intensively managed ecosystem where control of the water has allowed agricultural, urban and economic development, while struggling to meet biodiversity conservation goals. The over 100 year history of control began in response to a disastrous series of floods and droughts followed by environmental crises at an ecosystem scale. Each of these events precipitated technological fixes that extended control of water resources. Institutional structures have been continually reorganized over the last century to meet shifting social objectives, the latest of which is ecosystem restoration. However, the basic response, which employs engineering and technological solutions, is a type of social trap, where governmental mandates, planning-based paradigms and vested interests all interact to inhibit the resolution of chronic environmental issues. Experience from other resource systems indicates that in such an inherently complex system wrought with multiple uncertainties, restoration must be discovered through experimentation and learning embraced by adaptive management. Though minimal steps towards adaptive management have been made, we argue that adaptive forms of experimentation and governance are needed to resolve chronic resource issues and achieve restoration goals.

Keywords Water management · Adaptive management · Adaptive governance · Everglades

Introduction

The Everglades is a unique wetland ecosystem where water management has altered the quality, quantity and the temporal and spatial distribution of water in the system during the 20th century. The system is located in the subtropics, at the southern end of the peninsula of Florida in the southeastern United States. During the past century, the historic wetland was partitioned into different land uses of agriculture, water conservation, urban development and biodiversity conservation (Gunderson and Loftus, 1993; Light et al., 1995). This was

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accomplished by constructing and operating a massive water control system- levees, canals, pumps, spillways, other water control structures, and a complex set of operating rules, implemented by governmental agencies at the local, state and federal level (Light and Dineen, 1994). That system of water control has enabled development of an agricultural community in the north, and urban and economic development along the eastern ridge of the Everglades. In 2000, about 8 million people resided in the watershed and depended upon this large system for water supply and flood control. While the urban and agricultural sectors have prospered, the ecological sectors (wet prairies, ridge and slough complexes, mangrove fringe that support historic fish and wildlife conditions) have waned, as evidenced by the recently authorized 7.8 billion dollar plan to restore the Everglades (Davis and Ogden, 1994; Walters et al., 1992; CERP, 2000).

The Everglades is a national experiment in sustainability science, with some successes and a history of failures. Current efforts at restoration reflect the value of what society is willing to pay for ecological sustainability. Yet in spite of large amounts of money and the international reputation of the Everglades as an icon for conservation, the environmental values of the Everglades continue to decline.

The main thesis of this article is that the failure in sustainability is because the management system is pathologically resilient. In other words, the management system is trapped in a structure that is not only resistant to change, but able to withstand change. This topic is developed in the four following sections. The first section presents theoretical background on resilience and adaptive governance. The next section presents an historical pattern of Everglades management, indicating how regime shifts have occurred in the past. The next section discusses why learning is avoided, followed by a section that describes the trap of scientific management. The final section presents some alternatives for getting out of the current configuration.

Resilience and adaptive governance

Resilience is a property that reflects the ability of a system to withstand perturbations or shocks (Holling, 1973; Gunderson, 2001). Holling (1996) contrasted two types of resilience; engineering and ecological. He (op cit) defined engineering resilience as the time needed for a system to return to a pre-disturbance regime (defined as both system structure and process) and ecological resilience as the amount of disturbance needed to change regimes or system state. These properties have been applied to management and governance systems (Gunderson and Holling, 2002; Berkes et al., 2004; Folke et al., 2002; Olsson et al., 2006). Resilience can be viewed as a positive or negative property. In a positive sense, resilience reflects the ability of a system to adapt to changing circumstances or environments, and as such has been argued as a critical component of sustainable development (Folke et al., 2002; Walker et al., 2004; NAS, 1999). In a negative sense, resilient systems that do not change or adapt over time can be in a pathologic state or on pathologic trajectories (Holling and Meffe, 1996; Gunderson, 1999). These systems are also described as trapped (Gunderson and Holling, 2002). Of interest here is the resilience of systems of management and governance.

Adaptive management is an approach to resource management that was developed from ecological theories of resilience (Holling, 1978). Resilience theory suggests that managed ecological systems are dynamic and unpredictable. Moreover, management for optimality or efficiency tends to erode resilience, making the system vulnerable to dramatic and surprising change (Holling and Meffe, 1996). Adaptive management acknowledges the deep uncertainties of resource management and attempts to winnow those uncertainties over time by a process of using management actions as experiments to test policy (Walters, 1986). Adaptive management is a scientific or technical approach to resource management, but often requires a specific set of social, economic and governance factors for implementation (Lee, 1993; Gunderson, 1999; Volkman and McConnaha, 1993).

Adaptive governance is an emergent framework for the management of complex environmental issues. Dietz et al. (2003) used the phrase to describe the social and human context for the application of adaptive management. Folke et al. (2005) describe this form of governance as necessary for the management of complex ecosystems, particularly when change is "abrupt, disorganizing, or turbulent." Brunner and colleagues (2005), provide a rich set of examples to illustrate the emergence of adaptive governance as a way of solving problems created by top-down control of decision making and attempts at implementation of singular scientific and technical solutions that are bereft of political considerations. They (op cit), describe adaptive governance as operating in a situation where the science is contextual, knowledge is incomplete, multiple ways of knowing and understanding are present, policy is implemented to deal with modest steps and unintended consequences and decision making is both top-down (although fragmented) and bottom-up. As such, adaptive governance is aimed at integrating science, policy and decision making in systems that assume and manage for change, rather than against change (Gunderson et al., 1995). Adaptive governance deals with the complex human interactions that have been obstacles to the implementation of adaptive management (Lee, 1993; Walters, 1997; Gunderson, 1999).

Shifts in management regimes

The approximately century long history of water management in the Everglades follows a pattern of crisis and reconfiguration (Light et al., 1995). The crises arise from dramatically unexpected system behavior, such as floods, droughts and fires. Hurricanes during the 1920s devastated human developments along the east coast and south of Lake Okeechobee. Earthen dams which had been constructed to exclude waters of the Lake were breached during the hurricane of 1928, resulting in extensive flooding and a loss of about 2400 lives (Blake, 1980). In response, the federal government funded the construction of the Hoover Dike around the Lake, which was completed by 1938, in order to contain floodwaters.

During the 1940s, federal and state laws established the system of water management as it now exists. Rainfall during this decade varied wildly, creating conditions which prompted action. The early 1940s were extremely dry, resulting in saline intrusion into the freshwater aquifers of the coast and subsequent salt dam construction. Extensive flooding occurred during 1947, following an extremely wet summer and the passage of two cyclonic storms. The resulting flood led to passage of the federal Flood Control Act in June 1948 (PL 80-853). The act authorized the U.S. Army Corps of Engineers to develop a plan known as the Central and Southern Florida Project for Flood Control and Other Purposes, which would address the water management needs of the area. The plan contained three basic elements: (1) designation of the Everglades Agricultural Area, (2) construction of water conservation areas in the central Everglades and (3) construction of an eastern levee. The purposes of the water conservation areas were to protect the east coast and agricultural areas from flooding, recharge regional aquifers and prevent saltwater intrusion. In 1949, the state legislature created the Central and Southern Florida Flood Control District (FCD) to act as local sponsors for the federal project. The FCD was renamed in 1977 as the South Florida Water Management District (SFWMD), at which time an additional objective, enhancing environmental resources, was added to the other purposes.

In the 1980's, water quality degradation became a major environmental issue. Recurring algae blooms in Lake Okeechobee were attributed to nutrient runoff from cattle farms to the north of the lake and from agriculture to the south (Aumen, 1995). The water quality crisis in the lake led to a shift in policies of how water was moved across the landscape, and to management practices that limited nutrient inputs to the lake. When water could no longer be pumped from agricultural fields to the lake, it was moved south, resulting in shifts in vegetation, algae and benthic communities (Davis et al., 1994). In 1988, a lawsuit was filed by the US federal government against the state government, for violation of water quality laws and damage to federal resources (John, 1994). The lawsuit was settled three years later, with the development of government- funded wetland treatment marshes and agricultural Best Management Practices (BMPs). It also signaled a political challenge to the water management practices of the SFWMD.

Beginning in the 1980s, Everglades managers and scientists began adaptive water management (Holling, 1978; Walters, 1986). Following high rainfall in 1983, managers called for a new method of water delivery to Everglades National Park. A short-lived program of free-flow into the park was designed as an iterative testing plan (Light et al., 1989). This was codified by the adoption of PL 98-181, which allows for experimental deliveries to the park, but free-flow was ceased within a year following threats of lawsuits by urban water interests. As a result, a rainfall-based formula was developed which dictates water flow to the park as a function of upstream rainfall. The rainfall plan can be classified as a passive adaptive technique (Walters, 1986) whereby historical data are used to construct a model that guides management plans. A more active experiment was precluded by mistrust among landowners, as well as local, state and federal agencies.

Since 1990, a major focus of management in the Everglades has been towards ecosystem restoration. This effort began with a modest attempt by scientists in the system to synthesize existing information in ways to help solve chronic environmental issues, such as decline in wading bird populations, vegetation changes, changes in aquatic biota, among others (Davis and Ogden, 1994). This was done in a series of adaptive assessment workshops, where hypotheses were outlined, and experiments to test those hypotheses were planned (Holling et al., 1994). The result of those workshops was that restoration of lost environmental values was determined to be feasible (Walters et al., 1992; Davis et al., 1994), but would require integrative solutions applied at the scale of the ecosystem. Since then, a number of formal planning processes (US Corps of Engineers Restudy, Federal Task Force, Governors Commission for a Sustainable South Florida) led to the passage of the Everglades Restoration Act in 2000 by the US Congress. That act authorized up to 7.8 billion dollars for restoration purposes. The act specifically stated that adaptive management would be used to meet restoration goals. Since then, more conventional planning has occurred and generated a few pilot programs such as aquifer storage and recovery. But no structured ecological experimentation aimed at resolving key restoration uncertainties has been done.

Failures in adaptive management and governance

Adaptive management is a critical component of adaptive governance (Folke et al., 2005; Brunner et al., 2006; Scholz and Stiftel, 2005) that focuses on learning and uncertainty. That learning is fostered, not by trial and error, but by a structured process of investigation that involves assessment of competing hypotheses, agreement upon a set of hypotheses to test, structuring management actions to sort among hypotheses, and evaluation of management experiments (Holling, 1978; Walters, 1986) which in turn fosters further rounds of uncertainties, and iterative solutions (Loftin, personal communication). While many managers claim to be practicing adaptive management, most practice some variant of trial and error management or management by objective with updating. That is, social objectives are determined, management actions are structured to attain those objectives, then progress towards those objectives is evaluated, and actions modified as needed to meet objectives. One key distinction between these approaches is that adaptive management assumes policy failures will occur and that they provide a valuable contribution for learning, while other approaches seek to avoid policy failure. Avoiding failures only acts to reinforce the status quo and precludes opportunities for learning while doing (Blann et al., 2003; Light, 2001).

Walters (1997) cites from his experience in riparian systems that out of 20 assessments, only seven resulted in experimental management. Walters (1997) provides reasons for failure to include (a) the belief that further modeling and monitoring will resolve uncertainties, (b) experimentation is too costly and risky, (c) experimental approaches are opposed by special interests and (d) value conflicts among scientists and or stakeholders cannot be resolved. Some of the difficulties in adaptive assessment and management are illustrated in lessons from two regions of the US; the Everglades of Florida and the Grand Canyon in northern Arizona.

While both systems claim to have ongoing adaptive management programs, the Grand Canyon has an active experimental management program, while the Everglades has an active planning program. In the Everglades, key components of adaptive assessment, including conceptual ecological models, a monitoring and assessment plan, a systems and project level adaptive management strategy, and plans for field tests that remove interior canals and levees have been completed. On the other hand, the Grand Canyon adaptive management program has conducted two large-scale flow experiments, one in 1996 the other in 2004. These experiments consisted of simulating extreme events, the release of large volumes of water from the Glen Canyon dam as the primary control variable. The expectations (hypotheses) were tested to see if the floods would deposit suspended sediments onto sand bars and beaches along the river corridor. In conducting these experimental releases, scientists modified their conceptual model of sediment storage. Rather than sediment being stored primarily in bed loads, they discovered a large percentage was stored in eddies within the river. Another set of experiments were developed in 2002 to understand effects of flow, water temperature and predators on recruitment dynamics of the endangered Humpback chub. The Everglades, however, has been planning management actions for over a decade, with the promise of actions rather than any actual tests of hypotheses. Much of the early work suggests that the quantity and quality of water flow through the system is at the center of restoration hypotheses, yet these uncertainties remain unaddressed and unresolved.

The Everglades and the Grand Canyon examples diverge with respect to their ability to cultivate social learning. The Everglades process of experimentation has been hindered by (1) long standing feuds among special interest groups (agricultural and environmental) who seek certitude in policy, rather than understanding through experimentation; and (2) outmoded policies and practices that hamstring experimentation efforts and (3) resistance from agency scientists. A series of adaptive management experiments were designed (Walters and Gunderson, 1994) but have never been implemented due to resistance by special interest groups who wanted specific guarantees of water allocations. This is even more puzzling, as prior large projects in the Everglades, such as the Kissimmee Restoration and Everglades Nutrient Removal projects have had adaptive management elements to them, but the benefits of an experimentation approach have not been effectively translated into system practice. The Grand Canyon group, on the other hand, has developed a stakeholder-based 'Adaptive Management Work Group' which uses planned management actions and subsequent

Table 1 Everglades restoration management compared to typology of scientific management and adaptive governance (*sensu* Brunner and Steelman, 2006)

Category	Everglades management approach	Pattern of governance[a]
Science	Reliance on getting correct model	Scientific
	Multiple ways of understanding and evaluation	Adaptive
	Responses are known before action	Scientific
	Focus on piecemeal solutions	Scientific
	Surprises are ignored or assumed to be manageable	Scientific
Policy	Explicit goal setting, measurable progress	Scientific
	Heavy reliance on technological solutions (many of which are untested)	Scientific
	Focus on implementation and efficiency, rather than learning	Scientific
	Planning leads process rather than testing	Scientific
Decision making	Top down, authoritative	Scientific

[a] Brunner and Steelman categorize governance as either scientific management or adaptive governance

monitoring data to test hypotheses and build understanding of ecosystem dynamics. This group is characterized by a diverse set of leaders (not a single leader, but multiple, overlapping leadership roles filled by persons with divergent perspectives). The leaders in the Grand Canyon understand the uncertainties and complexities of the system, and believe that resolution of environmental issues can only be discovered, not achieved by predetermined policy. As such, they have not provided an overarching vision, complete with targeted goals and objectives, as much as provided opportunities and windows for experimentation. That is, they have created 'space' for experimentation and learning (Gunderson, 2003). This has generated a great deal of trust among stakeholders and a more open and flexible institutional setting for dealing with multiple objectives, uncertainty, and the possibility of surprising outcomes. Such emergent governance that creates new institutional platforms for adaptive management is evolving in many places around the world (Berkes et al., 2004; Folke et al., 2002). Even so, the systems are similar with respect to resource demands and uses, institutional complexity, and asymmetries of power among stakeholders. Nonetheless, emergent forms of adaptive governance are operating in the Canyon and are not yet apparent in the Everglades.

Currently, the management approach used in the Everglades is focused on resolving past conflicts rather than discovering sustainable futures. Indeed, as shown in Table 1, Everglades management has and continues to be a scientific management approach, rather than an adaptive governance approach (Brunner and Steelman, 2006). Everglades management continues to focus on planning and seeking spurious certitude prior to action, rather than confronting the unknowns of such a complex and dynamic system (Gunderson, 1999). As such, the scientific approach persists and has proven to be resilient to dramatic change.

The trap of scientific management

For many decades, Everglades water management has followed a pattern of crisis followed by policy reformation. Much of that reformation is based upon a culture of scientific management and planning (i.e., rule-following behavior that is not easily translated into ecological predictions). That is, to achieve an acceptable plan, one must be able to rigorously predict outcomes before acting. This is consistent with the scientific and engineering basis of the design, implementation and operation of the water management system since the 1940's and recent role in the Restudy project that led to the current restoration plan. The problem with this paradigm is that so many constraints are placed on future actions, that stalemate is the most common outcome. Managers are not sufficiently encouraged or empowered to employ innovation through experimentation. While crises can be learning opportunities, learning in the Everglades is compromised because of other social and political considerations. That is, following crises, the system generates new highly constrained engineering solutions that do not fully capitalize on past experience and opportunities for learning (the lack of understanding about the restoration of flow in the remnant Everglades is a classic example). The Everglades management confronts extremely complicated problems, many of which are 'wicked' (Rittel and Weber, 1973) with singular responses. To date, the approach to management of restoration has been to engineer solutions – there are 68 elements to the Comprehensive Everglades Restoration Plan. While primacy of engineering solutions is appropriate for some complex problems, such as sending a human to the moon, they are not appropriate for complex social-ecological systems such as the Everglades. Engineering can help design experiments that are based on the latest scientific understanding of what is known and what is uncertain, but cannot be used to resolve the complicated social and political uncertainties. This mismatch between problem and solution sets is a major obstacle to social innovation (Westley et al., 2006).

Because of the perserverative response to crises, the Everglades management system has and continues to be in a management trap (Gunderson and Holling, 2002). This is a type of social trap (Rothstein, 2005), defined as a system configuration or regime that persists over time in spite being subjected to a wide range of shocks or perturbations (Allison and Hobbs, 2004). It is a very resilient system, (*sensu* Holling, 1973) that is maintained by considerable infusions of money, which are tied to the conventional bureaucratic system. This system is governed by rules and procedures that are no longer fitting and appropriate to accomplish a highly complex and multi-objective mission. The result is that for the sake of consistency, Everglades restoration remains in a policy straitjacket.

In addition to a linear or 'command and control' (Holling and Meffe, 1996) culture mentioned in the above paragraph, there seem to be other symptoms of this including (1) avoidance of learning (from past mistakes), (2) lack of trust among management institutions and stakeholders, and (3) strong feedbacks that maintain core elements of the status quo. Certainly hundreds of millions of dollars have been put into Everglades research over the past three decades. Yet, understanding is and always will be incomplete and partial. While adaptive experiments were designed in workshops held in the early 1990's and suggested in scientific articles (Walters et al., 1992; Walters and Gunderson, 1994), discussions still persist as to what should be done. There are fiscal and political costs to experimentation. Moreover, the reasons that more experiments have not been done are related to the fear of risking conflict and fear of failure to produce desired or even meaningful results. This is compounded by the inability of current bureaucratic elements to comprehend the value received from learning now when compared to the costs of inaction.

Unfortunately, current practices have government agencies supporting large scientific endeavors that focus on modeling and data collection rather than on using experiments to reduce uncertainties and explore new options. A recent NAS panel (2003) indicated that ongoing and future research should move away from self-serving, piecemeal studies to ones that are more synthetic and integrative. To do so will require scientists to become motivated to pursue collective learning. Perhaps the main reason for the rigidity trap is a lack of social capital and trust fostered by institutional power imbalances in the region (Rothstein, 2005). Special interests and resource managers who felt that experimentation would supplant an opportunity to secure water options for the Park and conservation interests have stymied attempts at adaptive experiments. Rather than acknowledge that it is currently unknown what it would take to restore the lost environmental values, some chose to replace scientific uncertainty with political certitude, as false as it may be.

Finally, another reason for the stability of the rigidity trap is the presence of strong positive feedbacks. For the dozens of non-governmental organizations and governmental agencies that seek to preserve conservation values, many have sought advantage through conflict rather than cooperation. Their organizations have come to depend upon environmental problems as their raison d'etre. There is a belief that confrontation and adversarial forums command the political and thus the fiscal attention needed for their wellbeing. While these tactics may have been rewarded in the past, the threat of a growing rift between state and federal interests over Everglades restoration could spell disaster for conservation ends. If the problems were to disappear, suddenly so would their funding. As unlikely as this seems, positive feedback in the form of money flow does stabilize the current arrangement of management institutions, for better or worse. Regulatory agencies are handicapped and often unable to make effective decisions due to interest-based demand for certitude. This not only thwarts progress, it undermines confidence in working relationships.

Escaping the trap – seeking adaptive management and governance

We argue that the Everglades should seek a transition to adaptive governance (Folke et al., 2005) as a way to increase responsiveness and generate more diverse and versatile competencies that create options for the future and develop the adaptive capacity to improvise and adjust to recurring crises. While adaptive governance may not avoid the pattern of a crisis and a fix, it will allow for better preparation for the next crises. Adaptive governance consists of social structures and processes that link individuals, organizations, agencies, and institutions at multiple organizational levels (Olsson et al., 2004). Cross-scale linkages are a key element of transformations, as described by theories of polycentric institutions (Ostrom, 1996) and panarchy (Gunderson and Holling, 2002).

Adaptive governance also seeks to deal with the management of problems in different domains. Westley (2002) describes that complex environmental issues are comprised of problems in a policy domain, social domain, economic domain and ecological domain. Gunderson and Holling (2002) describe the pathology when one of these problem domains receives attention at the expense of others, that is, partial approaches lead to partial solutions. Hence adaptive governance seeks to provide a set of composite policies or solutions that address and integrate these different problem domains. Leadership, diversity, versatility in competencies and timing seem to be key factors in this respect. In the Everglades there seems to be a network which is strongly dependent on regular crisis to evoke federal subsidies and state spending, but is unable to find alternative patterns of reorganization once the current system fails.

Scientists are all too often segregated from social and economic drivers as they address technical considerations. This separation is as much a function of their choosing as it is a component of the decision-making environment. They generally prefer not to have these drivers as part of their deliberations and seek "pure science" as a safe harbor from these other vectors that influence policy development. Those that desire to meld these factors regrettably often find themselves excluded from the decision-making arena. This is largely due to a pre-conceived bias by policy makers who shy away from overly technical assessments and scenarios requiring complex tradeoff considerations. This fragmentation of domains perpetuates the pattern of failed responses.

Developing shadow networks for adaptive ecosystem governance

In the Everglades, at least three networks that operated off center stage can be identified as playing key roles in institutional transformations. All can be categorized as epistemic networks that were comprised of technical and scientific personnel (Haas, 1992). In 1939, the Soil and Crop Science Society documented effects of previous drainage efforts on the ecosystem. Their work provided the foundation for land use, management and governance changes following the flooding crisis of 1947 (Blake, 1980; Light et al., 1995). Arthur R. Marshall, a former federal scientist who directed a team of ecologists and planners at the University of Miami, led the second shadow network that appeared in the 1970's. Impending eutrophication of Lake Okeechobee prompted management transformations that eventually led to the restoration of the Kissimmee River and eventual nutrient pollution management in the Everglades (in order to stop nutrient runoff into the Lake) (Light et al., 1995). The current efforts at ecosystem restoration are also the result of the adaptive management group that began in the late 1980's, led by Buzz Holling, Carl Walters, Steve Davis, Lance Gunderson and Steve Light. Their work in a series of modeling workshops discovered that the long-standing environmental degradation in key wildlife populations and vegetation trends is reversible. Subsequent planning efforts built on this understanding and led to the current restoration efforts (Gunderson, 1999).

Leadership is a critical element in preparing the system for change, especially when it comes to strategies for exploring new configurations of social-ecological systems (Olsson et al., 2006) and a transition to adaptive governance (Folke et al., 2005; Brunner et al., 2006). In the Everglades, leadership involved integration of the extant scientific understanding of the ecosystem, summarizing that integration, and communicating that understanding to a wider audience. That has been done many times, starting with Marjorie Stoneman Douglas who was a leading advocate for the Everglades and whose key contribution was in the book, *Everglades, River of Grass*, (Douglas, 1947). That compelling volume was beautifully written, based on conversations and interactions with leading scientists. In the 1960's and 70's, A.R. Marshall provided the same leadership at a research institute at the University of Miami, and communicated his understanding with 'the zeal and passion of a country preacher' (Light et al., 1995). Scientific leadership that formed a consensus on restoration guidelines in the 1990s as captured in Davis and Ogden (1994) helped break the policy logjam of the late 1980s. Clearly, the surfacing of such a cohort of dedicated scientists is necessary for successful restoration implementation. Equally critical are political leaders capable of working shoulder to shoulder with scientists of this caliber.

A fleeting opportunity is present to foster this linkage. Scientists, with the blessing of management, have begun to explore in CERP implementation a series of experiments that are intended to initiate the restoration of sheetflow in the remnant Everglades. Efforts to build a scientific consensus on sheetflow restoration are not new. The Science Coordination Team (SCT) published a significant paper (SCT, 2003) on hypotheses regarding the interaction between vegetation types and sheetflow. However, this consensus paper met with resistance and has been sidelined. Initiation of such experimentation would provide insight into options and opportunities for restoration, as was recommended by the SCT.

Opening up opportunity for change- creating space

Assuming that the generation of novel and alternative visions of futures is a critical feature of interventions and transformations, at least three types of opportunities can be described. These are opportunities that generate policy space, that is, the potential for rearranging relationships and components of social networks. The first is an ecological window, or one that opens following an ecological crisis. Many times these crises occur as a result of the loss of ecological resilience, such as algae blooms in Lake Okeechobee, or cattail dominance in the freshwater Everglades (Gunderson, 2001). The ecological crisis may also occur as a result of fluctuations in larger scale processes or drivers, such as hurricanes, floods, or droughts and fires. In any case, opening the ecological window can provide the basis for transformational change in the system. The second type of window is a political window, one that is created by social activists, politicians, or other groups intent on changing extant policy. Expert panels and lawsuits by environmentalists are two such mechanisms for opening a political window. In these cases, the groups interpret information from ecosystem components (such as data on water quality declines) to support an action to open the system for renegotiation of rules, norms and other institutional relationships (Scheffer et al., 2003; Schusler et al., 2003). The third type of opportunity is an epistemic space. This is space created by groups such as think tanks, skunk-works, and other learning based organizations. These groups are able to suspend extant beliefs, question mental models, contrast possible futures and other such rules that allow for exploration of new and novel system configurations. Examples from the Everglades include all of the shadow networks mentioned elsewhere, such as the adaptive management group of the early 1990's (Gunderson, 1999). All of these opportunities are critical for the transformation of these systems to meet sustainability objectives (Walker et al., 2004).

Summary

The history of water management in the Everglades has been one of increasing control over the water resources of the region. The manipulation of water resources has enabled urban and agricultural development. Yet, that control has led to a loss of ecological resilience, and a series of ecological crises, or failures in policy. Responses to ecological crises have been large scale, expensive and technologically based solutions. The system appears to be locked into a single response to crises. That response focuses on spending more money on more control of water in order to sustain economic and agricultural development while protecting or restoring environmental functions. Yet, the environmental values that are an important social objective remain at risk. An adaptive management strategy has been drafted for the Everglades CERP and large-scale experiments are being designed and budgeted for at the technical level. Leaders must embrace uncertainty and should foster a culture that seeks and encourages opportunities for learning through experimentation. Without managing the uncertainties in the social and political relationships in a way that integrates the ecological concerns of the area, restoration will continue to founder on the shoals of special interests. Without experimentation supported by broad-based stakeholder engagement, stalemate will continue in restoration efforts. Meantime, ecological values continue to deteriorate.

The implications of embracing uncertainty and the opportunities for learning and experimentation and discovery are huge. The Everglades is a flagship for regional restoration efforts in the US. Timing, attention and politics have converged to make this effort in sustainability a saga that no one can put down. Adaptive approaches in management and governance are critical components for recovery of the ever-changing Everglades.

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