Ripple Marks

The Story Behind the Story

BY CHERYL LYN DYBAS

COASTAL DEAD ZONES

In this MODIS image from January 15, 2002, the Gulf of Mexico awash in a mixture of phytoplankton and sediment. Each summer, the phytoplankton population explodes. As the phytoplankton age, die, and decompose, oxygen is used up, creating hypoxic zones. Photo Credit: Jacques Descloitres, MODIS Land Rapid Response Team, NASA/GSFC.

PAST AS PROLOGUE? It steals in by night on an east wind, this low-oxygen water that moves shoreward from the Gulf of Mexico into Mobile Bay, Alabama. Cries of "Jubilee!" carry along Mobile Bay's eastern shore, for ahead of this dead zone known to local citizens as a jubilee, bottom-dwelling fish and crabs sense the low oxygen levels and scuttle away to avoid suffocation. Some are trapped as the hypoxic, or low-oxygen, waters approach shore. Crabs, eels, flounders, and other marine creatures wash in like so much flotsam and jetsam. Fishers line docks and beaches, poised to grab this last line of life before the poisonous waters reach the shoreline.

Jubilees, once known mostly in the Gulf of Mexico region, now happen in Chesapeake Bay and other areas, wherever coastal dead zones occur. Worldwide, there are now 146 such dead zones, waters with oxygen too low to sustain life. Excess nutrients like nitrogen are an important factor in the increase in coastal dead zones, and also in the expansion of harmful algal blooms (HABs), according to a paper in the June 2005 issue of *Oceanography* by Patricia Glibert et al., "The Role of Eutrophication in the Global Proliferation of Harmful Algal Blooms." Since the 1960s, according to a report by the U.N. Environment Program (UNEP), *Global Environmental Outlook Year Book 2003*, the number of dead zones has doubled with each passing decade.

When did these killing fields for fish and other marine life begin? Perhaps longer ago than anyone thought, according to scientists Lisa Osterman, Richard Poore, and Peter Swarzenski of the U.S. Geological Survey, and Eugene Turner of Louisiana State University. In a paper published in the April, 2005, issue of the journal *Geology*, the researchers discuss results showing that dead zones in the Gulf of Mexico are nothing new. They existed as far back as the 1800s. But the dead zone's modern-day extent is what's astounding, says Osterman.

During summer 2005, the Gulf of Mexico dead zone reached 11,840 square kilometers, according to biologist Nancy Rabalais, director of the Louisiana Universities Marine Consortium (LUMCON).

To look at past dead zones, Osterman and colleagues took sediment cores from areas where the Gulf's recent dead zone has been found. The scientists dated the specimens and counted three species of foraminifera ("forams") in the cores; these species tolerate low-oxygen waters. As long ago as 1823, the forams thrived during Mississippi River flood years. This suggests, says Osterman, that nutrients like nitrogen in spring floodwaters, coincident with the timing of plankton blooms, can indeed trigger hypoxia.

But the forams in Osterman's core samples were most abundant after 1950, when farmers began using more fertilizer. "Our data show," wrote Osterman and co-authors, "that low-oxygen events since 1950 were more extreme than any that had occurred in the previous 180 years, and support the interpretation that increased use of fertilizer has amplified this process."

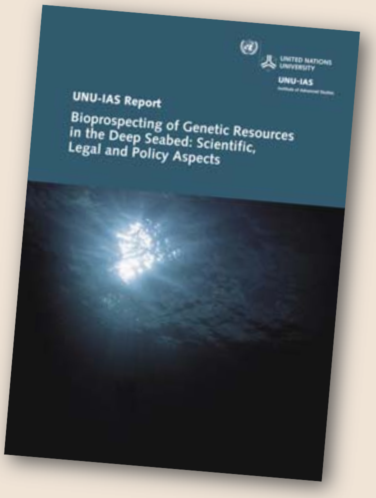
Far north of the Gulf of Mexico and hundreds of years before farmers grew crops along the Mississippi River, fertilizer of sorts was in use near Crawford Lake, Canada. And early Native Americans living near the lake had their own dead zone with which to contend, according to scientist Erik Ekdahl of the University of Michigan in Ann Arbor.

In a paper published in the September 2004, issue of the journal *Geology*, Ekdahl documents changes in Crawford Lake's diatom community. Increased nutrient input to the lake, perhaps from forest disturbance to clear fields for corn and other crops, caused bottom-water hypoxia and altered the lake's diatom community structure—within a few short years. Iroquois settlements in the region died out in the fifteenth century. The ghostly remains of a dead zone, however, still lurk in Crawford Lake, waiting to surface should excess nutrients again be added to its waters.

States Ekdahl, "The eutrophic diatom assemblage from the time of the Iroquois occupation remains in place, primed for further nutrient input despite the hundreds of years that have passed." Will that be the fate of the Gulf of Mexico...Mobile Bay...Chesapeake Bay...hundreds of years after we're gone?

This piece was adapted from an article by Cheryl Lyn Dybas that appeared in the July 2005 issue of the journal BioScience.

PROTECTING BLUE GOLD



THE "TRAGEDY OF THE COMMONS" brought to the fore by Garrett Hardin in his 1968 *Science* paper has found its way to the farthest reaches of our planet: the deep-sea floor.

Vast genetic resources—"blue gold" in the ocean depths—need protection from commercial exploitation, warns a recently released report from the Japan-based United Nations University Institute for Advanced Studies (UNU-IAS).

The report, *Bioprospecting of Genetic Resources in the Deep Seabed: Scientific, Legal and Policy Aspects*, cites rising concerns about the absence of clear rules governing access to and sharing of benefits derived from the "global commons" of the sea bed. It also warns of the potential for severe, perhaps permanent, damage to these unique and sensitive ecosystems, which include seamounts, cold seeps, and hydrothermal vents.

Increasingly recognized as important for their potential medical and other uses, life forms in the deep-sea are now more accessible, and therefore more vulnerable, because of rapid advances in exploration technology, according to the report.

Known as "extremophiles," the organisms of the deeps that live in extreme conditions are drawing interest from scientists and from private companies bioprospecting for possible pharmaceutical and industrial applications.

"Deep-sea ecosystems hold the promise of huge potential contributions to future human well-being, to providing our planet with vital climate-related and other ecological services, and have much to teach us about life's processes," says UNU-IAS director A.H. Zakri. "The unregulated exploitation of international seabeds and the organisms living there could have serious long-term consequences for humankind. For the private sector, uncertainty caused by the absence of clear, globally-agreed-upon rules deters important research and investment decisions."

Adds report contributor Sam Johnston, senior research fellow at UNU-IAS, "The legal and policy framework is not even close to keeping pace with the fast-evolving science and technology of deep seabed bioprospecting."

These resources lay within the global commons, says Salvatore Arico of UNESCO, a visiting research fellow at UNU-IAS and a lead author of the report. "Are they free for anyone to take, or are they the heritage and property of all humankind?"

All major pharmaceutical firms, according to industry reports, including Merck, Lilly, Pfizer, Hoffman-Laroche, and Bristol Myers-Squibb, have marine biology departments. Worldwide sales of marine biotechnology-related products have reached 100 billion dollars. Anti-cancer agents from marine organisms are valued at $1 billion. Annual profits from just one compound derived from a sea sponge, used to treat herpes infections, are more than $50 million.

"Even so, we still know very little about the genetic resources in deep-sea environments," says Craig Cary, director of the Center for Marine Environmental Genomics at the University of Delaware, "and need many more years of basic research and exploration. The R&D investment necessary to make good on a bioprospecting find is enormous, and unless the path to discovery remains somewhat clear of major legal and financial obstacles, few companies will be able to take the walk."

Bioprospecting in the deep-sea within a nation's territorial limits is currently regulated by the UN Convention on the Law of the Sea (UNCLOS), which determines countries' jurisdictions, rights and obligations in the oceans, as well as by the Convention on Biological Diversity, which governs access to genetic resources and benefit-sharing. While most nations have regulations on marine scientific research in their waters and seabed, only a few have legislation regulating access to and exploitation of their marine genetic resources.

One nation that does is Canada, which in 2003 established the Endeavour Hydrothermal Vent Marine Protected Area. The area lies in Canadian waters on the Juan de Fuca Ridge southwest of Vancouver Island at a depth of 2250 m. It covers 100 square kilometers of seabed and overlying water column, and is composed of four fields of "black smoker" structures—the Main Endeavour Field, the Mothra Field, the High Rise Field, and the Sawlty Dawg Field.

Canadian regulations state that no person shall damage, destroy, or remove from the area any part of the seabed (including a vent structure), the subsoil, or any living organism or part of its habitat. However, removal for scientific research for the conservation, protection, and understanding of the area is allowed.

Other sea-bottom locations under consideration for protective measures include the Lucky Strike and Menez Gwen hydrothermal vent fields, proposed as a Marine Protected Area by Portugal. These vents are found at the Azores Triple Junction in the northeast Atlantic Ocean, stretching from the Mid-Atlantic Ridge to southwest of the Azores.

The UNU-IAS report suggests that more nations should develop such regulations. Before that can happen on a large scale, however, states the report, there is a need to define bioprospecting; establish whether the sequencing of a genome can be considered an invention; develop guidelines to help countries determine the implications of marine scientific research in the deep-sea; and decide whether marine scientific researchers/academia and private companies should be treated differently with regard to access to deep seabed genetic resources.

What happens with regard to policy-setting for living resources in the depths of the oceans, many believe, could set precedents for exploiting similar resources in places like Antarctica, the Arctic, even outer space. Garrett Hardin likely never imagined how far the tragedy of the commons might reach.

Chechessee golf course near Callawassie Island, Beaufort, SC. Photo credit: H. Kelsey.

GOLF COURSE PROTECTS TIDAL CREEKS

OCEAN AND BEACH. SAND AND SHELLS. Hilton Head, South Carolina, and golf courses. Where there's one, there's almost certainly the other. But the manicured greens of golf courses, an increasingly familiar sight in the United States and especially so in Hilton Head, often come at a price to the environment. Fertilizer applied to the greens, and to wastewater used for their irrigation, can increase levels of nutrients like nitrogen. These nutrients eventually flow into nearby waterways.

A golf course might be the last place, then, where a best management practice (BMP) for nutrient management could be developed. But that's exactly what recent results published in the journal *Estuaries* show.

Known as a golfer's paradise, Hilton Head is home to more than 50 golf courses. Many are adjacent to tidal creeks; these estuarine feeder streams are unique to the southeastern United States.

One of Hilton Head's golf courses, Chechessee Golf Course on Callawassie Island, was the site of a comparative study of nitrogen pollution in four environments: grassy golf course swale; marshland near the golf course; undeveloped marsh; and an undeveloped forest area. Results of the study, conducted by Karen Tuerk and Marjorie Aelion of the University of South Carolina, were published in the June 2005 issue of *Estuaries*.

Tuerk and Aelion measured concentrations of nutrients in the sediments and overlying waters at each site. Surface water nitrate levels were highest at the golf course swale site. But that's also where the highest denitrification rates of the four environments were observed.

Microbes living in the swale, it turns out, are filtering out much of the excess nitrogen before it's washed into the surrounding marsh. "Microbial denitrification [in the golf course swale] plays an important role in the biogeochemical nitrogen cycle, and could have a significant effect on the removal of excess nitrogen from coastal sediments," write Tuerk and Aelion in *Estuaries*. "As golf courses are constructed, best management practices (BMPs), such as swales, retention ponds and vegetated buffers, should be in place to maximize denitrification and filtration of nutrients."

It's certainly counter-intuitive, says Aelion, "that a golf course would be the site of a BMP for coastal nutrient management. But that's exactly what we found, and in the unlikeliest of places."

JELLYFISH SWARMS

ONCE A MONTH, on the darkest nights near the new moon, otherworldly beings emerge from Pacific Ocean depths and drift onto the beaches of Hawaii. Hundreds, sometimes thousands, of these quivering masses of jelly float in with the night tide. Near shore, time grows short to complete their mission: to reproduce, leaving behind miniature versions of themselves fastened with a glue-like substance to reefs and rocks in the shallows.

Box jellyfish, the invaders are called. Scientists from around the world are studying Hawaii's box jellies. The sting from this jelly can be lethal, leading Hawaiian authorities to post warnings to beach-goers whenever the jellies come ashore. Over the past few decades, more and more box jellies have been found in the waters around Hawaii.

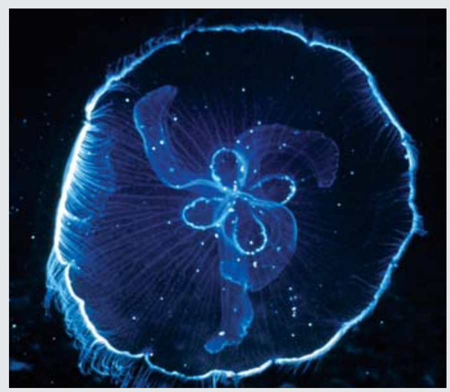
Jellyfish swarms also are a problem well beyond Hawaiian waters. Last August, hundreds of moon jellyfish took over another coastal territory: the cooling system of the Oskarshamn nuclear power plant in southeastern Sweden, which uses water from the Baltic Sea in its cooling tanks. The plant shut down one of its three reactors until the jellies, splattered through the reactor's pipes, could be removed. When jellyfish clog power plant cooling waters, according to plant managers, the flow is hindered. The reactor automatically shuts down.

The Baltic is known for its high numbers of late-summer moon jellies, but last summer's population reached a new level.

"As parts of the oceans become increasingly disturbed and overfished," wrote biologist Claudia Mills of the University of Washington in a 2001 issue of the journal *Hydrobiologia*, "energy that previously went into production of fishes may be switched over to the production of pelagic Cnidaria or Ctenophora."

If overfishing continues in the North Atlantic and elsewhere, "fishing boats could soon be chasing jellyfish instead of fish," said fisheries scientist Daniel Pauly of the University of British Columbia.

In fact, that's exactly what's happening in Pulicat, a small fishing town at the southern border of Pulicat Lake, Tamil Nadu, India. In recent summers there, huge jellyfish swarms have floated in Pulicat Lake's waters. Export industries based in the Far East, looking for jellyfish for a thriving edible jellyfish market in countries like China and Japan, moved in and began buying up Pulicat Lake village buildings and boats. Jellyfish quickly became the number one export product there.



Moon jellyfish. Photo credit: Florida Keys National Marine Sanctuary.

But local fishermen, in their haste to make a profit from the swarming jellies, began to fight over the resource, destroying each other's huts and damaging jellyfish industry processing facilities.

Marine resource economists are concerned about the fate of these fishermen: if the jellyfish industry leaves the area to follow jellyfish blooms in other places, what becomes of the fishers' livelihoods? Jellyfish are affecting far more than the marine life with which they share the seas; their swarming numbers also may turn the tide against human coastal communities.

NATIVE LORE TELLS TALE

FROM GENERATION TO GENERATION in Sumatra and Sri Lanka the stories are passed, tales of floods and earth-shaking and devastation. The disastrous Indian Ocean tsunami in December 2004 added the latest story of nature's havoc to the lore of these island nations.

The tsunami was an event unprecedented in the written history of the region, says Ruth Ludwin, a University of Washington seismologist. Hundreds of thousands of people lost their lives, and whole villages were wiped out.

"But members of native tribes in the Andaman and Nicobar Islands survived the tsunami in a way we would do well to examine closely," says Ludwin. "They made use of ancient oral traditions handed down from family to family, stories that foretold the approach of a huge wave. These islanders reached safety before the devastation hit."

"Sea gypsies" who live along the Thai-Burmese border and call themselves the Moken escaped, they say, because they heeded tales of monster waves created by the spirit of the sea. The spirit gave the gypsies a warning, they believe. First the earth shook. Then the sea quickly receded, the natives' cue to run for high ground. Finally, a wall of water descended upon any unwise enough to remain on the low coastlands the sea spirit wished to reclaim.

The Moken live exactly where last December's tsunami hit hardest. Not one member of their tribe was lost. Ludwin also discovered that native stories point the way to a large earthquake that happened around A.D. 900 near the Seattle fault, and to a massive earthquake and tsunami in the Cascadia subduction zone in the year 1700.

Stories of epic battles between Thunderbird and Whale, figures common in the lore of native peoples of the Pacific Northwest, have their roots in this seismic history, Ludwin believes.

The tales are handed from person to person living in areas from northern California to the northern edge of Vancouver Island. References to Thunderbird and Whale, or to similar figures that represent the forces of earth and water, are found in native stories of earth shaking and flooding all along the Pacific coastline.

This illustration depicts a late 19th century interior ceremonial screen from Port Alberni, on British Columbia's Vancouver Island. It shows Thunderbird carrying Whale in its talons, a common native depiction of seismic activity. The original screen is in the American Museum of Natural History. The image is taken from *Northwest Coast Painting – House Fronts and Interior Screens* by Edward Malin, ©1999, Timber Press, Portland, OR.

"It appears that these stories reflect actual earthquakes, tsunamis, and landslides," says Ludwin, who published results of her research in two recent issues of the journal *Seismological Research Letters*, July/August 2005 and March/April 2005. "There are many, many of these tales, suggesting that past earthquakes and tsunamis had profound effects on early inhabitants of the Pacific Northwest. Importantly, there's corresponding evidence for these events in geologic studies, both on the coast and in the central Puget Sound area."

One story mentions a powerful "spirit boulder" south of the ferry terminal in Seattle. Ludwin was able to locate the boulder, then look at LIDAR images of the area. She found a large prehistoric landslide ending at the boulder. Details of the landslide, hidden by development and centuries of plant growth, are clearly visible with LIDAR. LIDAR also revealed parts of the Seattle fault, the source of the earthquake experienced by native peoples in 900.

One northern California native story describes a huge earthquake, relates Ludwin, during which elders tell young members of their tribe to run for high ground to avoid coming floodwaters. After spending a night on a dark, forested hill, the young find that all trace of their village has been washed away by a tsunami.

"If we'd listened closely to these stories," says Ludwin, "we might have guessed that a year 900 earthquake and the existence of the Seattle fault were related, and that a later earthquake in 1700 presaged a tsunami in this region.

"We also might have known that last December's tsunami was coming—in time to save thousands and thousands of lives. Who knows what we might learn by investigating the story-knowledge of people who have long histories in natural hazard-prone areas?"

Cheryl Lyn Dybas (cdybas@nsf.gov) is a staff member in the U.S. National Science Foundation's Office of the Director and is a marine scientist and policy analyst by training. She also writes on a freelance basis about the seas for *The Washington Post*, *BioScience*, *National Wildlife*, and many other publications. Ripple Marks is a new department in *Oceanography* intended to provide readers with "the story behind the story."