# WATERS IN PERIL

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# Chapter 12
# MARINE BIOLOGICAL DIVERSITY: CONSERVING LIFE IN THE NEGLECTED NINETY-NINE PERCENT


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## THE HISTORY OF MARINE CONSERVATION BIOLOGY

Marine conservation biology is a synthesis whose time has come. As a marine scientist striving to promote the development of this new science, I have taken as a model the multidisciplinary science of terrestrial conservation biology, a growing scientific field that has made an enormous contribution toward resolving complex questions that traditional disciplinary approaches had shed little light on. For example, before the advent of conservation biology, traditionally trained silviculturalists could inform us on yields of board-feet of timber, but they could not tell us about the demography of spotted owls or describe the relationship between owl populations and the distribution of trees. Likewise, landscape ecologists could look at patterns of landscape features but they could not explain how those patterns reflected the genetics of tree populations. Such phenomena seemed to be unrelated until terrestrial conservation biology brought together zoologists and botanists, pure scientists and applied scientists, and natural scientists and social scientists. As a synthetic science, conservation biology has achieved a great deal for land conservation in the United States and elsewhere. Marine conservation biology is about twenty years behind conservation biology on land, but hopefully this fledgling discipline will catch up and make contributions on a similar scale in the marine realm.

All my life I have been fascinated with the processes that generate nature's patterns. During my training as a marine ecologist, for ten years I studied blue crabs of the genus *Callinectes* in the Caribbean and tropical Eastern Pacific. I examined the comparative ecology of the species of this genus and discovered that as many as seven species live sympatrically in some locations in the Caribbean. This experience taught me a lot about diversity.

At the same time I became interested in another aspect of diversity: its loss. As a student I read stories about extinct species such as the dodo bird, a fifty-pound pigeon that was indigenous to one island in the Indian Ocean. Dutch and

Portuguese sailors discovered the dodo in 1598 but over the course of about a century — a mere wink of an eye in evolutionary terms — it became extinct. Reading about the extinctions of dodos, Atlas lions, Caspian tigers and other animals convinced me that it was worth dedicating my life to understanding what was causing these losses of species.

## EARLY CONSERVATION ETHICS

When I entered the field in the 1970s, "conservation" was about producing greater quantities of commodities that could be shot, hooked, or cut down. This utilitarian ethic is a very pragmatic way of looking at the world. A little thinking suggests that this approach leaves a lot out, specifically, the vast majority of living things. Unfortunately this "conservation" ethic from thirty years ago is still widely held by many people.

Another conservation ethic came of age in that era. It became embodied in the 1973 US Endangered Species Act. The central idea of this second ethic is that all living things are important, and we should not be causing them to disappear, whether or not we desire to make immediate use of them. This considerably more-evolved ethic removes humans from the anthropocentric position of being at the center of the world and makes us instead one among many species.

However, the Endangered Species Act (ESA) also has a pernicious aspect in that it applies lower standards of protection to invertebrates and plants than to vertebrates, our closest relatives. This amounts to another, albeit more subtle, sign of anthropocentrism. Nevertheless this ethic underlying the ESA was a significant advance, for it signified that Americans did not want to cause California condors, pig-toe mussels, and myriad other species to disappear from Earth.

But as important an advance as the endangered species ethic is over the utilitarian ethic, it has another, even more serious problem. To wait for a species to reach the verge of extinction before starting to work on its conservation is akin to basing a health care system on intensive-care units. We cannot afford such a strategy. To be effective, it is necessary to use a more proactive approach.

## THE LOSS OF BIODIVERSITY

In December 1979 I began working for President Carter as Staff Ecologist on the President's Council on Environmental Quality (CEQ). This put me in a position to learn things that are common knowledge now but were new and alarming at that time. One such disturbing situation was the ongoing, remarkably rapid disappearance of tropical forests. The scale and rate at which humans are logging trees and burning forested lands had, and continues to have, momentous consequences, because tropical forests are believed to harbor more species of living things than any other ecosystem on Earth. Thomas Lovejoy, Peter Raven, Norman Myers, and other biologists predicted that the widespread loss of tropical forests would cause an enormous spasm of extinctions.

When my supervisor at the CEQ asked me to write a chapter discussing the loss of life on Earth for the 1980 CEQ Annual Report, I thought it was an awfully big topic and asked if he meant for me to cover the extinction of species. He replied that he did, and I pointed out that species losses was not the only problem, that we also needed to discuss the loss of genetic diversity in our crop varieties and livestock. My assignment grew bigger when my boss agreed I should include that topic as well. But with a little further thinking we concurred that, with whole ecosystems disappearing, I also needed to include that broader topic. Indeed, what we were concerned about was the loss of diversity at *all* levels of biological organization, that is, the loss of biological diversity.

The concept of biological diversity, or "biodiversity" has germinated from a little seed, sprouted roots, and taken hold. Thomas Lovejoy, Michael Soulé, Paul Ehrlich, Edward O.Wilson, and many others have been instrumental in making the concept almost a household term. It has become a driving force in conservation worldwide. When I hear talk about "harvesting" natural resources, a little light goes on in my head and flashes the message: Biological diversity has not penetrated here yet; we have some work to do.

## TYPES OF DIVERSITY

Twenty-two species of kingfishers inhabit New Guinea, while the Pacific Northwest has only one. The lesson here is that the diversity of species varies enormously from one place to another. This middle-level species diversity or richness is the most familiar component of biological diversity; the one that some people equate with biological diversity. But there are two other essential levels of biodiversity: below and above species diversity are *genetic diversity* within species and *ecosystem diversity.*

For example, all the varieties of tomatoes we know belong to a single species. However, the tomato genome contains genetic coding for gigantic and tiny sizes; red, orange and yellow color; late and early maturing; determinate and indeterminate growth; high-solids and low-solids content; and so forth. All this is part of the genome of one species. We have taken advantage of this genetic diversity to artificially select for the attributes we like, so that we can have both ketchup tomatoes and slicing tomatoes.

So it is with wild species. The diversity in the genomes of wild species is the raw material for natural selection, indeed the raw material for evolution. Protecting genetic diversity *within* species has received much less attention than protecting species diversity. I think it deserves a lot more emphasis. In the Pacific Northwest, where salmon runs are disappearing one after another, for instance, the consequences of the loss of genetic diversity are serious.

The highest level of biodiversity, *ecosystem diversity,* is perhaps the hardest to comprehend because it encompasses species composition, spatial structure, and functioning. Functioning refers to processes such as nitrogen and carbon fixation and energy flow. Ecosystems differ in these functions. These differences are part of ecosystem diversity, a real phenomenon that merits conservation just as species and genes do. The power of the concept of biological diversity is that it conserves all hierarchical levels of biological organization that are relevant, from genes to species to ecosystems, from the microscopic level to the biosphere.

## NINETY PERCENT OF THE EARTH'S SURFACE IS MARINE

When I talk before the general public I usually point out something that makes people scratch their heads and wonder what I have been drinking that morning: about nine-tenths of the planet's surface is effectively marine.

The reason I say ninety percent, and not seventy-one percent as most people state, is that we must also include the places with marine drainage. If you spray pesticides or drain your crankcase oil on land anywhere that eventually drains to the sea, those materials will eventually be washed into streams, rivers, estuaries, and oceans. In a biogeochemical sense, the sea is largely downhill from the land. Only in a very few cases, such as with anadromous fishes — for example, salmon — do organisms incorporate elements and compounds from the sea that end up on land. The much larger biogeochemical pathway brings substances, including benign ones such as salt and toxic ones such as polychlorinated biphenols (PCBs), from the land to the sea. In other words, the sea makes up more than 90% of the Earth's surface, not just the 71% that we read about. Even people in Saskatoon or Kansas City are in a marine drainage.

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## TERRESTRIAL AND MARINE BIODIVERSITY

In 1986, I was drafted to write a book about forests that led me to write yet another book on forests. I had never had training in forests and did not know a lot about the topic but I learned quickly at the feet of masters such as Jerry Franklin and Dave Perry. I trailed the smartest people I knew and asked them a lot of questions and learned a lot. In some ways that may seem like a digression but it has proved to be very useful in work on my real love, marine biodiversity, the patterns and processes in marine systems and the factors that are causing their loss. Later, I had a wonderful opportunity to edit a book on marine biodiversity with contributions from 106 authors. The book's sponsors were the Center for Marine Conservation, World Wildlife Fund, World Conservation Union, World Bank, and the United Nations Environment Programme. It was used heavily in discussions on the UN Convention on Biological Diversity and it is used domestically in the USA. It looks at conservation extensively and the conservation of biological diversity comprehensively.

I learned many things while editing this third book. One was that despite the notion that loss of biological biodiversity is thought to be a terrestrial issue (that is, it happens only in forests), it happens in the sea as well. Stories such as that of the Steller sea cow, tell us that loss of biological diversity is a marine issue of considerable importance. Steller sea cows were once very widespread, inhabiting a range that included the waters off Japan and California. But as people increasingly populated the North Pacific Rim, the range of the Stellar sea cow diminished. By the time Europeans "discovered" this creature in 1741, it occurred in one little redoubt in the Komandorskie Islands at the tip of the Aleutians. People very quickly eliminated sea cows. The Russian and German sealers killed them in considerable numbers to provide delicious food for themselves while they were killing North Pacific seals to provide coats for people in Europe. The Steller sea cow was driven to extinction only 27 years after its discovery by Westerners, and it is emblematic of the stories that surface again and again when we look at what has happened to biodiversity in the sea.

## THREATS TO MARINE BIOLOGICAL DIVERSITY

There are five major proximate threats to biological diversity in the sea, which are driven by five driving forces: population growth, growth in consumption of resources, institutions that degrade rather than protect biodiversity, insufficient understanding of living things, and our failure to adequately value living things. Stated more directly, there are too many of us who consume too much. Our institutions do not do the job of protecting, we do not know enough, and we do not care enough. We humans drive overexploitation of other species, physical alteration of the environment, pollution, introductions of alien species and global atmospheric change.

When I first got into marine conservation, the dogma was that there were only two major threats to marine biodiversity: overexploitation and pollution The others did not even deserve mention. However, there is ample evidence that suggests physical alteration is a real concern, and there are other factors as well. Let us consider them individually.

## OVEREXPLOITATION

Overexploitation came to the attention of the general public in the United States — and I assume that is true of Canada as well — as a result of the processes that were driving great whales to the verge of extinction. Colin Clark, a mathematician at the University of British Columbia, did a brilliant analysis showing, for example, the sequential overexploitation of great whales in a pattern that was very obvious to him, but seemed to have been missed by others. He found that humans took the biggest whales first, and when we drove their populations below the point of commercial extinction, we started taking the next biggest whales, and so on, until the biggest, the blue whales, were essentially gone.

This was a very important mobilizing process in the marine conservation movement but it was truly only the tip of the iceberg because overexploitation affects a lot of organisms, not just the great whales. Consider for example, invertebrates. The Triton trumpet snail that feeds on echinoderms in the Western Pacific has a price on its head. The price in this case is $100. That was the retail price in a store in Cairns, Australia. In the Philippines, where the snail comes from, it might have represented $5, possibly one-sixtieth of the annual income to the fishing family that found it. That is a lot of money, a very strong incentive for people to take every single Triton trumpet snail they see and sell it to a middle man, who then sells it to Australian shops that market the shells for $100 apiece.

But $100 is far from the highest sum one can pay for a marine organism. The record as far as I know goes to bluefin tuna. In his wonderful book, *Song for the Blue Ocean*, Carl Safina reports that not long ago a bluefin tuna sold for $83,500 US in the market in Tokyo. It was a very big fish, 700 pounds, but that is a pretty fair bit of change. With such a price on its head it is almost impossible to get people to conserve this species. Think of it this way: One fish sells for more than a professor's salary at most universities.

Fishes such as groupers also fetch a high price (though not as overinflated as the bluefin tuna). Groupers are one of the many types of fishes that are disappearing from the seas at an alarming rate. They have a peculiar population biology in that many, perhaps all, of them are protogynous hermaphrodites, meaning that they start life as females and end life as males. It is inevitable that the more groupers we kill, the more we are altering the species' sex ratio. We are effectively eliminating the males in the population because most groupers do not survive to the stage at which they turn into males. Groupers once reached the size of sheep and snappers grew to the size of turkeys. Today most groupers and snappers in warm waters around the world are small enough to fit in a frying pan. We are bringing about profound changes in the populations of these organisms, and it is all too possible that the outcome could be extinction.

What are the indirect effects of overexploitation? One is the creation of new types of marine ecosystems, or a greater prevalence of ecosystems that, to our knowledge, existed on much smaller scales than in the past. For example, sea-urchin barrens develop when sea urchins reach such high population levels that they overgraze the kelps on which they feed to the vanishing point. This overgrazing dramatically changes the composition, structure, and functioning of the system.

The question is, why does this happen? In many cases it occurs because we remove the predators that control sea urchin populations. Urchin predators in the tropics include hogfish, triggerfish, and off the West coast of North America, sea otters are important urchin predators. The particulars of the story varies, but the general principle holds that removing the predators of a dominant grazer allows the grazer population to increase and overgraze the system. It is a finding that is very robust.

Jim Estes, a conservation biologist from University of California, Santa Cruz, has reported the steep decline of sea otters in the Aleutian Islands, which suggests overgrazing by sea urchins will occur there. This situation represents a long chain of causality. Estes believes that sea otters are disappearing because killer whales are eating them. Killer whales formerly preyed on Steller sea lions, which have been disappearing for the last two decades in western Alaska. This is apparently related to the changes in fishery economics and/or oceanographic features in the region. It is hard to tease out these two probable causes. It could be overfishing, or an oceanographic regime shift, or some combination of the two.

From what we can tell, the chain of causation looks like this: Some natural or anthropogenic occurrence is diminishing the populations of Steller sea lions. This has caused some killer whales to shift their predation to sea otters, dramatically depressing the sea otter population. This in turn decreases otters feeding on sea urchins, which leads to an increase in their numbers, which decreases the growth of kelps. The loss of kelp decreases the populations of fish and invertebrates living in kelp forests. All life is connected, whether tightly or tenuously. Biological diversity is not just about saving the parts of nature; it is about processes, the connections between living things.

## ALTERATION OF ECOSYSTEMS

Much of the coast of North America has undergone physical ecosystem alteration, with profound consequences for biological diversity. Often some of the most important physical alterations of marine biodiversity do not even occur in the sea; they happen on land. Consider the logging of ancient coastal forests, on slopes too steep to stand on, at sites in Washington and British Columbia. Horrendous consequences to the land spread to the sea in the form of massive siltation, nutrient pollution, and other harmful effects. And once such physical alteration of ecosystems has occurred, you do not find the same species.

Some 2,500 years ago Plato remarked that the land of Greece had been stripped of its forests and its soils, revealing the bones of a decaying corpse. We are still turning our land into a corpse today because we have not learned an elemental lesson in physics: When you denude the land of its vegetation cover, gravity asserts itself and soils wash downhill. In many marine ecosystems around the world, one of the worst threats is siltation from farming, logging, housing development, and construction of transportation infrastructure. The land and the sea are linked: The destruction of a forest or construction of a golf course can devastate coral reefs offshore.

## POLLUTION: CHEMICAL DISCHARGES AND LOST FISHING GEAR

Chemical pollution is another threat to the well being of marine ecosystems. Even now, long after the passage of the Clean Water Act in the United States, coastal industrial plants pump out toxic discharges that have both lethal and sublethal consequences. For example, in Los Angeles harbor I once examined white croakers in the inner and outer harbors. I found that while white croakers in the outer harbor had a low frequency of anomalies, a large fraction of croakers in the much more polluted inner harbor had fin rot. In more polluted areas of Puget Sound a substantial population of the fishes now have liver tumors. These fishes are telling us something very important (see Burkholder, this volume).

However, pollution is not only about invisible substances carried in water; it also includes stuff that you can see. One kind of solid waste of special concern is the cause of "ghost fishing."

Fishing used to involve people going out in wooden boats, powered by the wind or the arms of the fisher, and using lines or nets made of hemp or other degradable natural fibers. Because the sea was enormous and the boats were small, the fish had a fighting chance. But everything in the game has changed in modern times. Now the boats are large to huge, made of steel, powered by

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fossil fuels, equipped with satellite navigation systems and freezers, and they use synthetic, non-biodegradable nets. When fishermen lose their equipment — as inevitably occurs — the nets continue to fish for years, decades, perhaps even centuries. Generations of animals disappear in nets that continue to catch fish even though they are no longer providing an economic return to the fishers. It is a serious and tragic loss of marine life.

## BALLAST WATER AND ALIEN SPECIES INTRODUCTIONS

Some bad things are one-time events; others just keep on hurting us. In Aberdeen, Washington, as in many other ports, ships fill up with logs taken from North American forests. In a world extolling free trade this is seen as a good thing. The ships cross the Pacific to places where people consume wood, but do not want to produce it. They have other land uses that have priority. So they use Canada and the United States to produce their raw materials, then send the ships back to North America. Without cargo the ships would sit high in the water and be "tippy." So the crew fills the ships' ballast tanks with water, from five to fifty million gallons of water. When the ships return they discharge their ballast tanks in North American ports, and in doing so they introduce billions of living organisms ranging from the cysts of dinoflagellates and algal spores, to the larvae of invertebrates and fishes. Around the world scientists are noticing a homogenization of the marine biota in our ports. It is another means by which we are losing biological diversity (see Ruiz and Crooks, this volume).

Notice I am saying losing, not gaining, because you can not gain biological diversity artificially. You do not introduce new species to an area and say we have come out better. You come out worse — automatically. What has happened in the case of ballast water, is that many organisms that are considered "cosmopolitan" only appear in the world's harbors.

Jim Carlton, a leading expert on marine alien species has told me that a new species of shrimp showed up in Pearl Harbor, Hawaii, the main staging area for the US Navy shortly after the war in Vietnam started. How did it happen? The naval ships going back and forth between Cam Rahn Bay and Pearl Harbor were discharging foreign organisms into Pearl Harbor that they had picked up in Cam Rahn Bay. Another introduced creature was a cone jelly native to the East Coast of North America that first appeared in the Black Sea in 1982. By 1989 its biomass in the Black Sea was estimated to be approximately ten times the world's marine fish catch. Since *Mnemiopsis* is a predator, it is not surprising that the organisms it feeds on showed a response. The fishery for sprats, a herring-like fish, went from maybe 80,000 tons annually to zero in that time that the *Mnemiopsis* was becoming an abundant organism.

The European green crab, *Carcinus maenas*, is another introduced animal with worrisome effects. Green crabs are voracious predators of invertebrates, including economically significant crabs and mollusks. Green crabs appeared in San Francisco Bay around 1989 and began spreading northward to Bodega and Humboldt Bays in California (see Ruiz and Crooks, this volume). By the late 1990s the green crab was in Coos Bay, Oregon, and Grays Harbor and Willapa Bay, Washington. Is the next stop Puget Sound? And after that the Strait of Georgia? A pest species like the green crab has many and varied consequences, not only for commercial fisheries, but for a large number of other species not viewed as resources, because their populations are affected one way or another by invading green crab populations.

## GLOBAL ATMOSPHERIC CHANGE

Finally there is the "big picture" threat to marine biodiversity: global atmospheric change, which includes stratospheric ozone depletion — the ozone "hole" is bigger than ever — and global climate change. An aspect of global climate change that has begun to loom large is the notion that Earth has a single major marine circulation system. This is important because so many marine organisms need to achieve life cycle closure. These organisms disperse their larvae as plankton, and after spending some time in the water column to develop they drift and settle, in the best-case scenario, in a habitat similar to where the parents lived. The local adaptations of such organisms with planktonic larvae (assuming they exist — a subject of debate among marine conservation biologists), such as swimming down to a certain depth that maximizes the likelihood of catching a current that takes the juvenile organism back toward it natal area, depend on a world current system that is predictable.

Wallace Broecker of Columbia University suggests that the wind-driven and thermohaline circulation of the oceans may be altered suddenly as a consequence of increasing carbon dioxide build-up in the atmosphere. This changes the heat distribution on the land which alters the positions of high and low pressure areas that determine wind directions. It also modifies precipitation patterns that affect thermohaline circulation. In short, we could find that marine biodiversity, including our fisheries, could be dramatically altered by sudden shifts in ocean currents that are nonlinear responses to linear, incessant increases in atmospheric carbon dioxide due in large part to human activities such as fossil-fuel burning and deforestation.

Some human activities have multiple consequences in the sea. Bottom trawling is one example. It is a type of fishing that drags a large, weighted net along the seafloor. To a far greater degree than fishing methods of the past, it

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can deplete the populations of targeted species and of other species caught unintentionally in the net, the so-called "by-catch." But it has another effect that people had largely overlooked until recently: destruction of structural complexity. This effect on the habitat of seafloor life could be the biggest "sleeper" issue in marine conservation.

## HIGH STRUCTURAL COMPLEXITY IS CORRELATED WITH HIGH DIVERSITY

Four decades ago ecologist Robert McArthur and his brother noticed something very interesting: that the diversity of warblers was highest in forests that were most structurally complex and lower in less structurally complex forests. As scientists have looked they have discovered more and more evidence of this phenomenon: high structural complexity in forests is correlated with high diversity of other organisms.

It is also true in the sea. As early as 1972, Mike Risk of McMaster University, working in the Virgin Islands, laid a chain over reef corals and found that the diversity of fishes is highest in the roughest seabeds. A variety of structures create "hidey-holes" for organisms (see Reaka-Kudla, this volume). Different physical regimes, oxygen and water flow regimes, and spatial arrangements offer opportunities for organisms to feed and take refuge. This diverse spatial arrangement in the sea is just as important to biological diversity as it is on land. An example is the structural complexity provided by sponges in the Gulf of Maine. Living organisms such as sponges and tubeworms contribute to the rough bottom topography that provides for a high diversity of taxa, including the young of many species of fishes as they settle from the plankton.

## EFFECTS OF TRAWLING ON STRUCTURAL COMPLEXITY

In 1996 I brought together a group of people at the Darling Marine Center at the University of Maine to look at the worldwide impacts of bottom trawling, which I suspected might be eliminating structural complexity from the sea bottom. Of all the methods of fishing, bottom trawling likely has the largest impact, not just to the target species and the huge numbers of skates and other fishes, crabs, sea stars, and other bycatch, but also because of the severe alteration of the seafloor from the trawling equipment. In the process of trawling for shrimp, as little as five percent of the catch is the desired shrimp. As much as 95 percent of the catch is what shrimpers call "trawl trash," but what I call biological diversity. This is a different way of looking at it. If you consider the seafloor like the structure of the forest on land, you get a hint of the destruction. On land, logging removes the complex forest structure, with its wide variety of trees, different foliage heights, and layers of others species. When you eliminate that structural complexity there is a sharp contrast between the two systems.

Most people have not yet awakened to the notion that trawling equipment, dragged across the seafloor eliminates its structural diversity. On Georges Bank in an untrawled area you can see that the gravel that was deposited by glaciers eons ago is completely covered, colonized by a wide variety of organisms. What happens when it is trawled is that most of these organisms disappear. The organisms that tend to get left in trawled ecosystems are starfish and hermit crabs, scavengers that can withstand being brought on a boat and left there for an hour while people pick through the catch and then shove the rest back overboard. The other organisms, the "structure-formers" in the ecosystem, are eliminated.

This is an important point. The structural complexity in the sea, even if it is a blanket of wormtubes two centimeters tall, is no less important to the benthic ecosystem than the structural complexity of the forest is on land. When a scallop-dragger goes through an area it leaves trawl tracks. The rate of recovery of the structure-formers on the seabed takes months, years, and in some cases decades or centuries. Ocean quahogs in the Atlantic can live for 220 years. Sea fans can live for 500 years or more — as long as trees live. These structure-formers are eliminated and do not come back again before the trawling occurs again.

The extent of bottom trawling is astounding. The area of forest logged worldwide is about 100,000 square kilometers a year according to the UN Food and Agriculture Organization. In comparison, in a paper in *Conservation Biology* (December 1998), Les Watling and I calculate that the area of seabed trawled each year is bigger than Canada.

## WHAT DO WE NEED TO DO?

The foregoing discussion leads me to ask: What do we need to do? Where do we go from here? How do we maintain biological diversity in the sea when human population and activities are expanding exponentially, human institutions often fail to work, and ignorance and lack of caring drives us to overexploit, pollute, and physically alter the marine environment? How do we deal with this overwhelming situation? How do we make the fishermen and the fish both part of the mix?

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Our abundance and the range of habitats we have colonized make humankind the most successful species on Earth, but our survival and well-being depend on our ability to maintain the planet's life-support systems, in which biological diversity provides the key roles. Scientists are now seeing countless signs that Earth is losing its biological diversity at a faster pace than at any time since the mass extinction that eliminated dinosaurs and countless other species occurred 65 million years ago. Although "the environment" is seen as a luxury by many short-sighted people, protecting, restoring and sustainably using the sea, freshwaters and land is absolutely crucial to our economic well-being and survival. If we are to avoid becoming the victims our own success, our highest imperative must be maintaining the living systems that sustain us.

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