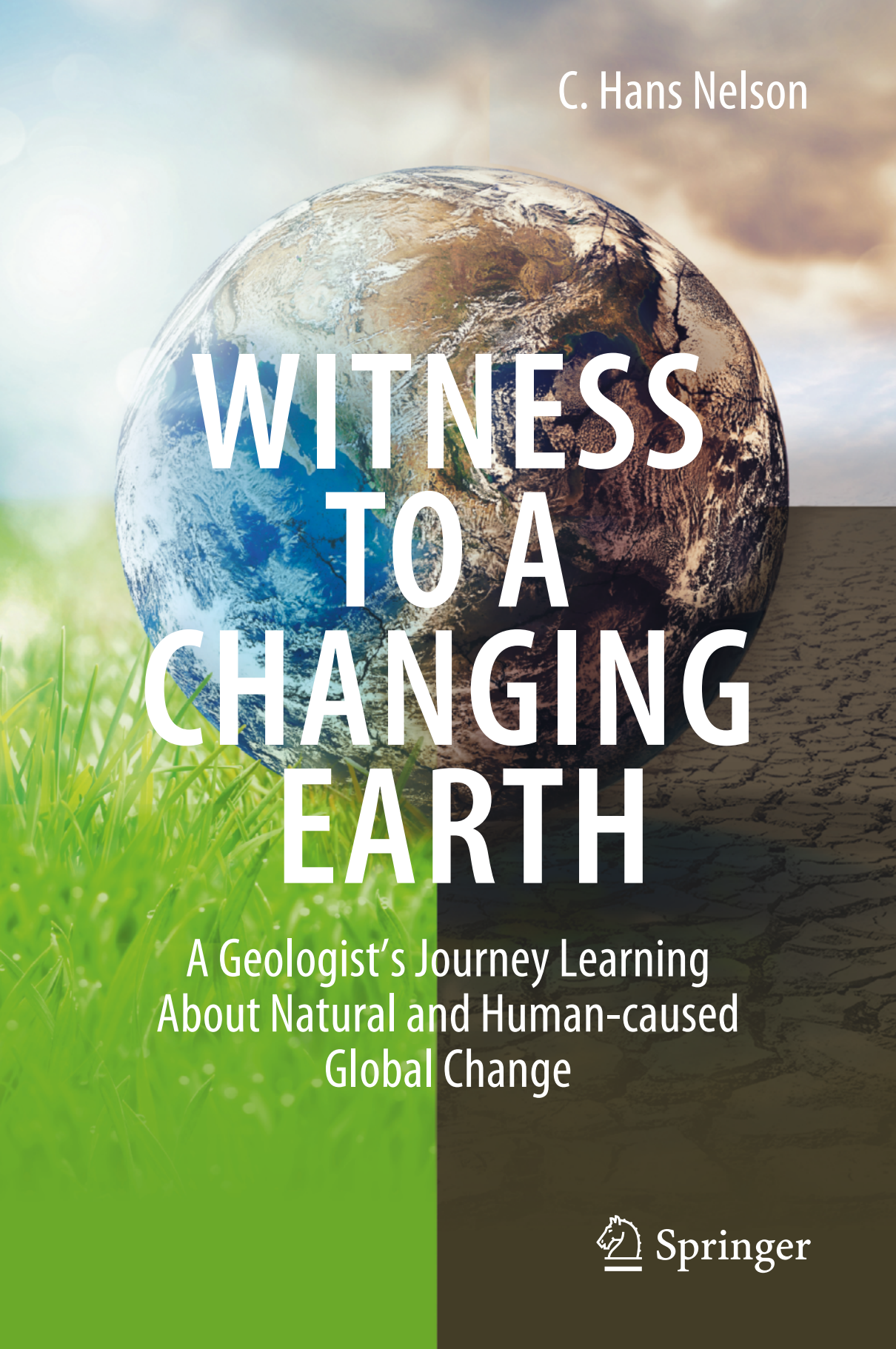
C. Hans Nelson



WITNESS TO A CHANGING EARTH

A Geologist's Journey Learning About Natural and Human-caused Global Change

Springer

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Granada, Spain

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To my family, friends, colleagues and readers in the hope you can work towards mitigating the effects of global change.

Foreword

Earth will survive our human-caused limiting factors, but will the human species?

Hans Nelson is well known in the global marine geology community for his pioneering studies on turbidite systems off continental margins as records of past earthquakes, along with potential hazards and petroleum reservoirs. He is the quintessential geologist, seeking to understand how our Earth System functions by studying records of its past, mainly beneath the sea floor using corers and seismic gear but also at times in lakes, and in outcrops on land for the more distant past.

Throughout a long and distinguished career he has worked with many colleagues on projects large and small from the Arctic to the tropics, with his findings well published and widely read. He has also noticed, like many other geoscientists, the many signs of change in the Earth System—atmosphere, biosphere, ice, land, and oceans, as Earth's human population rises and the demand for resources increases. We know this is unsustainable. Demand must be reduced at every level in human society if increasingly severe catastrophes are to be averted.

In this book, Hans draws on his lifetime of study and travel to share with others his experience of the natural world, because he, like many other scientists, has become deeply concerned at the growing degradation of our environment. Part I begins in the first section with close encounters in Minnesota with lightning and floods. He then introduces the reader with his own experience of first the natural and unavoidable hazards of floods, earthquakes, and

volcanoes, before going on to consider the human-induced hazards we are bringing about ourselves in global warming and ocean acidification, and the terrible consequences of both natural and human-induced combined.

In Part II, Hans expands to educate the reader about climate and global warming from many lines of evidence linking increasing CO_2 and methane in the atmosphere to rising ocean temperatures and sea level, as well as shrinking polar and mountain ice in addition to permafrost. He also reviews increasing extinction rates and separates natural climate variability from human-caused global warming, and recognizes contamination and pollution problems unrelated to greenhouse gases.

Part III of this book sets this book apart from most others with Hans' extensive review based on his personal experience of solutions for these growing global change problems, and his advocacy for a shift in attitude through education at all levels focused on a sustainable way of life for humanity and Earth itself.

Hans concludes "The bottom line is that our future outlook can improve with a change in attitude for the common good of humanity and health of Earth, particularly attitudes of populist politicians, the wealthy few and powerful multi-national corporations. Our choice must be to put the common good ahead of greed and short-term economic goals." His insights from a lifetime of scientific investigations covering all aspects of Earth System workings, along with his observations on the failings of the West in particular, and his many stories of experiences with fellow humans provide readers with compelling reasons and inspiration for attitudinal change.

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Preface

The most important reason for me to write this book and my greatest concern is the multiple types of human-caused global change that are accelerating rapidly, threatening the quality of life and even the existence of humanity on Earth. Many of the media and government reports equate human-caused climate change or global warming with global change. Unfortunately, humans cause many other types of global change that are occurring at the same time as warming. Most people are aware that humans are introducing carbon dioxide (CO_2) and methane (CH_4) into the atmosphere and these gases are warming the global climate and ocean. However, in addition to warming the ocean, which melts polar ice sheets and destroys coral reefs, humans are trashing the ocean with plastic that in a few decades will weigh more than the fish in the ocean. Similarly, on land humans are warming, eliminating, and polluting habitats, which results in animal extinctions equal to natural extinctions that occurred earlier in geological times, when humans were not present. We humans need to remember that we too are animals facing possible extinction as a result of our global changes.

In this book, I use the term global change to describe worldwide natural as well as human-caused events, because both types can have global effects on our Earth. My descriptions of natural global change focus on earthquakes and volcanoes, because these two natural types of geologic events result in the most widespread global change and I have spent much of my career investigating these events. Great earthquakes of magnitude (Mw) 9, like the one in Sumatra in 2004, result in tsunamis that spread globally across entire ocean

basins, and cause hundreds of thousands of deaths for distances of more than 1000 km (600 miles) along coasts and inland where the earthquakes occur. Catastrophic volcanic events like Crater Lake Oregon, which I have spent a lifetime studying, spread ash clouds that cover the Earth, cool the climate for years, and also cause thousands of deaths. My interest in investigating natural global change is to help mitigate the risk posed by these natural events.

These aforementioned few examples of natural and human-caused global changes are some of the many that I describe throughout the book. Because human-caused rather than natural geologic global changes are now dominating the Earth's environment, the present geologic time is called the Anthropocene (https://en.wikipedia.org/wiki/Anthropocene). Humans have become a force of Nature changing the Earth System, just as volcanism and glacial cycles do. For example, when I studied the Ebro River drainage system, the largest on the Iberian Peninsula, I found that humans caused the same effect as the changes of the Pleistocene glacial climate (from 2.6 million to 11,700 years) and Holocene warm climate (the last 11.700 years). Likewise, a biological study of mine has shown how the Pacific walrus population in the Arctic has been reduced by 50% because of global warming and loss of their sea ice habitat. These and other scientific discoveries on my geologist's journey have provoked me to alert the public about the multiple human-caused global changes in addition to climate change.

The force that drives all of the human-caused global change is population growth. The Earth's human population has tripled just during my lifetime. This exponential increase has led to the many global changes that I will describe. The huge increase in the population just in the last few decades also has resulted in a dangerous interaction between both natural and human-caused global changes. For example, large numbers of people have moved into coastal areas that are subject to great earthquakes and tsunamis such as the Pacific Northwest, California, and Japan. People also have crowded into areas around the world that are subject to hurricanes, typhoons, and flooding by rising sea level and higher storm surges. The 2020 typhoon in Bangladesh, which crowded refugees together during the COVID-19 pandemic, shows how natural and human global change can be interconnected. Unfortunately, the development of infrastructure has not kept up to protect the rapidly growing population from both natural and human-caused global changes.

Humans cannot prevent the natural events like earthquakes, but we can survive them, whereas we have the ability to alter human-caused global changes and keep a sustainable planet. For example, I have experienced an unusual number of dangerous natural events, but also have been lucky enough to survive them. While growing up I experienced a tornado, a flood, and

several lightning strikes. Later in my life I have experienced several earthquakes and catastrophic storms, which had winds up to 300 km per hour (180 mph) and waves up to 25 m (80 feet) high. My worst earthquake experience was the 1989 Loma Prieta earthquake in the San Francisco area. I thought we would lose our house because downed power lines had set a fire nearby and the main water line to the area had broken. Fortunately, the fireman arrived in time to put out the fire, and because of my previous encounters with earthquakes, I had designed my California house for earthquakes. However, others were not so lucky and several houses within a kilometer of mine were destroyed. My house example shows that we can plan for and survive natural catastrophes. Also, you can see how all these experiences with natural-type global change have provoked thoughts for my book.

As well as my experiences with natural global change, I have had many personal experiences with human-caused global change that also have provided background for my book. I have observed pollution in Lake Baikal Russia from the world's largest paper mill and seen recent coral bleaching while skin diving on Malaysian coral reefs. Now when swimming off the Costa Brava in northern Spain, because of the warming and acidified Mediterranean Sea, masses of jellyfish often sting you compared to swimming in the 1980s. Also while living in Spain during the past 20 years, I have seen African dust storms from expanding deserts become more severe. The fruit in our garden ripens and flowers bloom a month earlier. Our semi-tropical jacaranda tree, which never bloomed the first decade living in Spain, now blooms every year.

In addition to my widespread global experiences, how has my scientific background qualified me to write about global change? My first B.A. degree from Carleton College was with a major in geology and a minor in biology. Likewise, my M.S. degree from University of Minnesota was in geology and biology where I studied effects of glacial climate change and the geological limnology of Crater Lake, Oregon. My Ph.D. was in geological oceanography from Oregon State University where I also took every marine biology course taught including phytoplankton (microscopic plants), zooplankton and foraminiferal ecology (microscopic animals), nekton (marine fish and mammals), and benthic biology (the study of life on the sea floor). In sum, I consider myself to be an Earth scientist or marine geologist/biologist and have been trained in geology, biology, and oceanography.

From the title you may think that as a geologist I just look at rocks. However, as you will see from examples of my studies, I have examined the shape of the land, lake floors, and ocean seafloor surfaces; the plants and animals in the water and sediment at the bottom of lakes and oceans; the

history of this sediment; and the history of ice on land and in the sea. The reason that geological oceanographers or marine geologists like me are broadly trained environmental scientists is that we apply all the sciences to the study of lakes and oceans. We look at the physical oceanography of ocean circulation and currents; the chemistry of ocean and lake water; the biology of the water and sediments; and the geology of coasts, seafloor, and sediments.

My first global experience was teaching marine biology on the University of the Seven Seas and helping lead field trips in all of the temperate and tropical environments of the northern hemisphere. My professional onland and aquatic studies have taken place in the Arctic, Antarctic, Atlantic, and Pacific Oceans, Mediterranean, Bering, and Chukchi Seas, as well as Minnesota Lakes, the volcanic Crater Lake in Oregon, and the Rift Lake Baikal in Russia. This research has focused on resources, geologic hazards, and environmental assessment. My studies have included work for government agencies, universities, and industry. This breadth of academic training and research experience gives me a broad perspective on different viewpoints about global change.

For years, I have wanted to alert people to the challenges of global change and write a book based on my worldwide experiences from the last 60 years. So, why should you want to read this book? In this book, you will learn about how geologists study natural global changes such as earthquakes and volcanoes, and the adventures that happen during these investigations. You also will learn about human-caused changes of global warming; resource depletion; and pollution of air, water, and soil. Readers will find out that if we continue the present human habits for the next 50 years, the Earth faces dramatic decrease in water quality and quantity, farmland, wild marine fisheries, forests, fossil fuel supplies, and plant and animal species.

The general public, teachers, and students may wish you knew what to do about these human-caused changes, because our Earth's population continues to increase along with demand for those ever-decreasing resources. To counter these fears, my book describes solutions and examples of successful programs combating global change. By the end of this book, readers and policy-makers will understand how countries can learn to avoid and prevent catastrophic loss of life and property associated with natural and human-caused global changes. People and policy-makers also will find examples of global technical and political advances to achieve the goal of a sustainable Earth.

As well as the scientific purpose, I hope that this book will spark your interest in the natural world by showing how exciting studying nature can be. I hope readers will see that natural science studies can be as adventurous as any action movie or as humorous as a comedy. We need to encourage youngsters to spend less time in the virtual world of computers and more time enjoying

the real natural world. Maybe even some young readers will be inspired to become natural scientists.

To my knowledge, this is the only book you will find that describes both natural and human-caused global changes while showing the gravity of these combined changes occurring at the same time. Although much of this book describes the dangers of the combined effects of global change, at the end I point out solutions for global change problems and a sustainable Earth. My desire is that the book will empower you to make positive changes for global change problems and the severe challenges humans face to keep a sustainable planet.

I hope my book will inspire the readers to adapt the mantra:

MAKE EARTH GREAT AGAIN!

Granada, Spain C. Hans Nelson

Acknowledgements

There are many people to thank for helping me on my geologist's journey. My family has sacrificed the most because of my long absences for oceanographic cruises and scientific meetings. Some years my wife Carlota Escutia and I have only been at home together for as little as 2 months, because of our combined scientific activities. My older daughters Laurie and Lisa endured a divorce that resulted from months at sea for many years in the Arctic. My younger daughters Carli and Cristina also saw little of me in their earlier years. I cannot remember which of my young daughters once said that if dad dies it will just seem like he has gone on another scientific cruise.

I never would have embarked on my geologist's journey without the world-class mentors and teachers that guided me through my education and into my career. My high school teacher Bob Hanlon in the early 1950s was way ahead of his time in teaching ecology with his advanced biology course. My undergraduate geology advisor, Dr. Eiler Henrickson, not only led me to change my major to geology, but also taught me lifelong lessons for sports and physical exercise. Dr. Herb Wright, my MS advisor at University of Minnesota, encouraged my lake studies through his pioneering limnology group. My Ph.D. advisor, Dr. John Byrne, was the best teacher that I ever encountered, and allowed me to focus on my thesis research rather than his interests. Dr. David Hopkins, my first project chief at USGS, taught me about Alaskan geology and how to achieve scientific results in the logistically difficult remote areas of Arctic Alaska.

There are many scientific colleagues and friends who are too numerous to mention for their help with my scientific research and my family during my absences for oceanographic cruises and onland fieldwork. None of my scientific research could have been achieved without the help of hundreds of other scientists and technicians in laboratories on land and ships at sea. For example, I have had as many as 40 scientists and technicians on a scientific cruise and 35 scientists in my USGS/CSIC project in Spain. Also my marine geology projects could not have been completed without hundreds of shipboard officials and crew from USGS, NOAA, ONR, USNPS, Oregon State University, CSIC Spain, IFREMER France, Texas A & M University, Scripps Institute of Oceanography, and Academy Nauk, Russia.

Among many, Dr. Peter Barrett, Patric Coupland, Ranny Eckstrom, Dr. Carlota Escutia, Dr. David Lowe, Duncan MacMillan, Carli Nelson, Wim Velsink, and the editor Dr. Alexis Vizcaino have been, especially, helpful with my book efforts by providing scientific advice and reviews.

Contents

About the Author

C. Hans Nelson is a guest scientist at Instituto Andaluz de Ciencias de la Tierra in Granada, Spain, and a Research Associate for the Turbidite Research Group at University of Leeds, Great Britain. During his career in government, academia, and industry, he has carried out research on marine geologic hazards, resources, and environments mainly at the U.S. Geological Survey as well as at research institutes and universities in USA, Spain, France, and the Netherlands. This has resulted in more than 200 peer-reviewed articles and books, and the Geological Society of America Kirk Bryan Award for Research Excellence. He has taught short courses on deep-sea deposits worldwide, for governments, geologic societies, universities, and industry. Hans has served as a Chief Scientist for 30 scientific expeditions, in Bering, Chukchi, Pacific,

Atlantic, Gulf of Mexico, and Mediterranean Seas as well as Crater Lake, Oregon, and Lake Baikal, Russia. Photo courtesy of the author, taken while a lecturer on a cruise ship in Glacier Bay, Alaska, July 2000.

1

Introduction

I write this book because along my journey as a land and sea-going earth scientist I have witnessed natural geologic and human-caused global changes that have, or might have, a profound effect in human lives. Natural disasters can cause global changes that are as significant as human-caused changes, including climate change. Wikipedia defines a natural disaster as a sudden event that causes widespread destruction plus significant loss of life and collateral damage caused by forces other than the acts of human beings. Natural disasters include events such as earthquakes, floods, volcanic eruptions, landslides, and hurricanes. These disasters can cause profound global change effects and I will focus on volcanic eruption and earthquake changes that I have studied. However, the main focus of the book will be on human-caused global change.

Look around and you see signs everywhere of what humans have done to our Earth. Most of you have also seen news reports, prior to the coronavirus pandemic, of countries where people are wearing breathing filters and the sky is not visible because of smog. You have heard reports about how we pollute our drinking water supplies. You may have felt sadness every time you hear about another of our large wild animal species going extinct. We are losing productive farmland. Summers are hotter and winters colder than when we were young.

Many of these natural (e.g. Sumatra 2004 and Japan 2011 earthquakes) and human-caused global changes have occurred just during my lifetime as an earth scientist. The human-caused global changes give me grave concern

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because I have children and grandchildren that will have to face the consequences of these changes and live in a diminished world lacking the beauty and joy of experiencing the natural environments. My family also will have to live with the natural geologic hazards in their areas and have better protections against them.

Science can provide some answers to these problems, but citizens of the world have to have the political will as well, as has been starkly shown by the 2020 Covid-19 pandemic. For along with any improvements for global change problems is a cost; these may affect global economics and individual living standards. There needs to be a broadened world-view to include not only our own country, but all others as well. These issues are outside the realm of science to address.

Many people try to consider both the scientific and non-scientific aspects of human-caused global change and get caught up on one side or the other causing a large chasm between each other when trying to find solutions. These points of view need to come together for the greater good of our entire Earth.

How does the average person distinguish between science and non-science and recognize the roles of each? Science works by collecting data, the more the better. This often is limited by money and time available to collect the data and we need to be sure there is sufficient funding to collect critical data to understand human-caused and natural changes to our Earth. Scientists review each other's data and find flaws with it. If resources are available, other scientists may try to duplicate and thus verify or refute the data by collecting their own data. Scientists may then develop a "theory", to explain the data, and again this may undergo repeated review and criticism. The theory may then be used to predict what would be expected in similar circumstances.

In contrast, many non-scientific arguments lack data and continued review and scrutiny. It often is emotion-based opinion based on effects to the individual, such as loss of income, increase in production costs, loss of individual freedom etc. So to distinguish between whether a person, or point of view is scientific or not, ask yourself if there has been a rigorous collection of data, scrutiny by many individuals knowledgeable in the field, review and correction, and agreement by the majority of scientific specialists that the data and theory are correct. In this case, science can provide the direction for a solution. If a point of view is not scientific, the arguments will lack background data, a reliable cause and effect relationship in a theory, and responses to questions are repeated mantras. In this case, the response to global change problems requires a more emotional response to recognize and address the non-scientific concerns. As Nate Silver has noted, human-caused

climate skeptics cannot just rummage through fact and theory alike for ideological convenience, but must weigh the strength of the new evidence against the overall strength of the theory (Silver [3]). Cherry-picking scientific data to suit your beliefs is not an option to solve global change problems.

A great deal of the loss of human life and property can be avoided if global scientific studies are conducted and applied to warn people and plan for natural catastrophes. Similarly, human-caused global changes do not have to take place if humans unite, take intelligent control of our lives and choices to evolve towards a sustainable use of the earth's resources for future generations. This evolution will be most important for the developed countries that use the majority of the resources. Underdeveloped countries already face these oncoming changes. There are conflicts related to resources, the worst catastrophes take place related to extreme weather conditions of severe hurricanes, floods, and droughts, and these countries suffer from a lack of scientific knowledge about natural catastrophes.

An important purpose of this book is to point out that because many humans now live in cities in the developed world, there is an increasing disconnect with the natural world compared to a century ago when most people lived on farms. The rapidly advancing technology has resulted in people believing that technology can solve all of the global change problems. However, we still live in the natural world and need air to breath, water to drink and soil to grow our food. We still face natural catastrophes such as the recent earthquakes and tsunamis in Sumatra (2004) and Japan (2011) or floods in Houston (2017), hurricanes in the Caribbean (2017), and wildfires in western North America (2017, 2018, 2020). Some of these catastrophes are bringing human development into conflict with known natural processes. For example, the destruction of the Fukushima nuclear power plant occurred in the 2011 Japanese earthquake, even though earth scientists had warned that the world's strongest type of earthquakes were possible and they had shown that similar tsunamis struck these power plant sites about every 800 years (e.g. (Minoura et al. [2]; Goldfinger et al. [1]).

An additional purpose of the book is to show the importance of understanding both natural (e.g. 2011 Japanese earthquake) global changes in Part l and human-caused changes (e.g. global warming) in Part ll. The Part l memoirs and Part ll also will show examples of how earth scientists do their studies of natural and human-caused changes that are so important for human safety and a sustainable earth. In Part lll solutions for global change problems and a sustainable earth are suggested.

A bottom line purpose for the book, as shown in Part III, is that we need public education and political interest to support natural science investigations to assess natural and human-caused global changes so that we can reduce unnecessary deaths and find sustainable ways for the human population to continue to survive on our Earth. At present, the budget cuts since the 1970s have reduced USA federal research in science. For the most recent example, note how the budget cuts have hurt the health sciences and compromised the USA ability to cope with the covid-19 pandemic.

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Part I

The Journey

2

First Lessons in Global Change

2.1 Youth Adventures

Several experiences with extreme weather were my first exposure to possible global change while growing up in the Minnesota River valley within tornado alley of North America. The first was with lightning on a summer day in 1946. A severe thunderstorm was taking place in North Mankato, Minnesota. Our whole family was eating lunch together in the kitchen. Lightning struck our house radio aerial and a fireball came down through the kitchen. Of course we were all terrified and ran out of the room to the living room, however at that time lightning again struck and split the tree in our front yard. When assessing the damage, we found that a fist-sized hole had been burned in the back steel plate of the stove and the frying pan on the stove had a hole melted through it that had sealed up. My sister still uses this pan today.

Do not believe that lightning can only strike once because I had many other experiences with lightning strikes. The second even more frightening experience occurred while my father, brother and I were backpacking in the northern Minnesota canoe country. We had portaged through two lakes and were standing on a large outcrop of granite on a gray day without rain. Suddenly, a bolt of lightning grounded on the granite block that we were standing on. The explosion of the lightning strike blew us apart. I looked up from lying on the ground to see my father and brother also lying on the ground about 3 m (10 feet) away from me. I thought they were dead, but then they too woke up and we started shaking together. We all had numb

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legs for the rest of the day and my brother's steel brace for polio was very hot, but did not burn him. Two later times in my life I was on planes that were struck by lightning, but there were no problems with the plane.

A second encounter with the extreme forces of nature also occurred during my early youth. During another severe storm, a tornado passed within a block of our house. We could hear it roar by, but we had no damage other than destroying my favorite woods to play in. Unfortunately, the tornado skipped to the other side of town and nearly 30 people were killed. I still remember seeing truckloads of injured people being carried through the streets to hospitals. Fortunately, the science of meteorology has advanced greatly and now accurate storm forecasts are made so that severe weather can be traced almost block by block through a town.

Unfortunately, these advances and the importance of science do not seem to have been recognized by some politicians. During the 1994 contract with America by the USA Congress, the head of a science committee wanted to eliminate the US Weather Bureau, which of course provides weather information for everyone including news outlets. When asked by a reporter how he would get the weather reports, he replied that he would just turn on the TV. Even in 2019 a non-scientist was nominated to head the US Weather Bureau and he wanted to privatize it. Privatization will greatly increase costs to taxpayers and cause a loss of scientific expertise that has taken decades to develop. This points out the severe ongoing problem with the lack of scientific knowledge or deliberate lying about scientific facts by some politicians, such as those who deny human-caused climate change.

From my own experience with the aforementioned extreme storms and the following extreme weather flood event, I have great empathy for what the global population is now facing. In 1950 the Minnesota River flooded the Mankato and North Mankato area where I lived. The river rose rapidly and the efforts to complete levees ahead of the rising river finally failed. The river broke through the levees and followed an old riverbed pathway in front of our house. My father rescued all of our family that he could fit in the car, and the water was rising to the car floorboard when he drove away. However, he had to leave me behind, so I began to carry things up from the basement. Soon rescue workers came by in a boat because the water now was 2–3 feet deep in front of our house and they insisted everybody had to leave. I was taken to the National Guard Armory and joined several thousand other people that had been rescued. My father did not know what had happened to me and spent much of the night trying to find me, which he did much to his relief early the next morning.

This flood was estimated to be a 1000-year flood (i.e. one expected every 1000 years) and kept our family out of our house for three months. After this flood, a much higher river levee was built. Several years later a similar flood took place along the Minnesota River. Fortunately, the levees held in my town of North Mankato, but this was a lesson that a greater number of major floods were taking place along the Minnesota River and its tributaries. Downstream from the Minnesota River, in the following years severe floods also took place along the entire Mississippi River. This increase in major floods from the Minnesota and Mississippi River system may have been a sign of a new pattern of more severe flooding (e.g. Kunkle et al. [15]).

Was my experience of the Minnesota River flood in 1950 a beginning sign of new weather patterns from human-caused global warming, because significant temperatures increases began after 1920 [12]? If you are not familiar with the question of global warming see the detailed explanation in Chap. 5. Each of my early experiences of extreme weather floods, lightning strikes and tornados may or may not have been beginning evidence for global warming. Scientists need to observe long-term multiple patterns of climate change to prove that global warming is part of the cause for the increased intensity of extreme weather events. However, the evidence for more and increased intensity of extreme weather events is building, particularly since the 1990s (see Chap. 5 Sect. 5.7).

Another adventurous experience of my childhood was occasional visits and then spending some summers at my father's original homestead farm near Spring Grove in southeastern Minnesota. My first visits to the farm began during World War II when the farm still had kerosene lanterns and an outdoor toilet, which was not enjoyable to use during the minus 32 °C (−25 °F) weather of a Minnesota winter. However these experiences on the farm gave me a feeling of what it was like to live close to nature like the majority of Americans did during the 1800s. For example, in the late 1940s and early 1950s we still used the McCormick reaper like the 1800s. After the reaper bundled the grain, I would have to take the grain bundles and make shocks. Grabbing these bundles full of thistles cut and stung my sweaty arms. However, it was great fun to be part of a threshing bee where the bundles were taken on a hay wagon to the thrashing machine. The thrashing of grain required a community of around 20 people from neighboring farms. Now when only about one percent of Americans live on farms, there is a loss of this community spirit and a close connection with nature.

A valid question is whether we have gained with the progress of agribusiness. Certainly, we have been able to feed the increase of five billion humans in my lifetime, but this has come at a cost. We are losing topsoil at a much

greater rate than is renewable because of erosion, too much fertilizing, and spraying clouds of pesticides [34]. We no longer have chickens, pigs and cattle grazing naturally in pastures, in contrast to now being caged in buildings or feed lots. Farmers sit alone in their combines rather than working together as a community with their neighbors. Previously, family farms could determine their own destiny, and although subject to market fluctuations, were not feeling out of control by the whims of agribusiness and globalization. A return to the 1970's small is beautiful family farm approach could give many a feeling of more domination over their lives and would help preserve topsoil as well as providing healthier livestock and food sources.

I was lucky to have my farm experience and it proved helpful for my later career in oceanography. At sea, you need farm type experience and resourcefulness to solve problems when you are isolated on a ship in the ocean. It was interesting to find most of my scientific colleagues at the United States Geological Survey (USGS) were of Midwestern Scandinavian and rural backgrounds. In our USGS marine geology group we had two Larson's, Olson, Peterson, Carlson, Johnson, Nilsen and Nelson, as well as other Norwegians like Eittreim and Kvenvolden. I was never sure whether it was the mid-western farm backgrounds, or that we were naive and didn't realize how difficult it was to work seasick on a rolling ship. We did not have many surfer dudes; probably because they realized it was much more enjoyable to sit on the beach and look at the ocean rather than trying to work in storms at sea.

2.2 Beginning Biological Lessons

I had the good luck to have probably one of the best high school biology teachers in America in the 1950′s and he won many teaching awards. Bob Hanlon at my Mankato, Minnesota high school was a pied piper who engaged even the most jaded student. He took students for bird watching in the early morning before classes started. He took some of us to South Dakota and northern Minnesota during school vacations for Audubon bird counts. For the Minnesota Audubon Christmas bird count, we camped out at minus 33 °C (−28 °F), but saw the rare Arctic snowy owl! In the summer after my high school senior year, Mr. Hanlon also took several students and me for a trip throughout Mexico. This provided the opportunity to expand my small town view of the world, observe other environments and see more human impacts on the environment.

One of the ways that Mr. Hanlon engaged students was to have each student report on the number of pheasants that they had shot during their hunting that week. Year by year the total number pheasants dwindled because the farmers were draining their sloughs, which were the prime habitat for pheasants to live in. When I went to my 50th high school reunion, I asked a friend how pheasant hunting was around Mankato and he said there were almost no pheasants left to hunt and you had to go to hunt in South Dakota. When I went to the 60th high school reunion, the Governor of Minnesota was in Mankato to start the pheasant-hunting season, but I am not sure why when there were almost none to hunt.

The fundamental lesson about global change that we learned in Bob Hanlon's advanced biology class was that it takes only one limiting factor, such as a lack of habitat for pheasants, to effect the population of a biological species. The increasing disconnect of humans from natural processes has resulted in a failure to remember this important biological control on any species. Any one of many limiting factor can cause a change and reduction in the population of the species. An analogy for we humans is that we may have all our organs functioning well, but if only one organ like our heart begins failing, this becomes a limiting factor for our life. The same is true for the habitat that the human population exists in. Consequently, if there is not enough water for the human population this will limit the size of the population, or if there is not enough farmland to grow food, the size of the population will be limited.

As a biological species, we humans face a number of limiting factors such as enough unpolluted air to breathe, clean water to drink and land to grow crops for food. All of these limiting factors are increasingly affected by human-caused global change. For example, when lecturing on an ecological tour to Antarctica in 1994, on dark rainy days everyone got badly sun burned and children on South Georgia Island had to go to school using umbrellas because of the human-caused ozone hole over the South Pole region (https://earthobservatory.nasa.gov/world-of-change/Ozone). In another example, many of the USA water supplies contain prescription medications from humans and growth hormones from animals (e.g. [14]). Also antibiotics were present in 65% of the rivers from 72 countries that researchers from the University of York examined in 2019**.** In addition, toxic heavy metals have polluted areas of Chinese cropland, and global warming plus overgrazing by farm animals have destroyed areas of African cropland. The bottom line is that the Earth will survive our human-caused limiting factors, but will the human species? I think the human species can survive if we immediately start planning for a sustainable future.

A second important ecological lesson learned in high school is the carrying capacity of the environment (Fig. 2.1). This carrying capacity is determined by the resources consumed (e.g. water used, nutrients of soils depleted, land deforested etc.) and by the capacity to absorb wastes (e.g. contaminated water, toxic mining wastes etc.). The problem for any population, like the human species, is that if there is a limiting resource factor (e.g. polluted air or water, limited food), the population will decline or become extinct if the carrying capacity of the environment cannot sustain that resource. For humans it is important to realize that since 1950 there has been an exponential growth of population from 2.5 to 7.8 billion people and use of multiple resources (wikipedia.org/wiki/World_population).

There are many examples that the carrying capacity of the earth is threatened for many species (Fig. 2.1). The most recent global analysis estimates that the present species extinction rate is 10 to 100X compared to rates for the past 10 million years (United Nations IPBES [38]. For example, during the past 50 years, half the world's vertebrate species have become extinct (e.g. [5]. We do not want our human vertebrate population to suffer the same fate of decline or extinction because we have not planned for a sustainable use of the finite limited resources and carrying capacity of our planet. And do not

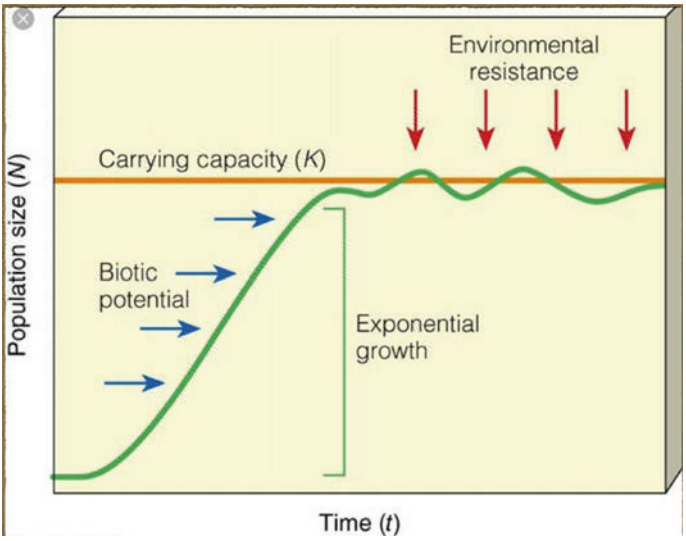

Fig. 2.1 Schematic diagrams showing human exponential population growth versus time with the eventual result that carrying capacity of environmental resources will limit population growth. It is estimated that the carrying capacity for the earth's resources is about 10 billion humans and this will be reached by the end of the twenty-first century [45]. Figure source is https://en.wikipedia.org/wiki/Carrying_capacity