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## The Oceans Are Coming Ashore

by Don Hinrichsen

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# *The Oceans Are*

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by Don Hinrichsen

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# Coming Ashore

**W**ilson Vailoces stands knee deep in mud as he inspects his prized stand of red mangrove trees—trees that he planted himself over a decade ago on the tidal flats in front of his house. Vailoces lives just north of Bais Bay on the southeast coast of the Philippine island of Negros. His mangroves are intended to reduce erosion of his waterfront property, and to provide breeding, feeding, and nursery

areas for a wealth of commercially valuable marine life, such as shrimp and milkfish. The going is tough and he lurches from side to side like a ship in a gale, grabbing the roots of his “trees on stilts” to steady himself.

A decade ago, the coast here was eroding, and valuable stocks of fish and shellfish had been depleted by over-fishing, which sometimes involved the use of explosives and poisons. “We had cut down all the mangroves and reduced most of our reefs to rubble by dynamite fishing,” explains Vailoces, a self-educated small-scale fisher, who had to drop out of grade school to help his father pull a fitful living from the sea. Faced with the total collapse of his way of life, Vailoces decided he had to take the initiative to rebuild the region’s resources if there was to be any future for his children. And the only way to do that, in his view, was to plant mangroves.

Vailoces began his mangrove rehabilitation project with help from the marine laboratory at nearby Silliman University in Dumaguete City. After his neighbors saw how well the mangroves worked as natural fish farms and shore stabilizers, they followed his lead. Lush mangrove forests now cover 100 hectares of coastal land in Bindoy Municipality. By the late 1990s, over 100,000 trees had been planted—one-tenth of them by Vailoces himself.

Vailoces didn’t stop with mangroves. He also built and sank 1,000 artificial reefs made from bamboo, tires, or concrete. Designed as large pyramids, they provide excellent cover for a host of marine life. And he began working with local farmers, in an effort to convince them to use less harmful pesticides on their mangos and other fruit crops. He also turned his attention to the steep hills above the coast, where subsistence farmers eke a living from the highly unstable soils; Vailoces persuaded the Philippine Department of Environment and Natural Resources to encourage the farmers to surround their fields with trees, which help stabilize the slopes. “Great damage had been done to coastal fisheries from landslides and siltation due to deforestation in the hills,” he explains. “Coral reefs were buried and mangroves inundated. But we managed to turn that situation around.”

Or so he thought. “Unfortunately, the mangroves have not continued their seaward march. They are expanding laterally up the coast, but not towards the sea,” observes Vailoces, standing waist-deep in seawater. “We simply never anticipated the effects of sea level rise caused by global climate change. By now



PHOTOGRAPH BY ANNIE GRIFFITHS BELT/NGS IMAGE COLLECTION

these red mangroves should have been moving out another 20 feet or so," he says, pointing seaward. "But they haven't been able to get a solid foothold because the waves are running in higher and with more force."

The subtle, inexorable rise in sea level has already had an effect on the Bindoy coast. "I can't tell you how much the sea level has risen here, but it is discernable," says Vailoces. Already, storm surges at high tide almost reach the floor boards of his house, which sits on short, half-meter pilings atop a small hill. Computer models developed by the Intergovernmental Panel on Climate Change (IPCC) indicate that a 1-meter rise in sea level could occur by 2080. Well before then, it seems, the Vailoces family may have to abandon their land and livelihood, and flee inland. "We would be completely swamped here by a 1-meter rise," he laments. "Even a half-meter rise would cause serious erosion problems, despite the protection afforded by the mangroves, and storm surges would routinely waterlog us."

On the other side of the world, rising sea levels are eroding the beaches and wetlands of the Chesapeake Bay, the huge inlet along the U.S. mid-Atlantic coast that contains the largest body of brackish water in North America. Maryland, the state that contains most of the bay's shoreline, is now on the front lines of climate change. On the state's eastern shore, the 8,100-hectare Blackwater National Wildlife Refuge has lost close to one-third of its land area over the past three decades, and many once rich bottomland farms are now either waterlogged or too saline to sustain crops. Out in the bay, Maryland's

Smith Island—actually a little archipelago 13 kilometers long and 6 kilometers wide—has lost about 490 hectares over the past century; land that was wooded a generation ago is now salt marsh.

More and more of Maryland's natural shoreline is disappearing behind a bulwark of revetments and bulkheads. According to the the U.S. Environmental Protection Agency (EPA), the permits issued over the past 15 years for this type of construction now account for 500 kilometers of the state's coast. In 1996, a conference at Washington College in Chestertown, Maryland brought together 140 scientists, property owners, and government officials who produced a blunt consensus statement: "The evidence that sea level has risen, is rising and will continue to rise along the coast of Maryland is so great that no informed person would suggest otherwise."

## 1 Billion at Risk

There is no comprehensive global assessment of the number of people who would be displaced by a 1-meter sea level rise, but it's thought that roughly 1 billion people live at sea level or just a few meters above it. Regional studies conducted by the IPCC suggest that the impacts will be devastating, especially in the tropics and warm temperate regions, where many coastlines are heavily settled. The most vulnerable areas are concentrated along the southern coast of the Mediterranean, the west coast of Africa, South Asia (India, Sri Lanka, Bangladesh, and the Maldives), all coastal states comprising Southeast Asia, and low-lying coral atolls in the Pacific and

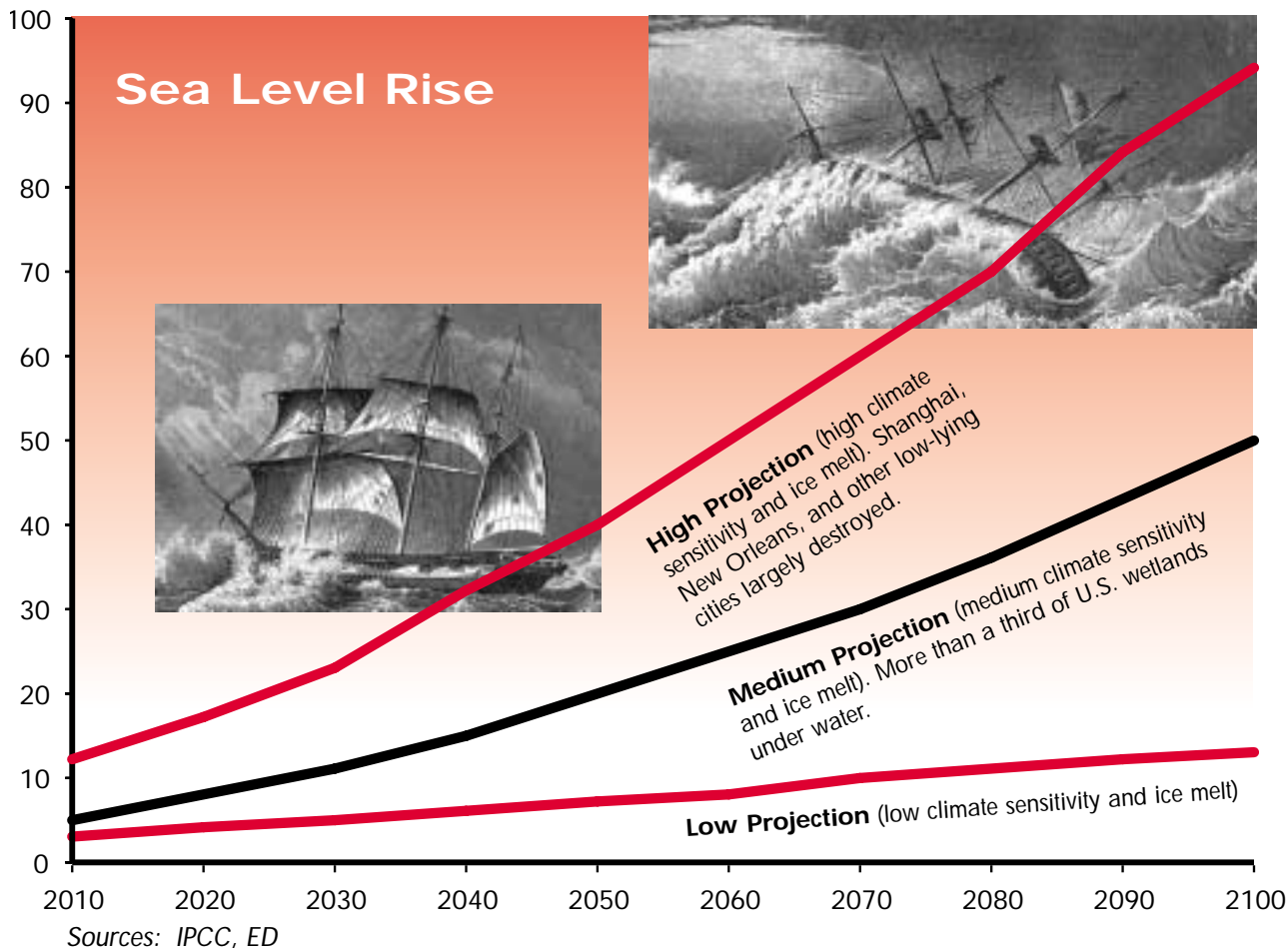
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Agence France Presse  
Bangladesh's Sundarbans forest threatened by global warming: experts  
DHAKA, Aug 29  
The world's largest mangrove forest, the Sundarbans, in southern Bangladesh faces the threat of destruction because of global warming, a report published Tuesday said. "A possible 45 centimeters (18 inches) rise in the sea level by the year 2050 may inundate 75 percent of the Sundarbans," warned the inter-governmental panel on climate change. In a draft report called "Considering Adaptation to Climate Change in the Sustainable Development in Bangladesh" the experts warned a climate change, could lead to a drop in the number of fresh-water plants. "Eventually, the species offering dense canopy cover would be gradually replaced by non-woody shrubs and bushes," the report said. This, it said, could lead to the extinction or degradation of the rich flora and fauna, including Bangladesh's Royal Bengal tigers which are on an endangered species list. The Sundarbans, which stretch to neighbouring India's West Bengal state, is one of the United Nations' World Heritage sites.  
<http://www.greenbase.g13/atmos/atmos2908000013.html>



Centimeters



Indian Oceans. These regions contain some of the poorest and most heavily populated countries in the world, with some of the highest fertility levels. Just over 2 billion people inhabit these places and up to half of them live on the equivalent of \$2 a day or less. China and Southeast Asia include the most crowded coastlines in the world, with population densities averaging over 2,000 people per square kilometer. All of these regions are primed for profound social upheaval, as a quick survey will show.

Take Asia first. In land-short Bangladesh, a 1-meter rise would inundate 3 million hectares, displacing 15–20 million people. In neighboring India, 600,000 hectares would be submerged, and 7 million people would be driven from their homes. Indonesia would lose 3.4 million hectares—home to at least 2 million people. Vietnam would likely lose 2 million hectares in the Mekong Delta and another 500,000 hectares in the Red River Delta; roughly 10 million people would be displaced. Malaysia would lose up to 700,000 hectares, much of it devoted to export crops such as rubber, palm oil, and coconuts; as many as 1 million people would be driven inland. And in the Philippine archipelago, up to a quarter of the entire

population—some 20 million people—could be affected, with 5–10 million displaced outright. Millions more would be forced out of their homes in Sri Lanka, Burma, Cambodia, and Thailand.

On the low-lying islands and coral atolls in the Pacific and Indian Oceans, there are of course fewer people to displace, but the inundation would effectively remove many of these places from the map. Take the Maldives, an island nation of stunning coral atolls that drop off the south coast of India like tears. A 1-meter rise would swamp about 85 percent of the country's capital island, Malé, which harbors 60,000 people on just 600 hectares of land. Like many of the rest of the Maldives' 1,196 islands, Malé averages just one meter above sea level. Nearly all of the islands would be converted to sandbars and tiny spits by an extra meter of water, or they would sink beneath the waves completely. The country's entire population—some 300,000 people—would be forced to flee to India or Sri Lanka. "We would have no choice," Maldives President, Maumoon Abdul Gayoom, told a British Commonwealth meeting in Kuala Lumpur in 1989. "For the Maldives would cease to exist as a nation." More than a decade later, Gayoom was still



PHOTOGRAPH BY DON HINRICHTEN

offering the same dismal assessment. In September 2000, he asked the 149 world leaders who had gathered in New York for the UN Millennium Summit, “when the UN meets to usher in yet another century, will the Maldives and other low-lying nations be represented here? My time at the podium is up, but I pray that of my country is not.”

Other island nations would fare little better. Even an 80-centimeter rise would inundate 65 percent of the Marshall Islands and Kiribati in the South Pacific; presumably, most of their inhabitants would hope to find shelter in Pacific Rim countries such as Australia or New Zealand. A 1-meter rise would displace around 5 million people throughout the South Pacific. Some 300 Pacific atolls would disappear from the map. Many would become uninhabitable long before they went under, because salt intrusion would foul drinking water supplies and more frequent, more

severe storms would batter them to pieces.

In West Africa, the countries along the Gulf of Guinea are facing a fate similar to Southeast Asia's. In Nigeria, for instance, up to 70 percent of the coast would be inundated by a 1-meter rise, affecting more than 2.7 million hectares and pushing some beaches 3 kilometers inland. Close to 4 million people would be displaced and part of the capital city of Lagos would be under water. Oil production in the Niger Delta and elsewhere would be impaired as well. This might seem like an appropriate form of economic loss, given the cause of the sea level rise, but it's likely to be painful for the Nigerian economy all the same: estimates based on current rates of pumping put the costs at \$6 billion to \$18 billion a year.

It's a similar picture elsewhere along the west African coast. Côte d'Ivoire, for example, would lose 180,000 hectares of coastal land and several mil-



*Shanghai, China's largest city with 17 million inhabitants, would lose a third of its area, displacing around 6 million people, if the sea level were to rise by one meter.*

lion people would be driven from their homes. Côte d'Ivoire's shoreline is already retreating inland and the rising seas would exacerbate this natural process, accelerating it to a rate of up to 7 meters per year. Both of the country's main coastal cities, Abidjan (the capital) and San Pedro, would be partly swamped and their port facilities damaged. To the north, in Senegal, a 1-meter rise would inundate close to 600,000 hectares and displace as many as 200,000 people, most of them south of the Cape Verde peninsula. Senegal's problems would be compounded by events in the Gambia, the tiny coun-

try that consists of little more than the flood plain of the Gambia River. On a map, the Gambia looks like a crooked finger pointing deep into Senegal, which surrounds it on all sides but the coast. The Gambia would only lose around 10,000 hectares, but unfortunately that includes all of Banjul, its capital city. The entire city is no more than a meter above sea level. Over 50,000 people from Banjul alone would have to be relocated, and since the Gambia already averages 300 people per square kilometer, many of them would presumably cross into Senegal.

On the south coast of the Mediterranean, Egypt would be the hardest hit by a 1-meter rise. At least 2 million hectares of the fertile Nile Delta would be lost to the advancing sea and another 10,000 hectares of productive crop land would be subject to erosion and salinization. Some 8–10 million people would be displaced, including nearly the entire population of

Alexandria. Most of the inundated area would consist of prime agricultural land currently worth close to \$1 billion, but this figure pales in comparison to the cost of losing Alexandria. The demise of this ancient city would cost the country over \$32 billion in lost land, infrastructure, and tourist revenue. And of course, there's no way to put a price on the cultural damage.

## When the Seas Invade Cities

As Alexandria's plight suggests, sea level rise is going to be an urban planner's nightmare. In many coastal cities, the problem is compounded by the fact that the land underneath them is sinking. Excessive groundwater pumping is the primary cause of this subsidence, but urban sprawl is a factor too, since buildings and pavement cause rainfall to run off instead of seeping back into the earth to recharge the groundwater. In addition to lowering the ground level, this overpumping makes the cities vulnerable to a kind of underground flooding: as the freshwater is pumped out of coastal aquifers, saltwater tends to seep in. Underground saltwater intrusion is a serious problem for Manila, Dhaka, Bangkok, and Jakarta. Obviously, continued sea level rise will tend to make the aquifers under these cities even saltier. Most of Manila's wells, for instance, might very well turn too saline to use at all if the sea level rises by a meter or so. That would force officials to spend billions of dollars that the Philippines doesn't have on desalination plants. The money would have to be borrowed from abroad, saddling the country with more foreign debt.

Since most of these cities are just a few meters above sea level, they would face another major expense in the need to beef up flood control systems. Manila's system is so antiquated that every year during the monsoon rains, scores of people drown in low-lying areas because the storm drains cannot handle the tremendous volume of water dumped on the city over the course of a few hours. "We are overwhelmed right now," shuddered one city water manager. "I can't even imagine what would happen if the sea rises by a meter. Hundreds would drown during the rainy season and we would be faced with massive capital investments in new, bigger pumping stations and storm drain systems."

Bangkok's problems are no less severe. Dozens of people living in swampy areas drown every year during the rainy season. Many more are made periodically homeless—most of them squatters occupying squalid, make-shift settlements along the Chao Phraya River and its tributaries, or along the city's many fetid, refuse-choked canals. Officials estimate that sea level rise will cost Bangkok an additional \$20 million per year in pumping costs alone. The cost of relocating displaced communities has not been esti-



mated, but is expected to be “astronomical.”

In terms of the sheer number of people likely to be affected, Shanghai, China’s largest city, may be in a class of misery all its own. A 1-meter rise would flood up to a third of this city of 17 million people, displacing as many as 6 million of them. Shanghai is currently attracting hordes of migrants from all over the Yangtze River Valley; that demographic current would be reversed, as immense waves of refugees flood out of the city.

## The Americas

Sea level rise is an equal opportunity destroyer. It will affect low-lying coastal areas throughout the world, regardless of the level of development. Even though the Americas are for the most part better prepared to cope than the regions just surveyed, these nations also face profound dislocation.

In the United States, a study carried out by the U.S. Federal Emergency Management Agency (FEMA) found that a half-meter sea level rise would inundate up to 1.9 million hectares of dry land along the eastern seaboard and Gulf Coast if no protection measures are taken. Up to 1.6 million hectares would be flooded if currently developed areas are protected. These figures do not cover the wetlands that would be affected, but a study by the U.S. Environmental Protection Agency (EPA) estimated that a 1-meter rise would inundate close to 3.6 million hectares, with the losses about equally divided between the wet and dry areas.

The FEMA study also found that a 90-centimeter rise would greatly increase the amount of the east coast floodplain that is vulnerable to storm damage—from 5.1 million to 7 million hectares. Over much of the floodplain, the frequency of storm damage would increase radically. A 1-meter rise, for example, would cause areas that are currently inundated only by the once-in-a-century “monster storm” to see such flooding every 15 years.

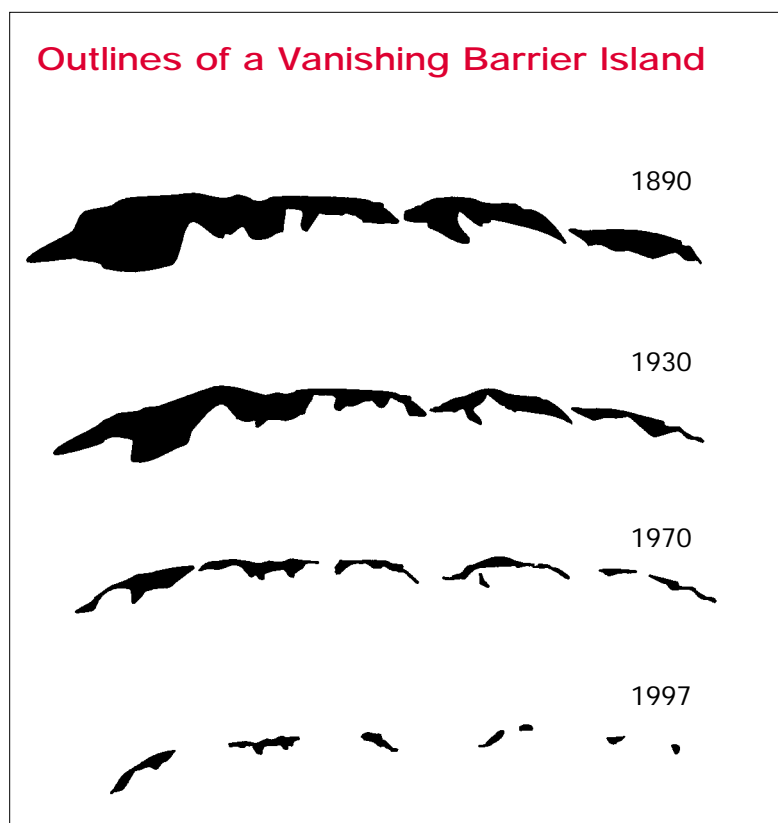
*The image depicts a time series of aerial views of a vanishing barrier island in the Gulf of Mexico near the Mississippi Delta. It is reprinted, with permission, from “Highwater Blues: Selected Coasts and Islands,” by Stuart Gaffin, Environmental Defense.*

The likely effect would be to push insurance costs beyond the reach of many or most people—depending, of course, on the extent of government subsidies. Overall, according to the EPA study, a 1-meter rise could cost the U.S. economy anywhere from \$40 billion to \$475 billion.

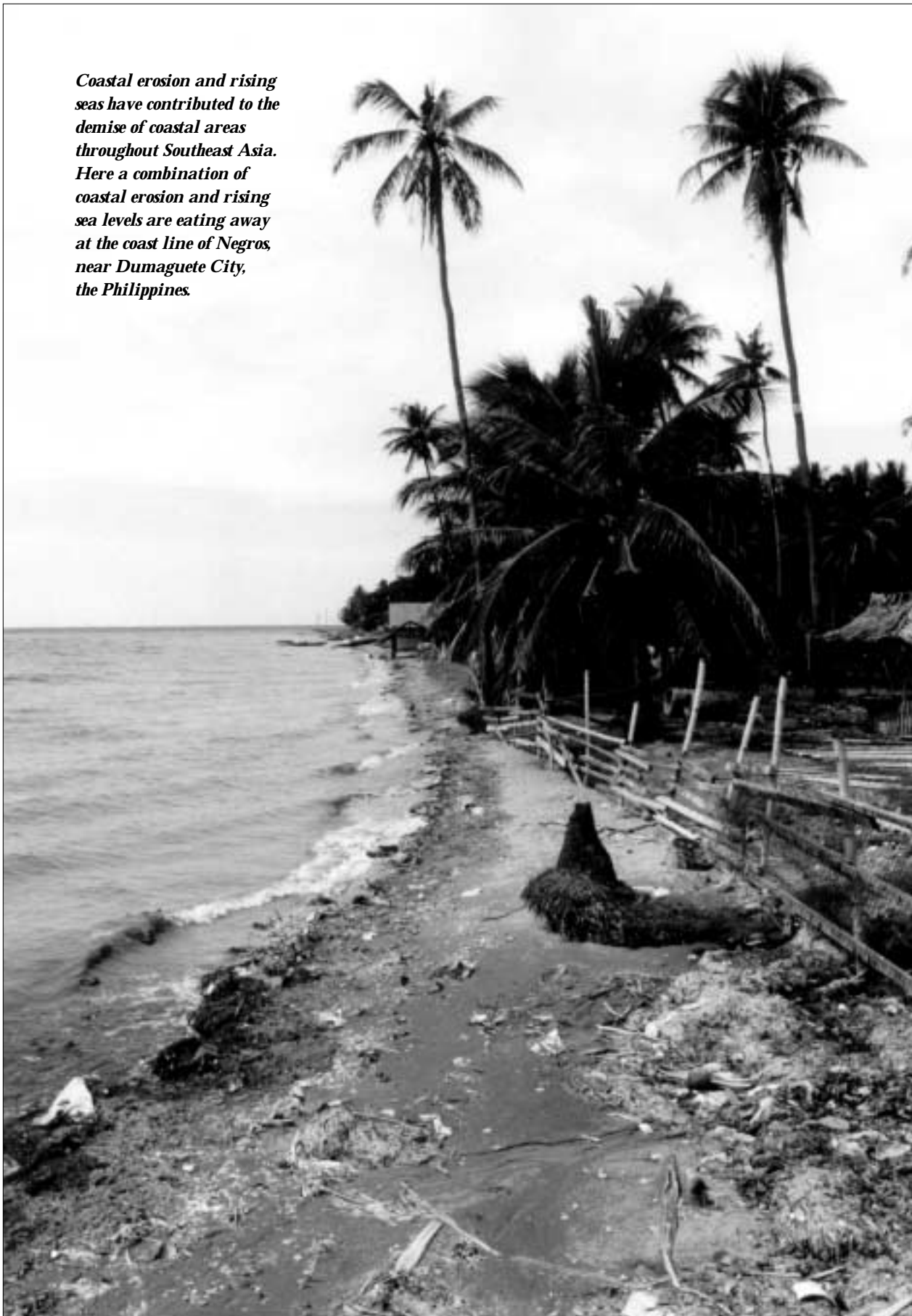
Similarly, an IPCC study of five east coast Latin American countries—Argentina, Belize, Guyana, Uruguay, and Venezuela—found that a 1-meter rise would inundate around 13.5 million hectares and affect upwards of 750,000 people, the majority of them living in poor fishing communities and squatter settlements. By far the worst effects would be felt by tiny Guyana. Out of a total population of 700,000, about 80 percent or 560,000 people would be affected; at least half would probably end up as environmental refugees.

## A Natural and a Human Disaster

Biologically rich coastal wetlands, such as mangrove swamps, marshes, salt ponds, and intertidal areas are also endangered by sea level rise. According to studies carried out by the Hadley Centre for Climate Prediction and Research in Britain, 40–50 percent of the world’s remaining coastal wetlands will be lost by 2080, due to a combination of drainage for agriculture, urban sprawl, and the effects of a 1-meter sea level rise. And this is the



*Coastal erosion and rising seas have contributed to the demise of coastal areas throughout Southeast Asia. Here a combination of coastal erosion and rising sea levels are eating away at the coast line of Negros, near Dumaguete City, the Philippines.*



PHOTOGRAPH BY DON HINRICHSEN

conservative estimate: it assumes that major conservation initiatives will offset some of the loss. In the no-remediation scenario, up to three-quarters of remaining coastal wetlands are lost.

The areas most apt to lose their coastal wetlands differ somewhat from those most at risk in human terms. The coastal wetlands most likely to suffer lie along the Atlantic coast of North and Central America, the U.S. Gulf Coast, and around the Mediterranean and Baltic Seas. These areas generally exhibit an appreciable slope once you move inland from the tidal range. There is little potential in such places for coastal wetlands to migrate inland—they would be trapped between the advancing waves and the high ground. In the United States, studies suggest that up to 43 percent of remaining coastal wetlands would be submerged, mostly along the Atlantic and Gulf coasts. Louisiana is already losing some 900 hectares of coastal wetlands each year to a combination of subsidence and sea level rise. Since nearly half of the world's coastal wetland has already been annihilated by development, the losses inflicted by sea level rise are likely to be far more disruptive than they might otherwise be. Many of these ecosystems will probably not be able to perpetuate themselves as residual fragments of what were once much larger wholes. Their characteristic species will begin to die out; the resulting landscape will be far less diverse and probably less stable.

These ecological tragedies will overlap with human tragedies as well, although the connection will be easier to see in some places than in others. Consider the Sunderbans, one of the most vulnerable coastal wetlands in Asia. The largest contiguous mangrove forest in the world, the Sunderbans carpets 100,000 hectares along the Bay of Bengal, partly in India and partly in Bangladesh. It is home to myriad wild creatures, including 315 species of birds; among the endangered species to be found here are the Rhesus macaque (a monkey), Irrawaddy dolphin, and Bengal tiger. A 1-meter sea level rise could well mean extinction for the local populations of many Sunderbans creatures. The Sunderbans tigers, for example, currently number around 350 and are an important reservoir of genetic wealth for their species. The rising waters would probably do away with their main prey animals and drive the tigers into heavily settled areas further inland, where it is unlikely that they would survive.

The Sunderbans is human habitat as well. At least half a million people are directly dependent on the forest—woodcutters, thatch harvesters, fishers, and collectors of honey and beeswax. In the event of substantial sea level rise, most of these people would share the tigers' fate: they would be forced farther inland and their forest economy would be badly crippled.

"We are, in essence, conducting a big geophysical

experiment with the Earth's climate," says Sydney Levitus, an oceanographer at the U.S. National Oceanic and Atmospheric Administration. "One of the possibilities is that [the Earth] could go into an abrupt climate shift." Thus far, there is little evidence that this possibility has captured the imaginations of many politicians or policymakers. "Unfortunately, as with most coastal management efforts," says Jens Sorensen, a coastal management expert at the University of Massachusetts in Boston, "most government agencies are doing nothing more than rearranging the deck chairs on the Titanic." The usual assumption seems to be that climate change proceeds by increment, so serious action can be deferred until later in the century. Real reform, in other words, is our children's problem.

No doubt, part of the reason for this complacency is that the climate computer models speak in terms of fractions of degrees—they sound incremental even when they are forecasting convulsive change. And indeed, the prospects of an abrupt shift, in one form or another, no longer seem that remote. For example, over the past three decades, the world's oceans have warmed by an average of 0.3 degrees Centigrade. But tropical waters in the northern hemisphere have been warming at the rate of 0.5 degrees Centigrade per decade, five times the global rate.

***Bangkok, Thailand's capital city, is situated no more than a few meters above sea level on drained wetlands and landfill. A 1 meter rise in sea level would inundate the entire southern part of the city, while subjecting the city's 10 million residents to more frequent and severe storms.***



“This may seem like a small number,” says Levitus, “but in fact it represents a huge increase in the heat content of the world ocean.” And of course, other parts of the earth’s climate system may also be on the verge of rapid flux. This appears to be the case, for example, with the world’s ice cover (see pages 5–7).

Nor is the climate system the only factor in play. Consider the increase in our own numbers. Today, about one-sixth of the global population lives within a few meters above sea level. (These, of course, are the 1 billion people most at risk from sea level rise.) According to mid-range U.N. projections, the global population is expected to grow from its current 6.1 billion to 8.9 billion by 2050. The U.N. also projects that a full third of these people may live in coastal regions subject to the effects of sea level rise. That’s the equivalent of nearly half the current

global population. Where are these people going to go? Our geophysical experiment, to use Levitus’s term, could become an unprecedented social experiment as well. Unfortunately, this scenario differs in one crucial aspect from experiments in the ordinary sense of the word: we won’t be able to start over if the results go awry.

But if 2050 still seems too remote to worry about, think again of the Vailoces family and their mangroves on the Negros coast. Vailoces doesn’t need projections to see the urgency of the problem. He knows that climate change has arrived. “It is here and now for us,” he says emphatically, gazing out to sea.

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Don Hinrichsen is an award-winning writer and U.N. consultant. His latest book is *Coastal Waters of the World: Trends, Threats and Strategies*, published by Island Press in 1998.



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