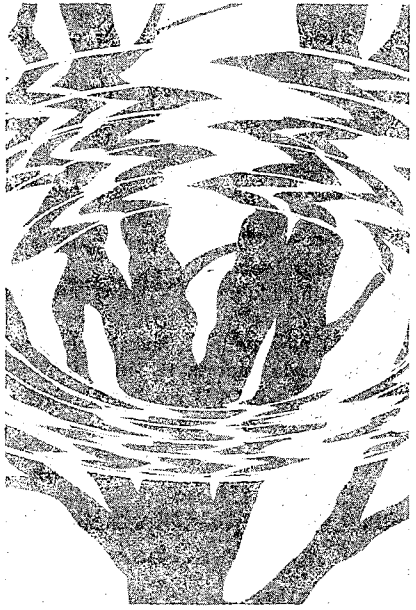
Resilience Thinking

Sustaining Ecosystems and People in a Changing World



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Foreword by Walter V. Reid

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Living in a Complex World:

An Introduction to Resilience Thinking

Life is full of surprises. Sometimes we take them in stride; some times they trip us up.

Consider these questions: In business, why is a competitor's new product sometimes only a minor hiccough but at other times a major shock that can destroy an enterprise? In industry, how is growth sometimes unaffected by medium interest rate rises but at other times the smallest change brings things crashing down? Why is it that the same drought that causes serious degradation of resources on one farm has little effect on another?

The response of any system to shocks and disturbances depends on its particular context, its connections across scales, and its current state. Every situation is different; things are always changing. It's a complex world.

We are all managers of systems of one type or another. That system might be a home, a company, or a nation. You might have responsibility of caring for a nature reserve, developing a mining operation, or planning fishing quotas. Be it a farm, a business, a region, or an industry, we are all part of some system of humans and nature (social-ecological systems).

How do you approach the task of management in this complex world? Do you assume things will happen in much the same way tomorrow as they did yesterday? Are you confident the system you are working in won't be disrupted by little surprises? Do you appreciate what's needed for a system to absorb unexpected disturbances?

All of these questions relate to *resilience*, the ability of a system to absorb disturbance and still retain its basic function and structure. They also relate to concepts of sustainability and the challenge of servicing

current system demands without eroding the potential to meet future needs. We live in a time of growing population coupled with a declining resource base and great uncertainty about a range of environmental issues such as climate change. How can we make the systems that we depend upon resilient?

But before we address issues of resilience, stop and consider for a moment our current practices of resource management.

The Drivers of Unsustainable Development

Our world is facing a broad range of serious and growing resource issues. Human-induced soil degradation has been getting worse since the 1950s. About 85 percent of agricultural land contains areas degraded by erosion, rising salt, soil compaction, and various other factors. It has been estimated (Wood et al. 2000) that soil degradation has already reduced global agricultural productivity by around 15 percent in the last fifty years. In the last three hundred years, topsoil has been lost at a rate of 300 million tons per year; in the last fifty years it has more than doubled to 760 million tons per year.

As we move deeper into the twenty-first century we cannot afford to lose more of our resource base. The global population is now expanding by about 75 million people each year. Population growth rates are declining, but the world's population will still be expanding by almost 60 million per year in 2030. The United Nations projections put the global population at nearly 8 billion in 2025. In addition, if current water consumption patterns continue unabated, half the world's population will live in water-stressed river basins by 2025.

The Food and Agriculture Organization of the United Nations (FAO) 2004 Annual Hunger Report estimates that over 850 million people suffer from chronic hunger. Hunger kills 5 million children every year.

The most famous fisheries in the world have collapsed one after the other, including those managed with the explicit aim of being sustainable (like the cod fisheries at Grand Banks, Newfoundland in 1992). Productive rangelands are turning into unproductive expanses of woody shrubs. Half of the world's wetlands have been lost in just the last century. Lake systems and rivers everywhere are experiencing algal blooms and a raft of problems associated with the oversupply of nutrients.

The World Wide Fund for Nature's (WWF) Living Planet report

BOX 1 A Few Stats on a Shrinking World

As far as humans are concerned, Earth is shrinking. The human population is growing but the resource base required to feed, clothe, and house this growing number of people is not. Indeed, in many instances it is declining. Here are a few numbers extracted in June, 2005 from the recently released Millennium Assessment, (www.millenniumassessment.org), and from the EarthTrends website, (http://earthtrends.wri.org.), maintained by the World Resources Institute.

- Worldwide, humans have already converted nearly a third of the land area—almost 3.8 billion hectares—to agriculture and urban or built-up areas. Most of the remainder is too dry for agriculture.
- Between 1960 and 2000, the demand for ecosystem services (benefits provided by ecosystems) grew significantly as world population doubled to 6 billion and the global economy increased more than six fold. To meet this demand, food production increased by roughly 2.5 times, water use doubled, wood harvests for pulp and paper production tripled, installed hydropower capacity doubled, and timber production increased by more than half.
- Global grain production, currently 1.84 billion tons annually, will need to increase by around 40 percent to meet demand in 2020.
- The average annual growth rate of cereal production in developing countries has dropped from 2.5 to 1 percent per year over the past 35 years. Water scarcity and land degradation are already severe enough to reduce yields on about 16 percent of agricultural lands, especially cropland in Africa and Central America, and pasture in Africa.
- In the last few decades approximately 20 percent of the world's coral reefs were lost, an additional 20 percent were degraded. In the Caribbean, 80 percent of coral has been lost in recent decades. Additionally, approximately a third of the world's mangrove areas were lost.
- The number of species on the planet is declining. Over the past few hundred years, humans have increased the species extinction rate by as much as 1,000 times over background rates typical over the planet's history. (The background extinction rate is the relatively constant rate—excluding major extinction events—at which organisms have been disappearing from the fossil record over the course of geological time.)
- Since 1750, the atmospheric concentration of carbon dioxide has increased by about a third (from about 280 to 376 parts per million in 2003), primarily due to the combustion of fossil fuels and land use changes. Approximately 60 percent of that increase (60 parts per million) has taken place since 1960.
- The use of two ecosystem services—capture fisheries and freshwater—is now well beyond levels that can be sustained even at current demands, much less future ones. At least one quarter of important commercial fish stocks are overharvested. From 5 percent to possibly 25 percent of global freshwater use exceeds long-term accessible supplies and is now met either through engineered water transfers or overdraft of groundwater supplies.

analyzes the eco-footprint of 150 countries around the world every two years. In its 2004 report it estimated that the average eco-footprint around the world was 2.2 global hectares per person (a global hectare is a hectare of biologically productive space with world-average productivity). However, there are only 1.8 global hectares available per person. This ecological overshoot means we are using the equivalent of about 1.2 planets or it takes 1.2 years to regenerate what humanity uses in one year. We are using nature more rapidly than it can regenerate.

Regrettably, like a cracked record, the story goes on and on, disturbingly repetitive (see also box 1, "A Few Stats on a Shrinking World").

You've seen or heard these claims before and it is not our intention to add to doom-and-gloom publications. Rather, this book is about options and hope based on a different way of doing things through understanding how the world really works. But we do need to keep in mind what is happening to the world. The imperative message is that the world is shrinking: the human population is growing while its resource base declines.

What lies behind this decline? There is, of course, no single underlying reason; instead, there is a broad spectrum of causes. But they can be grouped into three categories: in some situations people have no choice but to overuse their resource base; in others the decline is allowed to occur willfully; and the third driver of unsustainable development is misunderstanding—the application of inappropriate models of how the world works.

The first category (no choice) relates to problems associated with large populations coupled with poverty. In this case, no other option exists than to overuse resources. It's simply a matter of survival.

All too often, however, there is a choice, and a resource is allowed to decline or is purposely driven down. Sometimes rules and regulations encourage people to overuse resources, this is the case of subsidies for drought-stricken farmers. Often these farmers are either operating on marginal land or mismanaging resources but their operation is propped up by government payments designed to protect people from hardship. In other cases, tax breaks or industry support can lead to rapid loss of a forest or a fishery. These are what are known as "perverse incentives" (McNeely 1988). Furthermore, people sometimes deliberately choose to degrade a resource because they believe science and technology will always be able to come to the rescue.

In many cases, however, resource degradation is simply the result of humankind's insatiable desire to produce and consume, leading to willful short-term greed and corruption with no heed for the future. Some suggest this is just the way humans evolved—in a world without limits where success was based on maximizing your return. Human behavior is shaped strongly by drives from our evolutionary past (competition, territory, and power) without which we would not be here as a species or as the cultures we now have. Such evolutionary antecedents made sense when the human population was small and the world was seemingly endless but this is no longer the case. In today's world such behavior has begun to turn on us and will deprive future generations of the opportunities we enjoy.

But there is a third driver as well. Our environmental problems can't all be blamed on greed and overexploitation. Ignorance and misunderstanding also play a central role in the decline of our resource base. In many instances, such as in all of the case studies in this book, it's clear that in developing a resource or a region we have not understood well enough the functioning of the ecosystems involved. The people involved were not being greedy, there was no willful destruction. Many ecosystem collapses are occurring in places where enormous resources are being invested in understanding the system and where significant effort is being made to be "sustainable."

It isn't just the amount of knowledge—details about species and ecosystems—it's also the kind of knowledge. It's the way we conceive of resource systems and people as part of them. The way we currently use and manage these systems (which we describe in the following section as "business as usual") is no longer working and yet what we hear most of the time is that the solution lies in more of the same.

This book focuses on this third driver of unsustainability. The first driver (poverty) will only be resolved when the world has addressed the other two. We return to the second driver (willful excessive consumption) in the final chapter because our best hope for dealing with it also lies in a philosophy of resilience.

Despite Our Best Intentions

Why is it that, despite the best of intentions (and in contrast to the one or two recent books telling us that "everything is okay"), many of the world's productive landscapes and best loved ecosystems are in trouble?

Current "best practice" is based on a philosophy of optimizing the delivery of particular products (goods or services). It generally seeks to

maximize the production of specified components in the system (set of particular products or outcomes) by controlling certain others. Those components might be grain yields, fish catch, or timber harvest. Or, if conservation is the goal, optimization might be aimed at preserving as many species as possible in a national park or reserve. In the case of grain crops it might entail planting all the available land with a single high yielding variety and then maximizing growth with chemical fertilizers and pest control, and using large-scale cropping machinery. Production is maximized by tightly controlling each aspect of the production process.

Optimizing for particular products has characterized the early development of natural resource management, particularly in agriculture. Initially, it worked. Indeed, it resulted in enormous advances in resource productivity and human welfare. Now, however, those initial successes are bedeviled by a variety of emerging secondary and highly problematic effects on all continents and in all oceans. As Ogden Nash writes, "Progress might have been alright once, but it has gone on too long."

An optimization approach aims to get a system into some particular "optimal state," and then hold it there. That state, it is believed, will deliver maximum sustained benefit. It is sometimes recognized that the optimal state may vary under different conditions, and the approach is then to find the optimal path for the state of the system. This approach is sometimes referred to as a maximum sustainable yield or optimal sustainable yield paradigm.

To achieve this outcome, management builds models that generally assume (among other unrecognized assumptions) that changes will be incremental and linear (cause-and-effect changes). These models mostly ignore the implications of what might be happening at higher scales and frequently fail to take full account of changes at lower scales.

Optimization does not work as a best-practice model because this is not how the world works. The systems we live in and depend on are usually configured and reconfigured by extreme events, not average conditions. It takes a two-year drought, for example, to kill perennial plants in tropical savannas, and it takes extreme wet periods for new ones to be able to establish. The linkages between scales and sectors (agriculture, industry, conservation, energy, forestry, etc.) often drive changes in the particular system that is being managed. And, very importantly, while minor changes are often incremental and linear, the really significant ones are usually lurching and nonlinear—like mouse plagues in Australian wheat crops, insect pest outbreaks in forests in North America, and the sudden change from a clean, clear lake to one dominated by an algal bloom.

The Paradox of Efficiency and Optimization

"Efficiency" is a cornerstone of economics, and the very basis of environmental economics. In theory, an economy is efficient if it includes all the things that people want and value. An efficient economy, in this sense, is therefore a good thing and efficiency has become to be regarded as a laudable goal in policy and management. The paradox is that while optimization is supposedly about efficiency, because it is applied to a narrow range of values and a particular set of interests, the result is major inefficiencies in the way we generate values for societies. Being efficient, in a narrow sense, leads to elimination of redundancies—keeping only those things that are directly and immediately beneficial. We will show later that this kind of efficiency leads to drastic losses in resilience.

Optimization does not match the way our societies value things either. It promotes the simplification of values to a few quantifiable and marketable ones, such as timber production, and demotes the importance of unquantifiable and unmarketed values, such as the life support, regenerative, and cleansing services that nature provides (collectively known as "ecosystem services"). It also discounts the values placed on beauty or on the existence of species for their own sakes. Whether they realize it or not, societies depend for their existence on ecosystem services. And societies also value their ability to pass these things to future generations. Optimization, however, distorts this. It reduces time horizons to a couple of decades—the limit of the time horizon for most commercial investments. Values that do not have property rights or are publicly owned are not marketed, do not generate wealth, and gain little support, even if they involve critical ecosystem services. Often not enough people understand the criticality of the life support systems—the ozone layer and climate regulation are examples.

Though efficiency, per se, is not the problem, when it is applied to only a narrow range of values and a particular set of interests it sets the system on a trajectory that, due to its complex nature, leads inevitably to unwanted outcomes. The history of ecology, economics, and sociology is full of examples showing that the systems around us, the systems we are a part of, are much more complex than our assumptions allow for.

What it all adds up to is that there is no sustainable "optimal" state of an ecosystem, a social system, or the world. It is an illusion, a product of the way we look at and model the world. It is unattainable; in fact (as we shall see) it is counterproductive, and yet it is a widely pursued goal.

It is little wonder, then, that problems arise. And when they do, rather than question the validity of the model being applied, the response has been to attempt to exert even greater control over the system. In most cases this exacerbates the problem or leaves us with a solution that comes with too high a cost to be sustained.

In the real world, regions and businesses are interlinked systems of people and nature driven and dominated by the manner in which they respond to and interact with each other. They are complex systems, continually adapting to change. Change can be fast or slow—move at the speed of viruses multiplying or of mountains rising. It can take place on the scale of nanometers or kilometers. Change at one level can influence others, cascade down or up levels, reinvigorate, or destroy.

The ruling paradigm—that we can optimize components of a system in isolation of the rest of the system—is proving inadequate to deal with the dynamic complexity of the real world. Sustainable solutions to our growing resource problems need to look beyond a business as usual approach.

As failures mount, and as more and more people become aware of them, there is a growing dissatisfaction with the ways in which natural resources are managed. What are the important qualities of a system that need to be maintained or enhanced for a system to be sustainable? Resilience thinking is an approach (part philosophy, part pragmatism) that seeks answers to these questions.

The Key to Sustainability?

What is your version of sustainability? Is it summed up by the catch phrase "reduce, reuse, and recycle" (reduce your waste, reuse what you have, and recycle everything else)? Are you impressed by notions of ecological footprints and living within the carrying capacity of the land? Are you striving for a "factor four" improvement for the future in which we double the production from half of the input? Or maybe we should be aiming for a factor ten?

These approaches encapsulate some of the more mainstream thoughts on sustainability, and they all revolve around the notion that the key to sustainability lies in being more efficient with our resources. If we can be clever enough with the way we do things we can live within the carrying capacity of our environment.

Of course, this kind of efficiency will always be an important part of any approach to sustainability. But, by itself and of itself it is not the solution. Indeed, as we will show, by itself it has the potential to actually work against sustainability. Why? Because the more you optimize elements of a complex system of humans and nature for some specific goal, the more you diminish that system's resilience. A drive for an efficient optimal state outcome has the effect of making the total system more vulnerable to shocks and disturbances.

While that might sound counterintuitive, it is the inevitable conclusion reached by many studies investigating how social-ecological systems change over time. This book aims to explain the logic behind this seemingly perverse outcome.

By way of example of the tension between resilience and efficiency, consider the rise of the "just-in-time" approach where manufacturers dispense with big stockpiles of materials. Instead, parts and supplies are delivered to a factory at the exact moment when they are needed. The system, deemed to be efficient and optimized, yields big savings in inventory expenses but is very sensitive to shocks and has resulted in some severe industry dislocations when problems up the line with materials or staff have resulted in critical supply shortages.

The bottom line for sustainability is that any proposal for sustainable development that does not explicitly acknowledge a system's resilience is simply not going to keep delivering the goods (or services). The key to sustainability lies in enhancing the resilience of social-ecological systems, not in optimizing isolated components of the system.

The debate on sustainability has come a long way in recent decades. But if we examine it through a resilience lens, it's clear that we still have a way to go.

Embracing Change—The Heart of Resilience

At the heart of resilience thinking is a very simple notion—things change—and to ignore or resist this change is to increase our

vulnerability and forego emerging opportunities. In so doing, we limit our options.

Sometimes changes are slow (like population growth); sometimes they are fast (like exchange rates, or the price of food and fuel). Humans are usually good at noticing and responding to rapid change. Unfortunately, we are not so good at responding to things that change slowly. In part this is because we don't notice them and in part it's because often there seems little we can do about them. The size of the human population is a key slow variable, for example. So too is climate change. But few people believe there is anything they can do directly to influence either.

In and of itself, change is neither bad nor good. It can have desirable or undesirable outcomes, and it frequently produces surprises.

These broad statements, when applied to interacting systems of humans and nature (social-ecological systems), take on special meanings with important consequences. Resilience thinking presents an approach to managing natural resources that embraces human and natural systems as complex systems continually adapting through cycles of change.

Most of the concepts in this book are not new. Concepts of resilience and changing ecosystems have been around for decades. However, only recently have interdisciplinary groups of scientists begun to tackle the problem in earnest. The Sante Fe Institute, for example, is one well-known group that has spawned ideas about chaos theory, network dynamics, and, latterly, robustness. Another such group is the Resilience Alliance, a collection of researchers who have pooled their insights to develop a framework for understanding change in social-ecological systems. Through the efforts of groups like these, resilience thinking may provide valuable insights to sustainability.

A Roadmap to this Book

There are many ways to present a framework for resilience thinking. We have chosen to approach it by taking three steps. The first lays down a foundation for understanding, the second outlines the core of the approach, and the third begins to explore how resilience thinking might be applied to addressing challenges in the real world.

The first step involves considering a systems perspective of how the world works:

- We are all part of linked systems of humans and nature (referred to throughout this book as social-ecological systems).
- These systems are complex adaptive systems.
- Resilience is the key to the sustainability in these systems.

A traditional command-and-control approach to managing resources usually fails to acknowledge the limits to predictability inherent in a complex adaptive system. The traditional approach also tends to place humans outside the system. Resilience thinking is systems thinking, a concept that is more fully explored in chapter 2.

The second step is to develop an understanding of the two central themes that underpin resilience thinking:

- Thresholds: Social-ecological systems can exist in more than one kind of stable state. If a system changes too much it crosses a threshold and begins behaving in a different way, with different feedbacks between its component parts and a different structure. It is said to have undergone a "regime shift." This theme of thresholds and "changing too much" is discussed in chapter 3.
- Adaptive cycles: The other central theme to a resilience approach is how social-ecological systems change over time—systems dynamics. Social-ecological systems are always changing. A useful way to think about this is to conceive of the system moving through four phases: rapid growth, conservation, release, and reorganization—usually, but not always, in that sequence. This is known as the adaptive cycle and these cycles operate over many different scales of time and space. The manner in which they are linked across scales is crucially important for the dynamics of the whole set. These ideas are explored in chapter 4.

The third step is to apply this understanding to the real world:

- How might a resilience approach be put into operation?
- What are the costs of a resilience approach?
- What are the implications for policy and management?
- What might a resilient world be like?

While a framework for resilience thinking provides valuable insights into why and how systems behave as they do, to have policy and management relevance it needs to be able to solve problems in resource management, which is discussed in chapters 5 and 6. In chapter 6 we also discuss how managing for resilience has the capacity to create space in a shrinking world by opening up options rather than closing them down. Resilient social-ecological systems have the capacity to change as the world changes while still maintaining their functionality. Resilient systems are more open to multiple uses while being more forgiving of management mistakes.

While every effort has been made to keep jargon and terminology to a minimum, resilience thinking does contain several concepts that can seem a bit daunting to the uninitiated on first exposure. We encourage readers not to be too worried about understanding every detail on the first reading. Instead, try to take away a general appreciation of what thresholds and adaptive cycles are, while attempting to understand them in relation to the system in which you are interested.

Even if the finer details of some aspects of the resilience approach remain a bit obscure, if you can incorporate the broader themes presented here on living within complex adaptive systems you'll discover you've acquired a powerful set of insights about how the world works. Concepts of sustainability, efficiency, and optimization all begin to take on a new light.

Our hope is that readers will start asking questions about the systems in which they live or in which they are interested: What are the key variables driving them? Is the system approaching a threshold? What management actions do you need to consider in order to avoid such a threshold? What are the dynamics of this system? What are the connections between the scale at which you are concerned and the next level up and down?

These are all big questions that may not be easy to answer. However, the very act of framing them in relation to the system in which you play a role is an important step toward resilience thinking.

Between each chapter a case study on a region illustrates the significance of resilience thinking when applied to real-world situations. They demonstrate its value in interpreting and understanding what lies behind changes being observed in five very different social-ecological systems around the world.

Five Regions, Five Stories

The five regions we discuss are:

- The Everglades in Florida, United States: Possibly the world's most famous marshland system. Significant parts of the national park have crossed a threshold into a new regime dominated by cattails.
- The Goulburn-Broken Catchment: One of Australia's most agri-culturally productive regions. Saline groundwater now lies just beneath the surface of the region's most productive agricultural zone.
- The coral reefs of the Caribbean: Once one of the most magnificent coral systems in the world and a tourist draw that was the economic lifeblood of the region. In the last thirty years, 80 percent of hard coral reefs have disappeared and the remaining reefs are at risk.
- The Northern Highland Lakes District of Wisconsin, United States: A fishing paradise with an uncertain future. The natural amenity of this much-loved area is slowly being lost as its population grows.
- The Kristianstad Water Vattenrike: An internationally renowned wetland in southern Sweden. Its beloved wet meadows are being lost, water quality is in decline, and wildlife habitat is disappearing.

Why these five regions? To begin with, they are different. They have very little in common, with different levels and types of population engaged in different enterprises coping with a range of different challenges. What they do have in common is that each is confronted with a range of natural resource and social challenges that have major implications for their inhabitants and surrounding regions. And we know quite a lot about them; each has been studied over many years in an attempt to understand the ecological and sociological processes that drive them.

We have chosen case studies at a regional scale because this is the focus of much of the work of the Resilience Alliance. However, as the basis of resilience thinking becomes clear, it should be apparent that it applies to systems of people and nature at all levels: individuals, communities, businesses, and nations.

Of course, there are many other regions around the world facing enormous resource issues that are not discussed in this book. Many

parts of Africa, for example, are suffering chronic food shortages, disease outbreaks, and social instability. Two such regions (in Mozambique and Zimbabwe) are part of the Resilience Alliance's set of case studies and there are many lessons in resilience thinking that are relevant to these regions. However to meet the needs of this book as an introduction to resilience thinking we have chosen to examine five regions that are well studied and that reflect a range of contrasting issues.

Our first case study is the Everglades, a world-renowned wildlife wonderland at the southern tip of Florida in the United States. Attempts to tame parts of it for agriculture and urban settlement over the last hundred years have had mixed results. On the one hand the region supports a lot more people, industry, and agriculture. On the other, its natural qualities have gone into steep decline, including its water quality. Development has resulted in some significant gains but the costs are only now being understood.

Key Points on Resilience Thinking

- Current approaches to sustainable natural resource management are failing us. They are too often modeled on average conditions and expectations of incremental growth, ignore major disturbances, and seek to optimize some components of a system in isolation of others. This approach fails to acknowledge how the world actually works.
- Business as usual is about increasing efficiency and optimizing performance of the parts of social-ecological systems that deliver defined benefits, but fails to acknowledge secondary effects and feedbacks that cause changes (sometimes irreversible changes) in the bigger system, including changes to unrecognized benefits. While increasing efficiency is important for economic viability, when undertaken without considering the broader system's response it will not lead to sustainability; it can lead to economic collapse.
- Resilience thinking is about understanding and engaging with a changing world. By understanding how and why the system as a whole is changing, we are better placed to build a capacity to work with change, as opposed to being a victim of it.

CASE STUDY 4

Scenarios on the Lakes:

The Northern Highlands Lake District, Wisconsin

If you were looking for a nice place to escape the rat race, you could do worse than buy a plot of land in the Northern Highlands Lake District (NHLD) in Wisconsin. It offers a landscape of diverse lakes, rich forests, and a range of recreational activities. However, if that's where you want to head then you'd better move fast because most of the prime locations are gone, and what's left is skyrocketing in price. Why? Because it's an area a lot of people want to move into. Unfortunately, as more people move into the area, things change and the future becomes increasingly uncertain.

It's a recurring story all around the world. Landscapes high in natural beauty are experiencing growing populations, increasing pressures on ecosystem services, environmental degradation, and falling amenity. Some describe it as "being loved to death," some as "killing the goose that laid the golden egg," and others as "environmental vandalism." The people who are already there want the extra resources that usually come with a growing population (which usually includes social and economic infrastructure) but bemoan the loss of their beloved environment as it existed in "the good old days." And new arrivals often become upset as the various values of the region decline—values which had them moving into the area in the first place.

In general, the slow erosion of the natural values of an area is accepted fatalistically, but sometimes there comes a point when the things that once made an area a nice place to visit, holiday, or invest in, seem to vanish. And when that happens, call it a tipping point or crossing a threshold, suddenly no one wants to be there, and the region begins to slide.

How do you make decisions that will avoid potential risks while taking advantage of potential opportunities? How might the NHLD plan for an uncertain future?

The NHLD in a Nutshell

The NHLD lies in the north of the state of Wisconsin. It contains around 7,500 natural lakes that together in area comprise over 13 percent of the region. Some four fifths of the region is forested. Lake Superior, the world's largest freshwater lake, lies a short distance to the north. The climate is heavily influenced by its proximity, giving cool summers and cold winters.

The region has experienced several periods of glaciation which have left a relatively flat landscape. When the last glaciers retreated twelve thousand years ago many lakes were formed. Unsurprisingly, lakes are the NHLD's most conspicuous and distinctive feature. Some occur in hollows in outwash gravel plains; others are formed in depressions in the ground moraine or were created by the melting of buried ice chunks.

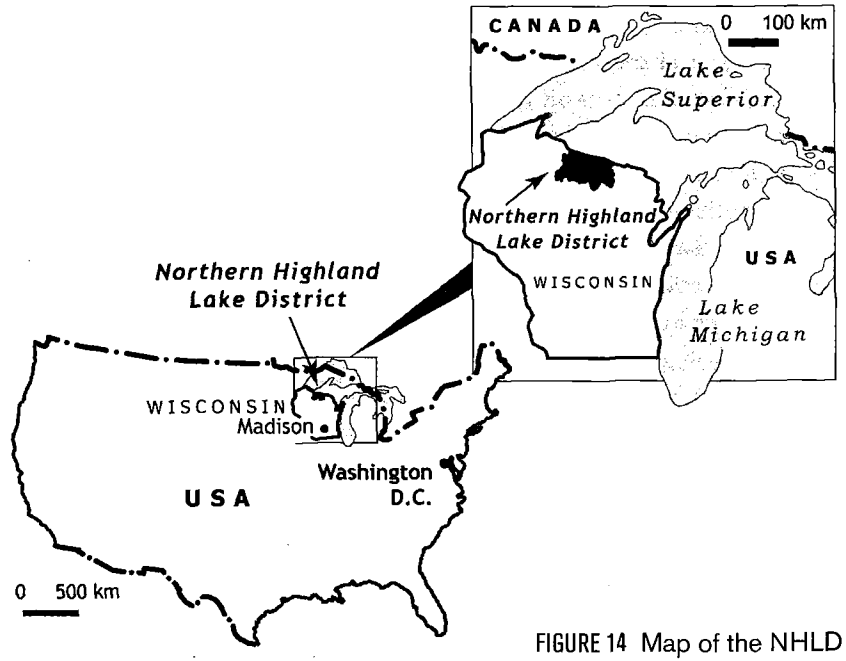


FIGURE 14 Map of the NHLD

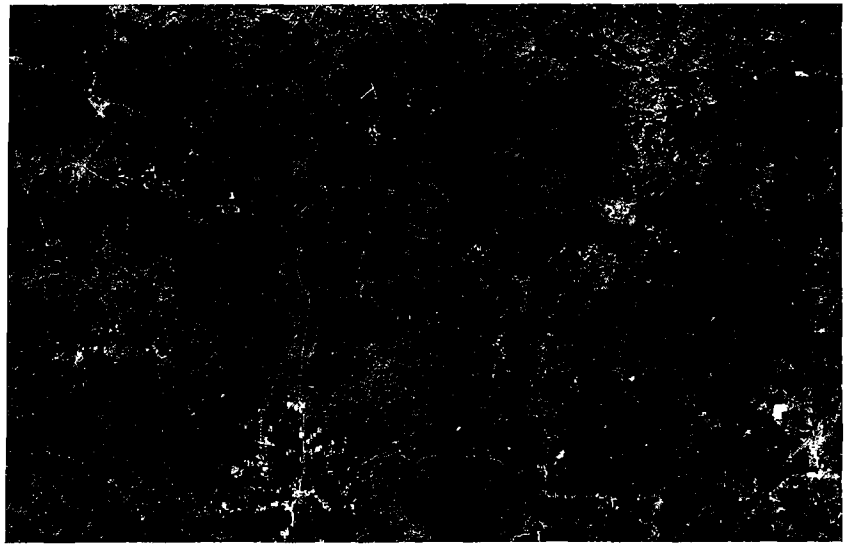


IMAGE 10

A satellite view of the lakes district in the northern highlands of Wisconsin. The lakes range from small ponds to vast expanses of water. *(Courtesy of the University of Wisconsin Environmental Remote Sensing Center.)*

They range in size from small, temporary ponds and darkly stained "bog" lakes to large expanses of water covering well over a thousand hectares. Depths range from one to more than thirty meters.

The NHLD has been sparsely inhabited for thousands of years. In the seventeenth century, European fur traders entered the region and transformed the lives of the Native Americans, its original inhabitants. In the nineteenth century, the expansion of the United States led the First Nations to surrender their sovereignty in exchange for land use, hunting, and fishing rights in a series of treaties.

In 1900, the population of the area was approximately twelve thousand. Over the past century it has grown to around sixty-five thousand permanent residents, with growth accelerating over the last three decades. Recreation and tourism are major components of the economy, and there has been substantial development of vacation and retirement homes around local lakes. Fishing is one of the major tourist attractions of the region. The region lies within a day's drive of several major urban centers, including Chicago, Milwaukee, and Minneapolis-Saint Paul.

The Crowding of the NHLD

Everyone has noticed it but no one has been too sure what it all added up to. The Lake District is simply not the place it once was. There are more people, more conflicts, and more tension.

In the decade leading up to the year 2000 the population grew by 15 percent and property values doubled. Highways connecting the region to the big cities have expanded, bringing more traffic and more visitors. The NHLD's urban centers are larger. International or national chains are more prominent in the business community, displacing many of the "old," traditional businesses (such as lodges and restaurants).

Almost all the lake shore that can be developed has been developed, and now the region is experiencing significant levels of redevelopment as older and smaller cottages are replaced with newer and larger houses. Development has led to the deforestation of riparian areas, invasion of exotic species, and the pollution of lakes through runoff and leaky septic tanks. In many areas the lake edges have also seen the removal of reed beds and woody debris, both being valuable habitat for wildlife. Fishing has thinned the larger fish on most public-access lakes. Anglers are common on the lakes but so too are highly polluting speedboats and personal watercraft.

Invasive species are a growing problem for both terrestrial and aquatic ecosystems. Lakes are being invaded by exotic fish (e.g., rainbow smelt), plants (e.g., purple loosestrife), and invertebrates (e.g., rusty crayfish). Many exotic species gain access to previously uninvaded lakes in bait buckets or by attaching to boats.

However, it's not all bad news. The increased population has seen improvements in health care. The development of service-orientated industries has increased, including niche businesses such as gourmet coffee shops and delicatessens that would normally only be found in bigger cities.

A History of Change

The NHLD is in rapid transition but, as with most regions, transitions have happened before. Twelve thousand years ago the current lake landscape was molded as the glaciers receded. Archaeological evidence suggests that humans moved in soon thereafter. This has been dubbed the Age of Discovery, and it was marked by the early disappearance of mega fauna such as the woolly mammoths.

Europeans entered the region about five hundred years ago through

IMAGE 11
An aerial view of the lakes landscape. *Photo credit: ©Steve Carpenter.*

the fur trade. Following their arrival, native populations decreased significantly while newcomers took ownership of the land.

The old-growth forest of the NHLD was extensively logged in the late nineteenth and early twentieth centuries to provide timber for the growing cities south of the NHLD. By the 1930s, much of the Northern Highlands had been clear-cut. Over four-fifths of the region has since been reforested.

The region is now entering a new age, in which woolly mammoths have been replaced by mammoth homes. Fishing and canoeing are competing with motor sports such as power boating and bush bashing in all-terrain vehicles.

Invasive species and emergent diseases are threatening the quality of the environment in the region. The quality of the fishing is declining. Warmer, shorter winters with less snow are impacting on the tourism industry as well as the region's ecosystems.

What do all these changes add up to?

Exploring Uncertain Futures

A traditional approach to exploring the future has been to extrapolate from the past. You look at past trends, construct a model that simulates how

things are working and wind it forward. But experience has shown that there's limited value in this approach when attempting to explore the future of social-ecological systems. They are simply too complex, while the models are invariably too narrow in their focus. Plus, the future has a habit of throwing up surprises, a product of the complex nature of social-ecological systems, which often make the simulation model irrelevant.

Because many changes in the NHLD are happening simultaneously it's difficult to know what the cumulative impact will be. With so many changes happening at once, it seems hard to think about the future in a cohesive way. The problem facing those in charge is how to make the

BOX 7 One Size Does Not Fit All

Lake districts such as the NHLD are often managed as if the lakes are independent, similar, and only affected by factors local to a particular lake. Consequently, when it comes to setting up rules and regulations to manage activities such as sports fishing a one-size-fits-all approach is often applied. Careful analysis of such approaches, based on the NHLD, however has shown that that this approach simply doesn't work (Carpenter and Brock 2004). Such policies actually lead to the domino-like collapse of fisheries across the system of lakes.

Carpenter and Brock used detailed analyses of both fish population dynamics in a lake, and of angler movements and fishing efforts between the lakes. Because lakes differ significantly in terms of their attributes that determine fish population resilience (shoreline habitat is particularly important), a regulation that ensures all lakes will always be safe leads to big losses in angler benefit (fish harvest), and incentives for anglers to break the regulation (a decline in social resilience). If regulations are too lax, ecological resilience declines and some lakes collapse, leading to increased pressure on the others.

In either case, the collapse of fish populations on some lakes causes anglers to shift to other lakes creating a cascade of collapses and the degradation of fisheries in most lakes. Under one-size-fits-all management the natural resources of the entire landscape become more vulnerable to unwanted change.

The basic problem with one-size-fits-all is that it doesn't acknowledge that

- The lakes are inherently different
- There are linkages connecting the lakes

Applying the same regulation to all the lakes is bound to fail through loss of either ecological resilience or social resilience.

system that people like and want resilient in the face of future surprises. Rather than simulate the future, researchers from the University of Wisconsin decided instead to explore what the next twenty-five years might have in store for the NHLD by constructing a series of scenarios (Peterson et al. 2003a; Carpenter, in press).

Scenarios are not predictions of what *will* happen. They are an exploration of what *might* happen. They are structured narratives about the possible future paths of a social-ecological system (Peterson et al. 2003b). Rather than forecasting the future, they involve a group of experts working together with a representative cross section of local residents to explore what might happen to the region if certain trends are followed.

Scenario planning began after World War II as a type of war game analysis. Later it was used as a part of business planning. The oil company Royal Dutch Shell pioneered it in industry planning and, indeed, it played an important role in that company's success during and after the world oil price crises in the 1970s. More recently, scenarios have been used in global environmental assessments such as the Millennium Ecosystem Assessment. Scenario planning has also been used during the transition to democracy in South Africa, and in community planning exercises in the United States, Europe, and Asia.

The process of building a scenario involves bringing together the best available information on the current condition of the region (biophysical, social, and economic) and then identifying key uncertainties, vulnerabilities, sources of resilience, and the hopes and fears of people for the future of the region. These considerations lead to many scenarios. Typically the scenarios can be clustered into a few stories that capture the main points. In the case of the NHLD, four scenarios emerged (Carpenter in press).

The stories that are developed through this process about how the region might change over time usually identify a range of issues for ongoing discussion. The scenarios, therefore, are not so much the end of the process as the beginning of an ongoing debate and discussion.

Scenarios help organize information, and they are easy to understand. Scenario planning is also a good way to open discussion among different groups of people who might not otherwise interact. Scenarios allow us to consider several possible futures instead of trying to predict a single one. These possible futures are not likely to come true exactly as described in the scenarios, but they let us think in broader terms about the impacts of the plans and choices we make, and how to make the kinds of system regimes we might like more resilient.

Involving and engaging the local residents is an essential part of the overall process. Not only do they possess many insights on what drives a region, but scenarios can also help the people of the NHLD consider how they might prepare for possible change. It also encourages people to see their region as a social-ecological system—as a complex adaptive system in which no one is in control and which has the capacity to cross thresholds into an undesirable regime. Building scenarios through social networks helps people appreciate many aspects of resilience thinking.

And the process in many ways is just as important to building resilience as the scenarios it produces. Through people sharing and building social networks that span different areas and scale of operation, the community is in essence building trust and social capital that is basic to enhancing adaptability and resilience.

Scenarios for the NHLD

Four different scenarios were developed for the NHLD through a series of workshops in 2003 (Peterson et al. 2003a; Carpenter in press) involving

IMAGE 12

Networking by the lake: members of the NHLD community discuss scenarios of what the future holds for their region (seen here listening to Dr. Steve Carpenter). *(Courtesy of Susan Carpenter.)*

people from the NHLD and the University of Wisconsin. The NHLD people included officials from the county and Wisconsin Department of Natural Resources, members of area lake associations and the area's Native American tribes, local realtors and business owners, and part- and full-time residents.

Each scenario grows out of a shared baseline story that encapsulates what is known about the present and what is expected in the near future. Each scenario then traces a different sequence of events until 2027. While there is insufficient space here to describe each one in detail, the following descriptions provide a flavor of what was created. (See the 'Future of the Lakes' website for more details, http://lakefutures.wisc.edu).

The Common Baseline

Native Americans are an important component of the region's future development. On the Lac du Flambeau reservation the casino operated by the Lac du Flambeau Indians* is bringing in new wealth. The number of tribal residents has increased as members return to participate in the growing economy, and young people stay because jobs are available. The number of pupils in the Lac du Flambeau Public School has increased even as the school-age population in most of the NHLD has declined. Living resources—fish and game—on tribal lands are flourishing.

In the rest of the NHLD, things aren't so positive. The place is filling up. There are confrontations in county boards over land use and shoreline regulations. Communication is poor between nonresident lakeshore property owners and local residents. Many residents are unhappy about the replacement of old businesses—lodges, restaurants, and stores—by outside chains.

Over the years, the environment has been changing. Weather is seemingly more variable. Warm, wet winters reduce skiing and snowmobiling. There is debate about whether all-terrain vehicles could or should fill the economic niche once filled by snowmobiles. Conflicts arise between jet ski lovers and haters and there are disagreements about how much of the landscape should be devoted to loud, motorized activities versus quiet, muscle-powered recreation.

*The Lac du Flambeau area of the NHLD has been inhabited by the same band of native Indians since 1745 when Chief Keeshkemun led the band to the area. The band acquired the name Lac du Flambeau—"Lake of Torches"—from its practice of harvesting fish at night by torchlight. The Lac du Flambeau reservation has 260 lakes, sixty-five miles of streams, lakes, and rivers and twenty-four thousand acres of wetlands.

Anaheim North

In the first scenario, called "Anaheim North" (and also known as Wal-Mart nation), tourism takes over. Theme parks, big businesses, and urban sprawl cover much of the landscape (as can be seen in the city of Anaheim in California). Population and commercial activity increase, but many of the jobs in the NHLD are low paying and much of the profit of the theme parks does not stay in the NHLD. Locally owned businesses become less common. Problems with urban sprawl and pollution intensify. The dramatic increase in annual visitors also leads to an expansion of the Lac du Flambeau Casino.

Motorized recreation replaces muscle-powered recreation, except in the most remote areas and on private tracts of land. Public hunting and fishing lands are heavily harvested, and quality hunting and fishing experiences are found only in a few remote sites and on large private landholdings.

By 2027, the region is transformed. The population has almost doubled, the economy is larger, and so are the size of businesses and the role of corporations based outside the NHLD. Much of the profit generated from tourism flows out of the NHLD. The gap between rich and poor has grown, urban sprawl is notable around the region's main centers, and air, water, light, and noise pollution are increasingly common problems. The level of trust and cooperation among people in the region has declined to resemble that of other urban regions across the United States.

Walleye Commons

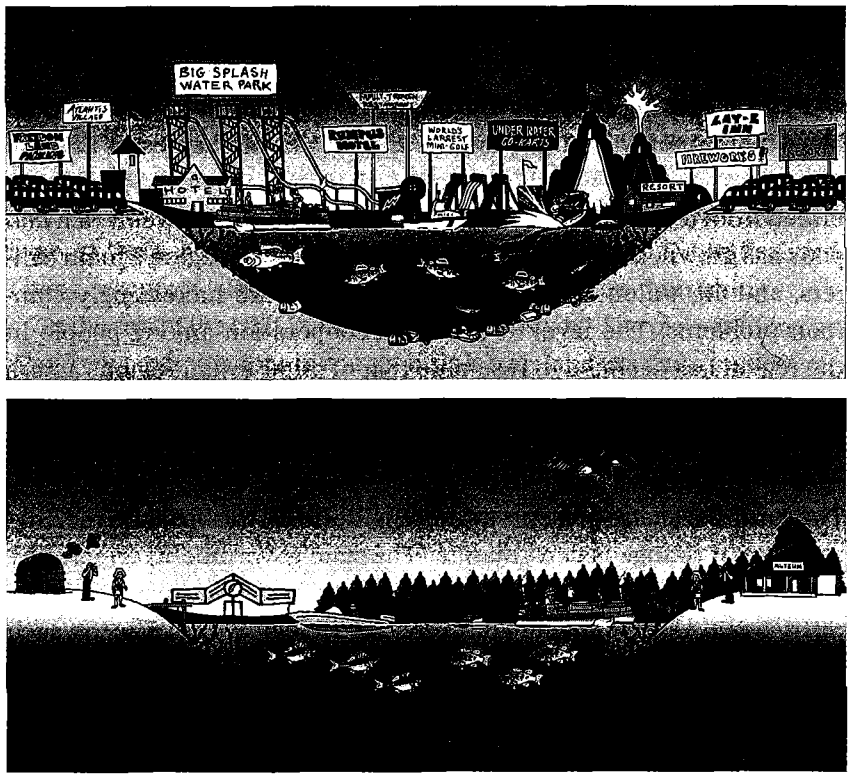
The second scenario presents a different future. In this scenario the driving force of change is deregulation. The state government, crippled by financial crisis, relaxes shoreline management practices and building restrictions. Along with difficult-to-control ecological disturbances, such as the spread of chronic wasting disease in deer and invasive species, the landscape changes, encouraging many tourists and residents to pack up and head to new destinations.

The visitor population declines as a result of intensifying conflicts over resource use, environmental deterioration, and collapse of a real-estate bubble. Despite economic hardship, the Lac du Flambeau tribe persists. Ecosystems recover slowly. The economy is smaller in 2027 than in 2002, but more diverse with contributions from

ethno-tourism and slow recovery of recreational opportunities on feral ecosystems.

At the same time, the Lac du Flambeau tribe expands its land holdings, introduces experimental management strategies and experiences a cultural renaissance. Through their efforts, the quality of the lake and land slowly recovers. The name "Walleye Commons" refers to shared use of an ecosystem dominated by walleye, a favored game fish of the region.

Although the economy is much smaller that it was, many residents feel that their rural lifestyle and the gradually improving environment of the NHLD more than compensates for their low incomes.



IMAGES 13 & 14

Will the future of the NHLD resemble the Anaheim North scenario in which the tourism industry takes over, or will it be more like the Walleye Commons in which deregulation leads to economic collapse followed by regeneration. *(From Carpenter et al. 2002.)*

Northwoods Quilt

In the third scenario, recent retirees who relocated to the NHLD play an integral role in preserving the natural beauty that originally attracted them to the area. The lake associations to which they belong become effective fora for discussing management strategies. One practice adopted is to designate certain lakes for certain uses, such as power boating or canoeing. There's a patchwork of different kinds of ecosystems.

The retiree population expands and becomes more influential in the politics and economics of the NHLD. The economy diversifies because some retired professionals work part-time via travel or telecommuting. Resource conflict resolves in a multi-tiered system of regulations and incentives that allocates considerable power to lake associations.

By 2027, the NHLD is a mosaic of diverse ecosystem uses. The NHLD is buffered from ecological disturbance by the diversifying composition of its landscape.

Refugee Revolution

The final scenario presents an extreme situation. A plane flying over Chicago drops two tanks of radioactive dust, causing people to flee from the urban terrorism to the NHLD area. As a result, the population doubles in size and new businesses emerge. The government also turns to the region as a national resource for water, fish, deer, and even trees.

Terrorism makes urban life chaotic and dangerous. Many people abandon cities for rural areas. Owners of recreational properties in the NHLD move there to stay. Initially the infrastructure is severely stressed, but strong interventions by state and federal governments eventually create a viable economic base for a much more populous NHLD.

By 2027, working ecosystems producing water, cranberries, fish and game for market, and forest products dominate the NHLD landscape.

Engaging with Uncertain Futures

Particular events may seem implausible, but they're a class of event—a plausible category of what could happen. The final scenario, for example, is not predicting that Chicago will become a radioactive wasteland. It is only suggesting this as a possible future storyline in which the NHLD undergoes a sudden population increase due to some major, external event.

For this reason the scenarios should be considered together, not separately. They should be thought of as a set that provides us with a range of insights on what makes a region vulnerable and what confers resilience. Together, they present different dimensions of how things might change (Carpenter, in press).

So what do these four scenarios suggest about the NHLD?

First, the region is vulnerable because of the low diversity of economic opportunity and its openness to economic and political forces from outside the NHLD. Ironically, the traditional self-reliance that is valued by many local residents may undermine the networking and collaboration that could make the region less vulnerable to external influences.

Resilience is conferred by several features of the NHLD. One source is the tribes, who intend to stay in the region come what may. Another source of resilience is the capacity for renewal of the ecosystems of the NHLD. Ecological breakdowns can occur due to poor stewardship of shoreline habitats, biotic invasions, overharvesting, and so forth. However, the diversity of lakes and the capacity to manage different lakes for different purposes provides a range of alternatives from which future success might arise.

Key sources of innovation in the scenarios are the tribes and the newly retired or semi-retired professionals who immigrate to the region. The tribes are an important source of young people who want to stay in the region. In addition, they diversify the perspectives on resource management and the kinds of tourism opportunities in the region. Incoming older residents bring different viewpoints on resource management, different economic activities, and new problem-solving skills.

Unforeseen events might open up or close down different futures, but it's the underlying mix of vulnerability, resilience and innovation that will craft the region's future.

Can Scenarios Change the Future?

Will these scenarios change the future? In a sense, we will never know, because there is only one NHLD and the scenarios are now in play with no control or reference system to help us interpret the outcome (Carpenter, in press).

However, we do know that these scenarios have stimulated debate and new thinking. In surveys undertaken after the release of the scenarios, most respondents hope that the future brings something like Northwoods Quilt or Walleye Commons. Against that hope, most respondents actually believed the future would most likely resemble Anaheim North given the existing trends at the time.

About 70 percent of respondents said they would like to become involved in a group working for desirable change in the NHLD. Although they are willing to act, most respondents believe that they have little influence on the future of the NHLD. Twenty-five percent said they will move away if the NHLD begins to change in undesirable ways.

Better networking is one key to building the adaptive capacity of the NHLD. The workshops that led to the writing of the scenarios have already formed new networks of contacts in the NHLD. More connections among key people and groups are necessary for adaptive change in the region (a theme that is explored further in the final case study on the Kristianstad Water Realm).

Substantial benefits could emerge from more frequent exchange of ideas between the innovative institutions in the region, such as the tribes, lake associations, and research organizations. A few interesting experiments in governance, collaboration, and ecosystem management are already underway in the NHLD. It will be important to share the results of these explorations.

The present already contains elements of all four scenarios, and the same is likely to be true of the future. Also, the future will contain many surprises that are not in the scenarios. Which scenario elements and what unforeseeable surprises will dominate the future? What parts of the past will people choose to carry in the future, and what parts of the past will be abandoned? What boundaries will be accepted by the people of the NHLD? What boundaries will people revolt against, and overcome? As the NHLD reorganizes, what new boundaries will be created? These questions will be answered over time, as the people of the NHLD act on the expectations and visions for the future.

Adaptability and transformability depend on the capacity of people to maintain or change the social-ecological system in which they live. Adaptability to upcoming challenges depends on human choices being made now. Better choices are likely if evolving changes are faced clearly and collaboratively, with minds open to the surprises to come.

Resilience and the NHLD

The residents of the NHLD are engaging with their future. They are imagining what the future may hold given changes in key uncertainties regarding population and ecological vulnerability. The very process by which they are doing this, through the creation of scenarios, is enhancing the region's adaptability and resilience by establishing networks, and encouraging the various actors in the system to explore the region's vulnerabilities, resilience, and sources of innovation.

It's interesting to note that a quarter of the NHLD survey respondents indicated that they would move out of the region if its natural values continue to decline. This begs the question: Move to where? To some other region rich in natural values that hasn't filled up yet?