Chapter 2
Adaptive Management, a Personal History

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Introduction: How it All Began

The choice was made at 30,000 feet, flying over Managua, Nicaragua on the way home from a workshop in Venezuela. The workshop was about comparing different disturbed regional systems, by exploring both theory and possible management actions. It was a workshop that brought together a Russian (a grand and wonderful mathematician who, sadly, later got into trouble with Soviet authorities), Canadians, Americans, Venezuelans, Argentineans, and Europeans from different countries. We had a great meeting but were still groping for an appropriate name for the planned book.

The news was full of the recent Managua earthquake and I had just read a review of Bob Kate's work that emphasized how the poor formal facilities in the city provided little help to survivors of the quake. Instead, they drew upon their extended families, and thereby mobilized the key help needed for nurture and recovery. It became help at the scale of a neighborhood. And the image of that kind of crisis and that kind of recovery acted as a metaphor for the way ecosystems and

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regional systems function. Suddenly the word “adaptive” popped in my mind, and the name became the one that was beautifully suited for our work- both applied and theoretical.

We used the term adaptive management for the applied aspects of these new ideas, the adaptive cycle to describe the fundamental structure and dynamics of systems and adaptive assessment for the methods. And resilience, along with panarchy (though developed much later) were the words we used that eventually captured the theoretical foundations of the core ideas—non-linearity, surprise, alternative stable states and cross-scale dynamics in space and time.

The Theory Behind it All

Theory shaped the emergence of adaptive management. The 1973 ‘resilience’ paper (Holling 1973) really launched the adaptive management work we subsequently developed at the University of British Columbia. Resilience is the ability of a system to experience disturbances, to be changed thereby and then to re-organize and still retain the same basic structure and ways of functioning. It includes the ability to learn from disturbance. Flexibility and break points are at its heart. The precepts of adaptive management were developed as a response to defining an ecosystem in terms of resilience.

A resilient system is forgiving of external shocks. If resilience declines because of resource exploitation and loss of diversity, the magnitude of a shock from which it cannot recover gets smaller and smaller. Resilience shifts attention from growth and efficiency to recovery and flexibility. Growth and efficiency alone can often lead ecological systems, businesses and societies into fragile rigidities, exposing them to completely unexpected turbulent transformation. Resilience, in contrast, adds learning, recovery and flexibility as inherent properties of complex systems. It opens eyes to novelty and new worlds of opportunity.

Growth, as economists see it, is important, but equally so are the resilience forces in a healthy system that dominate during infrequent crises and collapses. And systems are healthy when they can grow for periods but can also generate creative collapses and can renew after collapses. During episodes when growth is halted or reversed, deep uncertainty appears, and alternative futures are unexpectedly perceived. Suddenly, the resulting unpredictability stifles informed action or triggers ignorant and fearful reaction, and there is a search for certainty.

That search for certainty smothers opportunity. Alternatives are suppressed and rigidity increases. Security is what is being sought, independent of evidence to the contrary, and often, when possible, such evidence is masked or hidden. In contrast, adaptive management seeks ways for the system itself to provide clues about opportunities and their consequences by setting up policies that in part provide products and in part are experiments that test causes of uncertainty and suggest solutions. For adaptive management the unknown is ever alive and present, with monitoring a constant need that can always be launched, but is difficult to sustain.

Applied Developments

Once some of the relevant theory was developed, it led to more applied phases of investigation, where Carl Walters became a central partner. He was and is a truly brilliant, maverick scientist who walks a non-traditional path that creates new traditions. His work on adaptive management methods has been a classic contribution to the field (Walters 1986), and more recently, he has advanced our understanding of ecosystem dynamics (Walters and Martell 2004).

The resilience research led a group, largely at British Columbia, to mobilize a series of studies of large-scale ecosystems subject to management, including terrestrial, fresh water and marine. Each study was coordinated with the key scientists involved in the ecosystem, and, in some cases, policy people who "owned" the systems and the data. Typically, several organizations were involved because of the different home bases of participants. The process encouraged two major advances.

One advance was that the set of deep studies allowed a comparative analysis of the theoretical foundations of ecosystem behavior and ecosystem management that was ecological, social and economic. That was the part that was particularly interesting, and it led to the book where the term 'adaptive management' was used for the first time (Holling 1978). The second advance was that in the course of conducting these ecosystem studies and comparisons, we developed a sequence of workshop techniques for working with experts in order to develop alternative explanatory models and suggestive policies. In the models, several scales were chosen, based on where we thought the causes lay, and we posed alternative hypotheses for the unknown relationships. Subsequent simulations then showed which, if any, of those alternatives were important in affecting behavior of the integrated system. If they were unimportant they were forgotten; if important they became a focus for further research. The models were then used in a second phase of the workshops to search for effective alternative policies. Three or four extreme policies with contrasting objectives were tested, and then a sustained policy was discovered that balanced economic, social and ecological objectives.

An immense amount was learned from our first experiments, which focused on the beautiful Gulf Islands, an archipelago off the coast of southern British Columbia. We chose to develop a simulation model of recreational property development. I knew little about land speculation, but we made up a marvelous scheme that used my earlier predation equations as the foundation of our modeling exercise—the land of various classes were the "prey", speculators were the "predators" and a highest bidder auction cleared the market each year. The equations were modifications of the general predation equations (Holling 1988). The predictions were astonishingly effective and persisted for at least two decades. As much as anything, it reinforced the earlier conclusion that these equations were powerful and general. But the important conclusion concerned the workshop process and the people.

The essence of those workshop methods were fun to present in a critical paper where the workshop processes were described and where key personalities were represented in delightful cartoons drawn by Roy Peterson, a cartoonist in Vancouver, and methods were expressed as a game (Holling and Chambers 1973). It was fun to reveal the truth about characters like Snively Whiplash, The Blunt Scot, The Utopians, the Compleat Amanuensis and The Peerless Leaders in this way. But a reviewer in *Ecology* turned the manuscript down by saying "no one wants to know about the games people in British Columbia play!" Bioscience reviewers were more enlightened so I happily published there.

I learned that the key design feature for these workshops was to start with two goals. The first goal was long term: to identify large, unattainable goals that can be approached, but never achieved, that relate to fundamental values of freedom, equity, tolerance and education. And then, for the second goal, to add a tough design for the first step, in a way that highlights or creates options to design, later, a second step—and then a third and so on. We found that the results were steps that rapidly covered more ground than could ever be designed at the start. At the heart, that is adaptive design, where the unknown is great, learning is continual and actions evolve. But it is tough for staff of a granting agency, who when they ask what specifics we expected, blanch at being told "wait and see".

Theory and Practice Both Trigger Institutional Needs

My work always shifted between fundamental theory and applied research. Surprises occurring at one stage became explored in the second, so the old categorization into basic or applied research had no meaning where my work was concerned. Each was intertwined with the other, and each benefited thereby. I found so much of existing theory seriously irrelevant at that time in the 1970's. It was too simplistic, too static, too uniform in scale, too linear and perceived by the originators as too certain. Traditional ecological practice based on such ideas was therefore grossly ineffective. As an example, it was no wonder that cod collapsed on the east coast of Canada, and since 1992 still shows only a weak sign of recovery even with fishing banned.

We had no difficulty in facing and discussing these issues when people were in workshops. The majority of participants grasped the non-linearity, the thresholds separating different quasi-stable states, the varied spatial patterns at different scales, the inherent uncertainty, the unknown and the necessary complexity of social-ecological systems. When these concepts are understood, the fixed world of standard environmental protection is recognized as being rigid and wrong. Those who got it became the subset of folks in ecology, economics, social science, political science, etc., the ones who could work together to design different solutions as acts of mutual discovery.

That rationale of mutual discovery, developed over 30 years in workshops and in theoretical studies from fish to forests, led us to form an internet organization in 1999 called the Resilience Alliance (http://www.resalliance.org), that combined several groups around the world in collaborative research and collaborative publishing. Fundamentally it was meant to sustain the international cooperation that had emerged in several of these earlier projects, and assist in the continued search for a deeper understanding and ever-broader examples of complexity in nature.

However, when such groups attempt to encourage implementation of adaptive management, the success is often only partial. Carl Walters described the failures well in a paper (Walters 1997). It is a failure of implementation, not of analysis, evaluation, understanding or policy. I found that two projects I got deeply involved with provided beautiful examples of successes and failures. Both moved to a phase of implementation with variable success, but prior to that, the models, understandings and alternative policies coming from the workshops were central to the initial suspension of regional conflicts in each case.

The first project concerned the Florida Everglades, with Lance Gunderson contributing deep insight and personal experience in the process. The Everglades project was undergoing one of its crises of transformation. That project succeeded in developing an understanding of a system functioning at three different spatial and temporal scales, from sawgrass and tree islands, to slough structures and sugar plantations, to topography. But it was also the example that failed on implementation, because the adaptive experiments were lost and the system became locked into an enormously expensive effort of ecosystem restoration. There was no respected, responsible leader who could survive the political games among the four jurisdictions involved—municipal, regional district, State, and Nation. No one, therefore, could continue with the responsibility to manage a transition. There were just committees of local, state and national government, combined with a good NGO, which became politically active and politically rigid.

The other project concerned forest growth, forest crises and harvesting in the eastern Boreal Forest in the face of spruce budworm outbreaks. This project was housed at the International Institute of Applied Systems Analysis (IIASA), with links to a team in New Brunswick led by Gordon Baskerville. Bill Clark, Dixon Jones, Mike Fiering and I led the effort at IIASA—a wonderful group with a remarkable ability to blend different experiences. Over the centuries, spruce budworm outbreaks periodically swept from Manitoba, through Ontario and Quebec, into New Brunswick and Nova Scotia and still further east to Newfoundland and the eastern U.S. We focused on New Brunswick, Canada, an area just big enough to contain the essential scales and to connect to still larger areas. The project depended on the deep understanding of ecological dynamics that had earlier come from Frank Morris' classic study of Budworm outbreak dynamics and forest growth (Morris 1963). It succeeded in the sense that non-linearities and cross-scale dynamics were discovered, and we also developed a three-scale simulation model (Holling et al. 1977). Simplified versions of the model (Ludwig et al. 1978) were developed, adaptive experiments were identified and eventually flourished. Three scales of management evolved, monitoring and forest inventory was transformed, and the partner on our project, Gordon Baskerville, became continuing leader of the implementation (Clark et al. 1979).

Some of the leaders in those fields were part of IIASA's wonderfully innovative early days and found that the small budworm and its up-scale effects presented a rich set of data at a large scale. Howard Raiffa, George Dantzig and Tschalling Koopmans became our partners in this evaluation of the usefulness of those methods for multi-scale ecological/economic systems. The conclusions are reviewed in Bell (1972, 1977).

This leads us to a third revealing example of implementing adaptive management from Carl Folke, now Director of the Beijer Institute of Ecological Economics, and his colleagues. This is the example of a cycle of the continuing transformation of Kristianstads, a small city in southern Sweden, and its wetland landscapes (Olsson et al. 2004). After a major flooding crisis the traditional response of dike building and land draining was rejected and replaced by a vision of land and waterscapes integrated with a variety of peoples' activities. Solutions, when discovered, often "stayed in the back pocket" until public understanding emerged—a very real process of bottom-up design and implementation. Experiments and education were deeply involved in the transformation, which became a continuing effort with deep and extensive public involvement. A senior leader, Karl Magnusson, orchestrated the process from its beginnings. Vision, practicality, and leadership came together.

Each of these three cases succeeded in having participants from a broad range of organizations. But one, the Everglades, failed in implementation because for political reasons, options or experiments to test uncertainties were not explored and tested as part of the management design. The other two succeeded in opening options for the future through experiments in policy that were tested, allowing some options to be rejected, and some to be adapted.

Complexity

The complexity of these examples is considerable even when you look only at the behavior of people as they create and modify the associated social, economic and ecological processes that are part of systems. But when you examine the core of the causation of each problem, the examples look simpler. Most practical people deal with explanations created by the supposed actions of one or two variables. That is too simple. But we find we do not need more than about 5 variables at different scales to capture the full range of possible qualitatively different behaviors for the core part of the problem. We call that the Rule of Hand!

It is, however, very hard for people to think through explanations and devise policies or strategies by thinking of five things. So the Rule of Hand challenges the conceptual ability of people. That is why models are so essential at the beginning of adaptive management projects, and extensive and persistent monitoring needed at the end and thereafter. Without modeling, practitioners feel they are operating in a barren world of inadequate knowledge and conflicting explanations.

The other reason why the systems discussed seem so intractably complex is because many practitioners and scientists are not truly integrative. Some act purely as environmentalists, or industry advocates, or developers, or citizen helpers, in a society where the environment, economy, society and politics are all in a turbulent relationship with each other. The result is that so often too many become narrow "lobbyists", pushing simplistic explanations, avoiding shared discovery, ignoring uncertainty and the unknown, and are hostile to or fearful of adaptive experiments.

Hence that narrowness and avoidance of the unknown is true of all vested interests, so what is needed is to add an integrative overarching synthesis. That was the goal behind adaptive management.

Key Features of Adaptive Management

Jim Lovelock, the noted chemist, atmospheric scientist and innovative thinker, once asked me, "Why don't ecologists consider the environment?" It left me speechless, since ecology is meant to be focused on the INTER-action between the biota, physical structure and the environment. What he meant was that population and community ecologists at that time ignored the two-way dynamic nature of the interaction of the biota with the physical attributes of the environment. They did not recognize that the interaction between the living world and its physical structure modified and created attributes of both. That is what his Gaia is all about (Lovelock 1988). The biota in Lovelock's Daisy World regulate and manage the atmospheric chemistry to sustain a consistent temperature for life.

But population and community ecologists saw the environment and slow physical structures as a fixed (including stochastic) backdrop for the biota to apply exclusively biotic variables to understand ecological dynamics. Animals and plants can affect each other, so that paradigm goes, but animals and plants cannot develop interactive impacts on the physical structure and environment of their world. But we know, for example, that the savannas of Africa and the forests of Canada have physical spatial patterns caused by the action of animals from the small grazer to elephants, and from the small budworm defoliator to the moose, and that those patterns in turn facilitate the organisms that created them.

These notions created a new paradigm that characterizes ecosystem science. Such interactions between the biota and the physical world generate self-organized patterns that re-enforce the very processes creating them. The consequence is interrelated variables whose relationships are astonishingly robust and resilient (though not infinitely so—hence abrupt surprise). Jim Lovelock was right! Slow variables and fast variables set the interaction across scales, and the slow variables determine the resilience of the system. When you add evolution and natural selection, you get panarchy —clumps of function and structure across scales from centimeters and days of leaves and needles, in a series of steps to the hundreds of kilometers and millennia of forests and savannas (Gunderson and Holling 2002).

Where it Went

Since that flight back from Venezuela, a series of books emerged on Adaptive Management. Adaptive Environmental Assessment and Management (Holling 1978) was the first major book. Work on it started at IIASA and the resulting manuscript was finally reviewed at a meeting of senior international environmental people who offered critiques that were then incorporated into a final version. Carl Walters' book on methods was the next feature (Walters 1986) of significance that laid out the methods to deal with complex non-linear resource systems. Then came Compass and Gyroscope by Kai Lee (1994) and Barriers & Bridges (Gunderson et al. 1995).

The experiences of those early workshops helped shape the essential design and maintain the flexibility of the Resilience Alliance project that began about two decades later. The Resilience Alliance project was the third of a new program run by the Beijer International Institute of Ecological Economics. It produced a turbulent, broad and delightful process of mutual discovery for those who chose to be part of it. Hundreds of people, natural and social scientists, mathematicians, economists and ecologists from many countries attended one or more workshops over 5 years. All or most were held on islands around the world where deep differences could be discussed, resolved and highlighted. Adaptive management and resilience are intricately interrelated. Adaptive management is the process that allows safe to fail experiments of complex, large systems where there is uncertainty but a need to manage.

Collaboration was typical of my work since the discovery of multi-stable states in systems. That was when I realized that my knowledge only covered a part of the full story. Anything that dealt with regional scales and with ecosystems, economies and societies, required partnering with those who were deeply knowledgeable of each particular subject. Comparing different systems needed experts in each, ones who could think and search for commonalities.

The Resilience Alliance is a network of international scholars from many disciplines that continue to collaborate. The internet has provided an alternative means to develop an integrative and adaptive organization at low cost, and a journal, Ecology and Society, that is fully internet-based (arguably the first of this type). The Alliance is formed by about 20 groups from around the world, people who all share the same enthusiasms and flexible desires for novel and relevant work on resilience, complex systems and case studies. They each provide a modest annual membership fee to publish the journal and maintain the organization. Committed people are the key and grants do the rest. Integrative workshops interspersed with integrative research, integrative educational material and programs, and novel modes of communication provide a foundation for both fundamental integrative science and policy research.

A core part of the Resilience Alliance project was the design and preparation of four books. One was the integrative book Panarchy (Gunderson and Holling 2002), which was meant to show what we developed to test and integrate the separate theories and knowledge in ecosystem science, economics and aspects of the social sciences. The other books were designed to separately address the ecosystem, social and economic dimensions of resilience. The ecosystem book focused on multi-stable states in large scale ecosystems (Gunderson and Pritchard 2002). The social science book was a lovely one on governance of and institutions for social-ecological systems (Berkes et al. 2003). The economic one concerned non-linear economics focused on renewable resource ecosystems (Dasgupta and Maler 2004).

Resilience and multi-stable states now seem to be pervading notable parts of ecosystem science and related social sciences, and even emerging in policy. Both features are affecting international policy of some nations. And I note in a bibliographic survey by Marco Janssen that the original 1973 resilience paper has been a central reference that links vulnerability and resilience research (Holling 1973). That is indeed pleasing since it took such a long time to happen. And it was delightful to have a major review paper on resilience appear in the same Annual Review series that my original paper did 31 years earlier (Folke et al. 2004).

The Resilience Alliance publication that was particularly novel was the synthesis volume where resilience and panarchy were offered as names to combine the adaptive cycle with hierarchical structures across scales in space and time (Gunderson and Holling 2002). I poured out all I had discovered in the first three chapters of Panarchy and in the two summary chapters. A complete, personal mind dump! It was densely written but of sustained value still, after 13 years. That was a lovely effort. A marvelous group of people became the heart of the panarchy component–Buz Brock, Steve Carpenter, Carl Folke, Lance Gunderson, Don Ludwig, Lin Ostrom, Garry Peterson, Martin Scheffer, Brian Walker and Frances Westley. This is a mix that is strongly ecosystemic but also has extensive economic, social and mathematical science expertise.

The development of Panarchy led to a number of other books of real consequence–first is the Foundations of Ecological Resilience, which identified key papers that started the process (Gunderson et al. 2010). Frances Westley's Getting to Maybe (Westley et al. 2006), which provided interpretations for social behavior, and Thomas Homer Dixon's The Upside of Down (Homer-Dixon 2006), which provided insights into interpretations of international politics and turbulence. Marten Scheffer's Critical Transitions in Nature and Society (2009) is a deeply revealing explication of theoretical foundations, and Terry Chapin's Principles of Ecosystem Stewardship (Chapin et al. 2009) provides the first perceptive textbook of resilience and transformation in regional resource systems.

In addition, Craig Allen has tested and significantly extended the discovery that ecosystems are structured in a clumped manner across scales (Peterson et al. 1998, Allen et al. 1999). After critiques from some macroecologists, a workshop of supporters, skeptics and complexity theorists explored the data and examples (Allen and Holling 2008), leading to new projects from across the spectrum of reactions. The key was to use your own data and ask the question. The result provided still further evidence of the lumpiness of ecosystems (Allen et al. 2006) and of regional human populations, institutions and economic systems as well (Garmestani et al. 2006, 2008).

To my mind one of the many good papers published during the early years of the Resilience Alliance was the paper by Steve Carpenter, Buz Brock and P. Hanson (Carpenter et al. 1999). It used a meta-model of a watershed, a lake, individualist farmers and intensive farmers, a market manager, a land manager and a governing board. It was a synthetic, appropriately simple meta-model built on the basis of the deep knowledge that Steve Carpenter has of water and phosphate dynamics and

Buz Brock has of microeconomics and decision theory. It showed multi-stable states, and generated the adaptive cycle in its three dimensions of net economic yield (potential), population of intensive farms (connectedness) and attractor width (resilience). It showed the inevitability of periodic collapses in the face of fixed policies and showed the results of a strategy where one individual achieved a persistent system without collapses in the only way possible—through the probing, monitoring and learning policy of adaptive management. The structure of the foundational model (game) is provided as downloadable software and it thereby becomes important for the training of any resource manager (available at http://www.ecologyandsociety.org/vol3/iss2/art4/append9.html). As Si Levin said in a commentary, "The potential for this powerful combination of ordinary and extraordinary fare is just the sort of advance that sets Conservation Ecology (the name later changed to Ecology and Society) apart from standard journals" (personal communication).

Prediction, Uncertainty and What is Unknown

In response to a question in a press briefing on the Iraq war in December 2003, Donald Rumsfeld, U.S. Secretary of Defense said:

> Reports that say that something hasn't happened are always interesting to me, because, as we know, there are known knowns; there are things we know we know. We also know there are known unknowns; that is to say, we know there are some things we do not know. But there are also unknown unknowns- the ones we don't know we don't know.

Now that is a realistic statement for planning. It is all about behavior you can predict, behavior you can possibly expect, and behavior that is a complete surprise: prediction, uncertainty and surprise. That is what motivates the panarchy work and adaptive management. The surprises come from the way evolved systems are structured, the non-linearity that creates alternative stable conditions, and the influences that cross scales, from the fast and small to the big and slow.

I cannot prove it, but all our experience suggests that the key parts of regional systems can be captured with five to six sets of variables, similar to ecosystems. That makes understanding for policy actions difficult. It is easy to imagine the effects of single variables or of two, but three or more are a challenge to our minds and to those who live and endure those systems. That level of minimum-expected complexity helps create different lobby groups, each of which grabs a different small piece of the whole to explain the whole.

We deal with that in workshops involving people drawn from different organizations and lobbies. We initially mask the discussion and arguments of different goals by disaggregating the system into parts that can then be discussed, modeled and tested separately, with less emotional argument and more substantive ones. Combining all the modules makes an integrated model which opens the ability to discover what causes are important, what causes are unimportant, and what alternatives need further examination.

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