PLANET IN CRISIS

"This meticulously researched book underscores what I have been teaching for decades. Albert Bates illustrates the imperative need to act now before it's too late."
Captain Paul Watson, founder, Sea Shepherd Conservation Society

DARK SIDE OF THE OCEAN

The Destruction of Our Seas, Why It Matters, and What We Can Do About It

ALBERT BATES

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Introduction

I am fortunate these days to find myself in a place where I can swim every day. I head offshore about 250 yards and then paddle along, parallel to the beach for a quarter mile, before returning to where I started. Tucked inside the great Mesoamerican Reef, the shallow turquoise waters in this part of the world are usually safe from sharks and jellyfish. The waves are calmer, making swimming easier on this old body.

We are of the oceans, you and I. Floating in the sea, gazing up into a blue sky, I return to human origins. My cells are from the single-cell life-forms of the sea. Indeed, the amniotic fluid I "breathed" for my first nine months in 1946 had about 2 percent salinity, only about a third less than the ocean.

While we speak reverently of *Madre Tierra* and *Terra Firma*, all life depends on water, the *élan vital,* the universal solvent, *aqua mater.* Our mythology is full of stories of great deliverance—the raising of Mount Ararat out of floodwaters to heel Noah's Ark, the landing of the Pilgrims at Plymouth Rock, George Freeth's heroic rescue of eleven Japanese fishermen caught in a gale off Venice Pier in 1908. In a small fishing village in Japan, they still light candles to remember that deliverance and rebirth.

In the course of this book, I have to reference some significant numbers and long periods. Most of us can't relate when we speak of a billion or trillion of something. We can't wrap our heads around something that big. Also, if I say something could happen in 2050 or 2100, that is difficult to picture because we don't know what the world will look like in 30 years or 70 years. If we look back 30 years, to 1990, the world may not seem very different—but no one had smartphones, few even had email or text messaging, and the World Wide Web did not exist. There were no digital cameras, CDs or DVDs, hybrid cars, GPS, or genetically modified foods. If we go back farther, to 70 years, most households did not have a TV; offices did not have copiers, computers, or coffee makers; and there were no commercial passenger jets, nuclear plants, or a NASA space program. So, how can we possibly imagine ourselves in the year 2100?

To get past that difficulty, whenever possible, I am going to use the example of an eight-year-old boy named Xen. He was born in 2012 and will be 18 in 2030, 38 in 2050, and 78 in 2100. In his lifetime, he will witness a world that changes more each year than it would have changed in decades for his grandparents. The world that exists for Xen today is still the world of his parents. It is what it is, and he has only just arrived.

This book will explore how the oceans are today and how that may change during Xen's lifetime and beyond. We begin with the origins of life, move on to the arrival of early humans and their changing relationship with the sea, and then peer into the depths to see what changes that has caused and what is likely to happen in the future. We look at temperature, oxygen, acidity, ice, sea level, ecosystems, populations, and, finally, how all this affects humans on land. It is a fascinating journey, but one that may also be somewhat alarming, as it should be. Over the past thousand years, humans have set in motion some very unexpected trends. Those trends are now starting to bite us. It is not too late to stop the worst of it if we can act quickly enough, but it will be up to Xen's generation to make those decisions. The time remaining is very short.

As I swim along looking at the coastline, I see massive new hotels and homes of concrete and steel, the materials brought in by barge, literally weighing down the sandy beach, more each day—the sand and gravel from quarries in Yucatán, the steel from China, the cement from factories in distant cities. From where I sleep, I can hear the first barge unload even before the first chirps of the dawn chorus.

Each year, more than 92 gigatons (1 Gt is a billion long tons) of these materials—metals, minerals, fossil fuels, and biomass (mostly food)—are drawn out of the Earth and deposited in coastal places like this. This number is growing at a rate of 3.2 percent per year, doubling roughly every 20 years.

Since 1970, extraction of fossil fuels has increased from 6 Gt to 15 Gt a year; minerals such as sand and gravel for concrete have gone from 9 Gt to 44 Gt; biomass harvested for energy and construction has risen from 9 Gt to 24 Gt, and that production is accelerating now. Land-use change for agriculture, subdivisions, and mountaintop mining accounts for over 80 percent of biodiversity loss and 85 percent of stress on drinking water supply, even without factoring in the fertilizers, pesticides, and herbicides. The entire extraction economy accounts for 53 percent of climate change, even before the fuels are burned. What will it be at the next doubling, expected around 2040, when Xen is 28? Without change, resource demand will more than double to 190 Gt per year, greenhouse gases will rise 40 percent, and demand for land will increase by 20 percent.

Since 2000, we have witnessed what is being called the "blue acceleration." Frenetic economic expansion has placed unprecedented human pressure on marine ecosystems, which are experiencing overfishing, acidification, heat waves, plastics, noise pollution, and radioactivity. But, the rhetoric of a "blue economy," which would combine economic growth with sustainable use, is placing unwarranted expectations on antiquated, complex, and uncertain governance structures.

Jonathan Watts, writing in *The Guardian,* observes that for rich countries, our resource extraction works out to the weight of two elephants per person per year. In emerging countries, it is about the weight of two giraffes, appearing less as second homes on a ski slope or beach and more as smaller items like mobile phones. The piles of materials that went into making these objects are invisible to the consumer.

The UN's Sustainable Development Goal #8 calls for "sustained and inclusive economic growth," which it proposes to accomplish by expanding access to financial credit to create more jobs. Looking at this from a biological perspective, in any ecosystem—and human-dominated ecosystems are no exception—individuals and institutions can only exist at a scale determined by biophysical limits. Whenever limits are uncertain, it is better to err on the side of caution than to suffer collapse. In any system, production and consumption are a balanced pair. Overproduction without consumption creates waste and pollution. Overconsumption without compensating production sets up a system crash.

For more than the past half century, *ecological* economists like Herman E. Daly, Manfred Max-Neef, Hazel Henderson, and Robert Costanza have proposed a useful substitution for *both* production and consumption. Instead of viewing higher-intensity consumption or successful shopping trips as appropriate societal goals, these economists suggest that after meeting basic human needs we could focus on supplying subjective well-being, which will not be found in ever-greater material extraction, but instead in the pursuit of enjoyable lives that do not tax the planet's regenerative capacity.

That kind of economy would be much better for the health of the ocean too. But whatever we do, something needs to change, and soon.

The ocean has absorbed more than 90 percent of the heat humans have added to the Earth's system since the Industrial Revolution. The Arctic is poised for "blue ocean," ice-free summers sometime in the next decade. Even if, through a combination of sharp emissions reductions, biochar, and reforestation, we were to bring greenhouse gases down to where they were 200 years ago, it would take thousands of years for the ice in Antarctica to form again. In the meantime, a combination of all that melted polar ice and the thermal expansion of water means that the 1.9 billion people who live on or near a coastline (about 28 percent of the world's population) may have to relocate.

The ocean plays a significant role in regulating climate and weather. As we shall see later in this book, that means we can anticipate increased marine heat waves, coastal flooding, extreme tropical events, and wildfires. What happened in Houston in 2018 and Australia in 2019 through 2020 is only a preview.

Changes in ecosystems, such as ocean oxygen, acidification, and sea ice loss, have caused ocean animals to migrate in search of new food sources. Local and global extinctions are cascading. Because of overfishing and pollution, the ocean's health as a living organism is in peril. That will have a dollar cost, currently put at $428 billion per year by 2050 and $1.98 trillion by 2100. When so many species suffer, the effects ripple out to the entire biosphere, affecting us all.

Adaptation and conservation measures will determine survival for many species. Individuals, organizations, and governments need to increase efforts to build resilience. Politicians need to become leaders in cutting carbon emissions and protecting their local constituents with better environmental regulations.

There are many things we can do. Blue carbon initiatives prohibiting deep-sea mining, replanting mangroves, protecting salt marshes and seagrasses, curtailing cruise ships and trawlers, and restoring coral reefs give multiple co-benefits. We know how to do these things, and we know it is more cost-effective and financially rewarding to do them soon rather than wait. Let's get going.

CHAPTER 1

We Are the Salt of the Sea

If you were to wake up one morning and all you saw around you was a vast expanse of open ocean, that would be an average landscape of the Earth. Our tiny planet, orbiting around its sun and slowly rotating, shines blue against the blackness of space because of all this water.

Seven-tenths of Earth's surface is water, and 97 percent of that is in the ocean. Before we knew any better, we gave the parts of this big wet thing names like Atlantic, Pacific, Indian, Arctic, and Southern, but those are just descriptions of its regions because it is all one single ocean. At its deepest, it is deeper than Mount Everest is tall. At its broadest, it crosses 13 time zones from beach to beach.

If we removed the seas and walked down into the dry basin, we would be, on average, about a mile deeper than the beach where we started. The bottom would not be a bowl, however, but a varied terrain of mountains, valleys, canyons, and giant boulders.

When you put back the water, you immediately notice it is not still but has strong currents moving one way or another: sideways, up, and down. Those currents have been so strong in some places and at some times that they have rolled a few of those giant boulders up onto a beach and left them there to dry.

Let's use the example of our young man named Xen again, because we need to talk about the size and age of the world in relation to mere humans.

Long before there could even be an eight-year-old boy, more than four billion years ago, when the Earth formed, you could think of it as a spongy rock. The sponginess was because it was not solid, but moist—nearly all its water embedded in pores in the red-hot rock. As it cooled, a process that took at least a billion years (so far, because it is still going on), a lot of that water condensed into a thin skin covering the rock's cooler external surface. You can think of it like the skin on an apple. Even though Earth's ocean can be up to four miles deep in places, our ocean and watery atmosphere are still just a thin skin compared to the size of the planet. We call our planet's skin the biosphere.

About half a billion years after the rock formed, the first microscopic seeds of life began, somewhere in that condensing biosphere. They likely began as something we would today call a bacterium, which could feed itself and reproduce by breaking apart CO_2 into separate molecules of oxygen and carbon, using the energy of sunlight.

Today, with the latest genetic sequencing devices and DNA libraries, we can trace the origins of modern bacteria to these ancient ancestors and then to the formation of the first protein strings. The genetic sequence, as it evolved by trial and error, formed a record, a kind of clock, that we can run backward to learn when different proteins took shape and how organisms eventually came to look the way they do today. Gradually, proteins fit together, absorbed and shed oxygen and nitrogen, and added carbon to themselves to grow more of themselves, which is to say they "ate," inhaled, and exhaled, so much so that over the next few billion years they filled the atmosphere with compounds of oxygen and nitrogen and created the ideal conditions for more complicated forms of life, such as Xen, you, and me, to exist. Other green and purple bacteria came along to eat, exhale, or excrete various combinations of hydrogen, sulfur, iron, calcium, sodium, molybdenum, and other nutrients, and in the process created webs of differentiated single-celled organisms that set the stage for the next great leap in evolution—multicellular organisms.

Beginning about 542 million years ago, and over the next 20 million years, there was a biological explosion—a proliferation of thousands upon thousands of new and different forms of life. Many of the ancestral creatures went extinct, although some of the world's oldest—lobsters, crabs, millipedes, spiders, and some flying insects—still survive. Plants also evolved rapidly and covered the land with ferns, mosses, conifers, and flowering, seed-bearing varieties of all shapes and colors. As their roots extended into the ground, they formed beneficial relationships with the soil microbes that converted minerals into food and released nitrogen, phosphorus, potassium, and other elements that found their way back to the ocean, fertilized the marine food chain, and made it possible for the evolution of larger animals, like swimming dinosaurs and giant sea turtles. As recently as five million years ago, sharks the size of whales roamed the seas, with teeth the size of little Xen.

Five mass extinctions caused the vast majority of species that evolved to disappear, and the worst of those events, so far, came 251 million years ago at the end of the Permian Era, when more than 90 percent of ocean life and two-thirds of land species disappeared from the fossil record. That extinction event may have begun with a half-million-year outbreak of volcanoes. As the lava flooded an area of 620,000 square miles in what is today's Siberia, it burned away peat and coal deposits and released enormous volumes of carbon dioxide, which over thousands of years warmed the Earth 6°C (11°F). The ice at the poles melted, and the oceans rose. Vast deposits of methane frozen undersea or in permafrost warmed and bubbled up into the atmosphere, causing a runaway warming that fed upon itself. Land plants withered, and deserts formed. The ocean became acidic from all the CO_2 and methane it had to absorb. Corals, sea urchins, sponges, and shelled animals died. While this event nearly wiped life off Earth entirely, it eventually subsided short of that, and over the next 10 million years, corals revived; sea urchins, sharks, and turtles returned; and new species filled the oceans and spread across the land.

Our ancestors began in aquatic environments and, like salamanders and mosquitoes, passed from something like gill breathing to air breathing. When animals emerged from the ocean to live on land, they needed lungs—to take oxygen into their blood and exhale the wastes of cellular metabolism to keep the body's elements in balance.

Ecosystems have a balance to maintain, as well. They have stomachs and lungs much as we do and also have to eliminate, or at least recycle, their wastes. Throughout evolution, these systems moved from very simple, growth-oriented, trial-and-error functioning to more sophisticated, steady-state relationships of very diverse and complex groupings of plants, animals, and microbes.

Keystone species are those upon which entire ecosystems rely. While every species is important to its ecosystem, if you take a keystone species away, the system can crumble. Marine animals form relationships with each other that help define their roles. Two organisms might have a predator/prey relationship, like a sea otter and a sea urchin, or they might have a friendlier sort of relationship called mutualism, like when a cleaner wrasse cleans a moray eel's mouth by snacking on the stuff between the eel's teeth.

When we evolved from reptiles to land dwellers, we needed to develop a colon to retain and conserve our internal body fluids. The colon gave us time to remove excess water from digestive wastes before expelling them. Our more transparent marine skins needed to adapt to shield the body from stronger solar radiation, especially ultraviolet, and to better regulate heat, using hair follicles and sweat glands. Inside our organs and glands, however, are a facsimile of the microbial communities we evolved with in the ocean. Each of us has millions of tiny microbes living within and between our cells to help us digest our food, transfer oxygen to our blood, move electric signals to our brains, and communicate with the microbial world outside.

Our blood is salty like the sea for a good reason. Blood is a private ocean that mirrors what life was like for microscopic, single-celled organisms that dominated the first billions of years of life on Earth. The watery portion of blood, the plasma, has a concentration of salt and other ions that is remarkably similar to seawater.

Seawater is the circulatory system of our planet. When Earth gets a fever, her blood runs hot, and she responds by perspiring (casting off more heat to space and making more rain), taking deep breaths (more absorbed carbon dioxide and fiercer winds), and drinking more water (melting ice, floods, and super-typhoons).

When we and other animals left the ocean, we chose to carry water with us as an internal store since we could no longer be sure of a continuous supply. Our skins converted our bodies into portable canteens. Today, over 70 percent of us is water, and the lymph system is the internal ocean we carry about with us. All our organs float in this sea of fluid; our intracellular pericardial blood, cerebral, and spinal fluids are fed by electrolytes regulated by our kidneys. Our respiratory tracts—nostrils, sinuses, trachea, bronchi, and lungs—and digestive and reproductive systems are lined with another saltwatery ring of protection, our mucous membranes.

Some creatures returned to the ocean some 50 million years ago after having already evolved to mammals resembling dogs or cats. Earlier in their evolution, without water to provide buoyancy, these animals had lined their skeletal joints—including between vertebrae—with synovial tissue to pad and lubricate joints against the greater force of gravity. Once freed of the gravity of land, their pelvises reduced in size and separated as their vertebral columns extended to improve locomotion. Because of this, dolphins and whales swim with horizontal tail fins that move up and down, rather than back and forth like the vertical tail fins of fishes. Their backbones bend up and down like those of dogs or cats when they are running.

Humans share with elephants, iguanas, turtles, marine crocodiles, sea snakes, seals, and sea otters our ability to weep salt tears. Of the various salts found in solution in our bodily fluids and the ocean, by far the commonest is table salt, or sodium chloride (NaCl). On average, there is slightly more than 6 milligrams of NaCl dissolved in each milliliter of our tears' lacrimal fluid. Average ocean salinity is 3.5 percent, or nearly six times our tears (35 mg/ml). Most of that salt is the same as in our bodies—sodium chloride.

More than 80 percent of ocean pollution comes from land-based activities. As chemicals from agriculture and other human activities wash from land, they increase the ocean salinity. The saltier a body of water is, the less likely it is to absorb carbon dioxide from the atmosphere, and the more likely it is to give it off. This absorptive capacity is a crucial recovery element at the end of ice ages, when salinity peaks due to ice impoundment of fresh water from rain or snow, causing more CO_2 to off-gas to the atmosphere and to positively force the greenhouse effect, rewarming the world. It is not, however, an effect we want to be encouraging when we are trying to reduce global warming.

From coral bleaching to sea-level rise, entire marine ecosystems are rapidly changing. We can see many of these changes in newspaper headlines and scientific reports:

- Many pesticides, fertilizers, and animal pharmaceuticals end up in rivers, coastal waters, and the ocean, resulting in oxygen depletion and toxins that kill or maim marine plants and shellfish.
- Factories and industrial plants discharge sewage and other runoff into the oceans. This, too, results in oxygen depletion and toxins that kill marine plants and shellfish. In the US, sewage treatment plants discharge twice as much oil each year as tanker spills or drilling disasters.
- Oil spills like Deepwater Horizon and nuclear spills like Fukushima pollute the oceans, although air pollution is responsible for almost one-third of the toxic contaminants entering the water.
- Microplastics—dumped by cruise ships, spilled from container ships, or making their way via land or river from factories and garbage dumps—will soon outweigh all the fish in the sea.
- Countless plants and animals, including invasive species such as poisonous algae and cholera, have crossed the border between land and harbor waters and disrupted the ecological balance, due to transoceanic commerce and other human activities.
- Many kinds of seafood are either fished to capacity or overharvested As the climate rapidly changes and microplastics take their toll, the ability of fish to replenish their populations is dropping dramatically, leading to fishery exhaustion, fish extinctions, and wider famines, seen and unseen.

The ocean is not merely our birth home; it sustains us now. It is possible to live within its limits and the limits of the good Earth. The sooner we can learn how to do that, and get on with it, the better off we will be.