Marine Biodiversity at Risk

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There seems to be a widely held belief that the sea, reservoir for 97 percent of earth's water, is so enormous that humankind can do little to change its nature. Lord Byron expressed this view two centuries ago when he said, poetically,

> Roll on thou deep and dark blue ocean, roll!
> Man marks the earth with ruin—
> His control stops with the shore.

That was before thousands of miles of drift nets strip-mined the sea; before mega-trawlers with maws large enough to consume a dozen 747 aircraft scraped the ocean floor, taking entire ecosystems in extracting the desired fish. In 1800, there were no nuclear wastes, no nerve gas–disposal sites, no oil spills, no plastic debris, no pesticides or herbicides, or runoff of chemical fertilizers from lawns, fields, and farms into the sea. From prehistory to the edge of the year 2000, great chunks have been removed from the Earth's treasury of genetic and ecosystem diversity because of habitat destruction, overkill, and the introduction of exotic chemicals and other pollutants.

In Byron's time, the sea was largely a wilderness, the distillation of four-and-a-half billion years—still largely intact. Since then, numerous species and entire complex ecosystems millions of years in the making have been significantly altered, from the obvious—populations of whales and other large mammals—to dozens of commercially valued fish species, all marine turtles, many sharks, and numerous small creatures including certain krill, crabs, and shrimp. Policies that subsidize and encourage the unsustainable taking of wild animals from the sea on a commercial basis have brought the fishing industry—and many populations of fish—to a state of near collapse. Despite efforts to curb the fishermen's enthusiasm for taking more tuna, cod, herring, pollock, halibut, and other species each year than populations can reproduce, many more have been taken than populations can tolerate without serious decline. And declining they are. Currently, 80 percent of the world's commercially taken marine species are regarded as seriously depleted. Worldwide, the living network of organisms that shape the basic ingredients of the ocean's "living soup" has been tugged, and the supporting ecosystems have been nudged in new directions.

Too little is known about the earth's living processes to know or predict the results of our tinkering, but disrupting the nature of the sea, both by changes in ocean chemistry and in the composition of the living elements, is not likely to be in our best interest. The ocean is, after all, the cornerstone of the planet's life-support system, the place that comprises more than 95 percent of the planet's living space, the biosphere. It is the realm that contains by far the greatest genetic diversity, considering the basic broad categories of life, and it is the primary source of much that is generally taken for granted—climate, weather, basic planetary chemistry. When I try to imagine earth without its mantle of salt water, I think of Mars. No ocean there. And no life. Without an ocean, earth would not be a congenial place for our species, nor, perhaps, for any of earth's other inhabitants.

Clearly, species have come and gone through time, and so have orders, classes, and even phyla. But there is no precedent for the rapid loss of biodiversity caused by humankind—superimposed on the changes brought about by forces over which our species has no control. For a biologist, it is satisfying to see the growing awareness of the significance of biodiversity and of healthy natural ecosystems to the survival and well-being of humankind. As a marine biologist, it is puzzling to witness the disproportionate attention given to terrestrial creatures and terrestrial ecosystems.

Concern about destruction of well-known areas of high diversity on the land is certainly justified. While comprising only about 7 percent of the earth's land mass, rainforests are thought to provide home for more than half the species known. However, most of this incredible richness can be accounted for by creatures who share a common genetic program that insists they have six legs and otherwise fit the criteria established for insects. It may be that half the planet's species are insects and that most of them are beetles, but sweeping generalizations are premature until the oceans are at least as well known as terrestrial environments. This is especially true of microbial forms, to date virtually unexplored. It is estimated that less than one-tenth of 1 percent of the deep sea, below 50 meters or so, has been explored, at all. Most of it remains unknown, except with respect to gross anatomy, and much of that is based on educated guesswork.

New technology developed in the past few decades has provided unprecedented access to the sea and has given us a glimpse of the magnitude of the "unknowns" about most of the biosphere. Widespread use of self-contained underwater breathing apparatus—scuba—in the past several decades makes it possible for modern scientists to explore the ocean directly, instead of viewing only the scrambled remains of samples taken in nets and dredges. Underwater camera systems, remotely operated vehicles such as *Phantom* and the famous *Agro-Jason* system, have revolutionized the nature of underwater research and documentation. Recent discovery of hydrothermal vents in the deep sea and their diverse assemblages of a marine life awaited use of remotely deployed underwater vehicles and the manned submersible, *Alvin.* Subsequent investigations have been limited to brief visits by a privileged few using one of the small number of manned and robotic vehicles now in operation. Currently, only five submersibles exist that can transport observers to as much as half the ocean's depth, about 6,000 meters. None now exist to go to full-ocean depth, although once, in 1960, the now-retired bathyscaphe *Trieste* transported two men

for a brief look at the nature of creatures living at the bottom of the Marianas Trench near the Philippines.

By using a submersible, *Deep Rover*, in 1986 I explored a steep ocean wall along the edge of Lee Stocking Island in the Bahamas and gained a new appreciation for the magnitude of biodiversity in the sea. A chunk of rock about 0.5 m^2 taken from 200 meters underwater along the wall appeared, superficially, to be as barren as a moonrock. In fact, I soon discovered upon inspection that within an area that I could embrace with my arms there was represented a fair slice through the history of life on earth, alive and well. The rock provided living space for three divisions of plants—red, green, and blue-green algae—and representatives of eleven phyla of animals—foraminifera, sponges, coral, nematodes, brachiopods, bryozoans, arthropods, mollusks, polychaetes, sipunculids, and echinoderms—brittle stars, a tiny urchin, and a number of highly specialized crinoids. Such broad-scale diversity is normal in the ocean, whether a sample is scraped from a piling, the deep seafloor, or a thriving forest of kelp.

Although coral reefs have few insects (i.e., sea-going water striders skate over the water's surface), they are rich in species, from numerous variations of red, green, brown, and blue-green algae and representatives from nearly all the other major divisions of plants known to numerous kinds of invertebrates. Most phyla of animals can be found on coral reefs and other marine habitats; only about half have ever made it to terrestrial areas.

Like rainforests, coral reefs are now in jeopardy, but the specific causes of global decline of reef systems are not as immediately obvious as the clear-cutting and burning of forests. While some reefs are being mined for building materials or smothered by obvious silt and debris from coastal development, and others are being dynamited by fishermen for extracting the resident fish, even in areas accorded protection such as Australia's Great Barrier Reef and reefs within the Florida Keys National Marine Sanctuary, serious degradation has occurred in the past thirty years. Causes may include pollution from agriculture and other sources, loss of critical fish species, and more subtle, overarching factors such as a possible global warming trend and increased ultraviolet radiation. Whatever the cause, or causes, if the decline continues at the same pace for another thirty years, there will be little living reef remaining in many parts of the world where coral has thrived for hundreds of millennia. The consequences of losing conspicuous living ecosystems such as tropical forests and coral reefs are not easy to predict, but no amount of clever human engineering, scientific brilliance, or financial commitment can restore such systems once they are gone.

Kelp forests, not coral, should perhaps be awarded the title "rainforests of the sea." They are even wetter than rainforests and have a crown of foliage nearly as high above the seafloor as the rainforest trees do from the leafy ground below. As in coral reefs and most other marine systems, nearly all the major divisions of plant and animal life are represented. Fish, sea hares, jellyfish, and the planktonic stages of numerous groups of animals flit, fly, or balloon among the blades of kelp. Mollusks, echinoderms, brachiopods, bryozoans, crustacea, and various other invertebrates creep, crawl, burrow, or simply attach to the substrates below. And there are mammals, of course.

Sea otters are among the residents of the central California coast so sought after for their warm, furry hides that they came perilously close to being eliminated many decades ago, as did the large cetacean species that once traveled along the western coast of North America in large migrating pods. It once was thought that large numbers of marine mammals could be removed from the sea on a sustained basis—that the sea is so vast, the number of seals, whales, walruses, and otters so great, that humankind could do little to reduce their kind, let alone eliminate them forever. Yet marine mammals proved to be vulnerable even to rather crude killing techniques used in the 1800s and early 1900s. Within a century, all the great whale populations were drastically reduced, and even with widespread protection in recent years, most have shown little evidence of recovery. Despite policies to manage the taking of seals, walruses, and other marine mammals, these, too, have sharply declined. E. O. Wilson remarked in *The Diversity of Life* (1992) that as human population spread, "Mankind soon disposed of the large, the slow and the tasty!" In North America, more than 70 percent of large mammal genera that existed at the time human hunter-gatherers crossed the Bering Strait from Siberia are extinct. A similar pattern is emerging in the sea, where marine mammals, large fish, and anything edible, no matter how critical to other species or ecosystems, are most vulnerable to human predation.

To encourage the recovery of species that are threatened with extinction, an obvious, good first step is to stop killing them. Beyond that, it makes sense to protect vital habitats. For whales, this is tricky because most species require huge tracts of healthy ocean where they can feed, socialize, and reproduce their kind. Humpbacks range over tens of thousands of miles, from polar feeding areas to tropical calving lagoons. Mindful of such requirements, recent measures have been taken to establish all the Indian Ocean and much of the ocean surrounding Antarctica as "whale sanctuary." The concept is also embodied in a growing network of more than 1,000 protected areas under national jurisdiction, worldwide, including the U.S. National Marine Sanctuary Program and a system of National Marine Estuarine Research Preserves. Protecting endangered species and ecosystems is part of the rationale for establishing such areas.

However, "protection" has many interpretations. Commercial fishing continues in Antarctica with little restriction on most species taken. Some guidelines are set for taking krill, *Euphausia superba*, but the limits established are based on guesswork including far-from-perfect understanding of what requirements are vital for krill to maintain their populations. Depleting krill in the southern oceans is sure to have profound implications not only for the krill and whales, birds, squid, fish, and numerous others who depend on one or more of the dozen or so stages young krill go through on their way to becoming a three-inch long adult, but also for the adults themselves.

There are thousands of species of crustacea in the sea, but only about eighty species in the genetically related group of creatures known as krill. While it appears that *Euphausia superba* has special ecological significance, each one of the eighty or so others has a magnified importance in terms of genetic information as compared to, say, a family of creatures that is represented by hundreds of variations. Among those most diverse of all creatures, the insects, each species lost is irreplaceable, and each vacancy jars some part of

the ecosystem. However, there is likely to be more genetic resiliency ensuring the continuity of insectkind when there is a starting pool of perhaps a million species. The magnitude of basic genetic information lost is arguably greater with the demise of one member of a group represented by very few species. There are, for example, only four species of horseshoe crabs in an entire class of organisms. The genetic equivalent of losing one of them might be equated in some ways to eliminating a quarter of a million kinds of insects.

There are only about 350 kinds of sharks—creatures described by the National Marine Fisheries Service as "underutilized" only a decade ago. Fishermen were encouraged to take what they could, however they could, in part to make up for low catches of depleted species. But like whales, sharks tend to mature and reproduce slowly, and thus are especially vulnerable. Within a decade, it has become clear that sustained taking of these creatures on a large, commercial scale is unrealistic, and some limits are being set for some species in U.S. waters to protect what remains, but there are few protective measures elsewhere.

Another group of creatures with a distinguished lineage and a possible short future is the cephalopod mollusks—octopuses, squids, nautiluses—in all, only about 350 kinds are known. Some individual species are numerous enough to be sought by commercial fishermen, and as a consequence, once-thriving populations are being swiftly depleted. Despite their apparent fecundity, it is conceivable that some heavily fished species could go the way of passenger pigeons—and for the same reason that it takes a critical mass under just the right circumstances, not just a handful, to keep the population dynamics going. Squid, in particular, are vulnerable to human-catch techniques. In the Pacific, the extraction of enormous quantities of squid from the sea not only threatens their survival but also disrupts ocean ecosystems where large numbers of squid are vital to the survival of numerous other creatures including fish, marine mammals, albatrosses, and other seabirds—all with few choices about what they can consume.

This is true, too, of other kinds of sea creatures: arthropods, echinoderms, mollusks, ctenophores, coelenterates, and so on. The list is long and growing. Marine biodiversity is threatened by deliberate extraction of huge quantities of living sea creatures—currently more than 90 million tons a year—by humankind. Just as serious a threat is the long and growing list of dangerous substances that are dumped into the sea. Some substances such as plastic debris, lost or discarded fishing gear, cans, bottles, and other forms of trash are visible; most of them are a legacy of the past half century. When Thor Heyerdahl crossed the Pacific aboard the Kon Tiki in 1947, he was impressed by the pristine nature of the wild, open sea. By 1969 and 1970, during his famous *Ra* expeditions, Heyerdahl encountered conspicuous evidence of human garbage, debris, tar balls, oil, and other substances floating throughout the open sea. Since then, the quantity and variety of trash and toxic substances entering the sea have increased dramatically. Shorelines around the world are littered with trash, largely plastics. Pesticides, heavy metals, and other toxic substances dumped into the ocean have made their way into the tissues of fish, birds, marine mammals, and the humans who dine upon them. Some species are more vulnerable than others to the recent changes. Plastic bags engulfed by sea turtles who mistake them for jellyfish,

one of their favored foods, die from starvation as their intestines become jammed with indigestibles. Death by entanglement, mostly with lost fishing gear, significantly impacts the fur seals and other marine mammals of the northwestern Pacific. It poses a serious threat to the Hawaiian monk seal, where every individual lost or gained tips the scales one way or the other toward survival or extinction.

Toxic materials more lethal than oil are being spilled into the ocean, but oil spills—especially big ones in pristine areas such as Prince William Sound—are hard to ignore. Say what you will about the impact of oil on marine life (some say it really is not so bad); 250,000 barrels of spilled oil were not exactly a prescription for health at Valdez, Alaska, in 1989 when the tanker *Exxon Valdez* went aground. After the spill, at the Reluctant Fisherman Inn in Cordova, a sign was posted: "Flags are at half mast because of the death of our environment." While overly pessimistic, for individual otters, birds, fish, and other creatures trapped in the oil, the message was no exaggeration, and for all, the spill brought into focus the difficulty of trying to put things back together once damage has occurred. It is difficult enough to restore familiar terrestrial ecosystems, whether the challenge is reestablishing a forest or returning a hawk to the wild after being in captivity for a while. It is virtually impossible to know what to do to restore a marine area such as Prince William Sound—or even a single depleted species of squid or shark, let alone minute microbeasts whose life histories are still a mystery.

Without pausing to understand the consequences to the living systems that support us, humankind has over the ages relentlessly diminished the genetic and ecological diversity to the point where full recovery is no longer possible. Each species lost diminishes the chance that we can "get it right," that is, to find an enduring place for ourselves within the living matrix that sustains us. If humankind proves its ability to be wise as well as clever, we will implement new and durable measures to maintain the living assets that we have too often taken for granted.

How can individuals stop the actions that are degrading the quality of life, closing the doors not only for future generations but also for those of us now alive? Whales are still being killed by wealthy nations as luxury food, despite worldwide outrage and awareness of their alternative values—economic, aesthetic, scientific, moral. Thousands of once and nevermore species are being rendered extinct each year, perhaps as many as four a minute through rainforest destruction and loss of other unique ecosystems. With a brazen indifference to world opinion and international agreements, some nations still dump/emit highly toxic materials into the sea and sky, a deadly legacy for the future, with immediate consequences for those here today. Despite evidence that ocean ecosystems are collapsing, that populations of fish, squid, and other species cannot sustain commercial taking, huge sets, trawlers, and factory ships are still being deployed—and more are being built, often subsidized by public taxes.

It is not possible to go back and redirect the course of history, but now—and not for long—there is a brief window of opportunity to restore and protect the remaining healthy ecosystems that support us. Far-reaching anthropogenic changes are sweeping earth's aquatic atmosphere—chemically, physically, and biologically. In the past few decades—

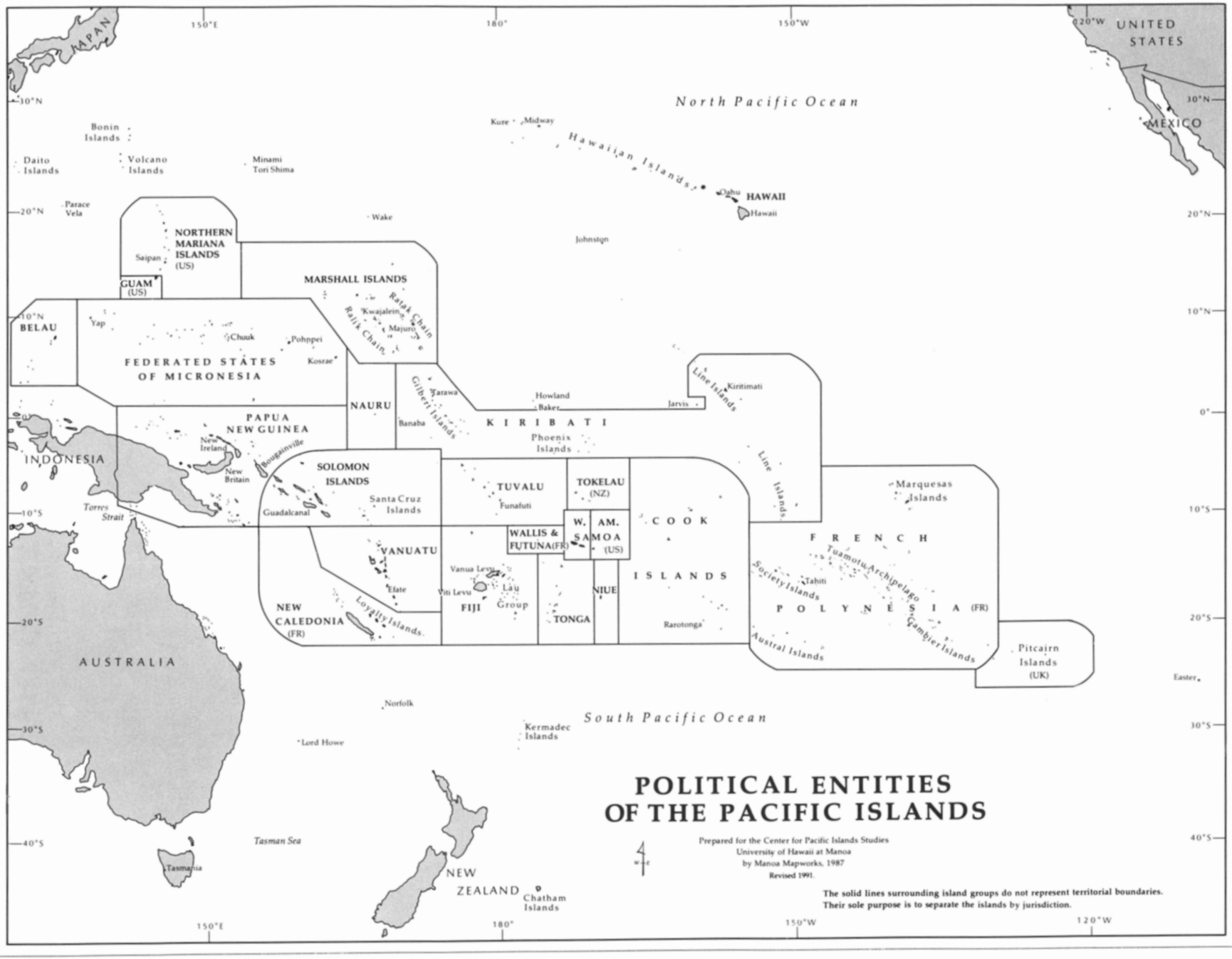
my lifetime—the sea has changed. Every day, the number and demands of humankind increase; the size of the planet does not.

Traditionally, the sea has been regarded as the common heritage for all humankind; now its care must be acknowledged as a common responsibility. To ensure a decent quality of life for the rest of our lives, as well as for all those who follow, we must develop policies that recognize the interdependence of life—and the need for nations to agree on mutually beneficial measures to protect and maintain the basic elements of life support—on a planetary scale. But it is difficult to be concerned about what we do not know. That is why it is absolutely vital to explore and come to understand the nature of the oceans—still largely unknown. Organizing complex information and making it readily and universally available—the subject of this meeting—is a vital part of knowing. With knowing comes caring, and with caring, an impetus toward the needed sea change of attitude, one that combines the wisdom of science and the sensitivity of art to create an enduring ethic. This is the time as never before, and perhaps never again, to establish policies—on a small personal scale as well as on broad public ones—to protect the ocean and the diversity of life that the sea sustains. How to achieve this most desirable goal is not clear, but the need to protect large marine areas from destructive actions seems to be fundamental.

Graeme Kelleher, for many years the Director of the Great Barrier Reef Marine Park Authority, suggested in a recent letter:

> It is my observation that administrative and bureaucratic problems often equal biophysical problems in importance when we try to maintain a healthy earth. . . . I believe that ultimately all of the world's seas should be zoned. In many places, marine protected areas are small islands of protection in an unregulated sea. Such small protected areas must be highly protected if they are to have any effect. On the other hand, large protected areas, covering complete marine ecosystems, can be zoned so that various human activities such as fishing can proceed within parts of them while other parts are totally protected from extractive and other exploitive activities. Such large protected areas can be seen as stepping stones towards the goal of integrated management of all the world's seas, with sustainable use being the overriding objective.

One thing is clear. We have an opportunity now as never before, and perhaps never again, to achieve for humankind, and for those with whom our species shares the planet, a prosperous and enduring future. If we fail, through inability to resolve thorny issues or by default born of indifference, greed, or lack of knowledge, our kind might well be a passing short-term phenomenon, a mere three- or four-million-year blip in the ancient and ongoing saga of life on earth.


POLITICAL ENTITIES OF THE PACIFIC ISLANDS
Prepared for the Center for Pacific Islands Studies
University of Hawaii at Manoa
by Manoa Mapworks, 1987
Revised 1991.
The solid lines surrounding island groups do not represent territorial boundaries.
Their sole purpose is to separate the islands by jurisdiction.
North Pacific Ocean
South Pacific Ocean
JAPAN
UNITED STATES
MEXICO
Bonin Islands
Daito Islands
Volcano Islands
Minami Tori Shima
Parace Vela
Kure
Midway
Hawaiian Islands
Oahu
HAWAII
Hawaii
Wake
Johnston
NORTHERN MARIANA ISLANDS (US)
Saipan
GUAM (US)
MARSHALL ISLANDS
Ratak Chain
Ralik Chain
Kwajalein
Majuro
BELAU
Yap
Chuuk
Pohnpei
Kosrae
FEDERATED STATES OF MICRONESIA
NAURU
Tarawa
Gilbert Islands
Banaba
Howland
Baker
Jarvis
Line Islands
Kiritimati
KIRIBATI
Phoenix Islands
PAPUA NEW GUINEA
New Ireland
Bougainville
New Britain
INDONESIA
Torres Strait
SOLOMON ISLANDS
Santa Cruz Islands
Guadalcanal
TUVALU
Funafuti
TOKELAU (NZ)
W. SAMOA
AM. SAMOA (US)
WALLIS & FUTUNA (FR)
COOK ISLANDS
Rarotonga
Marquesas Islands
FRENCH POLYNESIA (FR)
Tuamotu Archipelago
Society Islands
Tahiti
Gambier Islands
Austral Islands
Pitcairn Islands (UK)
Easter
VANUATU
Efate
Vanua Levu
Viti Levu
Lau Group
FIJI
TONGA
NIUE
NEW CALEDONIA (FR)
Loyalty Islands
AUSTRALIA
Norfolk
Lord Howe
Kermadec Islands
Tasman Sea
Tasmania
NEW ZEALAND
Chatham Islands
150°E
180°
150°W
120°W
30°N
20°N
10°N
0°
10°S
20°S
30°S
40°S