Chapter 12
Surprises and Sustainability: Cycles of Renewal in the Everglades

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She needs wide-open spaces—room to make the big mistakes.
—Dixie Chicks

In this chapter we evaluate some of the theoretical propositions of ecosystem dynamics and resilience set forth in Chapter 2. We will not attempt to rigorously refute hypotheses or propositions, but rather search for patterns of similarity and important areas of disagreement. We attempt to establish the utility of using the four-phase and panarchy heuristics from ecological systems to interpret dynamics of a coupled ecological and social systems.

We will do this by drawing from lessons learned from the Everglades, and where appropriate, from a wider set of case studies of regional development and resource management. Those systems, especially the Everglades development and attempts at sustainability, involve technology-based, bureaucratic approaches to large-scale ecosystem management in developed areas (Gunderson et al. 1995a; Johnson et al. 1999).

There are growing hints that limitations to these models could be usefully explored and perhaps the theory expanded by applying it to specific examples of development linking people, nature, and regional economies. Rather than forcing an ecological model on social systems, therefore, our hope was more to expose its inadequacies and to perhaps expand its generality. We attempt this in the next section, using the management history of the Everglades to provide a focus.

Interpreting the Management History of the Everglades

Water management in the Everglades during the twentieth century was characterized by four distinct eras (Light et al. 1995). The first of these four eras of water management began in 1903 with efforts to dig canals to drain the system for development and agriculture in a strategy labeled Cut 'n Try (Light et al. 1995). The second and most prominent era involved implementation of the massive federal and state public works project (1948–70) that created levees, canals, pumps, and operational guidelines in order to prevent flood damage, in an era dubbed Turning Green Lines to Red (Light et al. 1995). The third era (No Easy Answers 1971–82 (Light et al. 1995)) attempted to restructure the existing management agency into a new, system-wide management agency to deal with water shortages in addition to flood problems. The most recent era (Restoring the Everglades 1983–present (Light et al. 1995)) is characterized by attempts to restore the natural values of the system.

These four management eras illustrate four separate iterations of an adaptive cycle. Each era is characterized by a slow period of capital accumulation, followed by a perceived crisis and reformation. New eras occurred when the system made an evolutionary leap into radically new stability regimes, or *de novo* system configuration (represented by a different set of boxes in Figure 12-1). The crisis that created the first management era in

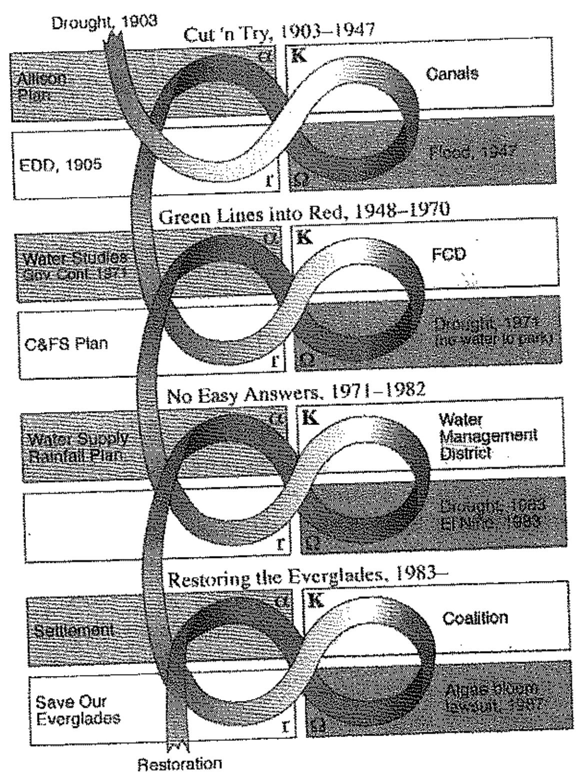

Figure 12-1. Time course of water management in the Everglades as represented by successive iterations of the adaptive cycle. The initial management era is shown in the top set of boxes, the last one in the bottom set.

1903 was a flood. This Cut 'n Try management era reflected a development from the r through K phases of system development, where increasing structure in the form of canals reflected an attempt to control the system.

Precipitated by the flood of 1947, the system underwent a major reconfiguration as it entered the second management period. During this period, the large bureaucracy-driven plan (called the Central and Southern Florida Flood Control Project) was implemented. The plan called for massive construction of levees, canals, pumps, and weirs to stabilize water levels and control flooding. The system developed, during the 1950s and 1960s, as the canals and levees were being built. A series of floods and droughts resulted in changes to the management rules, or to how water was partitioned among the user groups and institutional roles. The first cycle occurred when the droughts of the 1960s resulted in a guaranteed water delivery to Everglades Park.

The third management era was rooted in the drought of 1971. Although another cycle began, little new physical capital was created; rather, the focus was on creating new forms of social capital. This time it was an institutional reconfiguration that resulted in the formation of the South Florida Water Management District and was characterized by the label No Easy Answers.

The latest era, also called Save Our Everglades, reflects another cycle of the system, and was brought about by crises in the early 1980s. The coincidence of high rainfall and fear of pollution in Lake Okeechobee resulted in a reconfiguration that included modified regulation schedules in the water conservation areas and a rainfall-based formula for delivering water to the Park. The last major cycle occurred with the settlement of a water quality lawsuit. It has triggered yet another major cycle focusing initially on water treatment areas that are to minimize impacts of water movement from agricultural to natural areas.

The four-phase heuristic, therefore, provides a framework for explaining a complex history: periods of slow growth and policy implementation, and crisis followed by minor and major reformation when an entirely new system configuration is noticed. That pattern is followed in many of the cases listed in Berkes and Folke (1998) and in Johnson et al. (1999). The heuristic has been used in other historical interpretations as well; business organizational development and renewal (Hurst 1995). Perhaps the adaptive cycle construct is useful because at its foundation, the model is essentially a tautology of birth, growth and maturation, death, and renewal that must apply to any living system and perhaps to non-living ones as well. But viewed as such, the issue becomes one not of inappropriate transfer from one field to another, but of universal applicability—e.g., finding no situation where it does not apply.

The critical feature of the model that can distinguish among different systems, however, lies in the phase of renewal, the α phase of Figure 2-1. Renewal can simply mean the endless repetition of the same initializing condition for the four-phase cycle. That was what was implied in the initial

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revolutions leading to a paradigm shift. Abernathy and Utterback (1982) distinguish gradual from radical innovation sequences in industry. Friesen and Miller's (1984) theory of organizational adaptation contrasts periods of momentum with those of revolution, and Levinson (1978) sees individual human development as periods of stability alternating with abrupt rapid transitions.

Such theories identify so-called deep structures that provide the sustaining rules for the gradual incremental changes that occur throughout the "equilibrium" periods. Revolutions are seen as brief periods when a system's deep structure collapses to become subsequently reformed around new strategies, power, and alignments.

We earlier described related entities when we applied the four-phase cycle to ecosystems. For example, stands of even-aged trees are the slow structural variables that for long periods can provide the context for dynamic interactions among fast variables such as needles, insect defoliators, and their predators. The even-aged tree stands have a speed, or turnover rate, of approximately one hundred years and a spatial grain of tens of meters. The fast variables have a turnover rate of a year and a spatial grain of centimeters—two orders of magnitude faster and smaller. For long periods the budworm is controlled by predators at low densities, allowing trees to slowly grow to maturity. The "revolution" occurs when the control of budworm collapses because growth of the forest—the slow, structural variable—dilutes the effects of predation, and an outbreak of the insect—the fast variable—is generated that kills trees over large areas.

But this, as in the case of the social revolutionary change theories, is more a description of a phenomenon than an explanation of its causes. Recognizing the different variables that control each of the four phases deepens understanding of the dynamics. There are some detailed differences between these social revolutionary change theories and the four-phase adaptive cycle, but the fundamental difference is that the boom-and-bust dynamic, and the opportunities that at times are constrained and at other times opened, emerges from the interaction among variables that characterize and control each of the four phases. The behavior emerges from the way control shifts from r, to K, to Ω, to α to a new or repeated r set. We will expand that description of the variables and processes involved in that shifting control in a moment, but before doing so, one final set of social theories of change needs to be described, because these theories come close to and deepen the insights of the four-phase adaptive cycle.

These deeper theories explicitly recognize the four-phase properties of complex evolving systems and the tensions they generate to produce stages of growth and transformation. For example, the Austrian economist Schumpeter (1950) saw socioeconomic transformations proceeding such that market forces controlled the r phase of innovation; institutional hierarchies, monopolism, and social rigidity controlled the K phase of consolidation; forces of "creative destruction" triggered the release or Ω phase; and technological invention determined the source for a phase transformation at α.

application of the model to ecosystems. For human systems, however, that would mean that humanity was tied to a rack of determinism doomed to repeat the lessons of history with no option for individual will. And certainly much of the history of development, including the Everglades, is just that. How else could Marchetti (1987) so consistently describe the development of various technologies with a simple logistic curve that depicts a transition from the r to the K phase?

In order to explore those similarities and differences between ecological and social systems further, it is useful now to determine whether related concepts and theories, particularly those with an empirical base, have been developed in the social sciences.

Theories of Social Change

We can usefully identify three classes of social theories of change. The first is the life-cycle representation so common to many fields and to the logistic formulation that Marchetti (1987) uses to such good purpose. These life-cycle/logistic representations imply growth to some sustained plateau, with senescent elements replaced from some unknown pool. In ecology that was the foundation for Clement's model of ecosystem succession described earlier in Chapter 2. In organizational theory, that is the foundation for representing the time course for products, processes, and organizations (Kimberly et al. 1980). In economics, however, new expansions of theory expose the abrupt nature of the flip from one mature product to a competing one (Arthur 1990), much as we describe here for the shift from the K to the Ω phase. Mature products are seen as capturing a market and, for a time, freezing out superior, competitive innovations because of increasing returns to scale.

The second class of social change theories contrasts gradualist life-cycle models with those that model revolutionary change. Gersick (1991) has reviewed these using another biological theory as a template for describing change in complex systems. This is Eldredge and Gould's (1972) view of biological evolution as proceeding by punctuated equilibria rather than by gradual incremental change. The fossil record suggests that species lineages persist for long periods in essentially the same form or equilibrium, and that new species arise abruptly in sudden adaptive explosions of rapid change. That representation is consistent with the behavior generated by the four-phase cycle but aggregates the four into two stages—one prolonged period of gradual change and one of rapid transformation. The theory emerged as a description of the fossil record, with explanations for the sudden changes ranging from the consequences of external disturbances (e.g., planetesimal impacts on the earth) to internal senescent/reorganization sequences.

Similar representations have been proposed in the social sciences. For example, in the philosophy of science, Kuhn (1962) distinguished the alternations between long periods of normal science and sudden scientific revolutions leading to a paradigm shift. Abernathy and Utterback (1982) distinguish gradual from radical innovation sequences in industry. Friesen and Miller's (1984) theory of organizational adaptation contrasts periods of momentum with those of revolution, and Levinson (1978) sees individual human development as periods of stability alternating with abrupt rapid transitions.

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Such theories of revolutionary change provide insight by recognizing the paradox of the creative destruction or Ω phase and the uncertainty of the α phase. There is obviously a destructive element to the collapse of a company or to the occurrence of an intensive fire in a mature forest. But there is also a creative element, because previously tightly bound capital is released—money, skills, and knowledge in a business sector; organized carbon and nutrients in a forest. In contrast, the renewal or α phase lies behind a "veil of ignorance" by reason of its inherently unpredictable nature. Schumpeter's designation of capitalism as a "perennial gale of creative destruction" highlights precisely the same paradox in ecosystems at the transition from consolidation, or K phase, to release, or Ω phase.

An even more specific typology comes from cultural anthropology in the works of Douglas (1978), Thompson (1983), and Thompson et al. (1990). Four explicit types of individuals or institutions are identified, and they are organized within two axes very similar to the ones in Figure 2.1. The r phase is designated as the entrepreneur, the K phase is the caste or bureaucracy, the Ω phase the sects, and the α phase the ineffectual individual (Douglas 1978; Thompson 1983). The insights provided by their descriptions of sects resonate with attributes of the release processes that we describe for ecosystems. The sects are described as being small and tightly organized, often around a charismatic leader with a strong, singular ideological purpose. Their power emerges only occasionally when their tenacious allegiance to internal rules and purpose intersects with the vulnerability of a mature and rigid bureaucracy. This captures their role in triggering release and, for us, has been particularly helpful in illuminating our understanding of the role of the more extreme types of environmental activists in the earlier analyses of the case studies.

Their description of the critical α phase, however, only partly captures our description of the ecological analogue. They do see the dissociated nature of the elements of the α phase, describing them as atomized individuals with no control over their own destiny, caught by whatever winds of change are generated by the other players. But in ecological systems, that phase provides a repository of the capital that has accumulated during earlier phases of growth and maturation—r to K. Its dissociated, weakly connected state is the very attribute that makes unexpected combinations of associations possible and individuals most influential. It is the flywheel of the whole system, whose properties determine whether there is a repetition of past cycles, collapse of those cycles, or the emergence of a new system that is distinguished by its novelty.

Increasing attention is being paid to the micro-scale dynamics that drive collapse and reorganization. A number of people have focused on the simulation of the interaction of groups of heterogeneous agents. Brock and Hommes (1997) use a group of agents interacting in a simple market who have to pay to maintain a record of the past and to acquire information. These agents can choose the model they use to predict future behavior of the system. They can choose to use either a cheap, short-term, naive model of the future or an expensive, sophisticated, long-term model. When these agents interact, if the entire population of agents uses the expensive model, then the system is stable. However, in this stable situation the cheap model performs just as well as the expensive model, so due to its lower costs, agents begin to switch to using the cheap model rather than the expensive model. As an increasing number of agents use the cheap model, the system becomes unstable and begins to fluctuate. As fluctuations increase in size, the expensive model outperforms the cheap model, and agents begin to switch back to it. Brock and Hommes demonstrate that these dynamics and consequently both the prices in the market and the agents' strategies vary chaotically. These dynamics are similar to the four-phase cycle. The expensive strategies achieve an equilibrium, then agents gradually switch to the cheap model, which in turn gradually decreases the stability of the equilibrium until it becomes unstable, and the system begins to fluctuate widely, until it is rapidly stabilized by agents again adopting the expensive model.

This work is similar to work Karl Sigmund (1993) has done on populations of strategies playing the prisoner's dilemma. If the population can evolve, or agents can learn over time, they discover that with noisy communication, a similar set of dynamics occurs over time. A retaliatory strategy establishes an equilibrium that is then exploited by a more profitable naive strategy. However, as this naive strategy increases in frequency, the population as a whole becomes vulnerable to parasitical strategies, which causes the retaliatory strategies to rise to prominence once again. Lindgren (1991) produced a more diverse set of strategies that also gave rise to complex periods of relative stasis punctuated by periods of rapid change and reorganization. Leimar (1997) has shown that there are many strategies that can produce such cyclical behavior.

Janssen (1998) has used a population of agents that hold different models of the world/climate system to model response to climate change. His work demonstrates that a disturbance of shock to the climate system often causes the disintegration of a dominant model. If a system contains noise, often agents will persist with a model, due to the lack of any clear signal that it is inaccurate. Disturbances can provide such a signal, indicating to agents that their model does not correspond to reality. Often disturbances provide an opportunity for learning, resulting in models that better match reality; however, they can also produce at least temporary dominance by inaccurate models.

All these models offer interesting views of micro-processes that could produce four-phase dynamics. However, empirical evidence suggests that more complicated cross-scale dynamics occur, at least in social systems. For example, Alfred Chandler (1977) argues in *Visible Hand* that in response to the 1873 stock market crash, U.S. business managers learned and reorganized their corporations. They took advantage of new economies of scale and developed large, integrated companies, which could survive disruptions in credit availability. These large companies could successfully plan and manage their corporations since groups and individuals outside the company were relatively unorganized. The large corporations were not affected by short-term fluctuations in markets because their size allowed them to persist. However, this arrangement depended on the ability of large numbers of U.S. residents to fall back on subsistence farming during economic downturns. As more and more corporations were established, it became more difficult for corporations to predict and control their dealings with large corporations or government. The success of the corporate model depended upon there being a large segment of society that was not corporate; as that proportion decreased, corporations became more vulnerable to the business cycle. The success of this corporate system resulted in people moving from farms to towns and cities, leaving an increasing number of people unable to revert to a subsistence livelihood. In this changed situation, corporate policies, which formerly worked, failed, as firing of workers decreased purchases and initiated a downward spiral. Indeed, corporatization methods resulted in a bigger crash when it did arrive in 1929.

What this suggests theoretically is that people can organize institutions to avoid crashes or oscillations (such as climatic variation in the Everglades), but that focus on the spatial and/or temporal scale of the oscillations leaves these new institutions vulnerable to larger and smaller dynamics.

The α phase is the phase that is least understood because of its inherently unpredictable nature. The only treatment we have encountered that gives it some specificity is from the body of chaos theory (Stewart 1989). One of the key points of chaos theory is that slight changes in initial conditions can generate a great complexity of behavior and unpredictable outcomes. A favorite example comes from a simple model of the atmosphere developed by Lorenz (Stewart 1989), which showed that slight departures from initial conditions of weather lead to widely divergent futures. The behavior that results looks random, although within a bounded domain, and yet is completely deterministic and inherently unpredictable. Lorenz named this the Butterfly Effect, dramatizing the phenomenon with an analogy in which a butterfly flapping its wings in Beijing now can change storm patterns in Florida next month.

Many examples of chaotic behavior have been identified or proposed in physical, biological, and social systems. As with any new theory that is partial but gives fresh insight, chaos theory has generated an exuberant search for other examples, driven by the yearning for universality. Is healthy brain function chaotic and unhealthy functioning stable? Does heart function have chaotic patterns? Planetary orbits? But for ecosystems, at least, the question should not be whether they are chaotic, but under what conditions they are chaotic and under what conditions they are not.

For long periods, ecosystems develop growing connectivity and predictability as they progress through the r to the K sequence. During this transition, the conditions that generate chaotic behavior are unlikely because of growing regulatory processes functioning within wide stability

domains. But those same conditions also gradually produce a brittleness that sets the condition for the release, or creative destruction phase. That then leads to the conditions for chaotic behavior during the brief period when the cycle achieves the weakly connected state of the α phase. It is this organization that allows, in Kauffman's (1993) terms, systems to exploit the edge of chaos where adaptive opportunity lies. But the window for that opportunity opens briefly, in comparison with the longer period of accumulating capital.

To summarize, at times system behavior is determined by the r-strategists—pioneers, entrepreneurs, and opportunists. They set the conditions for control to shift to the K-strategists—to the effective competitors and consolidators of position and power. Resilience is reduced, controls intensified, and the system can become an accident waiting to happen. As the shift to the Ω phase occurs, the slow, extensive variables lose their control of system behavior; fast variables assume control and suddenly release the capital that was stored and sequestered in tightly organized form. This capital then becomes dissociated in the α phase, where a new set of variables, processes, and random events slow the leakage of capital out of the system, mobilize it in accessible forms, and precipitate possible unexpected associations between previously independent variables. The α phase is the one with the greatest uncertainty—both of risk and of opportunity.

Resilience in Social Systems

In this section, we examine the property of resilience in social systems. As described in Chapter 2, resilience is defined *sensu* Holling (1973b) as the amount of disturbance that a system can absorb without changing stability domains. But does that property of systems extend to social ones as well? We begin with some modest answers in the remainder of this chapter. Other contributors to this volume will embellish and extend those responses. We structure our arguments about resilience in social systems in the following three paragraphs. In the first, we discuss how social systems (primarily those linked to ecological systems) respond to disturbances and whether they (social systems) appear as multiple or alternative stable states. In the second section we discuss how social systems renew both themselves and ecological components through building adaptive capacity. We end with a section on the role of novelty in social systems, a property we suspect is greater than in ecological ones. We begin with the recognition of alternative states or organizational patterns in social systems.

In the preceding section, we argued that resource management institutions go through similar phases of the adaptive cycle. That heuristic is useful to depict founding, maturation, crisis, and reformation of institutions. The history of water management in the Everglades was used as an example to illustrate how ecological crises led to new configurations of water management institutions. Each of the alternative institutional configurations (or water management eras) can be thought of as an alternative stability domain of the social system. In each of the evolutionary transitions unforeseen ecological variation exceeded the resilience of the social system, resulting in a new configuration (Table 12-1). The flood of 1903 resulted in an institutional configuration called the Flood Control District, in which a board of trustees oversaw and funded the digging of canals and levees in the system. In 1947, the new social structure was called the Central and Southern Florida Flood Control District and reflected a partnership of federal, state, and local governments to build and manage the hydrologic infrastructure. In 1971, a drought created yet another institutional arrangement, the South Florida Water Management District, with a new set of management objectives—flood control and water supply. A similar reconfiguration was made in 1983, with the creation of an informal meshing group—the Everglades Coalition—aimed at coordinating governmental and nongovernmental organizations to seek resolution of chronic environmental issues.

Social organizations linked to resource systems can respond to environmental crises in a number of ways. Many organizations focus on the renewal and novelty, while others focus on buffering themselves against change. Long-standing (and in some sense successful) social systems that deal with natural resources focus on mechanisms that buffer disturbances or attempt to minimize the magnitude of perturbations (Berkes and Folke 1998). Yet in a wide range of systems, that approach appears to prevent crises from overwhelming the adaptive capacity of the social system (Folke, Berkes, and Colding 1998). Folke, Berkes, and Colding (1998) argue that this distinction is one of scale matching—that is, by managing disturbances at an appropriate scale, some stability of social institutions is achieved. Other institutional responses deal with environmental fluctuations or crises through a shifting set of rules, and other mechanisms for when alternative rule sets are invoked. These shifting rule sets often involve incipient institutions, where new entities come into play along with new rule sets. Such is the case with U.S.-based emergency management agencies, or in traditional societies' "sleeping territorialities" (Folke, Berkes, and Golding 1998). This pattern is similar to the role of species diversity in ecological resilience (Peterson et al. 1998; Walker et al. 1999).

Table 12-1. Institutional Reconfigurations in Response to Ecological Crises in the Everglades

Release/Trigger

Crisis (year)	Institution Created Following Crisis
Flood (1903)	Everglades Drainage District
Flood (1947)	Central and Southern Florida Flood Control District
Drought (1971)	South Florida Water Management District
Flood in park (1983)	Everglades Coalition
Lawsuit (1989)	Federal Restudy Committee, Governor's Commission for Sustainable South Florida

A unique property of human systems in response to uncertainty is the generation of new types of social structures. Novelty is key in responding to surprises or crises. Humans are unique in that they create novelty that transforms the future over multiple decades to centuries. Natural evolutionary processes cause the same magnitude of transformation over time spans of millennia. Examples are the creation of new types and arrangements of management institutions after resource crises in the Everglades (Light et al. 1995), the Columbia River Basin (Lee 1993), and the Baltic Sea (Jansson and Velner 1995). In technologies it is invention and adaptations that transform the future (Arthur et al. 1997).

One interpretation of this institutional creation is that these institutions are set up to resolve types of uncertainties. They provide a venue in which some technical and social uncertainties can be resolved (Chapter 6; Lee 1993).

Yet there are many situations where the institutions constantly struggle with resolving those uncertainties; and those with high r institutional inertia can be described as unable to reinvent themselves and adapt to changing conditions. Many agencies appear incapable of generating either novel solutions or policies to solve chronic resource problems; one of the few mechanisms for change is an ecological crisis, as appeared true in the Everglades (Light et al. 1995; Gunderson 1999).

One reason that management institutions have such high moments of inertia is that they utilize (directly or indirectly) ambiguities and uncertainties of resource issues to maintain a status quo. With a pragmatic focus on policy implementation, most agencies seem to have a twofold strategy that is aimed at reinforcing the status quo: prove that extant policies are correct, and don't act until confident of what to do next. Many agencies focus on implementation, without realizing either that narrow implementation schemes often subvert policy intent, or that implementation is an organic process that changes over time and reveals the failure of policy, not its success (Gunderson et al. 1995b). One example of this is the implementation of the legislation that guaranteed a minimum water delivery to Everglades National Park in 1970. The intent of the law was to ensure that the park got a minimum amount of water each year—at least 350,000 acre feet/year. Instead, over the next decade, the park received the legislated amount, regardless of ambient rainfall or storage within the system.

Another source of bureaucratic inertia is the power of vested interest groups, particularly those that have political and social sway over agencies.

While science uses uncertainty to drive the engine of inquiry, vested interest groups use and foster uncertainty to maintain a status quo policy. There are many examples—take the actions of sugar farmers in the Everglades following claims that nutrient runoff was changing the structure and function of pristine areas in the Everglades. Prominent scientists were hired to generate alternative hypotheses (other than those that involved phosphorus), which for a while stopped any movement toward resolving that crisis. Similar results of disinformation campaigns have been chronicled for health, climate change, and biodiversity issues (Ehrlich and Ehrlich 1996). Vested interests are not the only groups that generate or defend pet hypotheses. Agency scientists often generate policy recommendations that are politically correct in the sense of gaining what they view as a favorable policy. These examples further highlight the point that science is a highly social process, with lots of tacit and implicit factors influencing and shaping an "objective" process.

Our exploration of possible similarities and differences between actual ecological and social systems and between theories of change developed in each field has led us to better formalize two features that distinguish our arguments. One has to do with the adaptive character of the opportunity that is opened by the destruction and renewal phases (Ω to α) of the four-phase cycle. The other has to do with the nested nature of the elements that comprise complex ecological or social systems. We will deal with each in turn in the next section, where we attempt a theoretical synthesis.

Linking Theories of Ecologic and Social Dynamics

In contrast to existing theories of social change, the four-phase adaptive cycle emphasizes a loop from hierarchical consolidation in the K phase to two phases of destruction and reorganization where innovation and chance assume a dominant role. That reorganization phase occurs when a rare and unexpected intervention or event can shape new futures as an act of creating opportunity. The tight organization and hierarchical control of the K phase, which precludes alternatives, is broken because of maturing brittleness that often intersects with external events that provide the proximate trigger for the change. The resulting loss of control leads to the release of the accumulated capital (nutrients and organized carbon in ecosystems; money, skills, contacts, and experience in organizations) and to its decay or dissociation into constituent elements in the α phase. At this stage the system becomes ill defined and loosely coupled. The system is in a paradoxical phase; it is in a state most likely to collapse or be transformed by innovation. High risks are matched by great opportunity. In human systems, it is the stage where the individual, for good or ill, has the greatest potential for influencing the future. The disassociated nature of the α phase is the very condition that makes either good or bad outcome possible.

As an example, the adaptive model can help describe the dynamics of resource management institutions (Figure 12-2). Most bureaucratic

institutions are set up to carry out some set of policies, and indeed spend most of their time and resources implementing those policies and monitoring key indicators in the ecosystem. The Corps of Engineers and the South Florida Water Management District are those bureaucracies in the Everglades. Inevitably, crises arise and are usually dramatized by some outside activists claiming that existing policy is no longer viable. The reformation phase involves a temporary group, often outside the institution itself, whose members informally develop alternatives for formally empowered decision makers. Just as the activists are the agents of release (the spruce budworms of institutions), the temporary groups (or individuals) essentially create the future in the way alternative policies are designed and presented.

Note that as the system cycles through all of its four phases, although control shifts from one set of variables, processes, and events to another set, all variables and processes other than the ones controlling at the moment are present in all phases and function in either a maintenance or a "holding" pattern. For example, pioneer species or entrepreneurs are present during the consolidation phases when conditions are inimical to them; some trees and bureaucrats (or at least the seeds and saplings of each) persist through the release and reorganization sequence; soil processes function throughout all phases. It is that functional diversity that keeps critical actors in the wings or in a supporting role, while the lead shifts for a period to others. The four-phase cycle has helped make sense of the case studies we have explored, the actors involved, and the role they play. This is summarized in Table 12-2.

Although we see fundamental similarity between adaptive ecological and adaptive human systems, we propose that the human ones have much greater powers for both rigidity and novelty. The ability of the bureaucracy of a gov-

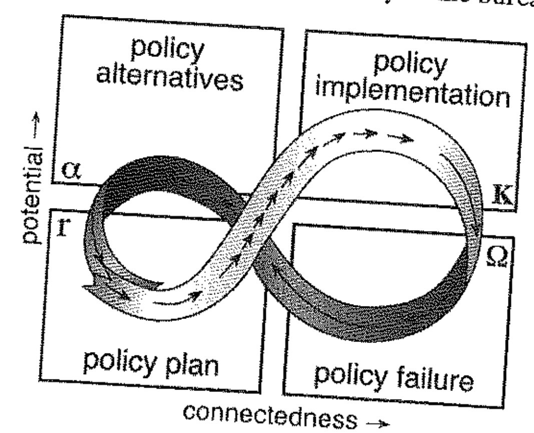

Figure 12-2. Generalized adaptive cycle applied to resource management policy. Note that the diagram is a specific rendition of the four-phase dynamic, and various groups facilitate the transitions among phases of policy development, implementation, and failure.

Table 12-2. Attributes of Human Groups That Dominate Activities in Four Phases of the Adaptive Cycle as It Applies to Resource Management Policy

Characteristics	**Phase of Adaptive Cycle**			
	$r \rightarrow K$	$K \rightarrow \Omega$	$\Omega \rightarrow \alpha$	$\alpha \rightarrow$ new state
Group type (government)	bureaucracy	loyal heretics	reformers	higher level decision body
Group type (collective)	NGOs	activists	epistemic community	visionary new leader
Policy activity	implementing	destroying	framing new options	resolution transformation
Science and policy relationship	science affirms policy	science invalidates policy	science integrates and assesses	science is politically expedient
Type of science	monitoring	rejecting single hypothesis	sorting among multiple hypotheses	expert testimony
Strategy	"Doing as before but more"	"Creating a crisis"	"Unlearning yesterday"	"Inventing tomorrow"
Response to change	ignoring and denying change	forcing change	creating new futures	compromising or reconciling
Guiding vision	stability	anarchy	reconstruction	reconfiguration of myths

Source: Modified from Gunderson et al. 1995b.

Note: The listed group dominates during the phase indicated, but is present and functioning in other phases as well. This table represents a centrist view of primarily North American institutions.

ernment agency to control information and resist change seems to show a level of individual and group ingenuity and persistence that reflects conscious control by dedicated and intelligent individuals. And certainly some empires and some institutions have long endured in their same basic form. But that observation might simply reflect the frustration the authors have experienced in dealing with inflexible bureaucracies. Alternatively, the possibility exists that the locus and speed of the adaptive cycle can be changed by conscious design so that renewal occurs internally while overall structure is maintained.

In the Everglades, there are examples of institutions that are reinvented (as suggested by the adaptive cycle). Examples include the creation of the South Florida Water Management District in 1971 and the Everglades Coalition in 1983. Yet there are also examples of long-lasting or apparently resilient institutions (such as the National Park Service and the Corps of Engineers). These institutions appear to keep the novelty of the reorganization phase and the consolidation of the r phase in some kind of working relationship. This appears to be done by periodically changing leadership. Some bureaucracies remain responsive and adaptive over long periods of time. These seem to be the ones that allow for deviants to continue to express alternate views within the organization and wherein those at the strategic apex remain aware and informed about the innovations. The Catholic Church is a good example of this: at critical points popes have recognized potential "heresies"—instead of attempting to suppress them—negotiated with the heretics to incorporate innovation into church practice while maintaining overall structure. Similar examples exist in the Everglades; a scientist with the Water Management District was shunned within his organization in the 1980s when he brought to light the issues of nutrient-induced vegetation change. Yet with a change in leadership a few years later, he became chief ecologist for the district and led the ongoing ecosystem restoration efforts. Chapter 13 provides a wonderful treatment of similar dynamics in another setting.

As indicated in Chapter 2, there are exceptions to the adaptive cycle, which are particularly germane to large, bureaucratic institutions. At times, the upward flow of information inside a bureaucracy is so curtailed that leaders do not hear dissenting views, or the leadership is so intolerant of dissenters that they expel them (as in the Protestant Reformation). Perhaps the lack of dissenting information is one condition that would precede collapse or reorganization within the bureaucracy. One unanswered question is whether social systems can get "trapped" in one of the phases of the adaptive cycle. This is suggested in Chapter 2, as poverty or hierarchy traps. Hints that social systems become trapped in a crisis or reorganization phase are what Kai Erikson (1995) has described as chronic disaster. But for the resilient systems and agencies, the key seems to be managing for change, not against it. We continue this argument into the next section, where cross-scale interactions are discussed.

Panarchies and Ecosystem Politics

In Chapter 3 of this volume the concept of panarchy is introduced as a construct for combining features of the adaptive cycle with processes that interact across scales. The history of water management in the Everglades can help highlight some aspects of the panarchy model, especially around up (revolt) and down (remember) scale processes.

In each of the four cycles of management eras in the Everglades in the twentieth century, an ecological crisis was key in precipitating the transition between eras. The crises during the first two eras were floods associated with excessive rainfall. The third crisis was associated with a drought year intersecting with a burgeoning human population. The most recent crisis was associated primarily with nutrient movement across an oligotrophic landscape, the result of earlier land-use transformation.

In all of these situations the crisis was the result of broader processes interacting with local vulnerabilities. In the first three cases, the crises were created by variations in larger-scale processes. The droughts and floods in the Everglades are linked to ENSO (El Niño Southern Oscillation) fluctuations—this coupling between sea surface temperatures in the southern Pacific and atmospheric flows can dramatically influence how much rain falls on southern Florida. Yet the variation in rainfall was intersecting with changing local situations—incipient agriculture in 1903, human development along the eastern coastal ridge in 1947 and 1971. A similar model can be used to explain the most recent, nutrient-induced, crisis, where changing soil nutrient levels reduced the resilience of the native vegetation to deal with variability in droughts, fires, or freezes (Davis 1994). So as the resilience was exceeded in each of these cases, the ensuing crisis created cross-scale reactions that cascaded and increased the scale of impact.

All of these crises brought into question the efficacy of water management policy at the scale of the Everglades ecosystem. The flooding in 1903 and 1947 was noted primarily in the developed areas south of Lake Okeechobee and along the coastal ridge. The drought of 1971 impacted urbanized portions of the historical eastern Everglades. The nutrient-induced vegetation shifts occurred in local regions near canals of water conservation areas one and two. Yet these local impacts cascaded to the spatial extent of the Everglades, in large part due to the perception that the policies of water management operated at the scale of the hydrologic system. Hence these crises would have to be resolved at the scale of the hydrologic system—where policies were operating.

The cascading or upscaling of crises at one level to a larger level is described as revolt processes in the panarchy model. The positive feedbacks of the temporal processes intersecting with the broader-scale connections create this rapid upscaling (Figure 12-3). In these Everglades crises, the social constructs seem to amplify and resonate with deep-seated myths or beliefs about the system. For example, the myth of a "fragile" Everglades ecosystem (similar to the myth of nature anarchic, Chapter 1) appears to be reinforced by media stories. It is that interaction, the propagation of the social constructs, that seems to provide the upscaling phenomenon. For example, a picture of a drowning cow was used in 1947 to depict the struggle to deal with a devastating flood and the need to recover from this unexpected natural disaster. In 1983, reports and pictures of the algae bloom in Lake Okeechobee provided evidence of the continued environmental degradation

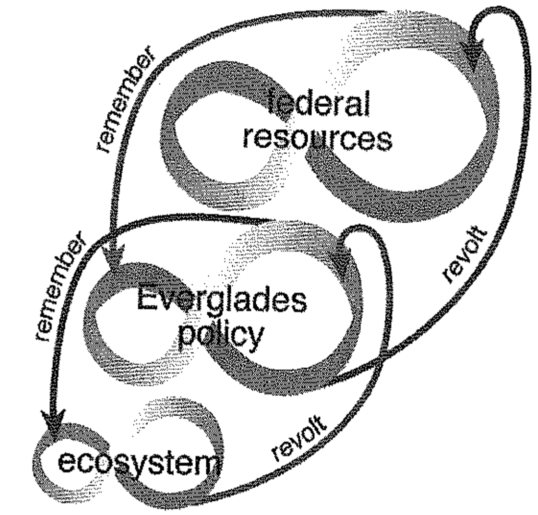

Figure 12-3. Panarchy of a linked ecological-social system. This figure depicts three scales of structures and processes as they interact in the Everglades. Processes that propagate upscale are labeled "revolt" and include the social contagion associated with an ecological surprise. Those processes create access to larger-scale resources that cascade downscale (labeled "remember"). In the Everglades, often federal capital (money, expertise, and values) is used to modify policy and adapt or modify the ecological surprise.

of the Everglades. The mass media of newspapers and television seem to provide the matrix or grid by which these events cascade across scale and are spread to wider audiences. So perhaps one of the keys as to why these ecological crises, and not others, played key roles in crystallizing deep social changes is that they were rapidly shifted to larger scales and created a larger arena in which alternative futures were determined. But there is something missing, which we can only identify for future research, as to what makes these larger systems vulnerable at some times and not at others. Another difficulty in this analysis is that the revolt and remember events in social systems are more difficult to pinpoint due to unclear bounds of social structures across scales.

If indeed these identified crises were events of revolt, the resulting solutions to the crises were also linked to broader and larger-scale structures and processes. That is, as the crises were scaled to larger-scale venues, suddenly the resources at those larger scales became available for solutions at the local or smaller scale. This is clearly the case in all of the crises in the Everglades since the 1920s, when federal resources or capital were brought to bear to resolve the local surprise. In 1947, it was tax dollars, and the expertise of the Army Corps of Engineers, that enabled the central and southern Florida flood control plan to be implemented. Local or state resources would clearly not have been able to accomplish such a massive undertaking. In a sense, a set of plausible alternative futures was discarded by the imposition of federal resources. The federal capital was accessed again in the 1970s, 1980s, and 1990s, but these times it was in the form of negative incentive, in terms of constraining the options for management available to the state water managers. The constraints were in the form of mandating water quality concerns and water supply needs for federally held properties in the Everglades. So the remembrance process—tapping into capital at larger scales—was critical in both creating and confining options for renewal in Everglades policy following smaller-scale crises that revealed the inadequacies of that policy.

Summary and Conclusions

In this chapter, we have used the heuristics of the adaptive cycle (Holling 1992; Chapter 2) and panarchy (Gunderson et al. 1995a; Chapter 3) to examine some similarities between ecological and social systems. We used a case history from the Everglades to illustrate linkages between ecological and social systems. In most of these systems the linked or composite system followed the four phases of the adaptive cycle. As new institutions (social rules, norms, and structures) matured, they became more and more vulnerable to disturbances or perturbations from the outside. In some cases, those disturbances were part of unforeseen or nonrecorded variation in key processes of the ecological system. In other cases, the effects of those disturbances were exaggerated by previous management actions, leading to an increased vulnerability of the social system. This is apparently the case in the history of many technologically based systems—including wetland systems such as the Everglades, where water level is the key management target.

Other similarities exist between ecological and social systems, in the back loop (renewal and reorganization phases) of the adaptive cycle. Many social systems focus on buffering mechanisms to maintain their resilience. Those institutions actively pursue ecosystem management actions to mitigate impacts of disturbances and maintain their stability through tolerable perturbations. Other institutional settings show a remarkable ability to reinvent themselves or create totally new solutions.

CHAPTER 13
THE DEVIL IN THE DYNAMICS: ADAPTIVE MANAGEMENT ON THE FRONT LINES

Frances Westley

Once upon a time, everything seemed fixed and solid. Now everything in the universe has begun to slide under our feet: mountains, continents, life, and even matter itself. To make future progress science must peel away all the coverings of apparent stability in the world.
—Teilhard de Chardin

This chapter focuses squarely on the management aspect of adaptive management. Much work has been done exploring, describing, and modeling the ecosystem dynamics. The phases of Holling's four-box cycle have been charted and analyzed in ecosystems around the world, and our understanding of the complex and unpredictable aspects of those dynamics has increased as a result. Less work has been done on exploring, describing, and modeling the social system dynamics and their interaction with the adaptive environmental cycles. However, here too, steady progress has been made. Gunderson, Holling, and Light (1995a) explored the interactions between management approaches and ecological crisis and renewal from a historical perspective. Holling and Sanderson (1996) have been developing a political ecological approach; Berkes and Folke (1994, 1998) with colleagues have been documenting and exploring the role of traditional ecological knowledge (TEK) in maintaining ecological resilience. For the most part, however, these studies have focused on the macro level, in order to apprehend the slow variables (institutions, laws, and cultures) and the ways in which particular management practices embedded in institutions support or undermine ecological resilience.

This chapter will take a micro-level perspective, in an effort to complement the work done from the institutional perspectives. It will focus on the case of one manager, Evan Karel, and a series of resource management challenges in which he tried to manage adaptively. Our concern is at the level of the individual decision maker, and at the level of the relationships in which he is embedded and seeks to work. We will explore how the larger institutional forces affect the individual decision maker, and to what extent the