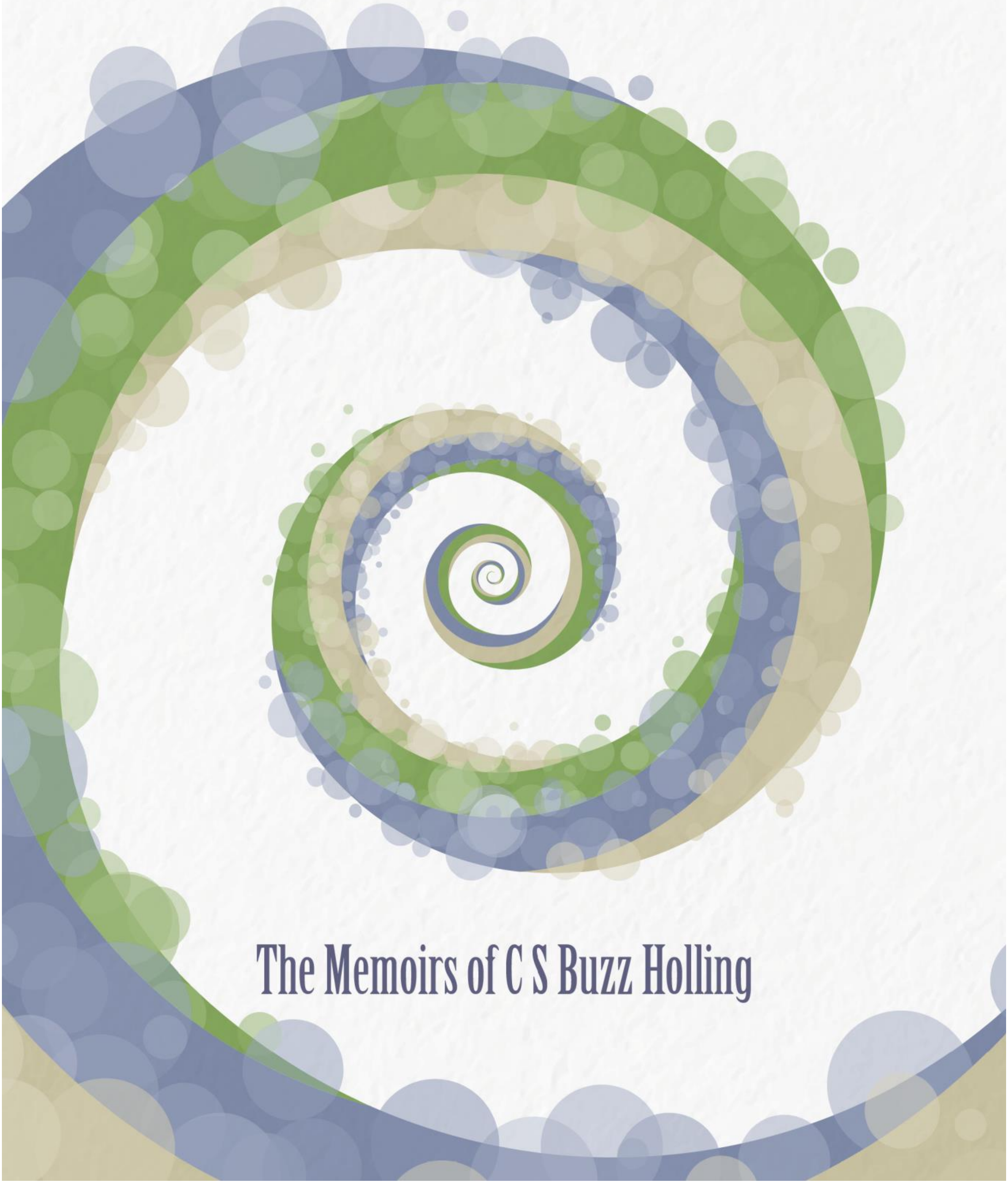
Bubbles and Spirals



The Memoirs of C S Buzz Holling

Bubbles and Spirals:

The Memoirs of

C. S. Buzz Holling

This is the second edition of *Bubbles and Spirals: The Memoirs of Buzz Holling*, based on a first edition published in June 2016. Further editions may follow.

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This memoir is dedicated to the RAYS,
the Resilience Alliance Young Scholars.

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Preface: As good as it gets!

During his whole life, Buzz has been driven by an insatiable thirst for knowledge from which he distilled novel discoveries. He emerged from an introvert boy and a shy young man to become a brilliant scientist with never ending new ideas and a magnetic personality that attracted the best minds of his time.

Buzz has received numerous awards for his scientific discoveries, most notably the Austrian Cross of Honor for Arts and Science (1975), and the Volvo Environment Prize (2008), culminating in the honor of being named an Officer of the Order of Canada in 2009. Yet, throughout his life he remained a modest, fun loving and caring man, a man who cared deeply for his family and friends, a man with great integrity in everything he did.

Alas, even the most brilliant of minds can succumb to disease. After finishing the first draft of his memoirs he fell into a deep depression (Cotard Syndrome). The memoirs sat there for two years waiting to be finished. I am thankful that now (end of 2015) he is able to work through them again and the final product will simply be "as good as it gets".

With my deepest love and gratitude for taking me along for the ride,
Ilse – December 2015

Special Acknowledgement

Without the persistence, encouragement, and attention to detail in editing by Jon Schnute, this memoir would not have reached its current state of perfection.

Thank you, Jon.

Figure 1. Samoa: Clay sculpture by Ilse Holling

The Glass Bubbles

by Samuel Greenberg

The motion of gathering loops of water
Must either burst or remain in a moment.
The violet colors through the glass
Throw up little swellings that appear
And spatter as soon as another strikes
And is born; so pure are they of colored
Hues, that we feel the absent strength
Of its power. When they begin they gather
Like sand on the beach: each bubble
Contains a complete eye of water.

Source: *The Oxford Book of American Poetry* (Oxford University Press, 2006)

http://www.poetryfoundation.org/poem/244824

Foreword: An unexpected neighbor

by Jon Schnute, February 2017

The house next door came up for sale. It didn't take long for a sign to announce "SOLD". My wife Laura Richards and I wondered who had bought it.

In the meantime, Line Christensen had just finished a work term at the Pacific Biological Station (PBS), from which I had recently retired. You can picture Line as a creative, talented, compassionate young woman with a delightful energy that engages people around her in worthwhile projects. She was then a recent graduate from the University of British Columbia (UBC), where her father Villy Christensen was (and still is) a highly-respected fisheries scientist. I offered mentorship to Line, particularly in the context of the R project for statistical computing (https://www.r-project.org/). By *mentorship*, I mean mixing with bright young people in the hopes that they'll keep my mind from going stale. Occasionally, I try to nudge the direction of research toward areas that interest me. In Line's case, I suggested that she explore practical applications of my R package *PBSmodelling*.

Her work term during the winter of 2007-2008 had passed quickly, and Line soon had to move from Nanaimo (where PBS is located) back to UBC in Vancouver. Her parents planned to assist the move, and Line arranged that we use the occasion to meet at a charming coffee shop named *Coyotes* in Nanaimo. A further email from Villy invited Buzz and Ilse Holling to join us. I had heard that the Hollings lived in Nanaimo, so I thought this would be an excellent opportunity to make contact at last.

At the fateful hour of 3:00 PM on Saturday, March 29, 2008, a little group gathered at Coyotes: Line, her parents Villy and Ellen, Buzz and Ilse Holling, my wife Laura Richards, and I. We quickly found much to discuss. Buzz and I pursued scientific ideas, while Ilse and Laura chatted animatedly about personal matters. Ilse mentioned that she and Buzz had recently bought a home on a small street that we might not even know about. Further discussion revealed that it was the house next door to ours. Buzz and Ilse would soon become our new neighbors!

To me, this news seemed almost incredible. Events happen in life, some more likely than others. This one pushed the bounds of improbability to new limits. On the following Tuesday (April 1), I sent Buzz this message:

> Laura and I are still reacting to the remarkable events last Saturday. In fact, the word *reacting* fails to do justice to our feelings. English seems to lack an appropriate verb, so I'll invent one. Define *resilate* to mean “react to events as if they indicate a transformation, rather than a mere change”. Another, more psychological definition might be “to suspect that the universe is trying to tell you something, even if that's scientifically impossible”. So, in that sense, Laura and I are still resilating to the events last Saturday.

I’m writing this in February 2017, almost nine years after the events described above. Living next to Buzz and Ilse has indeed proved transformative. Although Buzz had dedicated much of his career to a field called *resilience*, I didn’t know much about it except that I wanted to learn more. I even had some skepticism, because resilience theory seemed to lack the theoretical foundations necessary for a science. I’ll return to this later, but I want to start with more personal experiences. Remarkable opportunities come from proximity as neighbors. For example, you can share a good bottle of wine without concern for the need to drive home. You can meet your neighbor’s friends and family when they drop by. You can discover qualified tradespeople who work on your neighbor’s house. Most especially, you can share the daily experiences that bring meaning to life, for better or worse.

Most people who meet Buzz and Ilse quickly discover their remarkable qualities. For example, the woman who previously owned their home liked Ilse so much that she accepted the Holling’s offer even when better offers might have been available elsewhere. (Laura and I remain immensely grateful for her gracious gesture to the neighborhood.) Ilse has artistic sensibilities, compassion, common sense, and an appreciation of nature that stem partly from her childhood in Austria and partly from her unique attitude toward life. She claims no knowledge of science, yet she makes astute comments about the ideas that swirl around Buzz and his companions. She played a vital role in hosting high level scientists and bureaucrats when Buzz directed the International Institute of Applied

Systems Analysis (IIASA) in Laxenburg, Austria. If Buzz and Ilse invite you to a party, you absolutely can count on meeting remarkable people.

I've titled these comments "an unexpected neighbor" in refence to J.R.R. Tolkien's famous book *The Hobbit*. The first chapter, "An Unexpected Party", finds Bilbo Baggins surrounded by a wizard and thirteen treasure-seeking dwarves. As a neighbor, Buzz feels a bit like a wizard with connections to scientists pursuing treasures of ecological reality. They tell legends of forests, lakes, streams, and animal populations subjected to thoughtful scrutiny. During the next few years, I personally met many of the people mentioned in this memoir when they came to visit. Consequently, when Buzz started writing his opus in 2013, I could appreciate his efforts and assist where possible. I liked the human tone of his narrative, quite different from most scientific memoirs. Also, he had included original art by himself and others, thus creating a bridge between science and the humanities.

Sadly, Buzz's health took a negative turn in late 2013. The memoir project languished. Despite considerable progress, it remained far from publishable. I became a strong advocate for its completion because, I felt, it represented an important chapter in scientific history described in simple language by the man responsible for its development. I carefully archived all existing drafts from various computers that held traces of the project.

I then began extensive editing to fix errors, add tables of contents, and transfer figures from earlier drafts into the current version. Ilse went over everything with Buzz, who still had energy for the ideas, but not for editorial work. The draft slowly improved, and in some cases I revised text to make the meaning clearer. Fortunately, I could confirm directly with Buzz that every such change met with his approval.

In the summer of 2016, the Stockholm Resilience Center published a "First Edition" A limited print version went to various friends and colleagues of Buzz. Not surprisingly, the first edition still included numerous errors, and readers (notably Lee Gass and Larry Dill) spotted further problems. Hopefully I have fixed most of them in this second edition.

Earlier, I mentioned my skepticism about the theoretical foundations of resilience as a scientific theory. It certainly lacks the solidity of physics, where mathematical rules make precise predictions. But such precision clearly is impossible in ecology, and human beings must make decisions based on limited data, uncertain predictions, and conflicting values. For that reason, Buzz focused on collaborative teams and realistic data collection. He wanted people to work thoughtfully and collectively toward understanding the complexities of our world. This involves social behavior, such as having unexpected parties to break the ice and writing limericks to capture humor. A nice bottle of wine sometimes loosens a log-jam. Resilience emerges when many channels of thought and behavior remain open for exploration.

After resilating to the arrival of a wizard next door, I had a chance to witness his remarkable approach to science and the human condition. Readers of this memoir can witness it, too.

Introduction

As a child in Ontario in the 1930s, my house bordered the edge of a forest, and I became entranced by the secrets that it seemed to hold. I was often left to my own devices as a boy, and would sneak off into the wild woods whenever I had a free moment. The boughs of balsam and poplar, birch and spruce beckoned to me and tangled me in their mysteries. I began to explore further, discovering a passion for the land beyond the forest as well. I would take to canoeing rivers and lakes, and read voraciously about the various animals, trees, and forms of vegetation that comprised the land beyond my tame backyard.

What enthralled me most were the ponds scattered throughout the woods, each one like a small world within a world. I quickly discovered that there were two kinds of ponds, the first small and temporary, drying up as the seasons changed. Unique fauna made homes in these ponds, and could survive long after the water was soaked up by the soil. But there was little diversity, and it was the permanent ponds that captured my heart. They were rich with vegetation, and a variety of species of animals, which ranged from about an inch in length to microscopic size.

The caddis flies fascinated me, making their homes out of twigs and moss, and shaping them in small tubes. Their tiny heads would peek out and they could snatch at prey, and then withdraw back into the safety of their homes.

I found a sense of freedom and flexibility when immersed in nature, and a number of transformative ideas began to take shape, as I grew older. With each idea, it was as if a blind had been lifted and I now viewed the world in a slightly different light. I began to make connections, and notice things that I may have observed, but had never really seen clearly before. The world took on a new meaning with each major discovery, and I knew that an education in science and ecology would be the only way to appease my thirst for knowledge.

This memoir begins at the onset of my scientific career. I will demonstrate how that same freedom and flexibility I found as a child in the forest continued to follow me through the various spirals of my life. I deviate from my background in scientific writing to present a recollection of my life, and the most significant discoveries made throughout my career.

These discoveries begin as the sudden appearance of a new idea. They seem to emerge in a spontaneous, unexpected manner, their source often unknown, or one that is singular and rare. Where do they come from? Why do they appear?

Science, as an example, takes some ideas and, with an appropriate mix of enthusiasm and devotion of a few people and the skepticism of many, understanding grows. Normal science proceeds with hypotheses proposed and tests to disprove them, not prove them. It then abandons, accepts or modifies the original idea, often requires some additional tests, and then eventually pauses with a set of tested theories that form the basis for further enquiry that is now novel and different from what would have been.

But those tested models or theories are always incomplete, so observations occur that simply do not seem to conform to existing paradigms. Typically, scientists comfortable with normal science initially ignore these exceptions, except for a few who delight in periodic change or revolution. Then a new paradigm starts to struggle up, often launched by the sudden emergence of a new idea that is in principle testable. If it persists, then interest is aroused, and suddenly the paradigm shifts into a new view and a new emerging theory.

So understanding occurs in spurts: long periods locked into one useful paradigm, or myth, alternating with a spurt into a new one. This is basically Thomas Kuhn's description of science; Kuhn, the American physicist and philosopher of science who presented this argument in his ground breaking and controversial 1962 book The Structure of Scientific Revolutions. It perfectly reflects my experience, though I gather philosophers of science question his thesis. Typically, I have found that the spiral of exploration takes at least twenty to thirty years. I guess that is the same in all fields of enquiry. It is a reflection of people and their behavior, not of a particular discipline.

I compare the discoveries made throughout my life to the sudden, surprising appearance of a bubble, a tiny world on the verge of bursting.

These bubbles, or ideas, can pop and disappear, or expand into something extraordinary and life changing. This memoir focuses on these bubbles, melding my scientific life with my personal experiences. Art and music, nature and science, history, books and film, all in a jumble of interacting elements that define my life. These form a spiral: a spiral that interacts with the spirals of others and that lives on in succeeding spirals.

I delight in discussing ideas that were and often still are new to me, and their source and spiraling influence in my life. So here are the bubbles I have encountered, discovered or created. And here also are the spirals of thought and enterprise that followed.

My bubbles are personal observations- some big, some small. My spirals are explanations, some small, some big, but all incomplete, and all open to new thoughts. What is revealing is what is not observed, not explained. The unknown is always larger than the known and is the source of surprises. Surprises become crises in a world where resilience has been lost. And crises can become bubbles that open learning. And so it goes.

The Beginning of Beginnings

Undergraduate years (1948-1952)

While I was an undergrad student at the University of Toronto, working toward my Bachelor of Science degree, I learned of a program that offered summer employment through the Research Forestry Laboratory located in Sault Ste. Marie, Ontario. The program was directed toward exposing undergrad students to the work they were doing, and I jumped at the opportunity to be a part of it.

The team I was a part of had been set with the task of assessing how much damage had been done to the dead and dying trees damaged by fire and by the wood boring beetles. When I arrived at my location, a heavily wooded area that was known for an expansive forest fire that had taken place years before called the Mississauga fire, I was eager to put my education into practice.

There were no roads in or out, and nothing but dense trees and vegetation all around us. We did have access to an old fire ranger's cabin, and established ourselves there. There was no electricity or means of communicating with the outside world, and so we, as a team, became immersed in our work and each other's company.

The forest's edge skirted along a large body of water called Kindiogami Lake. The fishing was extraordinary - the lake was teeming with huge trout. During our second year there, two foreign camping groups were flown in for a fishing trip. My team and I objected to their arrival and decided to play a trick on them.

We gathered a bunch of blocks of wood, and scurried up the side of a cliff. We attached the blocks of wood to a large string of number-nine wire (which is used in bush telegraphs), and draped a sheet over them. The wire slanted down to the far shore, where the tourists had set up camp. We waited until nightfall to send the blocks of wood off, and one of my colleagues sounded a loud whistle that echoed and bounced off the cliff's face, sounding chilling and ominous in the night. The tourists awoke with a start and scrambled away from the blocks of wood that tottered toward them. Once we were able to contain our laughter, we made the trek down to their camp and informed them that it was just a prank.

We often had to eat off the land, because forest fires were abundant in the area and no provisions could be flown in during these times. So we ate spruce grouse, bull frogs, and trout. The spruce grouse were notoriously stupid animals. You could walk right up to them without them moving an inch, so they were very easy prey.

Much of our work took us from the comfort of the tiny cabin out into the woods, which were riddled with dead trees due to the infestation of the wood-boring beetles. We traveled by canoe between the various project sites, loaded with power saws and our crew of five to six people.

First, we identified the dead trees and cut them down at intervals, and then we took a one-foot block out of each tree, counted the number of wood bore cavities there were, and recorded them. We plotted the rate and extent of deterioration of the wood, with one question in mind: How much of that dead wood could still be used for pulp?

While in the small cabin hidden amongst the dying trees, I not only had my first taste of putting my scientific background to practical use, but I also learned to cook, and developed long-lasting friendships. I also learned of the long-horned beetle, *Monochamus notatus*, a magnificent insect ranging from 3-6 inches in size with long extensive antennae. It was an enriching time in my life that lasted for the following three summers of my Bachelor's degree, and during the summer of my Master's in Ecology.

At Work with a Master's Degree: 1952

My career truly began in the Fall of 1952. I had just graduated from the University of Toronto with a Master's in Ecology. After my years of summer employment, I was immediately offered a full-time position in Sault Ste. Marie, Ontario, to work at their Forest Research Laboratory.

When I arrived in Sault Ste. Marie and joined the other scientists at our remote location, I was taken aback by the lack of technology and the sense of isolation that came with it. The lab was located at the juncture of Lake Superior and Lake Heron and the small city was a steel town at the time. The lab was a relatively new development that stood out amongst the industrialization that ran rampant through the city.

The location had been chosen by J.J. de Gryse, a senior administrator in the Department of Agriculture and Forestry, due to his discovery that the local Algoma Hotel had a collection of rare wines hidden away in their cellar. Now that was a sound argument! However, the nearest decent library was at the University of Toronto, 500 kilometers away. There was no Internet, no email, and I was an awful correspondent.

I had no alternative but to draw on my education at the Zoology department of the University of Toronto and create my own science. That eventually led to two very long memoirs regarding my work on predation, sufficiently new and fresh as to achieve a prize from the Ecological Society of America. Those predation studies led to generalized models that cast the process into a number of distinct types, each defined by one parameter in the predation equation. Those equations became rooted in the science ever since, and the papers describing them continue to be referenced now in 2015, 60 years later. The functional responses triumphed!

Despite the obvious drawbacks of our location, the working environment was open, well-funded and freely enterprising, and I joined with other science figures who had established themselves as leaders in ecology and bioclimatic studies: particularly Frank Morris, Bill Wellington, and from a somewhat later generation, George Green, Paul Harvey and others. What a team we formed! Frank shaped interdisciplinary research in forestry with his focus on insect outbreak species, particularly the wonderful spruce budworm. I was awed by the knowledge and passion of the scientists at the lab, which only further fueled by own desire to produce excellent work.

Figure 2. Small bird in teak by Buzz Holling

Like me, most of the other scientists had grown up surrounded by nature, and the industrialization of the city came as a shock to all of us. We developed a small community of like souls who enjoyed art, music, and engaging in wild discussions of ongoing world events. Artistic activities, music, and theatre were encouraged, and we met weekly, displaying our efforts to each other with laughter, jokes, and good food. It was a way for us not only to survive but also to thrive in this unfamiliar place, and distance ourselves from the industrial development that had stripped the city of much of its natural beauty.

What was most remarkable about the lab was how it was established. During WWII, the nations fighting the war discovered novel ways to use science in war. The invention of operations research was a particularly large development at that time. From the various developments came the eventual success of the western allies, and after the war ended, each of the countries from the allied side shifted into a post-war mode of expanding in science. The United States, for example, had a long-term focus on universities and government.

In Canada, government labs were spread all across the country, from east to west. The Forest Research lab I was employed at was one such effort to make scientific developments relevant to the problems Canada faced. These issues surrounded fisheries, forestry, agriculture, and genetics. The labs were given a remarkable charge: do good science that was applicable to the general area. So I examined spruce budworm, a variety of forest sawflies, small mammals and insectivorous birds.

The work we did at the lab focused on the topic of predation, or predatory behavior. We strived to develop a general model of predation that was different from the familiar models that were derived deductively. Instead of being directed by deduction, our model would be directed by organized induction. I imagined components of predation: basic ones like rates of search, time exposed and handling time, and subsidiary components like hunger, learning, and avoidance.

We were set with the task of not just creating a model of predation, but developing a deep understanding of it. The goal itself was outrageous: achieve a model that is precise, general, holistic, and realistic, and do so with experimental data from any beasts that best suited answering the question of the moment.

With the scientific work that was going on at the time, this was an impossible feat. Non- integrated scientists drew largely from physics, which is basically simple in itself, to test their experiments. Ecology, on the other hand, is an integrated science, multi-faceted and complex, so when physics was applied, it couldn't extend to all four traits mentioned above. In an effort to do experiments that would explain a particular process, scientists intentionally fell short of achieving all four attributes.

However, I decided to challenge this notion and conduct experiments that would retain all four characteristics, even though I didn't have the language to do so at the time. I made use of components analysis, which was a way to examine key processes that affected animal numbers: predation, parasitism, disease, cannibalism, and so on.

This was an approach that took a particular process and then tried to deduce the basic and subsidiary components of the process. By basic, I mean the elements existing in every possible example, whether it is a bird, a mouse, or an elephant (or a submarine).

Once the basic components were present, the question must be asked: How will the subsidiary components affect the basic components? Using hunger as an example, when the hunger of an animal reaches a certain point, its behavior changes, thus affecting the basic components.

The animals I largely used for my experiments were praying mantis, birds, shrews and deer mice. It required a small zoo to rear and maintain the necessary beasts. The mantis work, for example, required a small stable that provided a continual source of prey, such as *Drosophila*, houseflies, and blowflies. Another stable was required for the praying mantis themselves, whose egg cases came all the way from Pakistan.

I chose to study the praying mantis partly because of their size, as I didn't require the use of highly expensive machines to measure them. Our budget was limited, and this was one expense we could not afford. Secondly, I wanted to study a creature that possessed clear responses from the predator to the prey. In the case of the praying mantis, these were: leaning forward, stalking, striking, and eating. Thirdly, they were practical to rear in large numbers and would have similar or identical behavior and attributes to each other, thus making them predictable and perfect for the type of experiments I was conducting.

Another creature I worked with were shrews, which were either bred in the laboratory or caught in the wild. They were also chosen largely due to their small size.

I set up a large experimental enclosure that they could roam around in, which was about 10’ to 15’ in size, in a room that had a large plate-glass mirror so that I was able to observe their actions without disturbing them. They were also filmed, and the camera captured how many holes had been dug in the bottom of the sand in the enclosure. Sawfly pupae were buried in the sand, and the digging of holes indicated the rate of attack. They were buried at various densities to display what effect density had on the attack.

In every instance with every species, it was a matter of how I could get individuals of similar condition that would leave some easy way to indicate what they were doing, whether it be through their movements, digging holes, and so on. It was a simple way to collect the data that I wanted to analyze.

While I conducted my own experiments, the other scientists were free to explore separate bodies of work as well, but they all combined to make up a better understanding of a larger topic. We chose to focus mainly on the spruce budworm, as it was a dramatic outbreak species. Every 40-50 years, budworm would appear, seemingly out of nowhere, and flood the skies and trees with larvae. Within three years of defoliation, the trees would be dead.

Enough research had been done at the time for us to predict that an outbreak would soon occur again. Such outbreaks typically stretched from Manitoba, Northern Ontario, Quebec, and New Brunswick to some northern states in the US.

Frank Morris was the genius who discovered that the methods for dealing with a problem of such massive scale and length of time were techniques that had actually been developed for small areas and short durations. R.A. Fisher, a well-known geneticist and mathematician who had applied a variety of statistical techniques to his work, had developed these methods. Statistics were developed to focus on data collection that could be reliable, as much of science had been anecdotal up until Fisher’s time.

Frank decided he would try to transfer the techniques that worked so well for the lab, and apply them to landscapes. This is what he did with the spruce budworm. Frank and his team were based out of Green River, New Brunswick, opening an exciting new method to field enquiry by applying the statistical approaches of R.A. Fisher for the first time.

The spruce budworm project was the first large-scale study that was at least a little interdisciplinary. There were foresters, entomologists, economists, and ecologists, all applying their knowledge to the same problem. Ken Watt, my university friend, appeared and set the stage for computer analysis and modeling, which was one of the first ecological uses of computers. And I carved out fundamental work examining the foundations for predator/prey theory that was precise, realistic, simple, and holistic. Achieving that combination was impossible, of course; something surely had to be sacrificed. But which ones, at what cost?

At the same time that Frank and his team were conducting their work, there was an effort to minimize the damage that the budworm was doing to the forest. An area was selected that would be undisturbed for Frank and his team to understand the outbreak phenomena, while other parts of the province were open to a spraying program.

Around the same time that the spraying was taking place, an illness started to appear in young people. It had nothing to do with the spraying, but the public, in searching for a focus for their fears, blamed the spraying that was being applied to budworm larvae. The government responded in two ways: by changing the type of insecticide to appease people, and by getting a good publicist who described the spraying program as not an effort to kill budworm, but to keep the forest green.

Frank and his team were trying to determine the density of budworm and measure the character of the trees at various stages of their infestation. That's where statistical sampling came in: it achieved reliable ways to estimate the damage and density of the budworm. The forest, which had once been lush and thriving, had now become a barren graveyard for trees, dripping with budworm.

As Frank worked concurrently with the spraying program, a committee was formed to organize various distinct interests. It comprised representatives of the forestry industry, the pulp mills, the government, and various scientists. They developed a budget each year to buy or rent airplanes and enough spray to use for the year. A small air force was developed because the budworms were so pervasive.

The committee also developed a rule for using the spray: whenever the trees reached a certain level of damage, that stand of trees would be sprayed. Each year, a different area of the forest would be sampled, and in each sample point there would be an estimate of how many spruce budworms were present, how many trees were affected, and what condition the trees were in. After this data was compiled, the committee would convene, analyze each area being sampled, and determine if the trees should be put on the spraying program.

While Frank and his team were conducting their research, I was working with my team developing our own models of the forest. When we added the spraying to the model, we discovered that something wasn't matching up. We scoured our research and tried to determine where our mistake lay, only to discover that the committee had actually broken their spraying rule.

A wealthy businessman who owned a large chunk of the forest was revolted by the spruce budworm. He secretly approached the more malleable members of the committee and convinced them to have all of his property sprayed, whether it needed it or not. This skewed the results of the model and provided a lovely example of a general principle:

> *The face of reality can change dramatically when one is forced to recognize the actuality of a situation.*

My own work shifted again when Ken Watt introduced me to FORTRAN, an early programming language for computers. It provided a language that a typical scientist could learn very quickly that interfaced with machine language, so the scientist didn't have to learn machine language. At the time, it was unimaginably new and exciting.

I suddenly had a language I could immediately apply to my praying mantis data and graphs. The basic idea behind the integration was the identification of thresholds and hunger. At certain levels of hunger, their behavior changed, and this could be measured by moving a model prey toward the mantis noting the distance for the mantis' reaction.

Depending on the level of hunger, it would react differently. These thresholds were what organized the research I had done. FORTRAN made use of "IF" statements, such as "IF the hunger is greater than such and such, then GO TO …" Those IF statements provided a language that captured behavioral changes by a series of thresholds. The accompanying "GO TO" statements allowed the program to jump past irrelevant formulas to the one that was applicable. While I had developed an understanding of the mantis work, I now had a proper language to explain it to others.

Bob MacArthur, the world ecological leader at the time, wrote me that analyzing predation in terms of its basic and subsidiary components work was fine and deserving of praise, but clearly it created too complex a result. Those results were precise, realistic and general, he argued, but not simple enough. After all, he wrote, if you are modeling a ball rolling down a hill, surely it is necessary only to know its height and the time available. Unlike MacArthur, however, I was also interested in the path down the hill, the bumps and stability regions where the ball can pause on its way down. That needed more.

In order to collapse the complexity, I shifted the creature being examined to a person who simulated attack. She was blindfolded and placed before a table to which discs of sandpaper were tacked. She tapped at random places for a while, stopped when she felt a disc was touched, and picked it up before continuing to tap. This simple experiment was set up with various densities of discs to mimic predation, where the basic components were rate of search, time exposed, and time spent handling discs. The resulting "disc equation" captured this basic set up, and effects of subsidiary components could be added: hunger, avoidance and learning. Four fundamentally different types of predation could be represented by four variants of a common equation.

My predation theory and models triggered a search for tests of large ideas by me and others, and also led me to introduce cinereous shrews to

Newfoundland. Newfoundland had no shrews present, nor several other groups like snakes. Charlie Buckner of the Manitoba Forestry Laboratory and I were the only ones who had ever discovered a way to capture shrews alive. Bucket traps, nesting material, mealworms and cat food did the job! Ask, search, and you will find.

The larch sawfly outbreaks in Newfoundland were killing trees, but Newfoundland had no means of dealing with them. My work displayed that shrews were a particularly successful insect predator, and Malcolm Prebble, the senior administrator of the Department of Forestry, decided to introduce shrews to the head of the Forest Pest Division of the Department of Forestry. I thought it was a great idea. It seemed to me there would be very little risk of unexpected consequences because of the insectivorous habit of cinereous shrews.

This took me to New Brunswick with a homemade carrying case sufficient to hold 24 shrews. I trapped 22 in Green River, and flew them by Beaver aircraft to Corner Brook, Newfoundland. We picked a plot partly isolated by roads and a river, and released the beasts over a gridded plot with lots of potential food added: cod and hamburger meat.

The next year, there was an explosion of shrews in and around the plot. As I recall, there were over 40 animals per acre, more than anyone had ever seen. That high density spread out in a wave front, collapsing back to normal levels as the wave passed, till the whole of Newfoundland Island was occupied by shrews several years later. It was a genetic bottleneck for sure, but a successful introduction.

One unexpected consequence was that trappers of beaver complained about the shrews eating their beaver pelts, but they learned to shift to the pelt-drying approaches on the mainland and all was well again. Years later, at my cottage in Ontario, I even met a 'Newfie' who talked with pleasure about the little shrews they discovered in hunting camps. He saw them as treasured myths of the woods.

The Four "F's": How animals Feed, Fight, Flee, and Fornicate

During my research, I launched collaboration with Ken Watt and Don Chant, who was Provost of the University of Toronto. As our work developed, we began to realize that the labs, which were once bursting with innovation and flexibility, were now moving to a more rigid phase as the leaders of the institutions aged.

Don established one of the first Environmental Organizations (Ecology Probe) in Ontario. That later led to Energy Probe. Both organizations have been remarkable in their combination of science with issues.

Don was seen as THE environmentalist in Ontario. He was also long on the board of the World Wildlife Foundation and entertained with Prince Philip, their patron, off and on. He once helped the Liberal Premier of Ontario escape an unexpected parliamentary vote that his party would have lost, by accepting the Premier's plea to be the first CEO of a new Crown Corporation, Ontario Waste Management. Don attached all sorts of conditions to accepting the position, such as opening new toxicology labs, having freedom to design in total, and the freedom to engage in a sequence of publicly advertised town meetings. His approach designed disposal, recycling and redesigning of wastes as part of a Provincial industrial policy.

It went on for about six years with lots of press attention, and was within weeks of being implemented when the Corporation was closed after a new election and the appearance of a new Conservative Premier. That was Harris, an enormously energetic used car salesman as I recall, who was called the "Newt of the North" because of his savaging of Government programs.

The government cutbacks initiated by Harris also resulted in the Walkerton scandal where several people died because of the absence, or reduction, in water monitoring, the absence of skilled technicians, and the appearance of a disease in the waters. Harry Swain, another good friend, was Commissioner of a Technical Commission on that very issue. This appropriately raised a big scandal in Canada.

Through all this, Don also maintained his research on the taxonomy of mites. He completed three monographs on this subject, from his home north of Belleville, Ontario. In the 70's he said that he gradually shifted from his large scale political/administrative life to concentrate exclusively on mites, learning in the process "more and more about less and less."

He added that, in contrast, I seemed to have moved to "learning more and more about more and more," from predation, to the functional response work of early years, to resilience of regional systems, to Panarchy in the world. But I objected. In fact, I have moved to "learning less and less about more and more!" The rule of hand (as opposed to the 'rule of thumb'), inevitable uncertainty, and evolutionary and sociological jumps make that true.

Don was a good man, and such a devoted fisherman as well, a fisherman in politics and science and life. He passed away from a heart attack in 2007.

The behavior of a complex system involves multiple causes and connections. A ***rule of thumb****, with its focus on a single feature, needs extension to a* ***rule of hand*** *that admits several important features. For the general public, three carefully chosen points (corresponding to the three central fingers of a hand) often suffice as a memorable summary.*

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Around 1960, we attended a large conference in which many Canadian government scientists were present, and decided to make a pitch to them. The key decision maker was Malcolm Prebble, whom I had had previous dealings with. He was a shy, introverted man who immediately took a liking to us and our sense of integrity.

In an effort to revive the innovation that had once been so prevalent in the labs, we proposed a new Institute of Complex Studies. After we delivered our pitch, Malcolm said, "I have utterly no idea what these people are proposing, but I like them." Despite that, there were other needs dominating government research and not enough resources to expand within the department. So change did not occur, at least not the fundamental change that we sought.

Even though our proposal failed, there were two developments that emerged of similar worth. The first was the Canadian Institute of Advanced Research, launched by Fraser Mustard. He was a brilliant physician, aware of a full range of science where the key in these different disciplines of science was a tremendous amount of innovation. He was so articulate and so well connected that he was able to get private money to establish this new institute, which had the unique feature of having no lab.

The argument was to let the scientists stay where they were at their various universities and institutes, but save enough money to bring them together for a short period of time, and include grad students. It was an open network solution. He got a board together, in which I was a member, which consisted of bright people who had unbridled fascination with innovation. A novel center with no center.

There was also an initiative that came out of the government. They wanted to get that innovation well placed in universities through endowment moneys. The person chosen for various endowment chairs would receive money for research.

The second institute that was established around this time was the Santa Fe Institute. Several scientists associated with a nuclear laboratory in Los Alamos, New Mexico started it.

It is a wonderful Institute that started in a monastery and later moved into a beautiful sprawling building of its own on a mountain. It is a welcoming, open space, with room to walk, talk and think. It also possesses a bicameral governance system, in which there is a policy and funding board of business, as well as an independent 20 to 30-person board of science. The first board gets the money and establishes overall policy; the second launches experiments and other studies that typically draw upon a group of thinkers and doers over a few days to a few months.

I was on the early Science Board and loved it and the people. Santa Fe developed strong ties not just to science but to influential business and to art as well. Stuart Brand, a columnist who created the Earth Catalogue, was the one who most impressed me in his imaginative leaps into lovely territories.

He wrote "How Buildings Learn," a book that gave the long-term life of buildings the kind of episodic evolutionary features reminiscent of ecosystems; features created as time passed and as users shifted interests and developed new needs. And in his book "Clock of the Long Now" he saw the world as one needing preservation and access to the slow processes that underlie complex systems.

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But back to the lab in Sault Ste. Marie, I began to grow anxious and craving change. The Department of Forestry had opened a lab in Victoria (1965), called the Burnside Road Laboratory, and I asked that my family and I be moved there. But that wasn't enough to satisfy the search for innovation.

After my family and I were settled in Victoria I decided to test the flexibility of the Department even further, with a proposal that would stretch them. I asked them to support me on a one-year sabbatical in Hawaii. The underlying argument was certainly a good one: I told them I had a desire to test the generality of the predation theory I was developing, based on extensive studies in the laboratory and in nature. After all, I did have a theory that was precise, holistic, and in organized sets, simple. But was it general? Where else to test generality than in the most unlikely place: not in my home forests of northern Ontario, but among the fish of tropical Hawaii.

The administrators of the Department actually agreed and applauded. They truly had vision, and wanted to support novelty and adventure. They were senior civil servants of the highest stature, in a system that, at the time, allowed freedom and flexibility. That is very rare today; bureaucracies in government now do not allow public innovation, and staff has grown tame, not revolutionary.

So off I went to Hawaii with family and ideas. My son, Chris, was five, and my daughter, Nancy, was two. The warm, balmy weather lured us into blissful contentment, and the gin clear waters of Hawaii enthralled and summoned us.

It was in Hawaii that I first bonded with my children over my work. The waters sparkled with diversity, alive with butterfly fish and goatfish. There were fish with the deep, rich hue of pomegranate, others as bright as burnished gold, some glimmering brilliant silver or black, all living and thriving on the reef at Kaneohe Bay. There were strange fish with snouts, stomatopod predators with grasping forelegs, and nudibranch invertebrates with colorful cloaks to confuse and capture prey. Chris spent more time in the water than out of it, and Nancy crawled through the waves till close to submergence. It was an entrancing environment ripe with opportunity.

During my time in Hawaii I started to see unexpected behaviors. Iao, a schooling fish, never touched the posts they gathered around, nor did they run away from predatory barracuda but instead swam around them, forming a zone of safety. So I caught schooling fish and barracuda, observed their behavior in large aquaria, and developed models to explain their behavior.

The behavior the iao demonstrated turned out to be the response of all species that were pelagic swimmers, that is, complete residents of open water. But schooling fish, which were not exclusively pelagic but also used hiding holes in the reefs, swam away from the barracuda as soon as they touched the safety zone formed by the iao. They would swim away in tangents, continuing at an angle that made them curve away from the barracuda and help them find a safe path back to the reef. Holding a fixed distance from an enemy gives a band of safety, for response if the predator shifts its attack. Caribou do it to wolves, iao to barracuda.

I did various experiments to test the reactions of fish to predators, often using myself as the model predator. Many years later while searching online, I stumbled upon a web-based example where the same essential behaviors I had seen in fish were delightfully shown with hovering and flying autonomous robots.

All it takes, according to their inventor, is for each robot to embody a simple rule regarding its nearest neighbor and the nearest obstacles. They calculate possible collisions from this information and adjust their own behavior to avoid them. They could even superimpose patterns of movement: figure eight through barriers, for example, or a full orchestra playing drums and cymbals!

In one of my later experiments, which took place at home in British Columbia, I used schooling salmon and developed mock situations where they were startled by the sudden appearance of a moving, endless patterned belt. Once they saw the belt, they would move away from it, but their startled flight stopped at the edge of their "zone of fear." The test showed that further movement was dictated by the appearance of a corner, and as there was no corner on an endlessly revolving belt, there was no change in the signal and therefore no further movement. They acted like the robots that could be designed to mimic them.

These observations in Hawaii are what got me into wonderful discoveries of near organism behavior, where movement rules of behavior popped out to explain trajectories of predator attacks, prey avoidance, prey flight, hiding, flocking and schooling. These simple rules were just sufficient to work, and I realized that they could one day be applied to technological advancements, such as robot movements or guidance for driverless cars, which now, in 2015, are close to being reality.

I captured much of the beauty of Hawaii's waters on film, snapping pictures of mahi-mahi under a raft as they attacked prey, and schooling and solitary fish reacting to potential predators. I saw the same reaction to prey in ducks off the coast of British Columbia reacting to boats, and of school children in a field reacting to a runner as an aircraft filmed the interactions. And later, to flocking ibis in Florida, sketching V's, W's, and Y's in the sky as they flew, almost with magic, from foraging grounds to nesting islands.

These were all beautiful situations that weren't really work at all, but glimpses that led me a little closer to understanding the patterns of life.

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My family and I returned from a happy, blissful year in Hawaii, to our new home in Victoria, British Columbia. Could there be a renewal in a place with traditions different from the lab in Sault Ste. Marie? Or was the state of growing rigidity persisting within the whole department?

I immediately began to sense that the flexibility and freedom I sought by making this move to the Burnside Road Lab would not be found here. This lab was even more rigid than the one in Sault Ste. Marie, and the shift from innovation to rigidity was a reflection of the age of most of the people, who had aged their way to less imaginative, less enterprising attitudes.

I worked there for about four years, and while the work itself was unremarkable, it was there that I found a connection with my daughter, Nancy. As she grew, she developed a deep interest in animals. I introduced her and Chris to the ponds that had once captivated me as a child, and her fascination continued to grow. She discovered garter snakes, and despite the off-putting smell they would expel when threatened, she would collect them and entwine them around her bicycle handlebars. She affectionately became known as the “snake lady” in our neighborhood, and now, in 2015, she is a veterinarian who specializes in acupuncture for animals.

When I later moved to UBC, one of my first PhD students was Larry Dill. Having discovered our shared interests in the topic, I invited him to co-author a grand book with me based on our experiments and models of animal responses to nearby objects. We had a good phrase to capture most of the research for the book: Our experiments displayed how beasts feed, fight, flee and fornicate, thus becoming "The Four F's." This enjoyable collaboration continued after Larry took a faculty position at Simon Fraser University a few years later.

For example, we discovered that Larry’s work on startle responses of fish to model prey of different sizes generated equations that were the same as the equations I had independently derived for attack by praying mantis to prey of different sizes. There was a slight difference, as his beasts used a monocular sensory system and mine used a binocular one, but they were essentially the same equation, with one parameter that turned the results from one for distance of startle to one for distance of attack.

Larry and I tested the basic rules widely. One test used 12-year-old school kids in a field. About 80 kids were gathered in an area where a runner ran at them as they were photographed from an aircraft overhead. They spun away, not directly, but at an angle identical to the way small fish escaped attacking barracudas in Hawaii. That is, all but one boy, who simply sat down. That boy told us later he decided that he would show us that we were wrong: people are not just like animals! The child did not realize how much truth there was to his statement, something I would come to learn in later work.

One day, when I was doing research, I ran across the super ellipses of Piet Hein, a poet and scientist from Denmark, who designed squares in cities that were easy to navigate. He gave the term "super ellipses" to the shapes he applied to city squares. They were approximate representations of the avoidance contours of my schooling fish and did, in fact, represent easy routes along paths that were free of tension.

Does this tell us that the world is created in an optimal and efficient way or an approximate and diverse way? Or is it a combination of the two?

All these observations illustrated the foundations that Larry Dill and I had discovered earlier. General laws, expressible in general equations of fairly simple form, described and explained all of the variants we observed and filmed, each as a limiting condition of a general equation. Moreover, we discovered that those rules were neither precise nor accurate, but rather were simple and just sufficient.

They were not based on careful measurements of speed and distance, for example, but on instantly detected rates of loom of the approaching signal. As the object comes closer to a fish, the diameter expands, and this is called the loom signal. When the object reaches a certain distance from the fish, it reacts. In short, they were "quick and dirty" estimates, and were adaptive. They aren't perfect, but when mistakes are made, there is room left to compensate for the error. Adaptive options are retained to correct a response if a mistake is made. Resilience, not efficiency, is the result.

We concluded that nature does not optimize for the "best" based on assumptions of complete knowledge, in the traditions of simple decision theory. Nor are its responses efficient. Actions are based on just sufficient information to assure adequately the object's fundamental nature and provide options for reversal: likely small enough to attack safely vs. likely big enough to avoid. That is all strictly the consequence of evolved responses.

> *With inevitably incomplete knowledge come surprises and mistakes. But the mistakes become possibilities for new learning, not routes to failure.*

When Larry Dill and I were working on "the book we never published," we rented a cottage on the Sunshine Coast near Vancouver to continue writing. The cottage was a retreat. While there I noticed Pacific Northwest Crows behaving strangely. They would discover a clam on the beach, fly out and pick it up, and then drop it on a large flat rock. Each time the clam broke, the crows landed and ate their fill.

It motivated me to write a children's story entitled "Maladroit Murgatroyt, The Clumsy Crow." The basic point was that Maladroit Murgatroyt, after clumsily dropping a clam first by mistake, learned a new way to forage, a way that he taught to his buddies and all other crows. When I later presented the fable to my grandchildren, they were thoroughly bored, but my 92-year-old father was delighted, enthusiastic about a creative way to show that novelty and learning could come from mistakes. He was a man of wisdom.

And the lessons of my story really do hold:

How to help create a new world that creates itself.
How to find the few key processes that do this.
How to keep on experimenting and perceiving that which is good.
How to make destruction creative. We all die at omega; we all live at alpha.
How to sustain diversity and equity.
How to encourage surprise and benefit from it.
How to think broadly, not narrowly.
How to integrate the pieces, not be controlled by any one piece.
How to make partners of local Common Crows (your pals).
How to comprehend the distant Ravens (your remote strangers).

Maladroit had discovered the beginning of the answers. He learned that mistakes produce surprises that can be turned into unexpected good. And that everything is in the timing: too soon and people ignore; too late and people oppose. It’s important to keep trying. Have fun. Be optimistic. Embrace risk. Collaborate.

Figure 3. Three cormorants in acrylic by Buzz Holling

Slow Growth and Fast Collapse in Regions

While employed at the Burnside Road Lab, an idea of sorts began to take form. I began to grow restless as the labs I worked at moved from a phase of innovation to that of conservation and rigidity. The adaptive cycle started to emerge. I sought change, and this deep need for something new seemed to present itself every eight to ten years.

The Department of Forestry seemed to be going through its own cycle of sorts, which I experienced firsthand. When I was first employed there, it was undergoing a phase of innovation, slowly achieving successful inventions and designs, then shifting to steps that attempted to control those very inventions, which led to overall rigidity.

But then I realized that there was also a subsequent, and rapid back loop when the rigidity suddenly broke as innovators bitched or fled, allowing them, and in some cases the institution itself, to recover and renew from the rigidity and collapse to a fresh, new innovation phase again. In Hawaii, for example, my personal adaptive cycle slipped back into the innovative, alpha phase of innovation. My various working locations and institutional history were shaping ideas about the adaptive cycle, just hints and items for jokes, and not yet for science.

I continued to grow restive at the lab (1967), but an opportunity for change soon presented itself. I had written a paper that essentially argued for interdisciplinarity, computer use and a systems orientation. That doesn't seem very revolutionary now, but it was at the time for university education and research.

Gordon Harrison, of the Ford Foundation, read my paper, and believed that it could give direction to his new program entitled Resources and the Environment. He was an historian who had written about the US General George C. Patton and had a breadth of vision and experience that suited him in this new job. The Ford Foundation is a well-known private foundation that gives grants to innovative programs.

I received a letter from Gordon about my paper, and we agreed to meet. We immediately hit it off and he offered a one-year-plus job as a consultant to help implement the plan I had described in my paper and he had amplified.

It was a time that was ripe with opportunity, as I had also been offered a faculty job at the University of British Columbia, partly in Zoology and partly in the Graduate school. I accepted the position with UBC, but arranged a start date a year later when the position with the Ford Foundation was completed.

I worked with one additional senior staff member, Bill Felling, who was an applied physicist whose main career was with NASA. He was one of the staff who projected the first satellite that went into orbit. We were based in New York, and were tasked with identifying programs consistent with the theme of the Resources and Environment program. If the program passed our judgment, we would bend them somewhat in the direction we sought and offer them a grant to continue with their work.

Bill and I functioned by getting independent information from papers that were written by an interesting group at a particular institute. Once we discovered these groups, we established contact with the head behind it, and received permission to meet them. We flew to various institutes around the world, met with the people behind the groups or programs, and determined whether they were worth supporting.

One program we chose to support was at the University of Manitoba. We traveled all over Canada, the United States, and even flew to Australia and Japan.

The visit to Australia was wonderful. The beaches, with their warm, gilded, sand and turquoise waves, seemed to stretch for miles, and like Hawaii, the fauna was visually striking. I witnessed a duck-billed platypus, lazily swimming through a body of water. I glimpsed a red kangaroo, sitting on its tail, facing another kangaroo. Both were in attack mode, a regular sight in Australia. Dogs would chase kangaroos up and down the beach and no one batted an eye. We visited centers and institutes along both coasts and in several major cities. While we met many brilliant people there, we didn't find anything that coalesced into a fruitful program.

The trip to Japan was just as interesting, but equally challenging. At the time, Japan was very hostile to the United States due to the Vietnam War. There was much public conflict, and our host was very hostile to Americans because of this.

As I was Canadian, they were very welcoming to me, and when we were first invited, I was asked, “Are you coming with your wife, or would you like entertainment?” I was shocked by their forwardness, and by the many strange, foreign traditions they clung to. It was a tradition that when a visitor comes to Japan, he was assigned a geisha.

Bill, however, was an American, and they made a point of making him uncomfortable. During meals, they offered him distasteful food that even they did not eat. One of the dishes was sea urchin gonads, but there were other dishes much more revolting. Bill, being the perfect gentleman, simply thanked them for the food and ate what they served him. The behavior of our hosts upset me greatly, but Bill remained unfazed.

The city itself was very commercial, with a high-speed train running through it. There was one place, though, where I could forget about the commercialism of the city: the palace gardens in Tokyo. They were stunning, and highly developed.

What was most memorable about the trip was our departure. We left for the airport and our host joined us. As we waited for our flight, he turned to Bill and said, “You are the better man than we.” It was a very difficult meeting and didn’t result in anything that was applicable or interesting for our program.

After a year, we spent about eight million dollars on programs in the United States and Canada, seeds that did have some consequence for the future of the field. The increases in computers, systems approaches and interdisciplinary design became new seeds for the future.

People Become the Central Subject: The UBC Years 1967

At the end of my year with the Ford Foundation, Bill and Gordon suggested I set up a program from the base I was just starting at the University of British Columbia. UBC had a very well known, appreciated institute of Fisheries on the west coast. It had done a lot of mathematical models of fish population dynamics that had been applied to the surrounding ocean, and I felt that there was a lot of freedom and room for growth here.

UBC was richly endowed with innovative people in influential positions. Peter Larkin, a key person there, was noted internationally, and was behind the application of novel mathematical modeling approaches to fisheries populations. He was a giant on the west coast, and allied with the other giant in the field, Bill Ricker, who was at the Fisheries Research Board Lab located on Vancouver Island.

Up until that point, the universities in Canada had been failing to change. There were few young Canadian scholars growing into the new world of integrative science. The government began to realize this, and resources were shifted from the government labs to universities.

I came to UBC with a large grant of $500,000 from the Ford Foundation, and I argued for the development of a new institute. These arguments took over a year, but resulted in moving the work that had been done in the fisheries program to living resources in general. I wanted to apply the lessons that had been learned in fisheries to a wider arena, and I planned on doing this by hiring people from a wide array of disciplines, such as mathematics, business, forestry, and ecology.

The new institute that came out of this conversion was initially called the Institute of Resources and Environment. The name didn’t last long, however, as there was a botanist on the council who argued that since there was no botanist employed within the new institute, the name had to be changed to something more specific. We finally agreed on The Institute of Animal Resources and Environment.

The Dean of Science and the Vice-President imaginatively sequestered money to match the salaries from university sources for the half dozen new faculty members after 5 years of Foundation support. So we hired great people, good people and unintentionally lousy ones in a set of interdisciplinary centers.

I situated these people part-time in the institute and part-time in a particular home that specialized in their discipline. I wanted to establish an interdisciplinary center for studying and learning about living resources in general, and we worked together for about four years.

We had to proceed cautiously because the university was rooted in individual disciplines, whereas our group worked in interdisciplinary groups. We set up new projects that were moving rapidly, outside of the institute, so that if they did fail, it wouldn't affect the institute, but if they succeeded, those involved would be recognized for their achievements.

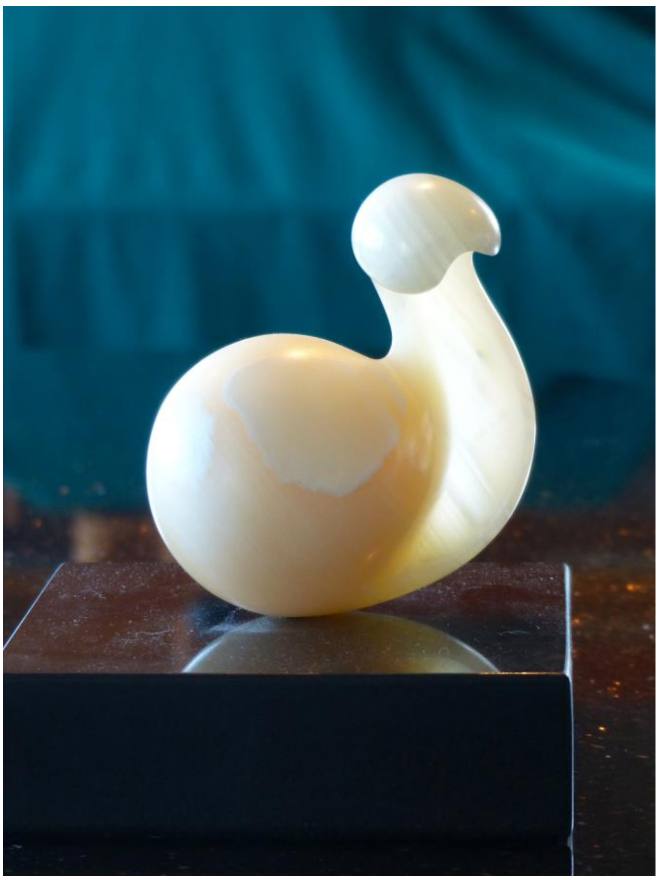

Figure 4. The Swan: Sculpture in white onyx by Lee Gass

Our buildings were temporary “huts” that provided primitive offices and labs. After WWII, the university established an agreement to rescue whatever huts they could from the military up and down the coast. Each hut was turned into a temporary university building with a lecture room, a big lab, and several offices. They were used by the university for decades, and were great because if you needed another lab you could simply build onto it yourself. Somehow the informality of the huts coalesced with the informality of the minds to enforce a synergistic connection. It was if the Rutherford Laboratory was born again.

The group at UBC included Lee Gass, who was a very fine observational scientist whose focus was on hummingbird behavior (he is now a talented sculptor); Carl Walters, who was a critical member of the team, and Don Ludwig, our insightful, brilliant mathematician partner. Collaboration with Don was a marvelous experience, and I learned a bit of mathematics, sufficient for my purposes. I was also delighted to take on Ric Charnov as a graduate student in the late 60’s. He became well known for his later work in animal behavior. I gave him all my mantis experimental data, the data that I had used to create the functional response types for predators. With that, he then created optimal foraging theory, which had a huge impact on the field.

A new body of science and theory that emerged after the Second World War that was rooted around the idea of optimization: the idea that any activity could be developed such that the components behaved in an optimal manner. An optimal manner generally meant an efficient manner, where the maximum benefit was achieved for minimum effort.

Ric picked up the idea of optimization and applied it to animals. He posed the argument that their behavior was optimal and was designed by evolution to be efficient. My work went further, and dictated that the organisms did not simply evolve designs that were efficient; they also designed mechanisms that were resilient. What I meant was that there was a measure of efficiency in the mechanisms, but there was a lot of latitude for mistakes. The real organisms evolved a method that would more or less succeed, but left room for failure as a means to learn from it.

John Krebs, a new graduate from Oxford, also joined our institute for a few years. He also became known as one of the key originators of optimality to animal behavioral studies. He later left, for family reasons, and ultimately joined the amazing group at Silwood Park, Oxford. It began as an ecology group out of Oxford, and took on new leadership with Richard Southwood, a senior scientist and ecologist of great repute. They had exceptionally fine scientists, who were good at both science and communicating.

Through the work of Southwood, and another predominant figure in the field, Bob May, they were able to tap into traditions of government research in the UK that led to the scientists in the Silwood Circle becoming recognized as policy people in the government.

Bob May was a noted physical scientist, mathematical ecologist, and former head of the Royal Society of the UK, as well as a formal science advisor to the UK government. The Royal Society is the first society in the world, dating back to the 16th century, to become a club for scientists. Richard Southwood actually lobbied over years to have several of his Silwood Park colleagues selected to be Fellows of the Royal Society. Such colleagues jokingly referred to FRS as Friends of Richard Southwood. Canada established a society of her own, of which I am a member, called the Royal Society of Canada. However, it has never been as distinguished as the one in England because it isn't as politically connected.

Bob May was also the recipient of the Crawford Prize in Sweden, the prize being a million dollars for those sciences not recognized by the Nobel Prize. It was well deserved, but in his speech he said, "Do not concentrate on ecological theory — most of the important advances have already been made." I was left gaping, for I was the runner-up, invited with Bob to Stockholm and to meet the King.

As president of the Royal Society, Bob May partnered with a number of the Silwood Circle to demonstrate the power of combining mathematics and experiment – John Krebs for foraging behavior, wonderful Roy Anderson for epidemiology, Mike Hassell for predation and John Lawton for ecology, and John Beddington for marine fisheries policy. They all became involved in official government service. Bob became chief government scientist, and the others were active in various aspects of the UK government. These were heady times indeed; all very well described in a recent book by historian Hannah Gay entitled *The Silwood Circle*.

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A similar ecological group emerged in Canada, scattered from coast to coast and collaborating in applied resource fields of forestry, agriculture and fisheries. These included Frank Morris, creator of regional scale ecological and statistical studies, Bill Wellington creator of bioclimatology, Bill Ricker and Pete Larkin mathematical ecologists of aquatic systems and, a little later, Ken Watt, in computers, Don Chant in population biology, Carl Walters in fisheries and systems ecology and me. We were spread out in Sault Ste. Marie, Ottawa, Fredericton, and Vancouver. While we never named our group, our focus remained on our budworm research.

Our own institute was highly effective in our first two years. This was a turbulent time, indeed, but perhaps the best new effort came from our first interdisciplinary workshop that was focused on the economic and ecological effects of development in the Gulf Islands, off the coast of British Columbia. The project was called the Gulf Islands Recreational Land Simulator (GIRLS), and the mathematical model we developed was called the GIRLS model. Lots of inappropriate jokes ensued. It was beneficial to work on projects that were colorful and fun, and also built up the spirit of those working on it.

We developed the model, not following the traditions of the time, but instead using the predation work I had done as the foundation for the model. We invited anyone who wanted to attend the first workshop, and it beckoned students and people from numerous disciplines, such as resource economics, fisheries, and forestry, who we could recruit for future projects.

There I began to discover the rules for interdisciplinary workshops, and to sense the rhythm of change that occurred as learning progressed. I posed the project as one of land acquisition and development on various classes of recreational land, using the grand predation equations to structure and focus our discussions. The land for sale was the prey, and predators were the buyers, settling the market each year in an auction. It worked just great and generated predictions of development and costs that matched the real world for 30 plus years.

We modeled the system with a new IBM 1130, a small institutional computer that freed us from the big university computer. We could play the kind of games needed for exploration; all coded on stacks of cards, every run of 100 years taking at least half an hour when now it would be a small fraction of a minute on a portable. The waiting time made room for discussions of previous runs and their significance and allowed exploration of the ecological, social and economic dimensions of the project that had much wider relevance. And this was at the time of the student revolutions, the ebullient explorations of alternate ways of doing and knowing.

At the end of each year we arranged to have a party. The party was held on a small houseboat, and as we drifted past the islands, we saw exactly what we had observed from the maps and discussed how effective we were at evaluating the quality of the land for development. There was a lot of booze and raucous times involved, and the trips were fun while still being productive.

On the first trip, I invited a man named Dick Bocking, a documentary-filmmaker with the CBC. He came on board with his cameraman and put together a documentary on the Gulf Islands. Our institute strived to produce projects and workshops that consisted of a lot of hard work, but were also flexible and fun.

The GIRLS model was further developed through the institute, and it came from fun experiments and my past research. I summarized the central equation in a lecture at UBC, and Geneticist David Suzuki objected that this equation had already been developed in enzyme kinetics. At the time, his argument made the work seem controversial, although from my point of view it highlighted a remarkable aspect of science. The same mathematical equation often occurs in different contexts with completely distinct interpretations.

The experiments we conducted at UBC expanded to embrace everything I had learned in more traditional experiments: hunger effects, learning, avoidance; experiments with several other predator and prey species. I had a factory in my lab; producing praying mantis, Drosophila, house flies, blow flies, deer mice, shrews, birds, and, by implication, submarines! It all resulted from experimental work with predators of various taxonomic groups, each chosen because it lent itself to answering one of the questions of the moment. The combined results were therefore a strange chimera of preying mantis, ichneumonid parasites, deer mice and shrews…and young ladies.

The equations described not only predation, but hoarding as well. Shrews, for example, specifically the short-tailed shrew and cinereus shrew, hoard items to a sustained level as prey density increases, while deer mice hoard to a maximum, then decrease hoarding to zero as density continues to increase. Shrews seek their certainty by continually covering their bet with uncertainty; deer mice seek certainty when it is essential, but shift to flexibility or resilience when it is not.

It was all great fun, and a complex simulation model captured the generality, the reality and the precision of all these systems. The disc equations and their variety captured the simplicity.

We held other workshops as well, in response to groups elsewhere in the world who wanted our assistance. One such workshop took place in Banff, at a time when we were using the Michigan Terminal operating system and running on the large computer at the University of Michigan. Our task was to present to them an example of the work that could be done with computers. There were no portable computers at the time, so computers had to be remotely accessed through the Michigan Terminal System.

It was barely possible to do that with the communication of the times, but we did. We had an early version of a big graphics screen to display the results to the group, a screen that could only be transported in a berth rented from Canadian National Railways. This logistical feat was achieved by Carl Walters.

As one of the rituals at workshops, we always had a competition for the first and second best limericks. A final section of this memoir shows a selection of them.

Deepening the Regional Focus

Around 1970, I received an invitation from Howard Raiffa to spend a sabbatical with his new interdisciplinary center, the International Institute of Applied Systems Analysis (IIASA). It was located in Laxenburg, Austria, in a grand summer palace of the former Habsburg Dynasty. Howard was a self-assured, engaging man who was a grand decision theorist and entrepreneur of institutional transformations. His offer enticed me to fly my wife, my children, and myself to Austria in 1973, to await the next adaptive cycle in my life to unfold. Chris was twelve at the time, Nancy was ten, and the newest addition to our family, Jamie, was five.

Despite the ugly name, which had been chosen by a committee that had to compromise with the USSR, IIASA was a wonderful place whose focus was both scientific and political. It was to be a place that investigated problems shared by nations, in the hope of building bridges between east and west across the Iron Curtain.

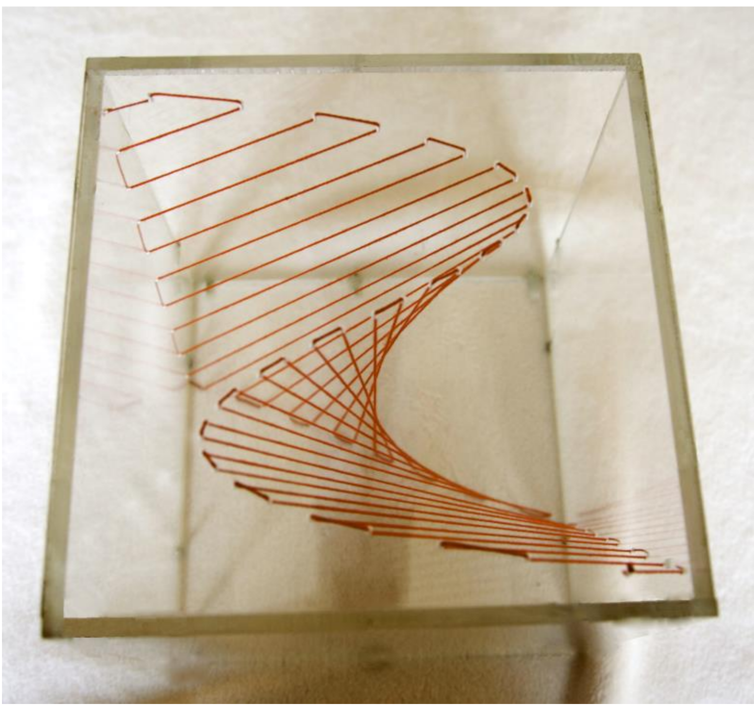

Figure 5. Three-dimensional response surface by Dixon Jones (red string in a Plexiglas cube)

I had no idea who would be there, who we would meet at IIASA, or even where we would stay. I arrived in late July, and brought Dixon Jones and Bill Clark along with me, both from UBC. I proposed to Howard that we work out of hotel rooms, and immediately launched into our work, preparing proposals to make at IIASA's first conference.

Dixon was still recovering from his experiences in the war in Vietnam, and decided to desert the applied physics background he was trained in and learn ecology. He ended up creating the first example of the broad application of isocline and catastrophe theory to any ecological system. Both theories had to do with mathematical ways to understand and explain abrupt changes in a system that moves it into a different regime. Sadly, shortly after our stint at IIASA, he passed away from a heart spasm while running, and a brilliant career was cut short.

Bill was an energetic, brilliant, and broadly based graduate student destined for great things, first at the Oak Ridge National Labs, and later at Harvard. His specialty became the vulnerability of social systems and institutions to shock, something that balanced and enriched our future research as it developed. I had first heard of Bill when he wrote me and asked me to accept him as a PhD student. He had all of the necessary credentials, as a graduate of Yale would, but I simply had no space at all -- none.

It wasn't long after I declined Bill's request that I heard from the Dean of UBC that Bill's supervisor had been in touch with him and had essentially told him that I must take Bill as my PhD student.

My dean, Ian McTaggert-Cowan, arranged for an open position for Bill. Backed into a corner, I agreed to the arrangement and promptly forgot about it. I was reminded six months later when Bill Clark turned up for his fellowship. I soon learned how bright he was, and a fine relationship took shape with this fellow who possessed a wonderful mind. He ended up as a faculty member of the Harvard Sustainability Project, and concentrated on social resilience from the reactions and actions of people affected by unexpected disturbances.

When we arrived at IIASA, I was told that Ilse Beckey was the conference coordinator at the institute, and had been appointed to be my guide.

However, upon my arrival, I discovered that she had not yet returned from her vacation. When she finally returned, in time for the conference, I was struck by the sight of this beautiful, vivacious woman, with her blonde hair and piercing blue eyes, who summed me up with one glance as an arrogant scientist.

The conference at IIASA consisted of pre-planned talks and parties that followed them, and guests arrived from fifteen organizations throughout the world. We came to the conference with five projects that we offered for collaboration with myriad scientists from different backgrounds and disciplines. George Dantzig, a notable creator of optimization approaches, was in charge of selecting the collaborative project for the institute. The attractive Austrian girls of IIASA adored George, and nurtured and cared for him as he stood and purred.

During one of the talks, a Russian scientist, Ananichev, stood up from his seat and suggested that the ecology group at IIASA center their focus on monitoring oceans. “It’s an interesting idea,” I said politely, “but we have a different focus.” He returned to his seat, and I was satisfied that my answer had placated him.

The following day, he interrupted a talk again to deliver the same speech. I tried to be amicable, but my irritation with this man was beginning to grow. “We’ll consider your proposal,” I replied, unable to keep the tinge of anger from my voice.

The third day, I noticed him seated near the stage, and I watched him warily as the talks were unfolding. Sure enough, halfway through, he stood from his chair and began to deliver the same speech once more. I erupted. “Enough! This is not the direction we plan on taking.” He sat down slowly, glaring at me through narrowed eyes. I tried to brush off the incident and enjoy the rest of the talk.

That evening, Howard threw a Heuriger, a fall event where the new wine of the year is sampled. It was a very popular event in Austria, and we mingled outside at a vineyard, dining at outdoor benches and tables and sampling simple foods and jugs of wine.

I glimpsed Ananichev from across the courtyard, shadowed by a group of his compatriots. I felt a touch of guilt for my blow-up earlier that day, and when one of his companions sauntered over to where I stood, I opened my mouth to offer an apology. It was cut short as he shoved a napkin in my hand. I unfolded the crumpled napkin to see a crudely sketched drawing of a skull with the word “beware” printed underneath. A knife was tucked in the fold of the napkin.

I knew I had to diffuse the situation then, so I turned my gaze to Ananichev and raised a two-litre flask of wine in a gesture of challenge. He grabbed his own flask, and we began to chug the wine as fast as we could. When we had both finished, Ananichev collapsed, and I somehow stumbled back to my room in a haze.

I awoke the next day to a wicked headache, but willed myself out of bed to attend the last talks of the conference. Everyone was there, except Ananichev. Ten minutes into the talk, the doors flung open and there he stood, held up by two henchmen supporting him on either side. They sat him down, and he remained silent through the majority of the talk. Then, just as it was coming to a close, he stood up and began to deliver his speech. I quickly rose and told him to sit down, and surprisingly, he did.

After the talks of the day had concluded, there was a small party, and each guest was given a glass of wine to toast. Ananichev was now standing on his own, and he approached me on unsteady feet. We stood in silence for a long moment, and then he raised his glass, and said, “Professor Holling, I like your style.”

During the conference, George Dantzig became fascinated with our budworm proposal. He was in awe of our models and the immense knowledge that had been obtained on the subject. He felt that this was a place for him to show the power of the optimization techniques he had developed. At the time, optimization could not handle such an extensive number of variables if the system was non-linear, and the budworm model, at its largest, extended to thousands of variables. But George was able to find a way to compress those thousands of variables into about three or four.

As soon as my team and I knew our proposal was going to be pursued, I contacted my old friend Gordie Baskerville, and asked if he would like to join our team and lead the research in Fredericton, New Brunswick. He was a forester with a deep understanding of the ecology of forests, and we worked together and held workshops at both of our locations.

The work we did for the IIASA Ecology project was enriching, and I easily lost myself in it. Skiing trips, the opera, the wine Heurigens and practical jokes were as much a part of the institute's function as was the work itself. Dear collaborator and partner of the Ecology Project Mike Fiering and I even got a visiting US Ambassador to delay a flight and join us in learning to yodel in the rooms of the Laxenburg palace. During another misguided adventure at one of our skiing trips, in the middle of the night, Andrei Bykov, the Soviet Secretary, and I lifted a small car parked outside the hotel we were staying at into the hotel's lobby. There was great consternation the next morning by the hotel's staff, when the car was discovered. Laughter, hard work, and good people gave the institute its life.

Despite this, my wife began to yearn for our home back in British Columbia, and after a year at IIASA, I flew our family home. But the work had only just begun to develop at IIASA, and I made arrangements to continue on a half-time basis, flying between Vancouver and Vienna every other week. This put a strain on my already crumbling marriage, but by the time I made this realization, it was too late to remedy it, and I wasn't sure that I wanted to.

After my first marriage failed, I launched myself whole-heartedly into the work we were doing at IIASA. The overall purpose of the IIASA Ecology Project was to take all of the techniques that had been developed in a variety of disciplines, and apply them to at least one case we were all familiar with to see what was successful and what wasn't. Out of it came a book, "Adaptive Environmental Assessment and Management."

It showed how management could be developed iteratively with interest groups in a way that could enhance resilience and effectiveness of the resulting policies. We held a final meeting after the book had been written, and all of the senior policy people who hadn't initially had any input on the book were given the opportunity to read it and offer their opinions.

We had great difficulty finding good scholars from the USSR to work with us as part of our IIASA Ecology Project. That difficulty was only exacerbated when Mike Fiering joined us, as he had just disengaged himself from a Soviet Water Project after exhaustion from fighting them for a more balanced approach. Those particular Soviet scholars at IIASA did not want balance, they wanted control. So there we were, not only with no good Soviet scientist in our team but also with an American who had deserted a Soviet project to work (and sing) with us. But then, suddenly, after lots of pressure from us, Alex Bazykin, a Soviet mathematician, appeared at IIASA and joined us.

Alex was such a fine fellow. He was a mathematician with both depth and breadth who could communicate and represent the simple heart of complex ecological systems. He became a coauthor of our popular book Adaptive Environmental Assessment and Management, and participated in a terrific workshop in Venezuela designed by good friend Jorge Rabinovich, an entomological ecologist. For several years that book was the most popular one at IIASA and was also translated into Russian. The authorities there simply could not have read it. It was so antithetical to their kind of control and their assumptions of sufficient knowledge that it might have been read as a revolutionary text. And Alex ended up suffering for it.

On our return from Venezuela, a pair of thugs forced him and his family on a plane back to Moscow, where he was consigned to regional arrest. The stupidity of a politicized bureaucracy is astonishing. His work with us was in harmony with the themes of non-linear systems. He offered a small number of alternative representations of key functions and showed how each could affect behavior. Multi equilibrium behavior was inevitable. We were just delighted and easily integrated his ideas with ours in a way that enriched both. I have no idea what particular act on his part made him unacceptable for IIASA, but we had no option to protest. It was done.

At the same time that we were working on the book, we also continued with the spruce budworm research. In my third year with IIASA, I felt confident that we were ready to present our findings at the second IIASA conference.

I enlisted my son, Chris, to help create a computer-generated animation of the output from our model of the Eastern Canadian forest, as affected by the spruce budworm. The technology then made such efforts slow and difficult. Chris sat for hours in front of a Techtronix screen, recording on film each fraction of a year's output as if viewed from space. It was consistently changing the entire province of New Brunswick with the height of the 3-D graph, showing budworm densities or foliage quality and quantity. As I recall, a 100 years run took him several hours. The results were beautiful.

For the first time, we could see the wave of the outbreaks that started in northwestern New Brunswick and spread progressively over the province. Every 50 years, outbreaks would appear, and spread over a 10-15 year period, leaving a large mortality of balsam fir in their wake. When a run was made with the policies we developed from the non-linear optimization model, the outbreaks were suppressed and the forest grew to maturity. Our models and the movie forced a change in spraying and harvesting policy in the Province that lasted for at least one or two decades. Gordie Baskerville ensured that it happened when he was named Assistant Deputy Minister by a new political government.

Chris' movie communicated the reality of the spruce budworm wonderfully well. In 20 minutes, an audience viewing the movie could understand our conclusions and the reasons for them. When the movie was presented at the IIASA conference in Vienna, the Soviet Chairman of the IIASA Board, Dzherman Gvishiani, remarked, "For the first time I now understand why this forest problem and solution is an example of good systems analysis." Our spruce budworm research showed the kind of fruitful collaboration that was possible with our team (and son) from Canada, and leading lights from optimization and decision theory, with the scientist and policy people on the ground in New Brunswick.

While we were at IIASA, we were also developing the Resilience theory. Resilience represented the ability of a system to persist under the influence of disturbances, giving room to evolve and adapt. Resilience, in a sense, encouraged flexibility, not efficiency.

It caught the attention of Wolf Häfele, the first leader of the Energy Project at the Institute. Wolf's goal was to systematically organize the full range of energy sources and uses to project alternative futures, costs and benefits, for various global schemes. He could, therefore, judge the value of different mixes of nuclear, water, wind and coal energy production.

The project was run in a highly organized German fashion with fine people and impeccable guidance from Wolf. It was structured top down, very differently from our bottom up, and horizontally collaborative design. But both projects worked marvelously well. Wolf became interested in resilience as we had discovered and written about it, and searched for a German translation. After half a day he came up with "Schlagabsorptionsfähigkeit". Where, I asked him, had the magic gone? The music? "Strike absorption capability!" The point is that words can open or close ideas.

What also came out of my time at IIASA was the mythical Ralf Yorque. It was a tradition that started at UBC, when an oceanography student recollected the initiation that students in Oceanography at the University of Washington had to take. Each would have to stand at the fantail of a small vessel, in rough, stormy seas, and yell "Ralf Yorque" over the stern. It signified the sounds that one might make when retching.

We developed it further at IIASA as a way to lighten up the formal aspects of the institute. Ulrike Hilborn, my secretary at IIASA became the instigator, with an utterly irreverent newsletter that gossiped and quoted the strange details of Ralf's life. It became a newsletter in great demand, and we arranged for Jim Thomson, a fine cartoonist of Ilse's staff, to illustrate him. What he produced was a strange man smoking a cigarette and waving a sign that read, "Leave No Tern Unstoned," a play on the phrase, "Leave no stone unturned."

Ulrike's husband, Ray Hilborn, got him into the American Men of Science as Ralf Yorque from the University of McMurdo Sound, with his wife Esmeralda and two kids. Every once in a while we elected a new member to the Ralf Yorque Society, ending up with a spread of very fine people. Andrei Bykov, the senior Soviet at IIASA, was one, as was wonderful Mike Fiering, the hydrologist from Harvard.

We picked it up further in Florida in November 1992 as we unrolled the five years of workshops for the Resilience Project. Again, a wonderful range of people were nominated and invested. Steve Carpenter, in fact, placed the award on his CV and highlighted it during his Australian Academy of Science lecture. Both he and Buz Brock, the economist and tap dancing guru, got the award on beautiful Heron Island where all the pieces of the Panarchy book came together.

After three years of travelling back and forth to IIASA, I decided to return to UBC on a full-time basis. But before I left, I had dinner with several of my colleagues, most notably Ken Arrow, a famous Nobel laureate economist, and Paul Ehrlich. The discussion that arose at dinner surrounded climate change, which had just begun to be studied in depth. The trigger for those studies, for many people, was the surprise in the Antarctic, where suddenly the signals of the ozone hole became apparent as an entity that was growing in size annually.

Now this was very much against the existing theory, which was largely linear, as the ozone hole was a non-linear phenomenon. Initially, those doing the studies thought it was a breakdown of their instruments, but after testing at their home laboratory in England, they found that their equipment was functioning properly and they were in fact detecting an increase in the size of the ozone hole.

Traditional scientists, in the normal mode of skepticism, criticized the reality of the discovery that only began to get credibility when Paul Crutzen added his backing and explanation of it.

During our dinner, Ken Arrow commented that traditional atmospheric theory, while it totally missed the Ozone hole, could still predict 98% of the tropospheric observations. That comment stunned me at the time, not because I thought it untrue, but because it made me aware that all my interest was on the 2% - the surprises that shape and reshape systems.

Ken Arrow's view was not one of skepticism, but one that made the point that many impacts of ozone depletion would prove to be near equilibrium ones.

Ken went on to be selected by the UN to assist on the first International project examining climate change, and he intentionally set up the protocol for the study to be wrong. He knew that the protocol had to recognize the known and unknown non-linearities of the atmospheric system, but he knew that choosing them would blind the minds of others and prevent them from seeing the bigger picture.

Upon my return to UBC, Wes Foell, an innovative environmental engineer, took over leadership of the Ecology Project. Wes is a true, sparkling engineer who studies energy systems, and builds buildings that create and store energy, not consume it. His house in Madison was one of the earliest examples. And he sings up a storm, with his wife Ankie brilliantly playing the piano.

Don Ludwig came to UBC in the footsteps of people protesting US Vietnam war policies. In a sense, he and Dixon Jones joined the flood of hippies seeking an alternative life style – Americans who settled on the Gulf Islands, enriching the art, food and culture of British Columbia.

After Don joined our enterprises at UBC, he offered to translate three quarters of a page I wrote about forest/pest dynamics into mathematics. He produced three differential equations, one concerning the density of budworm/rate of change of budworm, one concerning the rate of change of foliage, and the third regarding the rate of change in dying trees. He studied the equations, and asked me what he had missed. He surely was missing something, because the model predicted continual increase to an equilibrium state, not the boom and bust pattern observed in nature.

When I examined the equations, I discovered they missed the bird predation from 33 species of birds ranging in size from small warblers to the largest arctic three-toed woodpeckers. I discovered that the birds were distributed in clusters of sizes that I inelegantly called "lumps." These 33 species seemed to fall into three specific lump groups, or weight clusters. This was significant because I no longer had to study the behavior of each individual species, but only one of the sample birds within each lump.

This reduced the demand for data; in this case, it defined how many budworms each bird ate, and the rate at which they ate. An impossible job had now become feasible.

Simple equations had been developed from earlier work appropriate for predators with learning ability, like birds, and Don incorporated them into his model. The resulting new model produced a pattern of attack that rose as low densities of prey rose, reached a peak, and then declined as prey density increased further. That introduced a wedge of attack at low densities-- what we called the "Predator Pit."

If you plotted attack by birds against density of prey, the percent would rise as the density kept rising, then they would reach a peak, and it would slowly start to decline. This decline occurred because the birds were now feeding at their maximum, and the amount of birds was no longer increasing despite the budworm population continuing to grow.

The second thing that affected the bird predation was the amount of foliage and the age of trees. When the trees were young and there was little foliage to search, the birds would eat a large amount of budworm. But as the foliage increased, they had to search further. Finally, the trees reached an age that the crowns of foliage were too great for the birds to maintain their initially high rate of predation.

When this occurred, the budworm escaped the predator pit and densities burst rapidly higher toward an upper equilibrium set by tree maturity. This could not be sustained, however, because the burden of defoliation killed the trees, so that their density and age declined and the music started again. Three body mass lumps of birds suddenly made it possible to parameterize the suite of thirty plus species into three clusters, using scattered field data.

I so much liked what Don had done, which was a minimalist representation of one complex slice of nature. I suggested to Don and Dixon Jones that we write a paper showing how much data and process knowledge was needed to understand a complex system like the budworm and forest dynamics.

We used three models. One was Don's simple representation, one was the "site" model of bugs and growing trees, and one was the full simulation model with all its bells and whistles and spatial specificity. The latter was developed by Bill Clark, Dixon Jones, and me at IIASA, with the notable help of Gordie Baskerville in New Brunswick. We showed that good process knowledge and a simple model could capture perhaps 80% of the relevant behavior. Simple understanding can often go very far.

In general, species diversity affects the scale of the dominant patterns that emerge, as physical disturbance interacts with living elements. The simplest example is of forest fire in many different forests. In northern Canada, fires come every 50 years or so, and form a pattern of stands roughly 50 hectares in extent. Garry Peterson, a graduate student of mine at Florida, demonstrated this to me in a mini-model he created, where size of patches, age of trees, and accumulated fuel interacted via fire outbreaks.

Garry has a background in Systems Science from the University of Waterloo, in engineering from HT Odem in Florida, and from complexities science through his time studying under me. His solid background is a rare and essential combination in this field. When he received his PhD, he was offered a chair of Environmental Science at McGill. However, after three years of working there, he left to join the Stockholm Resilience Center in Sweden, where he also met his beautiful wife, Line Gordon.

Throughout his career, he has had an encyclopedic knowledge of the various writing and research that has occurred in the field, and he has the largest library collection of anyone I've known.

His contribution to our work was vital, and this kind of basic understanding suggested by mini-models provided a way to test the predator pit hypothesis in the field. To do it experimentally would have required shooting most of the birds in two or three 10 hectare plots in north western Ontario, where budworm were rare, for perhaps three succeeding years. We believed that would have triggered a spreading outbreak! It would have been possible to do so legally at that time, but there was no way I could muster the enthusiasm to kill hundreds of beautiful birds. So I did not! The price for certainty can be too high.

Later I encountered a young student Gayle Brown who similarly abandoned a "Grind and Find" approach to a hummingbird biochemistry question. Unable to face the destruction of beautiful birds, she shifted supervisors from a very fine environmental biochemist to another very fine behavioral scientist, Lee Gass. They found out that she could measure what was needed using an MRI machine in a hospital in Edmonton. So she did!

The best thing that came from my time at IIASA, and the following years at UBC, was my growing relationship with Ilse. After my first marriage fell apart, Ilse and I began to grow closer with each trip that I made to IIASA. Her initial reluctance slowly turned into affection, and when I returned to UBC, I asked her to come to Vancouver to spend Christmas with me. Since I was totally broke at that time, she had to buy her own flight ticket to see me – and she did!

I arranged for us to take a train to Banff. It snaked its way along sprawling, clear rivers, the sun bouncing off the train to shine like gold along the water's surface. Mozart played in our train cabin, and we were served an assortment of delectable dishes that made our mouths water. I proposed to her then, and she said yes.

After our engagement, we found a tiny, cheap apartment in Kitsilano – a district of Vancouver near UBC. It was perfect for the two of us. A few months after our engagement, I had a meeting in Parksville, BC, and Carl Walters and Ilse came along. As we drove and showed Ilse the landscape on Vancouver Island, we began to tease her and formed a plan to trick her.

We stopped at a restaurant, and while waiting for lunch, she picked up a newspaper. She pointed to a headline that read, "Giants Attack Kickbacks." She asked what it meant, and Carl and I were quick to reply that Kickbacks were a species of animal endemic to the forest here, who got their name from their mating ritual. The male would back up against the nearest dying tree, and the female would approach and turn around. When she was close, he would kick back, pounce on her, and latch his teeth on a knot of hair on her head.

We told Ilse that women in British Columbia would often sport their hair to signify that they were available to date. The Kickbacks helped the forest by kicking down old dead trees, regenerating the forest. I pointed outside the window at several tree stumps, and told her that it meant that the Kickbacks had declined and that was why the forest wasn't re-growing.

She seemed skeptical, but she went along with it, as she knew little of the landscape and wildlife in the area. We got on the ferry to Vancouver, and as we waited for it to depart, we looked out across the water to see the Bathtub Boat Race in action. Boats were congregating in Departure Bay, in Nanaimo, and by this point Ilse had begun to grow suspicious of our stories. When we told her about the Bathtub Races, she didn't believe us.

"Fine," I said, "let's ask that couple over there." We approached a couple who were also watching the boats, and asked if they knew about the Bathtub Races. The man was from Newfoundland and had a strong accent, and he told Ilse that he knew about the races. Her faith in us was renewed as she marveled over the strange spectacle.

Finally, when we arrived in Vancouver, we went to a well-known Swiss restaurant. I had a collection of wood-boring beetles in my car, and I took some and put them on a cardboard plate, held in place by pins. With the help of the maître-d' and Sandra Buckingham (Carl's wife), we conspired against Ilse one final time.

While we waited to order, we told her that this restaurant was famous for its insect fondue. Her eyes narrowed in skepticism, and when the waiter arrived, she tried to catch us in our lie by ordering the insect fondue. The waiter took her order, and told her he would return shortly.

He came out with the plate of beetles, and displayed it before her. "Madam," he said, as he edged the plate toward her face, "I advise you not to take the big ones. Most tourists are attracted to them, but it's the small ones that are most luscious."

Ilse became an integral part of my life, and dedicated much of her time to assisting me on my various projects. One such project involved her dragging a model net called the "Holling Hawler" through water, to see how movement affected its hydrodynamics. It was a hot, balmy day, and Ilse soon grew tired of running laps around the pool while I stood on its edge and photographed her. "Buzz," she said, "I'm getting tired." I waved her off. “Just a few more minutes,” I replied, just as she fainted and slipped under the water’s surface.

I dove in to rescue her, and it didn’t take long for her to wake and berate me for allowing her to pass out from the heat. She has never let me live it down.

Despite the few bumps along the road, soon after our engagement we planned a magnificent wedding, which would take place in Ilse’s hometown in Austria.

Our wedding took place on August 26, 1978, and all of the friends we had developed over the years came from at least a dozen different countries. The wedding took place in the town hall, and we were to be married by the Bürgermeister (which translates to the head bureaucrat of the city). He told us that this was his last marriage before retirement.

Ilse was breathtaking in a dress of pale blue and lace. She seemed to glow, as if reflecting the rays of sun that shone down from the windows of the hall. The wedding itself was over in a blur of vows and eagerly exchanged kisses, but it was the party that followed that still plays vividly in my mind.

We had a lovely lunch after the ceremony, at one of the Gasthäuser (traditional restaurants). It was a tradition for the bride to be stolen by the key men in the wedding party, and it was my task to find her as quickly as possible. As I searched for her, the wedding guests drank as much wine as they could, and I had to pay for however many bottles were drunk from the time she was stolen to the time she was found.

In the evening, there was a celebration in the nearby castle built to protect the good citizens from the invading Turks hundreds of years ago. We held a dance, and my best man, Carl Walters, had to dance with my mother-in-law as his duty. After getting thoroughly drunk, we staggered down through the thirteen gates of the castle to a happy future - the way lit by torches.


Figure 6. Fruit bat carved in arbutus by Buzz Holling

Excellence vs. Deep Political Conflict: The Adaptive Cycle

During the six years that followed my stint at IIASA, I continued to work at UBC, focusing on the spruce budworm research and my collaborative work on the Gulf Islands. But in 1982, an offer came for me to take over as Director of IIASA. I was delighted, because my early experience with IIASA, and my sense of its east/west political significance, was so positive.

During my early years at IIASA (1973), my group flourished with the stimulus it received from the purposes of the institute itself, and from the appearance of a group of outstanding scientists and scholars, some of whom helped shape the research program I launched within the institute.

Three years after Howard Raiffa took leadership at IIASA, he was followed by Roger Levien, from the Rand Corporation, who remained as Director for two terms of three years each. The original convention for the Institute, at its beginning, was to have a US person as Director and a Soviet as Chairman. The shift to select me, a Canadian as Director, came because the US person, who was the original choice, became ill before he could take the job, and a scramble took place to find a replacement. I ended up being the choice of Phil Handler, President of the US National Academy of Sciences, and Bruce Hannay, Foreign Secretary of the National Academy of Engineering.

Despite my wonderful memories of my time at IIASA, I quickly learned that it was now functioning in a much different manner. A few months after I arrived at IIASA as the new Director, the US National Academy of Sciences was forced to withdraw because US funding was being terminated.

That was the consequence of Reagan being elected as President of the US, and of Reagan's shift to heavy support of anti-Soviet activities and funding. As one of the Reagan people told me, the US no longer supported multi-lateral arrangements with the Soviets, which of course was at the heart of IIASA's organization. Only bi-lateral arrangements were supported because those could be controlled.

Because of this withdrawal of US funds, a major international political transformation occurred. Alumni and folks who worked at the Institute in previous years were swung into action by Howard. The American Academy of Arts and Sciences, located in Boston, near Howard's university of Harvard, substituted as the US member. But IIASA was flipped into decreasing in size, following its sharp budget constriction, and into a tumultuous reorganization.

As part of that, I helped hire a wise and insightful American as Deputy Director, and as an assistant both for program and local politics. His name was Chet Cooper, whose significance came because he had been an analyst for the CIA, a fact instantly known by the Soviets. It helped, at least, in controlling some of the mini eddies of Soviet individual mischief that had started to arise. None of the members of our National Member Organization wanted that mischief to turn into something more, as they were determined to try to develop amicable relations between east and west as part of the political thrust of the institute.

I had been employed in a variety of institutes during my career, all of which, up until that point, had been sheer fun, challenging and innovative. IIASA had now become the exception, simply because of the negative transformation forced upon it.

Yet, despite the challenges I now faced, some positive work did arise from my three and a half years there. Ilse and I were housed in a lovely two-story home that was around 100-years-old. The home was furnished by IIASA, and served as welcome retreat when the pressures of being Director became too much. It was wonderfully suited to hold large parties, which was one of my responsibilities as Director. There were celebratory parties, and those held to honor distinguished scientists. At these parties, a cook would come in and prepare magnificent feasts for our guests and us. I always looked forward to these parties, as it offered a brief reprieve from the smothering oppressiveness that had befallen IIASA. During these events, I could almost forget how vastly different IIASA now was, but then I would return to work the next day and be reminded that some things would never be the same again.

My children were now all nearly grown. In the summers, when Jamie had a break from high school, he would come live with us. Nancy was studying at a well-known restaurant management school in Salzburg, and when she wasn't studying, she would visit. Chris was studying economics at Queens University, and would also visit in the summers in between semesters.

The work that was most remarkable during my time at IIASA resulted from collaboration between good friend Carl Walters, who brought a team from UBC, Ray Hilborn and Randall Peterman. They set in place a new project that was small and was meant to focus on the host country of Austria. It was originally designed by Hans Moser, an ecologist at the University of Innsbruck, and then was focused on development in the Alps of Europe by Carl and his team.

The issue concerned high alpine settlements, like Obergurgl, Austria, where hotel developments were facing a sudden oil price shock. Skis, hotels, and farming had formed the village, but now hotel development was becoming constricted and the sons of hoteliers saw a grim future. Hans had used this looming issue to help the villagers assess their future and had asked IIASA to help. So Carl and company launched their respected workshop series, inviting villagers who represented farms, hotels, ski lift operators, and citizens.

The first organizing workshop was held at IIASA, but much of the following interactions occurred over glasses of wine in a local Gasthaus (traditional Austrian restaurant). A model was developed, and after several sessions examining and defining the discussions, a plan emerged.

It committed hoteliers to provide a subsidy controlled by farmers, thereby maintaining their part of village life. Ecological husbandry and tourism was defined as a modest additional activity that actually increased diversity. Eventually, the UN recognized this approach as a prototype for managing alpine systems. Interestingly, Hans Moser was later picked up as a faculty member at the University of Edmonton in Canada, where he instituted some of his novel schemes. For example, he used a combined monitoring program to connect schools on the prairies with global climate change evidenced by key indicator plants.

During part of that difficult time for IIASA, Bill Clark was able to establish and implement the work to launch the first assessment of Sustainable Development of the Biosphere. It emphasized the ecological foundations for biosphere change. The authors were not only distinguished figures in science and policy, they were also spread among physical, biological and social disciplines. It was, and still is a notable contribution, as a template for modern work 35 years later.

As part of that, I had to write a chapter for his book. It came at the end of my term as Director and I delighted in the sudden peace it gave me to analyze and write for a couple of months. That chapter became the major step bringing together as a synthesis the several years of work at IIASA and elsewhere where non-linear and multi-equilibrium reality featured centrally.

I referred, in some detail, to variables of five systems in nature: forest insects, forest fire, savannas, fisheries, and human disease. It was easy to pick the three variables of fast, intermediate, and slow speeds, and all are multi-equilibrial states. One of the best examples was the jack pine sawfly and jack pine, as described in an insightful paper by a good friend, Jack McLeod. Jack had been employed with the Forest Research Lab in Quebec, and later came to work with me at UBC.

His paper outlined that the fast variable, the insect, shows three equilibrial states; one very low state which was caused largely by bird predation of larvae, one at an intermediate level caused by small mammal predation of pupae, and one transient one at a high density that causes extensive defoliation and ultimate death of the trees. All the other systems have similar equilibrial conditions.

And I also outlined a theoretical cycle, that in later writings I called the Adaptive Cycle. While I had already been applying the Adaptive Cycle to my own life, it was the first time I had outlined it in a scientific manner. It traveled from exploitation, to innovation, to conservation, to creative destruction, to renewal. The slowest speed in the cycle occurred between innovation and conservation, where we now existed. And as I mused over the discovery, I began to be aware that this was what was happening to IIASA, caught in the period between innovation and conservation. There was a strong mix of work of the highest quality and lousy stuff that was: forced into a vulnerable system. I had to isolate the lousy stuff and protect the work of real excellence.

And I finally summarized an extensive literature, pointing out the different words that have been proposed in the literature for the four components of the adaptive cycle in economics, technology, institutions and psychology. The seeds or young plants of my theories were summarized at that stage of the work.

During the end of my term as Director, we held a meeting to summarize activities at IIASA, in which Jim Lovelock was present; he was the maverick atmospheric scientist of Gaia fame. Gaia, the Greek term for the Goddess of Life, is the word that he gave to his representation of the atmosphere. His thesis was that planets with life manage their relationship with the atmosphere in such a way as to maintain its livability for life.

While at the meeting, he mischievously asked, “Why don’t ecologists include the environment?” It was a beautifully outrageous comment triggered by one subset of critiques of his various Gaia papers. Those critiques were written by people who had a much more limited understanding of ecosystems and planetary dynamics. They were oversimplifying, and were therefore unable to see the essential point of what Jim argued: that living organisms manage the atmosphere.

They were deeply committed to a particular scientific paradigm, by rules of thumb as opposed to hands, and also by a narrow range of scales where organisms alone play their games. The term, “rule of thumb,” is shorthand for people making too simple a representation of ecosystems. These scientists used one or two variables, when in fact a handful of variables were needed. So I coined the term, “rule of hand” to encapsulate these situations, as discussed earlier in this memoir.

Despite the challenges at IIASA, I was pleased with the work that we were able to produce when faced with adversity. My time there dramatically highlighted how flexible and innovative all of the other institutes I worked at were when I was present. It highlighted the power of true flexibility when resources were available. It also suggested the problems that can arise as institutes age and become encumbered with projects that are not stopped. It was a perfect example of the Adaptive Cycle all over again.

All the institutional examples I have worked with started as experiments, and all created a rhythm that initially succeeded, but then froze and either collapsed, or persisted as a continuing irrelevance, consuming resources, but not contributing. Innovation then shifted elsewhere, leaving the system behind.

> *Darwin said it about 150 years ago: "It is not the strongest of species that survive, nor the most intelligent, but the ones most responsive to change".*

Fun Again: Florida (1988-1998)

My term as Director of IIASA ended in 1984, and our departure, though much-anticipated, was bittersweet. Ilse and I packed up and moved back home to Vancouver, and I resumed my position at the University of British Columbia. I was met with surprises upon our return, however. I found that a campaign had succeeded in returning the Institute of Animal Ecology into the Institute of Fisheries, and so its Adaptive Cycle moved on.

It wasn't long before I was drawn away from British Columbia again, however. Lincoln Brower, an acquaintance then and subsequently a good friend, called me and asked, "How would you like an invitation to apply for a new Ecological Chair at the University of Florida?"

I knew Lincoln from his work. He studied monarch butterflies, which were noted because they had a migratory pattern that covers the whole of North America, and part of South America. They reproduce in the north and up to southern Canada, feeding on milkweed plants, then emerge as adults and fly south, eventually ending up in Mexico. During their flight, they have two more reproductive phases, and even though they go through these different cycles, they still retain the intuition to head south to stop in Mexico. After spending the winter there, they fly back and repeat the cycle.

The opportunity for the endowed chair was at a well-funded, flexible environment, at a reasonably good regional university. Normally, I would have said no, but I was growing antsy at UBC, and opposed the changes that had occurred while I was away at IIASA. A grant proposal from the National Scientific and Engineering Research Council in Canada had been turned down, and the Dean at the time was rigid and opposed change. My eight to ten year itch flared, as I entered the creative destruction phase of my adaptive spiral.

So I said yes, and it was so. The chair came along with private money that had been collected through donations from the public, and the proceeds' interests were reserved for scientific work. It allowed about $60,000 to be set aside each year; the chair was called the Arthur R. Marshall Chair of Ecosystems Studies. I could use this money for anything I wanted, so long as it was legal, and I still was able to apply for various grants on top of that. It allowed my team and me to be independent and avoid getting trapped by various battling interests. This was the freedom and flexibility that I sought.

Ilse and I moved to Gainesville, Florida, a city of sinkholes of various sizes. We bought a house we called Misty Hollow at the edge of such a sinkhole. It was about 1½ hectares in size, containing swamp gum trees, here at their southern limit, growing in the water. We flew with our two well-travelled cats from British Columbia to Florida on March 1, 1988, and arrived in the late afternoon as a skein of Ibis flew whistling overhead. It seemed to be a positive omen, with ancient Egyptian echoes. We soaked in our surroundings with wide-eyed delight, surveying the unfamiliar landscape that was as flat, hot, and humid as Vancouver was mountainous, temperate, and wet.

We witnessed Misty Hollow in two states. For the first few years we lived there, Misty Hollow was bubbling and teeming with eight different species of wading birds in the air, on the trees, and in the water. The slope of the sinkhole was steep, covered in gumwood and dogwood trees, down to a shore with sparkling, translucent water. A stand of swamp gumwood breached the water's surface, with swollen trunks and elbows of roots stuck above the water for gas exchange. To my northern eyes, Florida was like a tropical getaway.

The fauna left us spellbound. First the birds, about eight species nested or roosted there, and one wintered. There were small Green Herons, dropping bait on the water and grabbing small fish that were attracted to it. There was the Little Blue Heron with its squawks, croaks and screams. Tricolored Heron formed colonies with other herons, running as they hunted through the shallow water. There was the silent Yellow Crowned Night Heron, and the Snowy Egret with its strange yellow feet on black legs, which wiggled apparently to concentrate fish. There were a few thoroughly handsome wood ducks with their nests and displays, and a significant ibis flock roosting there at night, but nesting elsewhere.

In the winter, a small flock of Hooded Mergansers arrived from the north. They were fast swimmers and divers that scooped up the fish in the pond, with the males displaying a bold white crest and a "wha-wha-woo" courtship display to their gentle ladies as they floated on the surface. The males courted all winter, which surprised me, and they did so from the branches of the swamp gum. They waited until a female appeared, then dove at a sharp angle to hit the water with a satisfying splash and a display of white and black.

But there were no Great Blue Herons or Greater Egrets. They flew overhead to larger sinkholes, like one that was significantly larger just one to two kilometers away. Our pond was an obvious “lump selector” accepted by the smaller waders, but not the largest. There were so many sinkholes in the overall region, from very small to very big, that I tried to get a grad student to do a quick survey of the bird watchers, measure the sinkholes from aerial photos and demonstrate the lump selector algorithm for wading birds. But I had no luck, no one had the time!

Those were the birds, but there were snakes, turtles, and alligators as well. The cottonmouth and coral snake were the poisonous ones, easily avoided, and the black racer was the quick wraith. There was a male alligator that normally lay in ambush on the shore, and then suddenly would make an insanely energetic plunge into the pond. Occasionally, a stray dog would vanish.

My favorite was the giant Alligator Snapping Turtle. We only ever saw two of them, four feet across, and only for two or three days in the Spring. The rest of the time they disappeared into the pond. But for those two or three days, they mated; in slow, ponderous displays of lust, twisting atop each other in deliberate, rapturous swings. After that display, they would disappear back into the depths for the year. But the female, in the dead of one night, lumbered up the slope of the sinkhole, laboring toward some soil in our garden, and laid and buried her eggs. As we sat in our breakfast room one morning, we looked out at the garden and noticed dozens of baby turtles that had just hatched, tumbling past the window down to the pond.

We also embraced the sounds, most obviously the songs of the four species of frogs, from peepers to bullfrogs. Each evening in the Spring, they started tentatively and then built their chorus to form the music of the pond, then faded to nothing before starting again. The chorus was loud enough that easy conversation was impossible. The loud, croaking music of the frogs was accompanied with the flashes from three species of fireflies, evoking a sense of magic and wonder every night. The state of the pond was one of abundance and variety.

Then one spring, there was a sign of a looming flip, the beginning of a three-year dither. Small patches of blue-green algae appeared in several spots along the edge of the pool. They disappeared that year, to reappear the second and third more extensively, joined by duckweed, the smallest angiosperm in existence. The latter spread, until, by the third year, the surface of the pond was covered. The dithering flip was completed, transforming from clear water, macrophytes and fish, to clouded water, plankton and a surface masked entirely by duckweed. With that, all wading birds and the ducks disappeared.

The same thing began to happen in a larger, nearby sinkhole, due to development. However, residents of the area introduced a machine to harvest the accumulated phosphate that had triggered the dither. It scooped up and removed the duckweed continuously each year. Because of this, diversity was precariously increased, but resilience was low, as it teetered on the edge of a stability region.

In the fall, sand hill cranes started circling overhead, chattering continuously with a click and rattle of gossip wondering, it seemed, where to go and when to go. That was repeated over a few days, the flocks getting bigger until a few birds reached out and began flying north. I imagined them talking to each other, high, high up there, with a full moon lightening them. Others followed, clicking and rattling their gossip, upward flicking wings high in the sky heading to the Dakota marshes, where they fueled up, some for a journey continuing to the tundra.

They never knew where they were, but they were never lost. Twenty years later I saw them again. In May 2013, on the west coast of Calvert Island, British Columbia, somewhat north of the tip of Vancouver Island, a small flock settled to feed – four or five thousand kilometers from where I first spotted them in Florida, diagonally across the continent.

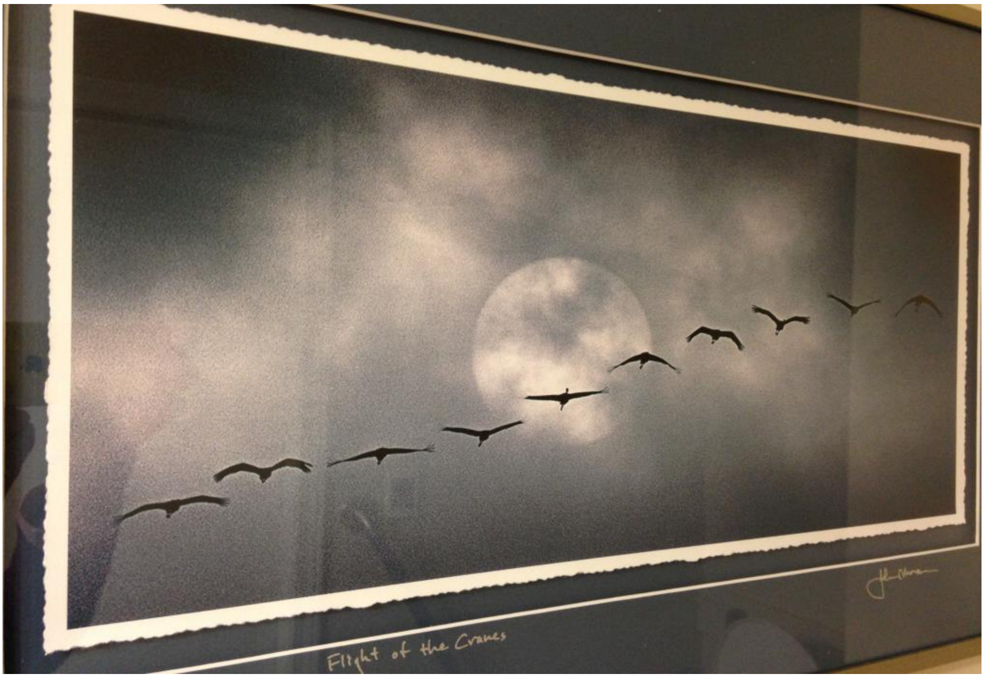

Figure 7. Flight of the cranes: Photograph by John Moran

The focus of my work while in Florida was on the Everglades, and my team consisted of Carl Walters, who managed the design of the models with participants, Lance Gunderson, who had lived in Florida and worked with the Everglades scientists and myself. Steve Davis and Steve Light, mavericks and heretics of the South Florida Water Management District, were our partners.

Conflict was extensive between various interests in southern Florida: ecosystems, economics, State, agricultural, and municipal. A lawsuit was looming against those in the Floridian community committed to the natural environment.

We brought together people who had been studying the Everglades from a technical perspective. They came from key institutions there: two universities, the National Park, and the South Florida Water Management District (SFWMD). In total, we found about 25 key people from these institutions who had each been examining some part of the Everglades. We didn't account for the lawyers and activists who joined us along the way, but we made room for them in our talks.

Throughout the history of the Everglades, water had gone through cycles of pattern of water distribution. The water was managed by dikes and pumps, and it took on the appearance of several, separate areas, each with its own source of water and hydrological characteristics.

We based our model on the depth of the marsh, and the rate of decrease in depth. We then mapped out three different scales: the water, the movement of the water, and the response of animals, birds, and salt marsh to the water. In the model, we allowed the water to move across the landscape. It moved very slowly, as the slope of the landscape is gentle, and as it moved, it affected the species along the way.

There were three depth levels, and three sets of things that emerged. The first were the alligator ponds, which were the last to dry up. From there, it progressed to the flooding of areas during the wet season, to slough, to salt marsh prairie extents with tree islands on extensive flats. The tree islands appeared in two different lumps: large ones, and very small ones. There was no middle ground.

With our model, we were able to do what my son Chris had done for budworm two decades earlier: produce a movie of the Everglades, using the model as the thing that drove it. We set the model up in three conditions: one with no modifications made by humans, one with the actual modifications that were made, and one with the modifications that we were suggesting.

We worked on the Everglades project for 18 months. I felt that, with our experience holding workshops and our combined knowledge, we had spent an appropriate amount of time to come up with a solution. In 1989, I was invited to give a talk on systems approaches to explain ecosystems. It was a keynote intended to help direct research and understanding of the Everglades.

I asked the organizer, Steve Davis, an ecologist with the South Florida Water Management District, to arrange a series of aerial photographs of the Everglades for me to present as a "Power-of-Ten" representation. The first photograph covered one square meter and depicted a saw grass plant at the edge of an alligator hole, a characteristic structure in the glades.

The sequence of photographs was taken as the helicopter rose over the starting point, increasing the area in the picture an order of magnitude, the "power of ten", at each step. At higher levels, the photographs then shifted to satellite images until, 15 orders of magnitude later, the image contained the planet.

The cross scale photos showed that the causes behind the huge arguments, conflicts and lawsuits in the Everglades depended on where the proponents located themselves: what economic lobby they represented and what political party dominated their time. Parts of the Everglades were wetter, other parts were drier, and water distribution of the overall system was dramatically screwed up. The senior manager of the Everglades National Park was a huge disappointment, protecting his turf, muzzling his scientists and hiding their data in a way that made the problems worse, not better.

To me it seemed like a constipated, overly rigid and pathological system, sustained by slavering greed and ignorance. Only wise people, like Lance Gunderson, saw it all from the inside and acted quietly and responsibly as they learned. Lance did that out of our laboratory. If anyone saved the Everglades, it was he.

We presented the findings of the synthesis workshops in a final meeting (we called it a colloquium) in Orlando, which convened all of the regional players – emphasizing wilderness, urban and industry. We did succeed in getting them to interact openly among each other even though a lawyer representing someone threatened to close the meeting at one point. Fat chance!

That meeting was the event that transformed the policy and brought into focus how cross scale interactions at key times can spawn dramatic transformations. Carl, Lance and I left the politics at that point, and the rest of the participants, having started to talk, continued to do so in increasingly formal settings- another adaptive cycle in operation.

While there was enough resilience in the Everglades itself, the question was whether there was enough within the institutions to make a change. It led to a public group called "Everglades Everlasting", where all the different sides finally were able to have talks that didn't lead to yelling. We held workshops that included everyone involved, and eventually, a solution of sorts arose. They built pumps and underground storage to store the water. It was a solution, but one that relied heavily on engineering devices, and cost $8 billion dollars to produce. Some two decades later, that system is still appalling, and although it somehow works, it fails to target the cause of the problem.

We later saw echoes of similar regional impacts across the globe, in Zimbabwe where sugar companies ignored water management policies for profit, and in Australia where increased sugar production contributed to pollution of the magnificent Great Barrier Reef coral ecosystem.

We did make one more step in south Florida Bay, where sea grass was dying over increasing areas. We used the same approach of workshops and models, and ended with a clear answer. Of the five or so impacts on the system, at various scales, the basic cause was the gradual disappearance of species – manatees and turtles – that maintained the diversity of ages of sea grass. It was no longer one homogeneous, single aged, “beautiful” carpet of sea grass of the recent past, but patches of sea grass of different ages, and a wider range of herbivores and predators maintaining the spatial diversity.

The growing and spreading death of sea grass in Florida, the increase in turbidity and the reduction in fish species was a transient flip from one state to another. We did not know whether the flip was irreversible or not, and I never returned to look or ask. I grew too busy with other projects to pursue it further.

The Resilience Project Germinates

During the time that I was immersed in my work in Florida, several of my colleagues and I formed the Resilience Project. It consisted of four or five colleagues and me conducting our own projects throughout the world. We were all trying to answer the question: “Were there common rules or a common language that guided a few dozen different ecosystem examples?” These examples included the Australian dry savannas, the European shallow lakes, the Boreal forest, the Everglades, and the Baltic Sea.

We were attempting to search for a way to develop a bridge between ecology and economics. Our hypothesis was that disagreements between the two occurred because ecologists examined a different scale than the economists. The goal of the project was to operate on that assumption, and explore how far it was true.

I approached the various grant agencies, and asked if they would be able to support a project based on the premise of the conflict between ecologists and economists existing because they worked on different scales. The McArthur Foundation agreed to support us, with me as the project leader.

We viewed each ecosystem from a number of different scales, and our research confirmed our analysis. We met every ten to fifteen months, at different, fun locations around the world, usually on an island. We brought together economists, ecologists, mathematicians, and social scientists.

The last major workshop took place in Australia, and that's where everything truly began to come together. While Ilse and I were there, we joined one of Larry Dill's graduate students as he tagged turtles. We sat on the beach and watched him catch turtles to tag in Shark Bay on the west coast. It was interesting work, and a lot of fun to witness, as the students caught a turtle, attached a camera onto it, and a day or two later, recovered the now-detached camera with its record of feeding behaviour. The big surprise was that, except for the types of biota, the physics of the area was roughly a replicate of South Florida Bay: a large, shallow seascape with substrate depressions.

But unlike South Florida Bay, it was fully diverse, ecologically. Sea grass was in patches of different ages, and dugongs, sharks and manta rays were all enriching presences. They maintained the diversity, persistence and resilience that had been lost in South Florida Bay.

Inventing a New Kind of Institution

The Resilience Alliance is born (1997)

After five successful years of the Resilience Project, we had a synthesis that I found satisfying. Over a hundred papers were published in various traditional journals in many disciplines, but the heart of the work appeared in four books.

I decided that the group of people in the Resilience Project worked so well together that it should be transformed into something more. In 1997, the Resilience Alliance (RA) was born, as my novel effort to get out of scrabbling for grants. At the beginning, it was horizontally organized around a core of five people who delighted in the joys of mutual discovery and in fun. Its horizontal design meant it was managed by a Science Leader, a Senior Research Fellow to coordinate collaborative research synthesis, communications, and outreach, a Chair of the Board of Members, an Executive Director, and one or two Editors of the journal.

The six founders of the Resilience Alliance were Brian Walker from Australia, Calle Folke from Sweden, Lance Gunderson and Steve Carpenter from the United States, and Phil Taylor and I from Canada. It was designed to be able to access grants when it was possible to do so easily, and to stretch resources across institutions when it was not. A minimal survivalist structure was designed because I knew that there would be times when grants might be hard to come by.

The RA needed to pay attention to its own resilience. To do that, we figured it could persist, if grant-getting failed, on the membership dues of the 15-20 member organizations. Because of this, the RA became international and informal, and good at discovering new science theory and applications. For we were good at inspiring each other to do our best, good at stimulating art and limericks, with a focus on people who were noted as “good on islands.”

On the surface, I was head of the RA, because the founding of the RA was funded by the grant that we had received from the McArthur Foundation. While the money had been bestowed upon us to fund our research on displaying methods to integrate ecology and economics, the Foundation didn't care if we used it to found the RA, as long as our initial influence and research was maintained.

Around the same time that the RA was under development, Bert Bolin, a Swedish atmospheric scientist, accepted a new task to design and manage a program of ongoing information in the international UN program of global change. He was asked to simplify it as being strictly linear, and strictly natural science. He knew that this was wrong, but he also knew that this simplification was needed to get people working together in an environment in which the real needs of the environment could emerge as acts of self-discovery.

Bert and I were both members of the Board of the Stockholm Environment Center, and he really liked the work my colleagues and I had done to develop an integrated theory that linked both ecology and economics. We met to discuss the different projects we were working on and my growing frustrations I had as I tried to get the RA off the ground. I realized that I might have to simplify things in order to engage people attracted to this type of work, in such a way to get them to truly understand the more complex ideas that would later arise.

As the Resilience Alliance was developing, I had also accepted a job as founding editor of a new Internet journal, with the hope that it would one day be a boon to the RA. The Internet journal was an idea that originated from the people in the biology department at Carlton University.

The grad students were having difficulty getting their hands on copies of papers they needed for their degrees, so Phil Taylor had the idea to establish a journal that was exclusively on the Internet and was accessible to everyone. It would offer opportunities for experiments in thought and communication, as well as more traditional papers of application and theory. Conservation biology was the original topic, and they wanted an editor and an institution to ally it with. Thus, I became the editor, and the American Ecological Society became the institution.

It was a very trying, maddening time for me, as I tried to juggle getting both the Internet journal and the Resilience Alliance running. It was the beginning of a new adaptive cycle. My colleagues and I scrambled for money to continue funding the RA, when we couldn't fully define what it was yet. It tested my patience greatly, and there were many times I cried out to Ilse in frustration, "If we can't find a solution by next month, I'm shutting it down." But I persisted, and finally, both projects began to become more professional and structured, and they started to function well. It was a long, slow process, taking about three years for both to be effectively running and established.

Once the Internet journal started to run efficiently and gain a widespread readership, I felt that its title was not consistent with my views. So we shifted to a larger scale and named it the Journal of Ecology and Society. After the first few years, the Resilience Alliance became the institute sponsoring the journal. Gradually, author fees paid the staff salaries and programming expenses, thereby freeing membership fees to support novel projects of the Alliance.

After my founding editorship, good friends Lance Gunderson and Calle Folke took over magnificently as editors. In a large sense, resilience has been the continuing theme.

This gave us our own journal that flourished completely on the Internet, which was one essential part of the Resilience Alliance. The second was the agreement among up to 20 member groups around the world to share, cooperate, and launch collaborative schemes together, to remain innovative and flexible, and to pay a small annual membership fee. Initially that was $15,000 each, but that slivered down to a more acceptable $7000. In our first few years, that money was so difficult to acquire.

Each of our members, initially all from the heart of the Resilience Project, had to find that money in any way they could. Most did it from grants they had acquired for their research. I did it from the endowment for the Chair I had at the University of Florida. The Ecological Society of America helped at a critical point for two years.

Lance Gunderson finally unlocked the jam. At a meeting at Emory University, Lance suddenly offered to join and presented a check of $7,000, provided by his wonderful Dean, Steve Sanderson. The rest of the groups gradually invented ways to get their dues in place, with South

Africa being the most imaginative by assembling various groups from across the country to contribute and participate.

The RA flourished, and unexpectedly started to spin off formal centers of resilience in the home bases of its members: Calle Folke and the wonderful Stockholm Resilience Center at the University of Stockholm, Frances Westley and the Institute of Social Innovation at Waterloo University, Terry Hughes and the Coral Reef Center at Brisbane. Marten Scheffer created an imaginative center in the Netherlands thanks to the magical prize he won of $8 million for any good things for science!

The Resilience Alliance mixed deep scientific traditions (the peer reviewed internet journal) with innovative research on resilience, in theory and practice. But it was also an institutional experiment. How far could we avoid the institutional adaptive cycle where traditions accumulate and eventually control?

The requirements for becoming a member of the Resilience Alliance were simple: the total number of groups in the Alliance must not exceed twenty, the groups must have the money to provide membership, and they have to agree with the rules. There were no formal rules, but we learned, retrospectively, that there had been a set of guidelines that were crucial in launching the Resilience Alliance.

-Start small and build an informal group of committed folks "Good on Islands."

- Do not own anything.

- Get flexible money, i.e. money that can be used to try something bold, that can be wasted when some initiatives fail, and that can be used to buy off potential partners who were failing by moving in a different, narrower direction. I worked hard to get that money: first from my endowment at the university, and then from private Foundations (Ford, MacArthur, MacDonnell, and Rockefeller). But never from government sources, which I found to be too fearful, or too jealous of innovation and gambles, or too stretched by competition for limited funds.

- Try to have maybe 70% of the money for the good stuff, the things that are working.

- Do not get trapped by a pre-existing vision, but use the work to learn and create a new relevant vision.

- Start small and continue fairly small, but try to be continually innovative, ex. the Resilience Alliance started with 4 groups and grew not to exceed 20 groups and about 100 people in about 9 countries.

- Keep membership dues absolutely as low as possible (in our case $7000 each, which rose to around $11,000), at a level where we could survive if grant money dropped to zero (this is the RA sustainability rule!).

- Use the Internet and web extensively, but always have face-to-face occasional meetings somewhere in the world where it is fun to be.

- Build a culture of fun, work and "rituals" such as limerick contests, music, and Ralf Yorque Society nominations with a special T-shirt.

- Outside the meetings, walk in the woods or on the beach with one or two colleagues, exploring a question you or they have been thinking about.

- Create something permanent and formal, with a traditional structure that anyone, inside or outside the organization, can recognize and benefit from. That was the journal Ecology and Society, the first except some early trials in Physics, to be entirely on the web, free because membership duties paid for it until author's payments gradually took over. It was traditional because it was peer reviewed, and had a distinguished editorial board from the disciplines concerned- biology, ecology, mathematics, economics, geography, and sociology.

- As solutions are developed (e.g. potential policies for future actions) keep them in a back pocket until external events and flows make the politics or people ready for new solutions (that is where we are now in relation to global climate change).

- Ultimate sustained solutions need sustained leadership in the region- someone broadly respected, influential and able to communicate and debate.

Panarchy: Adding an Unexpected Spiral

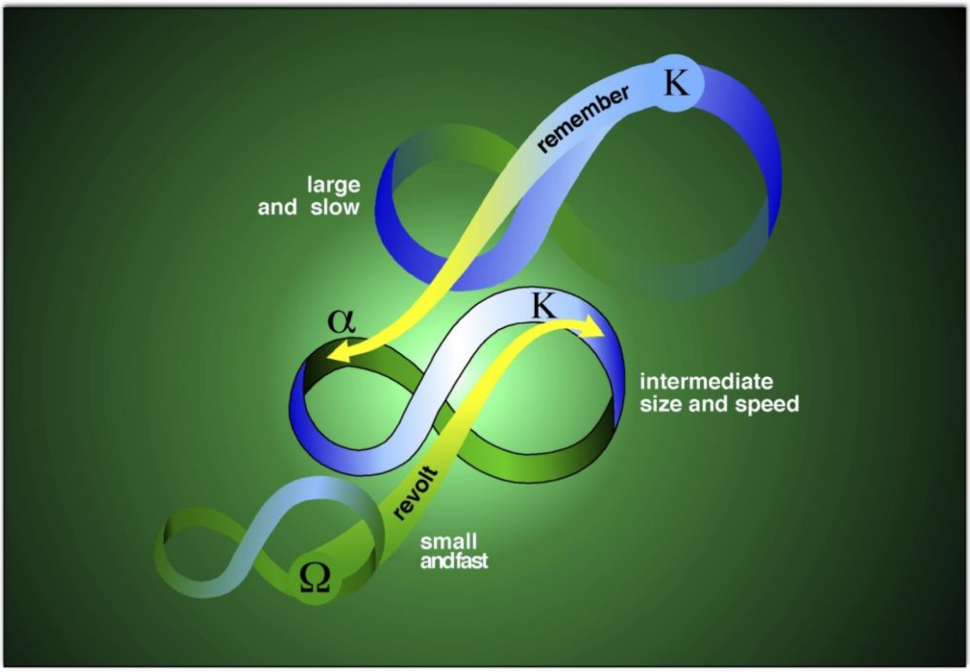

Figure 8. Panarchy graphic

A fountain of rich work burst forth from the Resilience Alliance, the largest being the publication of four books. These books focused on the various discoveries and research we had compiled.

• Discontinuities in Ecosystems
• Navigating Social-Ecological Systems
• Discontinuities in Economics
• Panarchy

The first book, Discontinuities in Ecosystems, was on multi-stable states in ecosystems, wet and dry, cold and hot. Ecosystems flip into different states, a condition that was broadly doubted at the time by skeptics, and

by those marching creatively to the rhythms of different drums. The book was a compendium of chapters, each on a different ecosystem, written by ecologists who knew that system thoroughly.
Lance Gunderson and his colleague at the University of Florida, Rusty Pritchard, nobly took charge of producing that book. In part, this project helped maintain the collaborative team, including the extraordinary limnologist, Bengt-Owe Jansson, who loved the Baltic Sea, loved novel thinking, and lived embedded in Swedish culture.

Ilse and I became good friends with Bengt-Owe, and he invited us to celebrate the longest day of the year on Askö, an island off the eastern coast of Sweden. He owned a chunk of property there and a laboratory – we were invited there for one of the book meetings. We joined him and his extended family, danced around the May pole, and ate escargot that had been introduced by a Swedish Royal person many years before; they were now easily collected on the island. We delighted in the songs, and dancing, and culture of the place, and the long, hot summer day.

The second book, Navigating Social-Ecological Systems, was an exploration of the institutions that had emerged to generate and deal with complex change on landscapes in regions. That was Fikret Berkes' and Calle Folke's creation. I always found both of them to be unique, with their interests dominated by social science.

They emphasized the different landscapes from village to nation, each with different institutions, NGOs as well as government, formal and informal. Resilience, they pointed out, was affected by the relationships between those different landscape entities and their institutions. Calle created the key innovations in the Beijer Institute and went on, years later, to create the unique Stockholm Resilience Center, its cross discipline energy, its projects and its international cooperation.

And I still remember Fikret's fascinating study of Indians in northern Ontario dealing with the disappearance of caribou because of a shift in their migration path, and their reappearance after more than a decade. Hunters savaged the herds the first year that they newly appeared. Subsequent memories of elders intervened to chastise wasteful hunters and renew the old strategy and tactics of the hunt. Herd sizes were low the second year as if the slaughter of the previous year was being addressed.

With sensitive hunting tactics restored, the herd size persisted at high numbers after that. It was as if the herd was listening!

The third book, Discontinuities in Economics, was economic and was meant to build a team, this time of economists and decision theorists. In one sense it seemed much more important than the ecosystems book, because the disciplines involved explored multi-stable states with models having only one or two variables. It was said to be a major advance for economics. Sir Partha Dasgupta and Karl-Goran Maler of the Beijer Institute of Ecological Economics were in charge. I personally found the project too limiting for the issues that interested me, but I supported them with substantial money from the grant in order to keep them engaged and their field advancing.

In general I found two variables to be fundamentally too few to capture the essence of any complex system. It was fine for analysis, but not enough to understand a complex system. So for the type of work that I did, and for the several ecosystems that I had studied, there had to be at least five variables, typically operating on three scales.

The problem was that economists were analytically vigorous, and they could be so by keeping their variables down to one or two variables. Some of my good economist friends said that none of their journals would accept the complexity that I worked at, or more accurately, the traditional economic reviewers would not accept that level of complexity. They argued, correctly, that it made formal mathematical analysis impossible.

What a dreadful culture, I thought, that now only hesitatingly is moving economics where I wished my own work to go. I still find policy and traditional theoretical economics too dominated by a desire to create policies that sustain and grow, and too passive about the instabilities that such policies create. Such instabilities, I am convinced, provide opportunities as well as crises. Note the 2008 financial collapse and the extremely slow and even spasmodic recovery since. Five years later and still erratic. I see that 2008 collapse as a creatively destructive event leading to perhaps 20 years of restructuring and transformation for societies where new enterprises can emerge. A historical transformation of the same consequence and depth saw agriculture shift to industrialization. But now global change is added to the mix, causing a linkage between economic, social and biophysical parts of the planet.

But the strategic purpose of the Resilience Project was to free the core of another group (who enjoyed the experience of mutual discovery), to journey in really novel territory with minimal baggage from those with more limited paradigms. That was motivated by Steve Carpenter, Buz Brock, Lance Gunderson and I, and it was those four who shaped much of what followed in Panarchy, the fourth book of the set.

The final book was Panarchy, in my view providing the synthesis that we sought. Panarchy was neither ecological, nor economic, nor social. It was all three. It not only represented non-linearities, but also the multiple scales of problems. It was hierarchical in part, but added dynamism by demonstrating that fast, small variables could in a sense "revolt" periodically and cause transformation of larger slower ones. At least 5 variables had to be present and three scales in any model, and, with those, a world of classes of response were possible, notably non-linear "surprising" ones.

Panarchy is perhaps one of the most important discoveries I have made throughout my scientific career. I had seen hints of it in my past work, particularly during the "Power-of-Ten" presentation. I applied this technique to a sequence of images of the Everglades. Each one was ten times the size of the previous one, thus becoming known as the power of ten. It was a way of viewing a particular landscape, and gradually, previous entities would disappear and new ones would appear.

For example, one might see the foliage on a plant in one step, then the full tree in the next, and so on until the whole crown of trees were visible. We, as people, are used to viewing the world on the scale at which we operate. It may include our house, our surroundings, our neighborhood, and our city.

I saw this again when I discovered the Stommel Plot, a graph that oceanographer John Steele described. Let's first think of a terrestrial ecosystem. Leaves form tree crowns. Trees aggregate to form stands of similarly aged trees. Stands aggregate to form forests, and forests to form biomes. That is a rough description of a hierarchy of objects that jump in size as they aggregate.

Figure 9. Panarchy ice sculpture by Mimi Chapin

As these objects increase in scale and size, they decrease in speed. For example, leaves cycle yearly from their formation, through growth, to maturity, to death, and reformation. Trees are not only larger and slower, they repeat that complete cycle from their appearance as progeny to their reappearance again as new progeny, in decades or even centuries. If you lay all the objects out in a plot of space and time, they form a line with the objects distributed as lumps along that line. This is the Stommel plot.

This can also be seen in human societies. Individual humans aggregate to form families, which aggregate to form villages, cities, regional associations, and so on. Similarly, it can also be applied to institutions that guide and control human decisions. They aggregate from informal rules for individual behavior, to contracts between groups, to legislative acts, to, ultimately, simple national goals that form a society.

There are two surprises in such plots. The first surprise is that all terrestrial systems lie along the same plot line. More accurately, they show the same slope. If they are terrestrial ecosystems like boreal forests, wetlands, or savannas, they also have the same intercept. That is, the lines representing those terrestrial ecosystems literally lie on top of each other.

In contrast, aquatic ecosystems, such as lakes, rivers and oceans, have the same slope, but possess intercepts that run parallel to the terrestrial lines and represent a faster set of overall properties. This extends further to properties of air, which range from small breezes to large hurricanes. Again, the slope is the same, but the intercept is still different, and the fastest of all three.

This is the underlying structure of panarchy, also known as the hierarchy of the ecosystems. The next step of the plot displays which elements have characteristics that are connected. For example, trees are connected to air in terms of the wind. The Stommel Plot demonstrates that the large, slow entities affect the conditions of the smaller ones, such as the temperature in the forest is dictated in part by the forest itself, so that the trees are affected by the temperature conditions of the forest.

However, there are occasions when the faster, small entities affect the larger-scale ones. I call this the “revolt.” A prime example of this would be the spruce budworm “revolting” and ravaging the forest. Thus the entire system must readjust. With the revolt and the memory, the system becomes quite dynamic.

The second surprise of the Stommel Plot comes from the realization that while physics sets the template, biology and society create the concentrations of opportunity along that template. While I was doing my research for the Panarchy book, the “lumpy” structure of things became more evident. I realized that these different size groups, or “lumps”, could be applied to every aspect of life. This work led to another book, Discontinuities in Ecosystems and Other Complex Systems, which demonstrated the existence of lumpy organization in a variety of ecosystems, in animal geographic ranges, in city sizes, migrating species, economic activities and company sizes.

However, although this evidence continued to grow, only a few ecosystem scale ecologists, social scientists and economists have accepted the theory and examples in a way to further test. Many traditional ecologists are critical and do not understand the essential foundations in theory, empirical examples and societal examples.

This need is easily perceived only for systems "close at hand", not for systems that are large in scale – i.e. for regional and upwards to global. At these larger scales adaptive management experiments become the only option.

Panarchy and the Stommel Plot can extend to the universe as well. Astronomy and celestial mechanics study on a grand scale, from whole planets to galaxies, to the entire universe and its evolution. There are no experiments except natural ones, such as when stars implode and galaxies collide.

Figure 10. Drawing by Eddy Carmack

Scientific investigations are broken up by discipline and scale, but much less work focuses on the scales between the quadrats and the heavens. While scientists have examined the different scales within our planet quite well, there are many regions in between where questions are just beginning to be asked.

Global climate change and ocean science and policy are all working at these scales and across them. They provide the legitimation for a science that links scales over which humans operate and travel. Most ecology doesn't reach to that scale. But ecosystem ecology does, and begins to link with social and economic sciences as witnessed by the Resilience Alliance and the Internet journal Ecology and Society.

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The name "Panarchy" came from my good friend and co-editor Lance Gunderson, who suggested that we needed a catchy, new word for the cross-scale addition to our theory of change in complex systems. Hierarchy was one idea that we toyed with, particularly as represented by the wonderful theory created by wildly inventive T.F.H. Allen, from the University of Wisconsin. But we added something new that we felt was extremely important. Hierarchy emphasizes the top down control in systems, where big and slow controls the conditions of smaller and faster. But that ends up with a static picture. Ours was very dynamic, because it added the possibility for small and fast events to suddenly explode and change the upper level of slower and larger parts, as part of the Adaptive Cycle. That is what a budworm outbreak, or a fire does to a fir forest.

So Lance suggested Panarchy. It was a great name because it captured the two faces of the Greek God Pan, the spirit of nature, and the horned and horny beast that mischievously disrupts and then re-balances with music. So we chose that name, and after much thought we decided to call the whole book Panarchy.

As I wrote the Panarchy chapter, I invented a figure that showed the scales and the two connections across scale. One was called Memory, and the other Revolt. It is at the time of revolt that accumulated novelties can suddenly explode out, and when the cycle begins anew, it doesn't just repeat what was, but introduces something new. That new element can be from mutated genes for an organism, invasive species for an ecosystem, inventions, or creative ideas for an economy.

My Panarchy work made me aware of economists I liked, ones who opened new ideas and chapters in my life. One was Herb Simon, a Nobel Laureate in Economics who was imaginatively dealing with organizational structures across scale. He showed how evolution could trigger change but not be destroyed by change.

I also learned of the work done by Elinor Ostrom, another Nobel Laureate in economics who was a treasured member of our Resilience Alliance. She focused on the small scales in societies, places where the treasured tenets of rational economics were simply stupid for her, and the *Tragedy of the Commons* became a place for people solutions, not rational ones.

There was Buz Brock, a dear friend, who described the hard and sensible story of the transformation of the AT&T, which was broken up in 1982 as a consequence of an insightful lawsuit against the Bell System monopoly. He was one of the consultants of the process. That was part of a panarchical story that focused on a series of adaptive cycles of transformation. He is an economist and non-linear mathematician, one of the few economists who see his world and mine in a similar way. He, too, is a loved member of the Resilience Alliance.

Frances Westley, another treasured member from the social sciences, was fascinated by innovation: where it occurs, why, what expands it, and what limits it. She became involved in our pre-resilience projects when we were assessing various regional projects. Then she became a central part of the resilience studies themselves and is one of the 20 or so of those who proved to be "good on islands." She was curious, committed, and enjoyed mutual discovery.

The chapter she wrote for Panarchy was so clear, vivid and relevant, like hitting a glass of ice-cold water in a rich tapestry of writings. When she finally moved to the University of Waterloo, she headed the new Social Innovation Institute, which became a critical node in the Resilience Alliance, joining other new and novel institutional developments from the RA in Sweden, South Africa, and Australia.

The Panarchy bubble grew delightfully, as traps were recognized as well as evolutionary transformations. The original bubble of a new idea or of a consolidating idea, are bubbles that provide glimpses through small ports of view, that together sketch a very crude, coarse pattern – a pattern that sketches parts of the canvasses of real change in a world of the known, partially known and unknown. I have always believed that a lot of the properties of transformative change at different scales are unknown or fundamentally even unknowable. That is because they are created by our actions and by our policies and only some of the results can we predict. We now create new worlds of economics, society and ecology at world scales, and also ones of art and music and dance. That is what informs evolutionary change over the millennia and of societal changes over centuries.

So evolution or transformation (or Panarchy) is the unifying theoretical foundation for a description of bubbles and cycles. Ecology, ecosystem science, and economics are very relevant but provide narrow slices of understanding. Social science, as I see it, is intermediate in its ability to address transformative changes in an integrated way. And art of all kinds imagines and communicates critical parts along the path.

Testing Panarchy with Lumps

The Panarchy book, like the other writings that stemmed from my work with the Resilience Alliance, was collaboration by its many members. While writing my own chapter for Panarchy, I was amazed at the myriad of discoveries that spiraled out from my research. During one of my efforts to test the Panarchy Theory, I stumbled upon one such discovery, which was perhaps just as profound.

If, as Panarchy stated, structures in ecosystems are organized in steps from small to large, from needles on trees, for example, to whole forests, then I supposed that animals living on those landscapes would have sizes that clustered in groups from small ones to large ones. I had first seen hints of this during my work in Florida.

As the first test, I chose birds of the Boreal Forest. Data on their individual sizes was easy to obtain, and it was not very difficult to identify the full complement of bird species. I did so, and astonishingly, I found that body masses were organized into clusters, that I called “lumps,” eight of them for the Boreal Forest; partly because of the breaks in scale, partly I suppose, because of sharp breaks of the adaptive cycles as they shifted between the growth and the recovery phases.

I then checked other ecosystems, also at boreal latitudes, and found similar lumps. But some of them occurred over different size ranges than in the Boreal Forest example. It began to look as if the pattern of lumps was a signature of the cross-scale structure of an ecosystem. Then Craig Allen checked other ecosystems in North America, Australia and Europe and all had lump patterns with features unique to each ecosystem.

Ilse and I travelled with two close friends, Harry Swain and his wife, to Botswana for Ilse’s 60th birthday. We arranged the trip through a company that flew small planes to three main centers in Botswana. It was a very intimate way to live while we were there, in the midst of hippos, elephants, and gazelles. We were housed in tents at night, and during the day we would either explore the land with guides or take small boats and drift down the river.

It was a way to get a very deep insight into the landscape, and also into the way the people of Botswana demonstrated the great wealth of the land. During one of our boat rides, a herd of elephants were immersed in the water as they trudged across the river’s floor to the other side. All that was visible were the tips of their trunks.

From Botswana, we travelled to Johannesburg, where we took the Blue Train down to Cape Town. The Blue Train provided us with a luxurious journey, with wonderful food, as we wound our way through the breathtaking scenery of South Africa. When we arrived in Cape Town, we celebrated with the marvelous wines this area of South Africa is famous for.

What was most fascinating about our trip brings me back to my work on lumps. I discovered the same thing among the birds of the Okavango Delta. Their sizes were distributed in lumps unique to the area!

Mammal sizes were also organized in lumps. Carla Restrepo, a graduate student, discovered that even the geographic ranges of North American butterflies and moths were lumpy. All those patterns of lumps reflected the lumpy nature of the geographic patterns they evolved under.

We saw the same thing in the fossil record, too. Dave Lambert, a PhD student in paleontology, investigated the sizes of Pleistocene mammals collected in bone deposits from the La Brea Tar Pits in Los Angeles, and compared them to those from the Ichetuknee River deposits in the south eastern United States.

All size distributions were lumpy pre- and post- the extinction event 11000 years ago when mega fauna went extinct. The lump structure in the eastern part of the continent was different from that in the west, but in both areas the lump categories of large body sizes disappeared after the extinction. We argued that the mega fauna, the giant sloths and gomphotheres, were creating landscape patterns at large scales on the vegetated landscapes, a coarse mosaic that supported their own existence.

The argument explaining why those large species went extinct continues among paleontologists. I buy the one that proposes that novel human cultures, through hunting megafauna with new technologies and use of fire, transformed the landscape vegetation patterns and the coarse scales patterns disappeared. The coarsest levels of the Panarchy collapsed, both in vegetation and large mammals body sizes.

The big monograph presenting and extending the results of testing Panarchy got a lot of attention, and some younger colleagues really liked the idea. But the elders of community ecology did not believe it at all. In particular, Jim Brown, who created Macroecology, argued against the idea. I suspect that was because his specialty was desert fauna, where panarchical structures are very simple.

Jim worked part-time at the nearby Santa Fe Institute, so I mentioned the disagreement to Murray Gell-Mann, the Nobel Laureate for physics, and one of the creators of the Institute. He suggested we organize a workshop, and invite proponents, skeptics, and neutral folks from the complexity community to evaluate the existing studies and the analyses. So we did.

Once Craig Allen presented his discovery that species on the edge of the body mass lumps were four times more likely to be endangered or invasive, opposition to the lump idea dramatically waned. Craig's discovery reminded us of "edge of chaos" imagery: great threat and great opportunity exists at those turbulent scales at which discontinuities in space or time exist. Several participants, formerly skeptical but willing to learn, agreed to collect entirely new data and test the idea. Those studies again supported the lumpy argument. Craig and I published the edited volume of the results in 2008.

What was very interesting about the lumps work was that the most invasive species of all, *Homo sapiens*, had a body size on the plains of Africa that was bang on the edge of a body-mass aggregation! And their companions, wolves, were also of that mass. Both species were a distinct evolutionary unit that travelled time and space together.

Even more important is the discovery that complex system behavior can have relatively simple causes, where *relative* simplicity is the key. Systems can often be narrowed down to only a few (3, 4, or 5) key variables. Enough complexity remains that the system dynamics appears unfamiliar to traditional ways of thinking. Nonlinear relationships can add limits, thresholds, and multi stable states. The causes of such behavior took 30 years to demonstrate after the 1973 resilience paper.

Thanks to the RA folks, this understanding of social and ecological complexity now is solid. Marten Scheffer, Steve Carpenter, Brian Walker and Calle Folke have all added specific examples and analyses. My own budworm research; fire and forest examples; and savannas with grass, shrubs and herbivores (in collaboration with Brian Walker) provided further support. Don Ludwig's introduction of different speeds in a three-equation mini-model led to suggestions about hierarchies and nested sets of cycles winking on and off over scales from tree branches to foliage crowns to forests. Together these observations led to Panarchy and hypotheses to test it.

I felt that those discontinuities in scales of landscapes should produce discontinuities in the distribution of sizes of taxa on the landscapes. That turned out to be the case first, of birds and mammals in the boreal forest and boreal prairies, then of birds, reptiles and amphibians in the

Everglades, and then the same patterns in 15 different ecosystems around the world. Craig Allen has been a central partner in this demonstration of lumps and gaps in body mass distributions. And it was he who discovered that species on the edge of lumps were most variable in space and time- a healthy signal of the reality of lumps and discontinuous patterns.

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With each new discovery surrounding the Panarchy theory, our understanding of it grew, and our discussions eventually spread and evolved to workshops that took place throughout the world.

The first was a wonderful joint meeting around 1998 in Malilangwe, a game resort in Zimbabwe. There had been a recent history of droughts, which induced the collapse of cattle ranching. With no loans for cattle ranching possible, the ranchers had to shift as a group to open savannas and a set of widely and narrowly ranging species for game and recreation.

I spoke with a rancher, who told me, "We have to remove the fences in our minds as well as the fences on our grounds." His poignant words struck my heart; I was moved by his likening the removal of those fences to the removal of inhibitions in his own mind.

With this new system, everything from dikdick, which are tiny antelope ranging about a foot in size, all the way to magnificent elephant, now ranged across the land once fenced in for cattle. These mammals of fundamentally different sizes interacted in this strange, magical country.

During the workshop in Zimbabwe, the senior economists present claimed a Theory Group must be established. I agreed, but reluctantly, since I realized their view was so specific that it would inhibit a synthesis of a broader multi-scale theory. So we supported their Theory Group, and left it to the determined economists and decision theorists. But I also suggested we add what was first called the Anti-theory Group, named as a joke for others of the group who were more openly curious. Wiser and cleverer heads quickly suggested changing the term to the Ante-Theory Group. That group formed and tested the full Panarchy Theory: adaptive management, cross scale, collapses and renewals, traps and transformations.

Figure 11. Ante-Theory cartoon by Jim Thompson

Buz Brock was one of the central leaders of that Ante-Theory Group. At the meeting, he described the way he viewed reviewers in economic journals who assessed his papers: as hyenas ripping out the guts of an impala hung in a tree. That image became the Ralf Yorque cartoon that launched the Internet journal of the RA.

As work continued at home bases, another workshop was held on the island of Gozo in the Mediterranean. Senior economists (including a Nobel laureate, in fact), mathematicians, ecosystem ecologists and social science types convened. It was the first workshop to be organized by the economists in the group, and it didn't go well, as there was too little shared understanding, too little time to acquire that understanding, and too much conflict.

I stupidly lost my temper, over what I saw was an attempt by some economists to smother innovation, in their reaction to a terrific proposal by Steve Carpenter and Buz Brock, the uniquely economic/ecological union of two extraordinarily knowledgeable, creative, curious blokes.

They proposed building a mini model of a lake in a watershed, combining the beautiful concepts and models of lake phosphate dynamics of Steve's, with landscape scale representations of farming with a decision "committee" of farmers that established yearly phosphate loads.

Why did I like their proposal so much? Well, it was just sufficiently complex, with at least five central variables, it was non-linear, and it was cross-scale. The results were marvelous; the adaptive cycle appeared, showing phases of growth, vulnerability, collapse and recovery, with capital, connection and resilience following the path we had earlier intuited.

That is what Steve Carpenter and Buz Brock did by representing phosphate management in a lake with farmers and a real policy team. That was published in Ecology and Society and showed just what I had predicted for the adaptive cycle: a spiral in three dimensions of accumulating capital, connectivity and resilience. That same spiral popped up in their model, and showed the flip from omega to alpha.

As a game with students acting as managers, only one student succeeded in controlling phosphates and retaining clarity of the water and its species mix. She did so by using adaptive management: probing, monitoring, and adapting each year. I discovered later that this student was Steve's daughter. So in a mini version, many of the fundamental properties of the adaptive cycle emerged in a model of tested reality. The figures were also beautiful, reflecting the potential of art that an Internet journal provided.

Despite the success of the model of the lake in a watershed, the breakdown in the meeting at Gozo was really extreme. Several of us left feeling that we never wanted to try this again. However, it was that step in the whole process that forced me to think more deeply, and to recognize that human expectations and responses can change the basic dynamics of ecosystems, adding a richness for not just ecosystems, but for linked social and ecological ones as well. Hence, the Panarchy book improved dramatically during this period of creative destruction. Out of crisis comes opportunity.

Buz Brock made that realization happen for me. He taught me that expectations of the future have a dominant role in consciousness, and affect the actions of people in the present. Some argue that that must smooth out booms and busts in an economy. But despite that, there are still breaks and collapses predicted by nested adaptive cycles. The financial collapse of 2007/8 is an example whose consequences very slowly reverberated throughout the world.

He taught me that expectations, laid on top of otherwise wonderful narratives and simulation models, generate a new class of growth, novel products, and novel societies.

Our last meeting together took place on Heron Island, and the final touches were made to the book on Panarchy before it was published. It was a wonderful time in my life, a pleasant balance between research, fieldwork, and writing, combined with good friends, drinks, and rich scenery.

I remember Heron Island for its abundance of diverse aquatic life, as it fringed right on the edge of the Great Barrier Reef, which teemed with the immense variety of life that called the reef their home. But what was most breathtaking about Heron Island was the blue flash – a striking flash of blue light that appeared the moment the sun set on the horizon. It would hold me in its arresting grasp and catch me unaware at times, its icy blaze piercing off a mirror or windowpane.

> *It was the perfect ending to that mesmerizing time in my life, when one discovery led to the next, and my curiosity and wonder at the world were continuously ignited.*

An Adventure into Retirement: 1999

While my time as head of the Resilience Alliance was exciting and highly rewarding, I could feel a deep seated need to stir things up in my own life.

The urge to step down from my position with the RA and my professorship at the University of Florida finally won, and I accepted that it was time for change.

It didn't take long to find a worthy replacement, as energetic Brian Walker stepped up to take my place. He was absolutely the right person, drawing on his immense success in establishing the Division of Sustainability at CSIRO. He managed to expand membership through the Internet and travel, and he created the RAYS (the Resilience Alliance Young Scholars), where the future rests.

The RAYS were people with recent PhDs who had been associated with some of the principles in the Alliance up until that point. They began interacting at meetings amongst each other, to the point that they decided there should be a formal structure behind the meetings, with someone to head it up. It was a relatively informal organization that received some money from the Alliance, but mostly was funded from their own institutes to pay for their travel and meetings. Subsequently, the new chair of the membership committee, Lance Gunderson, plans to get the RAYS more formally integrated within the Alliance. The ultimate wish is that, one day, whoever heads up the RAYS should also head up the Resilience Alliance.

After stepping down from my responsibilities, I felt as light as air, tied down by nothing and no one.

Ilse and I enjoyed our retirement together in sunny, ebullient Florida, giddy over the newfound freedom that had permeated our lives. Our favorite pastime was travelling, and we didn't have to go far to satisfy this need. There was a small island off the state of Georgia, called Little St. Simon's Island, a hidden treasure, teeming with diverse vegetation and a notably large number of armadillos, which Ilse and I delighted in seeing.

It felt like being transported to a different world, and brought me fond memories of my time with the RA, as it was where our plans to bring the RA to life were first established.

One day Ilse suggested that we make another trip to Little St.Simons that upcoming weekend. I happily agreed and, as usual, I left all arrangements up to her. The weekend came, and Ilse and I loaded up our dog, Cricket, and set off to meet the boat that would take us there. It was a beautiful, balmy day, the sky unmarred by even a single cloud. We rode in silence most of the way, basking in the sun's warm rays and simply enjoying one another's presence.

Upon our arrival, Ilse told me that she had spoken with the owner of the island, who wanted the pleasure of giving me a special private tour. I didn't question her further, or even suspect her motive, but before I knew it I was exploring the landscape of the island with this man, and Ilse had vanished.

"Don't worry," he said, as he led me to his car, "Your wife will be meeting us shortly." At this point, I began to wonder what she had planned, but nothing could have prepared me for what waited ahead.

We arrived at the eastern edge of the island, and a smattering of cabins loomed up to meet us. We stepped out of the car and I edged toward the main building, but was stopped as the man emphatically raised his hand. "Let me see if your wife has arrived yet. Perhaps she is out back?" He gestured to a path that led around to the back of the building, and he left me to follow his suggestion as he stepped inside.

I walked around the building, as I got closer, the sound of hushed voices could be heard over the pounding of the ocean's waves against the island. Curiosity piqued, I rounded the corner only to be hit by the biggest of surprises. Several tables had been set up for a meal, and seated around the tables were all of my closest friends, who had travelled from all stretches of the world to wish me well in my retirement. I caught Ilse smiling at me through the crowd that quickly milled around me to offer their congratulations, and all I could do was smile back, my face splitting in a happy grin.

We took over the island for the weekend, as Ilse had arranged for lovely country food, entertainment, and everyone to have accommodations for the night. While the sun was high in the sky, we dined outside for lunch, and everyone seemed to shrug off all their worries and responsibilities for the day.

As it grew darker and cooler, we withdrew inside, and were entertained by a series of mini-plays as we feasted on island food, the most delicious being poached flat fish. Our wine glasses were never empty, and singing, laughter, and jokes ensued well into the night.

That wonderful weekend on Little St. Simon's Island allowed me to reflect on all of my accomplishments throughout my life, and the wonderful people who helped make them happen.

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We expanded our cottage on the Gulf coast of Florida to make it our home and prepared to live out our lives there on the salt marsh. It was a wonderful time in our lives, filled with a rich circle of friends who were all from very different backgrounds but all with shared values that elicited stimulating conversation and lively debates.

One of those very good friends was Gordon Phelps, a senior VP of a large international banking firm who worked in North America, Asia, and most recently the Middle East . Others were just as interesting: there was a captain of the Marine Corp (who was, unexpectedly, the most liberal of our group, his wife an artist of note), the creator of a dental supply company in New Jersey, a senior high school supervisor from Wisconsin (who lived with Parkinson's disease and ran a business in artifacts on e-Bay), a senior regional planner from Florida, a Chairman of a food supply company from the Netherlands, a well-known marine/aquatic ecosystem ecologist from UBC (this was Carl Walters, a long-time friend who built a house there), the Principal of a large high school in Orlando, a security policeman from the Provincial Police of Ontario, and an engineer from the US Navy (who quietly took charge of building large and small places in Cedar Key that people could use and where they could dream).

Soon I formed a men's discussion group where we enjoyed each other's lively minds. We met weekly in someone's home, much like the discussion group I formed later in Nanaimo, called "The Buzzards".

But I was not really retired yet. I was still deeply involved in exploring and solidifying my work on 'lumps' and Panarchy. I wanted to bring everything together and invited my good scientist friends from around the world to

Cedar Key to exchange views and understanding with my local discussion group. It was deeply satisfying to watch all of these dear friends and lively minds come together, as there were people from Australia, the UK, South Africa, the Netherlands, Sweden, France, Canada, and the USA.

Despite the varied backgrounds and nationalities, it was refreshing to see that all members of both groups read widely, experienced widely, and had an insatiable appetite for knowledge and an instinct for exploration. They valued the treasures of equity and comradeship in their worlds, and they were among the 10% of the population who worked hard in collaboration with others, but also played hard: composing limericks, playing musical instruments, writing poetry, singing songs, and reproducing nature through sculpture and art.

Those two sets of local creative people, and of distant creative people represented two of several cycles I have. They joined cycles of family and of friends that, together with my physical body, mind and spirit, made me who I am today. All of those personal cycles and my physical body are in overlapping adaptive cycles of growth, creation, and renewal. They continue to form and adapt as existence flows, and my tiny contribution lives on in the transformations that result. I know that my death is inevitable, but my real identity will flow on in those cycles of being.

When Ilse and I weren't in the company of our close friends, we would visit art museums and find inspiration from the studios of local artists, we would explore the vast marshland around our property, fishing, walking, and marveling in the endless sights.

We saw young eagles harassing ospreys, playing with each other in tumbling displays. The air, as it's said, was like wine, and the various species of birds soaked it in.

During this time of the year, huge flocks of white pelicans were seen sailing south like ships at full mast. One morning, as we went for our morning walk, we were granted a rare sight: about 100 feet above us were 150 or so giant white pelicans gliding in a circle on the developing thermals. Whenever that circle came overhead we heard it: the shushing, slippery sound of wind through wings. The updrafts were not yet strong at that time of day, so occasionally all of the pelicans suddenly began flapping in order to retain altitude. At those moments, the sound would increase to a beat, continuing for a few moments until it subsided back to the sluicing, slippery sound of wind rushing through feathers.

When the cold front of the season came, the humidity would drop, and the temperature hovered in the low seventies (21-24 degrees C). It was only at night that we would cuddle under our blankets as the brisk air teased us in its winter façade.

First International Conference on Resilience: 2008

Despite my retirement from my position as Science Leader, my involvement with the RA did not end completely. The various research projects continued to burst forth from the members of the RA, and in 2004, we held the first international conference on resilience that was sponsored by the Swedish Academy of Science and the Swedish Academy of Arts, held in Stockholm. The organizers of the event advertised their wish for artistic objects and pieces that would illustrate multi-stable states, resilience, and the unexpected. Flowing out of this request were about 30 pieces of art that illustrated examples of crisis and opportunity.

A panel of three artists and three scientists was commissioned to select the pieces that best captured those ideals, and I was lucky enough to be on that panel. It was a wondrous melding of science and art, and made my appreciation of the correlation between the two grow. The submissions were rich and insightful, and in one example, sounds presented the biochemical and physiological rhythms of plants, normally displayed as numerical frequencies.

The meeting was worthwhile. It was attended by some 300 participants, and two conferences spun off of the success of the first.

The second meeting, held in Tempe, Arizona (2011) was attended by approx. 500 people. It repeated the focus on art, so that what accumulated was a growing constellation of paintings, music, sculptures, and live demonstrations, all intricately tied in with various themes of science.

The third conference was held in May of 2014 in Montpellier, France. It was remarkable that the French organizers again selected both arts and sciences for demonstration and display. There were about 1000 people in attendance, and at the end of the conference, I was asked to give an overall commentary. I supplied stories, anecdotes, and fond memories to the crowd, which were received with great applause.

The conference ended on an unpleasant note for me personally, as I suffered a bad fall just days before we were headed home, but resilience prevailed and I've made a slow but steady recovery.

Resilience Alliance Stutters

My children had all grown up and were scattered across Canada, and by now even the youngest, Jamie had children of his own. Ilse and I decided to take a trip to see them on Vancouver Island, as Jamie and Nancy both lived in the area. The adaptive cycle was stirring up again, and I could feel that Cedar Key had grown restrictive. It had been quite a while since our last visit, and I welcomed the sight of the vast ocean and the rugged, snow-peaked mountains clouded in thick, rolling fog.

Nancy picked us up from the airport and took us to a restaurant perched on the Malahat, overlooking the channel below. It was a beautiful day, with all traces of cloud and mist chased away by the sun. From our seats, we could see fishing boats below, Douglas fir surrounding us, and eagles soaring overhead.

I turned to Ilse and cupped her hand in mine. "I think we should move back to B.C.," I said. She was shocked, as it was the first time I had mentioned my interest in doing so, but it had been a decision I had toyed with for the past year.

Ultimately, she agreed, and we decided to move to Nanaimo to be closer to Nancy, Jamie, and my grandchildren. Nancy was now an accomplished veterinarian who specialized in physiotherapy and acupuncture, and Jamie was a thriving carpenter with two three-year-old twins and a lovely wife who is a nurse practitioner.

In my haste to make the move to British Columbia, we bought a large, sprawling house that was far too big for two people, near the Vancouver Island University. I loved the house but Ilse never felt comfortable in it, something just wasn't right. It was too large, too artificial. The energy just didn't sit well with everything that we so strongly believed in. But it had only been five months, and I was determined to tough it out.

However, unbeknownst to me, Ilse had begun the hunt for our next home. And then, one day, she told me she had found the perfect place for us. But I was crotchety and stubborn, and it took much persuading to get me to agree to look at it.

I was so glad that I did, because the instant I stepped inside, I knew we had stumbled upon our home. It was poised on the edge of a cliff that dropped down to the ocean. Douglas fir cushioned our home and the surrounding area, and directly across the horizon was Vancouver.

I stepped out on the deck, and was entranced by what I saw. In the sky, eagles and vultures circled overhead, and small swallows flitted by in an erratic dance. There seemed to be an abundance of two hummingbird species, *Anna's* and *rufous*. The courting flight of the *Anna's* is dramatic, as they rock back and forth as if on a pendulum, then suddenly shoot upward, turn around, and plummet precipitously down.

It was by a stab of luck that we were able to buy the house, as I had just won the Volvo Award for Science. After we moved to B.C., the real estate market plummeted to a record low, and so our first house sat on the market for quite some time. Eventually, the stress of owning two homes got to us, and we let the house go well below its value.

But we waved the loss off, and instead chose to be thankful that we had found our new home, despite the hiccups it took to get there. The house itself needed some work, but we enjoyed each change that we made to it, as we shaped it into our dream home. Each morning, I would wake up, sit in my chair, and watch the sun crest the mountain range.

We held a large party before we moved from Florida, as we had made many friends during our time there and it was very difficult to say goodbye. However, we chose the perfect time to sell our house, as the US-housing market collapsed shortly after.

The move to Nanaimo was easier for me than anticipated, as the diversity we loved so much in Cedar Key was found in abundance in British Columbia.

The beauty of Nanaimo encompassed the rest of the island as well, and shortly after our move, we took a weekend trip to Tofino with good friends Buz Brock and his wife. We stayed in a beautiful wooden lodge, run by a lovely couple who had earned the money to build the lodge by caring for yachts in the Caribbean. They were terrific cooks, and one night they took us down to the beach, where they cooked freshly caught crab for us. We watched the waves crash along the shoreline as the sun set, and a lone wolf wandered over the salt marsh in the distance.

It was a moment to remember, rarer and therefore more memorable than wind through the needles of pine.

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When we moved to Nanaimo, I stepped back from the RA and I am now only monitoring the work that they're doing. I felt that it was time to slow down a little, and focus on a smaller scale instead of the international scale I had operated at for so long.

With my reduced role in the RA, other changes came as well. Brian Walker, who had taken over the Chair of Science Leader when I initially retired, stepped down but still maintained his role as Chair of the Members Committee. The Alliance began to flounder a bit during our search to fill the Science Chair position. Two major thrusts were made to propel it in a new direction.

The first was to integrate a larger business element into the Alliance, and the second was to explore one or more formal, cross-scale tests of Panarchy. Several suggestions were presented, but three held real promise.

The first was regarding diversity in the forests of Scandinavia across large scales. With climate change, biodiversity was increasing in these northern regions. The proposal was to involve several communities in those regions, and help their residents set up projects that would encourage northward-moving organisms to move northward and to sustain themselves.

The second was focused on signs of salmon establishing spawning areas in rivers that ran into the Canadian Arctic. The focus of the project would have been new monitoring for salmon revival, protection and enhancement, again involving local communities.

But the activity that got my personal attention was the 'Mosquito Fleet', so called because the vessels were many and small. It was a scheme to link waters from the mouths of rivers along the coasts of northern North America to the seas of the Arctic, by encouraging interactions between local communities and scientists. It would involve community monitoring of the sources and impacts of local and global climate change.

It was this third suggestion that I decided to get involved with, and the only one of the three that has actually taken off the ground. It was led by a man named Eddy Carmack, who was head of Canada's program called Three Oceans. Three Oceans was based upon a trajectory to measure critical properties of the three oceans, the Atlantic, the Arctic, and the Pacific, as a way to set the basis of evaluating the effects of climate change. The data they measured and collected was the acidity, temperature, salt, currents, ice, depths and species from plankton to whales and polar bears.

The research was done on Canadian icebreakers, one coming from the east and one coming from the west. Eddy was in charge of this, and as part of his efforts he established the Philosophers Cruise in which he invited noted people, both from science, philosophy and First Nations living along the coasts. Each cruise would have about 12-15 invitees. It was on one of these cruises that I first met Eddy and became entranced by his work, when he invited me to join him and the other passengers.

What a wonder that trip was. It wasn't just the beauty of the Arctic itself, but the flight path to it from Edmonton as well. I was flown by helicopter to the ship, over rolling prairies, boreal forests, tundra, and thousands of lakes splayed out below. With each passing mile on the seven-hour flight came a new discovery of the immensity and beauty of Canada.

The ship itself was one of the largest icebreakers in Canada, and was called the Louis-St.Laurent. Observing from the icebreaker, sinuous patches of white ice seemed to emerge from the black, swirling ocean. We glided through the water and reveled in the silence that was only broken by the battering of the ship against multi-year ice.

The Arctic was, for me, an utterly new world at the top of the planet. It was a desert of ice and snow, with piercing glaciers reaching toward the weak beams of sun. And yet, in that barren land, life was plentiful. We saw it in polynyas, holes in the ice, as the turbulent flow of water brought nutrients that created rich living systems. We saw belugas, seals, and polar bears. And we learned much about the strong, adaptive Inuit culture, who had lived and hunted in the Arctic for over 4000 years, shifting away when climate became colder, and back again when the warmth returned.

On the ship, I conversed with people who lived in the North and knew it well. They told stories of the isolating, shattering Residential Schools, of forced movement of Inuit groups from northern Quebec forests to barren Arctic deserts. They spoke of the blindness of the government, the RCMP, and the Churches. After hearing their stories and the hardship the people had gone through, it was hard to imagine a more adaptive culture than the Inuit.

And we learned of, and saw remote images of the largest freshwater basin, the Beaufort Sea, and of the ice sheets covering the Arctic Ocean. Not just the freshest sea in the world, but an increasingly fresh one with a regime flip possible as currents shift, as light fresh water rises over heavy salt water. Remarkable people from NASA's Jet Propulsion Laboratory use a radar satellite in polar orbit to show ice thickness and extent to three centimeters of resolution. Hear the harmony; the floating ice is clearly vanishing rapidly as climate warms.

Between all of the lectures and deep discussions, I had the opportunity to learn more about Eddy's work. He and I hit it off, and we decided that the work he had done with Three Oceans would translate well to smaller areas. The basic notion was superficially simple: to attach a set of

instruments to small fishing boats, and measure and collect the same data locally that was being measured on a grand scale in Arctic waters and shores.
The goal was to first get six boats running in the Salish Sea, a “Mosquito Fleet” which would be crewed by people in the local communities in bays at the mouths of rivers. In the Arctic, another version emerged with people from Inuit communities operating from skidoos. The focus was on climate change, local, global and back again.

> *The harmony that exists between humans and nature hangs on a delicate thread, and when that harmony continually renews, it sustains us. Now, in the face of human-induced changes that have begun to affect processes throughout the world, that harmony is partially lost or transformed into something entirely new.*

One of those changes is climate change. How will climate change transform the harmony that once existed, as some species vanish, and others appear? As ocean currents shift across scales from the mouths of rivers to the Arctic Ocean, when will these changes occur, and at what scale? What early warning signals can alert us?

In order to answer these questions, we needed a new structure to monitor those changes, enacted by the people whose lives would first be affected. So Eddy decided that linking the activities of existing aboriginal communities along the coasts of the continents with the scientists studying the causes of climate change would benefit humanity at a continental and planetary scale.

Eddy’s hope was that the project would eventually cover scales from the Arctic to river systems along the coasts of northern Washington, British Columbia, Alaska, and northern Canada. The first site was chosen in Cowichan Bay, not too far from my home in Nanaimo. Eddy used his own boat for the oceanographic measurement, and Rusty Sweeting of the Department of Fisheries and Oceans used the Department of Fisheries vessels for the near-shore sampling of phytoplankton, zooplankton and salmon moving from river to ocean. Those Coho and Chinook salmon have been steadily declining for the last 15 years in the Straits of Georgia.

This is precisely what happened to cod fisheries on the east coast of N.A., where fishermen were the predators and government set the policy. The collapse of the cod populations, moreover, shifted the entire ecosystem into another region of stability in which competition and cannibalism locked cod into low levels from which, at the time of this writing, they have not yet recovered.

I wonder if something similar may be happening now with Coho and Chinook salmon on the lower Strait of Georgia. Old friend Carl Walters says there are enough seals to do the job, seals that have built up since they became protected over 15 years ago.

That is one possibility but there is always more than one cause and one set of scales to be considered. And therefore it is lovely to think that the subsequent increase in transient killer whales is in response to the seal build up - a fast seal/salmon cycle followed by a slower Orca/seal cycle.

Onboard Eddy's vessel were two volunteers, Peter Metcalfe and Bon van Hardenberg. Bon acted as captain, thanks to his experience on oil company boats. One day, I stopped Bon and asked him why he was so interested in helping Eddy. He replied, "Twenty years ago, when my wife would throw a dinner party, she would ask me to go out and catch a Coho or two for supper, and I always did so. Now that I no longer can, I want my children and grandchildren to be able to have that experience."

His simple response filled me with a deep respect, and he has become part of an army of volunteers on the coast. We have not yet found the answer as to what caused the steady collapse in Spring and Coho, but I suspect fast zooplankton surprises, plus slower seal predation, are involved. It is likely other slower-moving factors are active as well, one being transient killer whales that have begun to discover the Salish Sea seals, and the other being climate change influences, particularly in acidity.

It has been so rewarding to see Eddy's work grow and evolve. Eddy stitched together volunteers to monitor the cross-scale attributes of the waters. It led to the linking of scales with monitoring at small and fast, slower and larger, and even still slower and larger scales. Our monitoring started with weekly sampling along a 2 kilometer stretch of Cowichan Bay, then we used Eddy's boat, Wicklow, to do monthly sampling 20 kilometers from shore, to sampling the Strait of Georgia at 200 kilometers every four months. The Cowichan Bay activity linked with onshore collaborators, augmented by volunteers who hauled nets and collected plankton in the estuary that links the ocean to the Cowichan River.

Part of Eddy's plan is to add Rivers Inlet as a second small-scale unit and perhaps one other bay up the coast. It is amazing the number of volunteers who appear and who become part of the team. How are the data shared and the knowledge? That is in the process of development, now with help of Kate Moran of the Neptune and Venus underwater monitoring network, headquartered in Victoria, Vancouver Island. They will link us all via the web.

That network suddenly took a spurt forward in 2014, when Brian Riddell, head of the Pacific Salmon Foundation told us he now had the money to support four of Eddy's small vessels in the Mosquito Fleet. And our activity can link with others in the region. The ones I know well or have worked with are Kate Moran's Venus network mentioned earlier, and two others.

One is the Resilience Alliance node on the west coast at the School of Resource and Environmental Management, Simon Fraser University, and one the fish and crab-monitoring scheme of Ecosystem Canada. Each group adds a missing piece to the Mosquito Fleet, specifically a long term 1000 year picture from archaeological examination of buried herring scales, and close contacts and experiences with local communities and harvesters. Both groups are quite simply "winners" with deep experience and contacts on the coast. And each is willing to collaborate with our Mosquitoes.

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I was thrilled to collaborate with such brilliant people in British Columbia, but I had not forgotten the life I had built back in Cedar Key, or the friends I had left behind. Ilse and I decided that we should take a holiday back to Cedar Key, now that Nanaimo had begun to feel like home. During our stay, we caught up with many friends, one of whom was Gordon Phelps. He was surprisingly quiet during supper on the last evening of our holiday in Cedar Key. And then he broke the silence, and said that his doctor had just told him that blood tests had revealed that “phantom” cancer cells were in his body – probably in his bones.

On our flight home, I tried to think of a message that might have helped console him. Something that would face the reality and inevitability of death, but would also sustain each of our own places in life. I tried to compose something that would do more than simply focus on a person’s life from cradle to grave.

It was then that I speculated that the term “cradle to grave” comes from religions built on the concept of a beginning and an end. Christianity, Islam, and Judaism find comfort in that concept, as it is one way to deal with deep uncertainties and the unknown. But Buddhism and Hinduism are different. There, cycles of life dominate, as opposed to beginnings and ends. It is more like “cradle-to-cradle,” or even better, “cradle-to-cradles,” with a diversity of life forms.

Gordon and I were both at an age when we sense mortality, but it is still easier not to be reminded so bluntly. I choose to see existence as a “cradle-to-cradles” cycle of discoveries and adventures with family and friends. There will be bad events, as well as good ones, but we each are capable of creating our own balance.

Gordon achieved a balance that led to great success in giving wise advice, stimulating thought, and argumentative insistence that life is continuous, rather than a set of discontinuous phases such as those I argue exist. Gordon and I will never agree, but it is fun to debate with him. He has family and friends who are enriched by what he has done and accomplished. And his deep curiosity in the flow of existence continues on with them.

“The good that men do may be interred in their bones,” as Shakespeare wrote, but the best bits live on, thanks to those who remember them.

Gordon, happily, has been cured of his cancer and has gone on to do many remarkable things in his retirement.

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Upon my return from our vacation in Cedar Key, I was met with the news that another close friend, Steve Carpenter, was experiencing his own battle with cancer. He had been diagnosed with melanoma, and while they were able to remove the cancerous tumor, he had to undergo a grueling post-surgery treatment that wiped him both physically and mentally.

During the treatment, Steve was given a human hormone to inhibit the cancer from returning. The treatment lasted several months, and despite being tired and weak during this time, he continued his lectures at the University of Wisconsin.

When I learned of Steve's health problems, I invited him on a fishing trip to clear his mind. Eddy Carmack and Carl Walters came along, and we met up with a colleague of mine named Villy Christensen. He was a faculty member at UBC who specialized in ocean monitoring, and he integrated his own boat into his educational program. It was on this boat that we met, and I arranged for a meeting onboard with several members of the Biological Station in Nanaimo. I used this as an opportunity to describe the work we had been doing along the Cowichan Bay with the Mosquito Fleet. They received this with great enthusiasm, and I had high hopes that their interest in our proposal would help propel our work forward.

The next day, we did some fishing up and down the coast, but didn't catch anything. However, we discussed the potential of our proposal further, and a new project was launched from it. While we didn't have the money to support it, what we did have was much more valuable: a group of people around the world who were willing to join us in our search for early warning signs of the impact of climate change in marine waters.

During our fishing trip, we talked of early warning signals of regime shifts for many non-linear systems, as demonstrated by the work of Steve Carpenter, Marten Scheffer, Buz Brock, and Vasilis Dakos. Marten's expertise lies in complex systems, medical, ecological, and economic, in which he sees common properties. He received a top science prize in the Netherlands, of eight million dollars, which enabled him to have the freedom to pursue his research for many years. Vasilis was a student of Marten's, and their work each demonstrated that the variance in space and time, of a variety of indicators, started to change dramatically for a period before the flip of the system into a different regime.

This happened in a number of models of different ecological, economic, and physiological systems. For example, it was shown empirically in Vasilis' study of data from 8 global paleo-ecological climate flips, and in one of Steve's lake studies where a lake was progressively forced by adding increasing numbers of large predators.

Quite independently, my different line of enquiry had been exploring the second part of the proposal: cross scale structure of biomes/ecosystems. I believed that my work on lumps would benefit this proposal, and by analyzing existing data that had been compiled on the oceans we were studying, we could test lumpiness.

As a modest start, we proposed a project to friends in the Resilience Alliance to explore two big spatial/temporal data sets to see if the two discoveries could be combined to make a sensitive, integrative early warning indicator of regime shifts for aquatic systems before they occur. One limnological data set is from Steve's long-term studies of 16 Wisconsin lakes, and the other marine data set, accessible by Eddy Carmack, is obtained from long term but non-systematic monitoring of the Chukchi Sea in the Arctic (an area which is targeted for oil and gas development).

The limnological work so far comes from 11 of the Wisconsin lakes where Tanya Havlicek and Steve showed that the lumpy structure, from plankton to fish, exists in lakes (up to this time all the other biomes/ecosystems studied had been terrestrial). The data are long term and samples are from space and time. They allow a really rigorous application of solid statistical procedures to detect lumps. More years and lakes were added since those data were analyzed, with the same result.

The proposed marine data set is from the Chukchi Sea, an extensive Arctic region of shallow depth. This compilation would come from a synthesis of data collected in the Chukchi by diverse programs over the past several decades. The data include pelagic, surface benthic and subsurface benthic species. They include multiple taxa and abundance indicators over extensive space. From this it should be possible to calculate a standard maximum size for each species (such as the mass at first reproduction). And it is possible to calculate variance at each site. Do lump edge species consistently have a spatial variance significantly greater than that of those within the lump? If regime shifts have occurred, does the variance in abundances of edge species detect those flips earlier than that of those within a lump?

Eddy Carmack is one of the two advisors to the group synthesizing the data, and he thinks they might be willing to provide the basic data (species, abundances, size, depth classes, functional type).

We believe it would be interesting to examine how the variability of populations of species on the edge of those lumps compares to that of species near the core of the lumps over time and space. The question we want to test is whether the degree of space and/or time variability of a sample of easily monitored edge species might be chosen as indicators of a flip caused by climate change. Is this an economical choice for an early warning signal? The study is now underway with several others folks volunteering from the Resilience Alliance: Garry Peterson, Craig Allen, Shana Sundstrom, John Nelson, Thorsten Blenckner, and Calle Folke.

Resilience Perseveres

While I plunged forward with my work in British Columbia, the Resilience Alliance had begun to struggle with its lack of leadership. It had been several years since Brian Walker stepped down as Science Leader, and it had caused a dramatic change in the structure of the RA.
The first idea had been to transfer that leadership to another member of the RA. It was first tested with Calle Folke, who found that he was already over-committed from the demands from the co-management of his superb Stockholm Resilience Center. On the design for group leadership, Terry Hughes said gently that the design we chose would fail and it did. The Alliance and its associated enterprises and collaborative Institutes had swallowed up everyone’s time.

A second attempt was made, this time to have three key members of the RA share the leadership. This method of leadership lasted a year, but was ultimately unsuccessful as well.

It was in 2013 when the solution finally became clear. By this time, the Resilience Alliance had spread to all stretches of the earth, and it was in the South African node that Christo Fabricius stepped forward. He was a brilliant man who was deeply involved in the RA, but in South Africa they had a slightly different way of operating.

In the rest of the world, the members of the RA all operated from single institutes, whereas in South Africa, a band of individuals did great things on their own across the country, and it was the Resilience Alliance that brought them all together.

It was a novel way to make discoveries, and not be limited by the institution one is affiliated with. And Christo Fabricius has been a marvelous Science Leader since taking over, with the backing of his university, the wonderfully named Nelson Mandela Metropolitan University.

After the Science Leader position was filled, it didn't take long for another member of the RA to volunteer to take over the responsibility of Senior Research fellow. This was Allyson Quinlan, who had been managing the Internet Journal from the beginning, and while the Alliance itself continued throughout, it was rejuvenated with this change in leadership.

Common, unexpected events occur often throughout our lives, and this is one such example. One can never fully anticipate such events, but we can prepare for them, by taking into consideration how to deal with failure. One way is to build resilience into the program, and we successfully did so by conducting workshops on islands, where we came together, made familiar with each other's work, and deep, lasting friendships were established. We built a group that was able to both work hard and play hard together, and this ideal will continue to preserve the Alliance's novelty and influence.

Now we have great research and communication, and the addition of the RAYS (Resilience Alliance Young Scholars) is a centrally important addition. <u>It is the RAYS to whom I am dedicating this memoir.</u> They are indeed the rays of light into the future.

The new phase for the RA continues its innovative research and application regionally in several countries. But there have been two big new additions, one dedicated to resilience for business, and the other global. Gail Whiteman is organizing a meeting to get business organizations involved. She is a professor in the Department of Business-Society Management, Rotterdam School of Business, Erasmus University.

I first met her at the first international Resilience Conference in Stockholm, in 2010. She is now on the RA board and is associated with Marten Scheffer in the Dutch node. She has been active in the Davos Symposium and has co-published a marvelous piece in Nature in 2013 on Climate Change about the anticipated sudden release of methane pools in the Arctic within possibly ten years and its consequences. That paper really shook me, as I had no idea that this could happen so quickly and with such precipitate consequences on the climate.

In an email to several of our colleagues, Eddy Carmack says it well: "The Utterly Fantastic Gail Whiteman (UFGW) has just been published in Nature, and put a price tag on methane release from the Arctic. Her focus is the subsea reservoir in hydrates, but vast stores are also locked in the terrestrial landscape of northern Canada and Siberia. This issue, for you and me, is that lakes over permafrost and hydrates, act like thermal drills, and can penetrate to 1000m and beyond! With the Late-Freeze-Early-Melt of lakes/rivers -- these drills will accelerate and dig deeper."

Then Eddy adds: "Well done Gail, but now I have to go on the radio and say how, when ice melts off those 3 billion lakes rimming the Canadian Arctic, they will act like thermal drills through the permafrost and fast track into the methyl hydrate deposits. When Canada 'burps' its methane ... it will be a big and costly burp. Too bad the government is not evaluating this; we should prepare. This is definitely a Resilience issue."

The surprising bubble of Gail's article makes the complete Mosquito Fleet project so much more relevant. It taps the panarchical connections between local waters throughout the top of North America to the ultimate flows in the seas of the north Pacific and the Arctic to the North Atlantic.

Johann Rockström is another RA leader actively organizing policy positions regarding Arctic Resilience. He is the director of the Stockholm Environment Center, within which the RA is active. He looks after the economic basis for the Alliance, and he has been very successful at publishing papers that take the discoveries of the Alliance and communicate them to the general public. He headed up an Assessment of Arctic Resilience for the Arctic Council of Seven Nations. It involved a web of people, several associated with the RA. Brian Walker, Eddy Carmack and Gail Whiteman were central.

Ecotrust: 2009

My involvement with the Mosquito Fleet opened many doors for me, one of which led to the discovery of a tremendous organization called Ecotrust.

A man named Spencer Beebe, who used to hold a senior position in a well-known environmental organization called Nature Conservancy, founded it. While employed by them, his discoveries began to branch in various directions that the group found difficult to entertain. They lacked both the time and money to do so, so Spencer quit, and established his own group called Ecotrust. It is an organization that sponsors the development of new economic and social strategies, made possible or even necessary by the changes in the environment around them.

Founded in Portland, Oregon, Ecotrust bought a chunk of land in an abandoned district, renovated a warehouse, rented accommodation to like-minded folk, and added offices. This launched the renovation of a growing region in the city. The financial collapse in 2008 barely caused a ripple for Ecotrust, which has been highly successful in securing funds since its creation.

Ecotrust establishes commercial enterprises that balance individual fisher or harvester communities, backed by the power of big companies on the west coast of North America. While some attempts fail, others work and stabilize, and are shifted to a private enterprise. Ecotrust develops its innovations in a Living Laboratory, then spins the successful ones into moneymaking ventures. This approach, which relies on the support from outside donors and grantors to build their own private enterprise, is the only way such a group can survive.

The programs that have burst forth from Ecotrust all contain some major role for linking the environment, economics, and social well-being on the west coast of North America. Spencer realized the potential of Ecotrust, and decided to establish a similar group in Canada, which was named Ecotrust Canada.

It was run by Ian Gill, an imaginative, successful columnist, who had the same values that rang true in the US. Its purpose was to pick situations where there were natural opportunities or crises, and try to develop new ways for the local inhabitants to function, develop, and thrive. It was less about preserving nature, and more about taking nature as it was, and developing it in ways that were novel and sustainable.

A wonderful example of this is a project called "From Tree to Home," which was created by Ecotrust staff member Satnam Manhas, and is based out of the Clayoquot Sound on the west coast of Vancouver Island. Five First Nations families are located throughout the islands there, and decades before, the biggest protest in Canada against corporate forestry occurred there. It stopped MacMillan Bloedel and its plan to cut the last 800-year-old ancient forests in the region. As a result of the company's loss, they donated a sawmill to the First Nations community. With Ecotrust's help, the sawmill evolved into the "Tree to House" experiment.

It follows the progress of a house being built, from a log in the forest, to the panels of wood made from it, to the journey they take to the lot of land, to the house being constructed until it reaches completion.

There is now one such building that was designed by First Nations architects, and is financially supported by First Nations fishers. Why only one home? It is the difficulty of the Canadian Indian Act and of banks to provide mortgages to properties owned by an Indian band, rather than by an individual. It is the manifestation of a clash between two cultures.

A second project Ecotrust developed is called "ThisFish", which also involves local community participation with fishers. It was founded by Ecotrust member Tasha Sutcliffe, and is a web-based way to connect consumers, fishermen and producers through restaurants and Thrifty Foods grocery stores.
The project follows the various steps involved in bringing a fish to market: from how and where it was caught, treated, and prepared for the sale. Each fish caught under this program is given a number, and when the

consumer purchases the fish he/she can look up that number online and find all details about that particular fish.

A story begins to unfold, as a picture of the person who caught the fish is being supplied, as well as a picture of the community he makes his home, and his fishing boat. As mentioned before, a full description of the type of fish is being provided as well. With an email facility associated with ThisFish, the fisherman can receive direct comments and questions from the buyer of the fish.

It has even begun to catch on in restaurants, where a fillet of salmon will be given a number, and the patron of the restaurant can choose to learn its rich history. What this achieves is an activity that encompasses all of the fishermen from local fishing communities, maintaining their independence but allowing them to acquire the power to sell their products and compete with the big fishing boats.

ThisFish has even spread to lobster harvesting on the east coast, and to slow foods in Italy and Portugal. They also monitor crab harvesting in the north of B.C. and compete successfully against another company. That method exists thanks to their partnership with Dan Edwards from Ucluelet on the west coast of Vancouver Island. He is also the chairman of a local crab fishing association. With the energy of Amanda Barney, another member of Ecotrust, this monitoring system is moving to fishing vessels harvesting ground fish in Maine. All these are experiments that successfully strengthen independent fishermen in the face of a few big companies.

I had heard of Ecotrust and the work that they had done for some years, but it was in Nanaimo that my involvement with them was ignited. One day, as I stood on the docks waiting to board the Harbor Air seaplane to Vancouver, I encountered Ian Gill awaiting the same flight.

We got to talking, and it didn't take long before he invited me to become a board member of Ecotrust Canada. I was even quicker to accept, and through the organization, I began to learn more of the regional and local properties that made for resilience.

As a board member, I helped identify groups that could work well with Ecotrust, establish talks with those groups, and sell them on the idea and benefits of local resilience development. This would help open sources of funding. All the members of the board had that essential spark and experience that made such work so successful.

It was a treat getting to work with such individuals, and for me, now retired and back in home territory, I suddenly had a place to learn more about the local attributes of resilient development.

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I was delighted to be a part of Ecotrust, and to watch it blossom and grow. However, while Ecotrust in Portland, which had been established for years, hardly noticed the financial crises in 2008-2009, Ecotrust Canada did suffer a blow, in part due to the inevitable failures of some of its projects.

The worst failure was Cougar Annie's Garden, a place carved from the forest 100 years ago by an eccentric woman named Cougar Annie. She survived three husbands and drove cougars out of the area to build this remarkable place, an hour's boat ride from Tofino, with simple cottages, a small lodge, a remarkable garden, and crazy institutional complexities.

One of EC's board members offered the money to buy the property but his unexpected death left the place swallowed in legal complexities and high costs. It was a place for peace and restoration, but financially and administratively it dangled around the neck of EC. Brenda Reid-Kuecks, director of Ecotrust Canada and a very fine lawyer took on the task of digging us out.

Brenda took over leadership of EC, when Ian Gill left to establish Ecotrust Australia. He sold his house, and moved his family of remarkable kids and wife. But after three years he closed EC Australia when the options in Australia's investment climate simply withered, and reestablished everyone back home in Vancouver. Ecotrust has been a remarkable journey by truly remarkable people.

In addition to digging us out of the holes, Brenda created amazing new experiments and emerging businesses with an utterly committed, brilliant staff of over thirty people. She says she marvels at the dedication (and, in her words, vague craziness!) of the wonderful EC team, and in many ways she has created that environment.

For me the significance of Ecotrust is that they have created resilience as part of new kinds of economic and social enterprises. They created results that are part of the innovation that emerges when there is deep change, when established institutions, established leaders, and established experts cause established systems to collapse.

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Figure 12. Volcanic rock collected at Snake River, Oregon

Through Ecotrust, Spencer had asked me several times to join he and others on one of his river rafting trips to talk, over a few days and over good meals, of biosphere regions and of ways to sustain systems. Ilse and I were finally able to do so on the Snake River, Oregon, in 2011.

I still have the ball of volcanic rock I found on the shore, a molten blob that had been tossed upwards at some distant time to freeze in the sky like a teardrop of turbulence and renewal. It is from such creative destruction that beginnings and surprises come in nature and in human endeavors.

New friendships sprung from Ecotrust as well, and two in particular stand out. One was Ron Grzywinski, a banker from Chicago who created, with three other colleagues, the most successful community development bank and microfinance institution in the US. No one knew better how to combine a social mission with profitability – "doing well while doing good". Ron was a deep thinker and a wonderful cook. He was a man to trust, to play and work with. He was, in short, superb on islands.

The other was Rick Young, a social innovator from Toronto who knew no mathematics and little of nature, but whose mind and activities echoed what we argued from the Panarchy perspective. He possessed unique ways to grasp a large scene and find small words to capture and dramatize it.

I first met him in a February in Montreal. God was it cold – especially when coming from balmy Florida! I had been invited to an innovation discussion as part of a DuPont funded project on social innovation. I remember the walk to the meeting keenly. Rick and I fought against the wind, early in the morning, at -30 Celsius. I had inadequate clothing to withstand icy winds in the Montreal winter. So we walked backwards against the wind for several blocks, and survived.

I realize now that all my work has been based on 'walking against the wind'. In a frigid, rigid environment, looking backward for slow vital things that endure and provide opportunity, thinking deeply about a largely unpredictable future, and living in the moment, always alert to unexpected, "good" surprises. I walk backward into the future.

I have learned a lot from Ecotrust since I became a Board member. They are a transforming institution that can set a new stage, regionally and globally. They have begun to learn of the Mosquito Fleet work, and while their participation so far has been minor, I have high hopes that one day the two will link and lead to bigger things.

Currently, the present sampling at Cowichan Bay is a step in the Mosquito Fleet for the lower coast, and Brenda Reid-Kuecks and Lorin Gaertner of

Ecotrust Canada are offering the help they can- particularly a possible three or four scale web based system to store and display the data and orchestrate the discussions.

Reflections

Throughout my life, my training has been dominantly scientific, and so most of my published writing has had to fit into scientific rules and paradigms that are meant to bury the art and the magic.

However, the other side of my brain sees and perceives that art, and it has been in Nanaimo that I finally found the time and freedom to explore it, and start new local projects that interested me.

When Ilse and I moved to Nanaimo, we heard of a local church called the First Unitarian Fellowship of Nanaimo. We quickly discovered that it wasn't a religious group, but a group that simultaneously gives honor to society and spirituality. It was composed of like-minded people who possessed a multiplicity of talent and knowledge, and I developed many friendships.
I decided to replicate my discussion group with members of the Fellowship, and I asked six people to join, Debbie Goodman, Jon Schnute, Sam Cosco, Michael Miller, Chris Boldt, and Bill Hedges. They were all knowledgeable and articulate, and contributed greatly to our discussions. We met at a local café, appropriately named 'The Buzz' .

Our meetings took place once a week, every Thursday at 1 PM, and the subjects we discussed focused on anything we found interesting, although they were mostly related to science. Such topics ranged from the Barium Reactor design and the potential for energy regeneration, to Ecotrust projects.

During one of our discussions, the suggestion was made to hold an evening presentation at the Fellowship, describing the Mosquito Fleet and its recent success. I invited Eddy Carmack and the designer of ThisFish, Tasha Sutcliffe. The group who attended was first given an overview, and then it was broken into five subgroups.

Each subgroup was given a goal associated with one of the community interests that would be affected: the fishing community, the forestry industry, or First Nations groups. Then, each subgroup was charged with developing the goals they would like to see emerge, and how they would benefit each group.

The presentation was interactive and thought provoking, and everyone left with a newfound respect for the local efforts being made in our community.

It was clear that Nanaimo was meant to be my home, and for the first time in my life, my adaptive cycle was at rest. Through the Fellowship and the various friendships I've made here, I've been able to cultivate my artistic side by intertwining my scientific work into it.

Figure 13. Manta Rays carved in balsa wood by Buzz Holling

After having a knee operation, I sought a way to relieve my discomfort by sitting and carving. Balsa wood was the choice and Manta Rays the objects. I carved seven Rays of gradually decreasing sizes and laid them out in a logarithmic spiral along a linear vertical axis. It looked as if the Rays were rising from the depths, coming ever closer to the surface. I arranged them in a Lucite box with light displayed from the bottom to catch the sinuous beauty and to display the geometry. They now float happily in the corner window of our kitchen.

I had dabbled in woodcarving in the past, when I had just started courting Ilse. I carved my first tactile sculpture for her in butternut wood. It was an object that was shaped to the hand, with groves carved in it to contain fingers forming a loose grip. The thumb is free to gently rub a flat portion of the carving, and it has a soothing effect.

I had collected the butternut years before. A branch had fallen in a park near Peele Point, the place on Lake Ontario that is the most southerly place in Canada, at about the latitude of Northern California. That place, that object and that person somehow all came together.

When we married, I carved another beautiful piece for Ilse. It was of a cheetah, carved out of a block of walnut that my father had given me many years ago. I had been inspired by a group of two cheetahs I had seen in Kenya, perched majestically on top of a gathering of rocks. When I first saw them, I made great photographs, enlarging them on high contrast paper to make them appear more as black and white sketches.

Figure 14. Cheetah carved in walnut by Buzz Holling

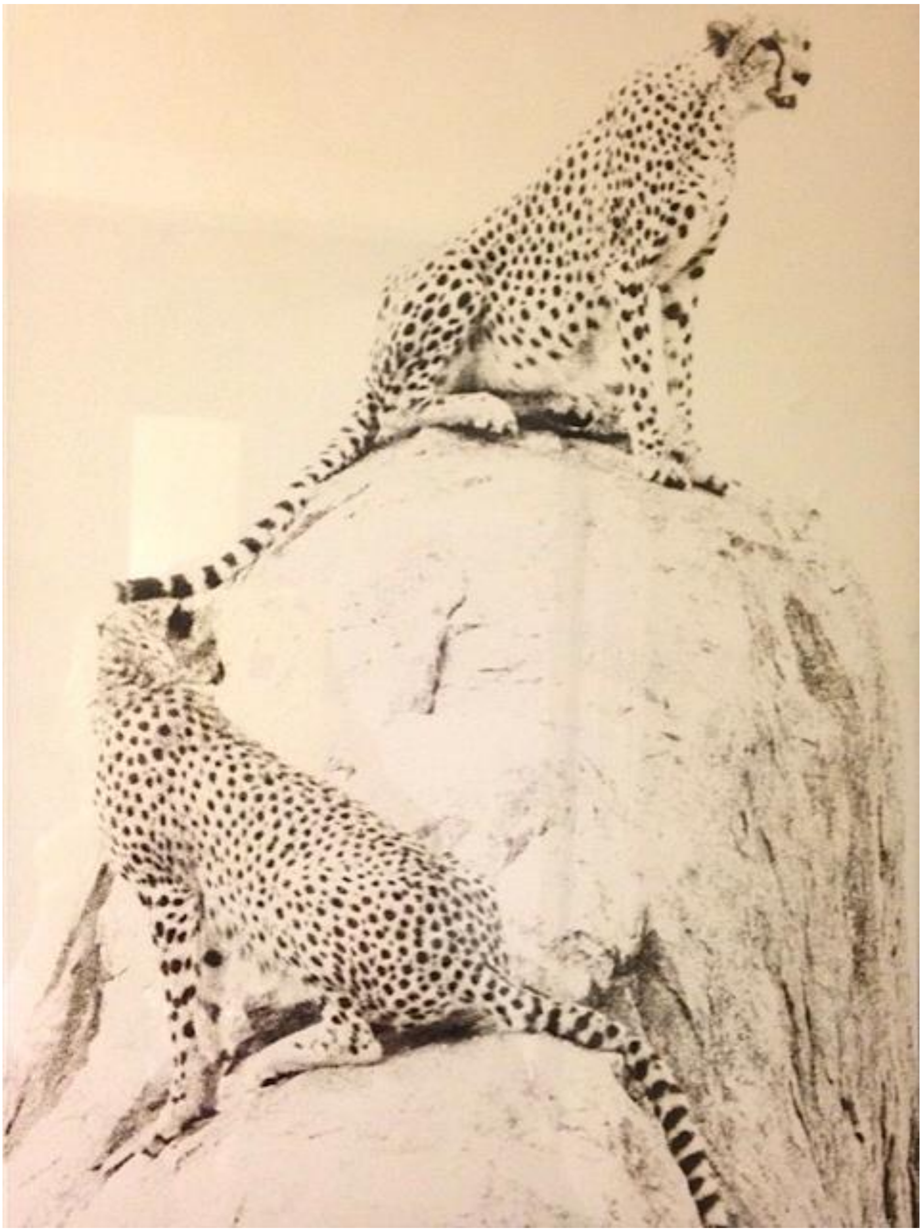


Figure 15. Cheetahs on the look-out in Kenya. Photo by Buzz Holling

Their tails hung loosely down the rocks, not around their bodies like domesticated cats. It was evident from their behavior that they had proprioceptors in their tails, and when they run at blinding speeds, then turn suddenly, their tail is an essential organ of balance. It was a treat to carve for Ilse, as walnut is a beautiful wood, and the block seemed to come to life. That carving sits splendidly in a cabinet at the top of our stairs in our Nanaimo home.

Throughout my life, many of my comments and hypotheses about nature have been triggered by visual images of science and art. But it has been during my retirement that I've begun to work with those who possess deep musical knowledge and a creative musical ability. Through these associations, I've been able to apply music to my scientific work, and have begun to convert visual images into musical ones.

Jon Schnute, my mathematician friend and neighbor, and a member of our discussion group, has helped me create digital music from my data of boreal landscapes and their occupants, from midges to eagles, and ants to moose. He is in the process of programming a musical algorithm for us to explore.

It has been so rewarding to see my work move into this new direction, and to know that the possibilities for binding the scientific world to art and music are limitless.

Leah Hokanson, our terrific choir director in the Fellowhip, learned of the work Jon and I were doing, and was more than willing to turn my work into music. She has taken the patterns proposed from the data sets to create the beginning of a harmony of nature, sung by our choir. The first focus is the landscape of the Pacific Northwest that I can view from my balcony. It ranges over scales, from the planet turning at sunrise, to the hummingbird courting a few meters away.

These are truly new bubbles for me that open my spirit in new kinds of collaborative experiments. My thirst for knowledge and collaboration will outlive me.

Here on my deck in British Columbia, I watch the birds coming to the bird feeders, from hummingbirds, through chickadees and nuthatches, to finches, juncos and sparrows; to Steller's jays and flickers, to hawks and owls, and finally to eagles and vultures soaring the sky.

Now in 2012 I am starting a new multi-part sculpture, in balsa because it is so easy to carve. I am carving 200 small fish and arrange them around a carving of a barracuda. I have the place on the wall where it will hang. Again art can demonstrate science.

From hummingbird to eagle; and also from shrew to moose: each could be a note on a musical scale across scales in space and time. That is what the lumpy world is. It is the music of Panarchy.

Figure 16. "The Mouse" Sculpture in clay by Ilse Holling

Ilse and I travelled to New Zealand for her 70th birthday in 2013, and were impressed by the transformations that people have imposed on the landscape since the arrival of Europeans. Extinction of flightless birds was common and the impacts of rats were pervasive, except on islands. As a result, residues of extinct species exist on some of the islands.

But still the two large islands are lovely in their hugely transformed state where much of the landscape was taken over by sheep ranching. New Zealand has now a new set of ecosystems that emerged out of the resilience of the transformed system. It is not a place, really, for a rigid Endangered Species Act that attempts to freeze the world in an unaltered state with no renewal through adaptive cycles and transformations.

The remarkable museum in Wellington was a revelation of New Zealand's history. And the Art Gallery nearby displayed wonderful art, where Len Lye, sculptor, had created bundles of fiber glass shafts vibrating in a motor-driven frenzy of non-linear patterns, at moments stable, at moments chaotic. It was a complex system bouncing on the edge of a flip from one stable state to another, just as Steve Carpenter and Buz Brock showed in their ecosystem and economic models.

Lye had also created an image of the universe plopping with deep sounds through cycles of steel balls bouncing on a large strap of stainless steel.

To me these art objects were beautifully provocative glimpses of places along an adaptive cycle, or between renewing adaptive cycles. Between gamma and alpha, they were art that captured evocative parts of a whole, and in my mind they were the science that displayed the whole. They were two views of the same patterns that intrigue me.

Figure 17. "Resilience" in granite by Lee Gass

Lee Gass' sculpture "Resilience" does the same thing for me. Not only is he a brilliant scientist, but a highly talented sculptor as well. He carved it from a granite boulder found at a beach near his studio on Quadra Island, BC. It provides a view of a three-dimensional adaptive cycle where capital, connectedness and resilience entwine. It sits in squat splendor on a plinth built by my creative son Jamie, and is the first object that is lighted when I rise at the early morning hours.

Collapse and Revival

Ilse began noticing a change in my behavior in the summer of 2013. I was becoming remote and passive, and was initially diagnosed in early October as being mildly cognitively impaired with dementia. But if that was mild, I'd hate to see more serious cases. I was mixing day and night, imagining dinner invitations that were not made, babbling weird ideas, and refusing food and liquids. That continued, gradually getting worse, until by late November I had become seriously weakened by lack of food and water.

In October I wandered away in the car intending to pick up Ilse from the airport. She was returning from Austria, where she had gone to join the memorial signifying a huge event in her life, the passing of her mother. Not only did I mix up the day of her return, I also ran off the road while driving to the airport, the car was towed away and I ended up in a paramedic's van. The final result was consultations with a hotshot nurse practitioner and suspension of my driver's license by the police.

Ilse became my "commanding officer", with advice from a very fine psychiatrist. She arranged for a bed in the hospital and asked the paramedics to transfer me. I refused and the move to the hospital was finally achieved when she called the police for help. They did the job! But when they got me to the hospital the psychiatrists quickly changed the diagnosis to a rare condition called Cotard's Delusion or syndrome. The patient believes he/she is dead, with parts of the body disappearing. Food and liquids are therefore refused.

'Life is an illusion', I whispered!

That grand switch in diagnosis meant I was no longer seen as being destined to a life of limited capacity, limited mind, with Ilse laboring as my guardian as all my friends and colleagues had assumed. Ilse's future looked as if it would be that horrible fate nobly undertaken by many partners of stroke victims. But thankfully, that was not to be!

I left the hospital just before Christmas. While I was there, I had received electro convulsive treatments (ECT) for the Cotard's syndrome. After five treatments, I suddenly recovered mentally, but physically weakened by lack of food. I do not remember any events during the first half or so of December and parts of November and October, but I gather I was behaving in a truly weird way. The originating cause seems to have been a sudden shift into depression, which became the deepest of deep depressions.

Why? I believe it was this memoir. When I was writing it I was absolutely delighted, as I usually am with writings that I treasure, when the creative spark burns brightly. But I always have a letdown when the first draft is completed. The creative fire dies down, and I wait for critiques. I had no idea that this time, however, I was at an age where critiques required a slogging response and hard, hard work. I apparently simply could not face that and slipped into another stability basin. Sadly, I escaped into a delusion where I could totally forget; indeed, I did totally forget to the point where I convinced myself I was dead.

Weird, eh? But that is the Cotard's delusion. Untreated patients are known to starve themselves to death or commit suicide, since they believe that only bits of their bodies seem to remain.

Ilse had been astonishing dealing with my strange behavior, and, despite inadequate sleep, she somehow coped with my weird ideas. I have just finished reading her diary written since early September. She was truly awesome. Jamie, my youngest son, and his wife Erica (who happens to be a nurse practitioner) were stalwart helpers, living as they do in our city of Nanaimo, as were my neighbor, Jon Schnute, the local medical people and my dear Unitarian friends who pitched in so ably. Daughter Nancy from Duncan and oldest son Chris from Toronto touched base when they could, giving me their love.

The treatment for Cotard's Delusion is very effective, and, as I said above, five ECT's brought me to reality. And I was able to celebrate a lively, wonderful Christmas with family.

So I am now truly back to being the old Buzz, or at least to the beginning of the old Buzz, and have returned to my interest in news and the memoirs I had finished, but not edited. I even see hints of resilience in my story! This is what one insightful friend messaged:

"It is a story of resilience with many elements -- Ilse's patience and wisdom, the Holling stability landscape of friends and family, and just the right shock at the right time to escape the trap and slide back into the good stability basin."

So that is all for now. I was enveloped by love from wife, kids, and so many friends, locally and worldwide. I was truly blessed. Life goes on, and I am thankful to carry on with it.

Acknowledgements

During a period of declining abilities, I could not have completed this memoir without the help of many friends. My wife Ilse played a pivotal role in the entire adventure described here. She patiently worked through final drafts with me, ensuring that my words and intentions were clear. Her intimate knowledge of our shared history made her advice invaluable. Her thoughtful foreword above illustrates her caring approach to everyone. Without her, this story would not exist.

Jon Schnute, my friend, colleague, and next-door neighbor, maintained a careful archive of text and images during several years and many versions of this report. He consistently encouraged everyone involved to persist, despite the obstacles. His extensive final editing helped bring everything together in a consistent, legible form.

Lee Gass, Debbie Goodman, Sam Cosco, and others provided helpful comments on earlier drafts. Debbie suggested that I include the poem by Samuel Greenberg, and she generously contributed her thoughtful observations below.

Calle Folke, Garry Peterson, and Phil Taylor provided funding through the Resilience Alliance to hire Sarah Smith who helped me craft much of this material, particularly after my affliction with Cotard's syndrome.

Jim Horncastle took some of the photographs here to replace earlier historical versions that needed improvement. My friends Bill Hedges, Chris Boldt, and Michael Miller provided valuable encouragement and suggestions, particularly during the final stages of preparation.

Eddy Carmack, with his characteristic good humor, gave me the ingenious drawing in Figure 10, comparing resilience cycles with those in everyday life.

Finally, I want to thank everyone mentioned in this report, as well as many others whose role I haven't cited, for their collaboration in my adventures with science, art, and humanity. It has been a great privilege to work with such outstanding, committed, and talented people.

Observations by a friend

We are now approaching the time when the Buzz Holling cycle, nested within the larger cycle of Ecosystem Studies (or perhaps the larger one of Systems Theory), is coming to an end; but it yields the way for new organisms, as in the RAYS (Resilience Alliance Young Scholars), the next generation of thinkers. This is natural and inevitable, as Buzz has so beautifully described in his life's work.

In summary, there are three important, and conclusive, things I have observed:

First, as Panarchy would have it, the "capital" that Buzz contributed to the system will persist, will outlive him, and will continue to perhaps manifest itself in ways we can't predict. This is a message of legacy, a hopeful view of our work outlasting our life span.

Second, that Buzz's theories of cycles are similar to cyclic themes in religion, literature, philosophy, human history, as well as the natural and social sciences that go back as far as human thinking goes back. But, as author Thomas Homer Dixon pointed out in his Worldwatch article about "Our Panarchic Future," Buzz has "done more than restate" those historic concepts.

What Buzz has done is "distilled the essential patterns" and greatly refined and advanced our understanding. He did this through creativity, perception, innovation, and courage, as well as by focusing on something for 50 years.

Finally, I would like to quote author Jill Purce from her book *The Mystic Spiral*:

At the center of any spiral is the calm core,
through which man passes to eternity.

Debbie Goodman
April 2015

Poetry

Buzz's Bubbles and Spirals

If you're looking for bright mental bubbles
that mirror your joys and your troubles,
then you'd best turn to Buzz
since that's just what he does
when a resilient measurement doubles.

To double your troubles
and double your fun,
hop onto a panarchy spiral
and run run, and run run, and run.

Jon Schnute – December 6, 2015 – For Buzz on his 85th birthday

Huts Without Ruts

Way back in the era of UBC huts
During glorious years before the big cuts,
Students would listen with rapt attention
Hoping Professor Holling would mention
A plan for beer to escape mental ruts.

Laura Richards (Former Student) & Jon Schnute – Neighbors
December 6, 2015 – For Buzz on his 85th birthday

For Buzz after his recovery from Cotard's Syndrome

Our Buzz disappeared, went away
To the dark in omega to play
But Ilse-The-Great
A formidable mate
Shocked him back into alpha - HOORAY

Laura Walker, Canberra, Australia – January 2014

Playing Flute with a Sideways Eight

(To perform, just add bongos, a performance artist and a beatnik)

Panarchy is a crazy, crazy complex cat
No longer just a Greek God playing cool jazz on his flute
He offers us a gaze into the heart of how everything
INTERRELATES! INNOVATES!
ACCUMULATES! and EVAPORATES!
Starting the whole crazy cycle again, in a sideways eight –
An image of change – in a play of four parts...

ONE! Enter *Entrepreneurial Exploitation* stage left –
Awash in opportunities and crazy possibilities...

TWO! Next is *Organizational Consolidation* growing
Fat and content – bulging with a brittle vulnerability...

THREE! The triptet in our play is our personal fave,
Creative Destruction (or *Omega* for short) –
When he gets disturbed, man, releases all his pent up energy
In a crazy storm...

FOUR! Only to reform in an *Alpha* dance spreading the
Seeds to next year's possibilities...

Now, this adaptive cycle occurs in panarchies of scales
From the way cool neighbourhood of little ladybirds during an afternoon tea
To the conversation... between the oceans... through the... currents... of... time...

For Dad
Love,
Jamie

Jamie Holling
Holling Family Reunion, July 2003

Cast
Beatnik: Jamie
Bongos: Erica
Dance of Pan: Chris

Early Pictures

Cold leather happy
Cards to Master Holling
Long wave crashes
Golden fur running
Pool of life fingers
Green canvass camping
Wild wind, keel bolts
Shrew hearts a-pounding
Salty gravy, salty tears
Apple cider clouding
Tight skin balsa
Yellow cedar wafting

All the worry and the love
Reflections of reflections
Peace.

For Dad. Love, Chris Holling – December 6, 2000
Buzz's 70th birthday

Winning limericks from 'Resilience Workshops on Islands' (1995 – 2014)

Each limerick had to contain the name of the place where the workshop took place, as well as the "buzzword" of recent resilience developments. The winner was determined by a carefully selected jury and the impartial assessment of two 'clap-o-meters' during a ceremony in the evening of the last day of the workshop.

First Resilience Network Workshop, 1995, Ulvøn, Sweden

From Ulvøn came work on resilience
That would bring the Beijer Institute millions.
But the economists swore,
"We wrote this before"
In streaks of neoclassical brilliance.

Lowell "Rusty" Pritchard, Jr.

Second Resilience Network Workshop, 1996, Little St. Simons Island, Georgia, USA

An econometrician named Stern
Had a large mathematical term.
When he tried to insert it,
In a model, he hurt it,
It said "It's for real data I yearn"

Nick Abel, CSIRO, Canberra, Australia

Third Resilience Network Workshop, 1997, Malilangwe, Zimbabwe

Malilangwe has huge wildlife herds,
With resilience and other big words.
A system so stable.
It proved fully able,
To cope with a network of nerds.

Raoul Du Toit, Zimbabwe

Fourth Resilience Network Workshop, 1998, Gozo, Malta

"On Tourette's and Senior Ecologists"

On Gozo, decorum was falling
When resilience turned to name-calling.
"Why, you da-da-da-da
Da-da da, da-da-da!"
Was all we could get out of Holling.

Lowell "Rusty" Pritchard, Jr.

Fifth Resilience Network Meeting, June 1999
Heron Island on Australia's Great Barrier Reef

Limerick missing

First Resilience Alliance Meeting 2000, CHAA Creek, Belize

In Belize, for the girls at the bar
Brian's manly displays went too far
Then his mate Buzz 'phoned in
To tell the girls "That's not him…
That's his fourteen-inch Cuban cigar!"

Lowell "Rusty" Pritchard, Jr.

Rusty wishes to record the fact that if it wasn't for the requirement to include the word "Buzz" he would have achieved perfect double rhyming in lines 3 and 4, as follows:

Then his mate Tim from Zim
Said "No, that's not him…

Second Resilience Alliance Meeting, 2001, Chang Mai, Thailand

The required two words were "Hang Dong" (the name of the area where the meeting was held) and "thresholds". It was won, yet again, by Rusty Pritchard.

To make us more gender-diverse
Buzz adopted a skirt and a purse.
But the bits that Hang Dong
From beneath his sarong
Cross the threshold from queer to perverse.

Lowell "Rusty" Pritchard, Jr.

Runner-up

The young CARTs have got it quite wrong
You can't play Ping without Pong
You only get nifty
On the threshold of fifty
And get the Hang of the ding with a Dong.

Laura Walker

Third Resilience Alliance Meeting, 2002, Marenco, Costa Rica

In Marenco a girl quite well-spoken
Announced that her portal was open
A change in regimes
Was coming it seems
At least, all the young men were hopin'.

Sam Scheiner

Runner-up

In Marenco girl power was growing
Regime shifts and transitions were showing
Ann Kinzig was heard
To tell an old nerd
Testosterone does not replace knowing.

Ilse Holling

Fourth Resilience Alliance Meeting, December 2004, Tobago

In Tobago it became certain fact,
The backloop's an intestinal tract.
For the rumblings abdominal
Were simply phenomenal
And resilience got farted off track.

Laura Walker

Fifth Resilience Alliance Meeting, 2006, Kruger

Compulsory words were ‘Kruger’ and ‘transformation’ or ‘transformed’, with extra points for ‘Shingwedzi’

To Kruger came bird-loving Laura
Who now sees all things with an aura
‘cause she fell from a truck
Watching two vultures ---‘perform’
Those bird watching leanings transformed ’er

Susan Abel

Sixth Resilience Alliance Meeting, 2007, Corsica

Limerick missing

Seventh Resilience Alliance Meeting, 2009, Gabriola Island, Canada

Limerick missing

Eighth Resilience Alliance Meeting, 2012, Camargue France

Des bateaux, j'en ai pris beaucoup
Mais le seul qui ait tenu le coup
Etait en Camargue
A big big blague
Tout small plaisir est beau pour nous!

The French team: Raphael Mathevet, Francois Bousquet, Aurelie, Martine, Olivier Barreteau

Ninth Resilience Alliance Meeting, 2013, Drakensberg, South Africa

The required words were 'Didima' (the camp where we were) and either 'novelty' or 'renewal'. There were two days of cold, wet weather in the Drakensberg mountains, on one of which we had an excursion to a village where there was a trial bio-gas experiment using cow dung.

At Didima a lady once said
I find novelty better in bed
I'm so cold and wet
Let's work up a sweat
Unless your poor wiki is dead?

Graeme Cumming

Tenth Resilience Alliance Meeting. 2014, Montpellier, France

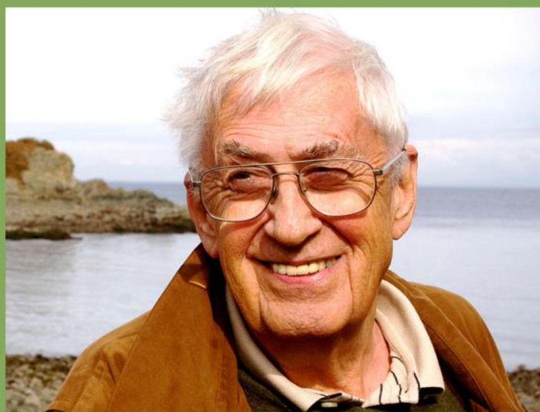
Creativity's just not a given
There's floundering and then there is swimmin'
The Hermitage shows
That nobody knows
The key is to just ask the women.

Emilie

Runner-up

Through L'Hermitage's wide open doors
Came creativity and mosquitoes in scores
The biggest blood suckers
Were resilient fuckers
Who got given the greatest applause.

Graeme Cumming



Crawford Stanley Holling was born in 1930 in the United States to Canadian parents. He grew up in Northern Ontario, which was where he first became interested in nature.

Throughout his research, C. S. Holling has blended systems theory and ecology with simulation modeling and policy analysis to develop integrative theories of change that have practical utility. He has introduced important ideas in the application of ecology and evolution, including resilience, adaptive management, the adaptive cycle, and panarchy.

His work is frequently cited in the fields of ecology, environmental management, ecological economics and the human dimensions of global change.