Death by Suffocation in the Gulf of Mexico

NEWS

Scientists have traced the origins of a vast hypoxic region in the gulf to inland fertilizer use; now officials must decide what to do

LAFITTE, LOUISIANA—Albert Darda, captain of the shrimp trawler *Misty Morn*, has never met Iowa farmer Bryan Sievers, who lives more than 1600 kilometers up the Mississippi River from this marsh-fringed Gulf of Mexico fishing port. But the two men have a common enemy: a huge swath of oxygen-starved, nearly lifeless ocean that spreads off the Louisiana coast every summer. The dead zone—as it is popularly called—drives away shrimp and fish, leaving a graveyard of strangled clams, starfish, and marine worms. Darda fears it will eventually smother his livelihood by damaging one of the richest fishing grounds in the United States, which pumped more than $3 billion into Louisiana's economy last year. Sievers is troubled for a different reason: He worries that regulators will soon ask him and other farmers to take costly but unproven steps to shrink the dead zone—a menace that many scientists say is primarily caused by nitrogen fertilizer washing into the gulf from millions of farm fields across the massive Mississippi Basin.

Strangled. Gulf's hypoxic zone *(top)* in July 1996, and a victim: a dead mud shrimp.

N. RABALAIS

Both men's fears are at the heart of an increasingly rancorous debate over the severity of the dead zone's ecological threat—and the practicality of trying to shrink it. Environmentalists and some scientists are convinced that the zone, which has doubled in size since 1993 and now ranks as the Western Hemisphere's largest, heralds the imminent collapse of Louisiana's valuable coastal fisheries. They are urging a special White House panel, which will issue a long-awaited report on the problem later this year, to recommend quick action to curb the flow of farm nutrients into the Mississippi River. But farm groups say a push to change agricultural practices in the Mississippi Basin—which covers 41% of the lower 48 states and holds more than half the nation's farmland—would be premature. Scientists can't show that the dead zone has harmed fisheries, they say, nor is it certain that new techniques applied to distant fields will help the gulf. "People seem to be pointing the finger at agriculture before all the facts are in," says Sievers, who raises corn, soybeans, and cattle on 400 hectares near New Liberty, Iowa.

Any steps taken to heal the Gulf of Mexico will be monitored intently across the globe: The dead zone is one of more than 50 similar oxygen-starved coastal regions worldwide (see map), most of which have formed in the last 50 years. Moreover, concern is rising that smaller oxygen-depleted regions off the U.S. coast could also grow—a topic that will be addressed later this year by the National Oceanic and Atmospheric Administration (NOAA) in a report on the status of U.S. hypoxic zones. Says marine biologist Robert Diaz of the Virginia Institute of Marine Science in Gloucester Point: "How policy-makers address the gulf's hypoxic zone is going to be a model for dealing with other serious coastal problems that have their origin on land."

Origin of death

That the dead zone is being debated at all is a testament to the doggedness of a few marine biologists and the wake-up call provided by the record floods that surged down the Mississippi in 1993. Researchers first documented hypoxic, or oxygen-poor, water pockets off the Mississippi's mouth in the early 1970s. But it wasn't until 1985 that a meagerly funded group of researchers, including Nancy Rabalais of the Louisiana Universities Marine Consortium in Chauvin and Eugene Turner of Louisiana State University in Baton Rouge, began to document the hypoxic zone by taking oxygen readings at dozens of offshore stations, often piggybacking the measurements onto other projects.

Rabalais and her colleagues showed that the zone is a creature of the Mississippi. It gets its start early each year when melting snow and spring rains wash nutrients—including nitrogen and phosphorus—off the landscape into the rising river. Except during drought years, the warmer, lighter river plume spills dozens of kilometers outward into the gulf, sliding over the heavier, saltier ocean water, forming a lidlike layer. Fueled by sunlight and dissolved nitrogen, massive algae blooms thrive near the surface, attracting tiny crustaceans called copepods and other organisms that graze on plankton. Dead algae and the grazer's fecal pellets sink to the bottom, where they are devoured by oxygen-consuming bacteria. Hypoxia sets in when oxygen levels in the isolated bottom water drop below 2 milligrams per liter, too little to support most marine life; anoxia occurs when the bacteria use up the rest of the oxygen, suffocating even themselves.

Although the dead zone can form as early as February and persist as late as October, it generally stays from May to September in coastal waters up to 60 meters deep. Contrary to popular perception, it doesn't just hug the bottom: In shallower areas, 80% of the water column can be hypoxic, and the smothering effects can extend to within several meters of the surface. "Hypoxia has the potential to affect organisms living far off the bottom," Rabalais says. Organisms that can swim, such as fish and shrimp, flee the area. But less mobile creatures, such as starfish and clams, desperately seek oxygen by abandoning the security of their sea-floor burrows or climbing to high points that might penetrate oxygenated waters. Some brittle stars even stand on their points, stretching to catch some oxygen.

In the summer of 1989, Rabalais and Turner found that the gulf's hypoxic zone covered a tongue-shaped area of up to 9000 square kilometers, west of the Mississippi's bird's-foot delta. But then came the 1993 deluge, when the river dumped into the gulf almost twice its

usual annual flow of 580 cubic kilometers. Within a few months, the dead zone doubled in size, stretching westward with the prevailing currents into Texas waters. Since then, despite hopes that the zone would shrink to its pre-1993 girth, it has receded only slightly, to about 16,000 square kilometers in 1997.

Call to arms

Alarmed by the dead zone's unyielding territorial grip, 18 fishing and environmental groups—quoting chapter and verse from clean water laws—in January 1995 petitioned federal and Louisiana officials to take steps to cut off the nutrients that spur the zone's growth. Last year, the Clinton Administration responded by appointing six committees to assess hypoxia science and decide, by the end of this year, how to tackle the problem. "There is little disagreement that nitrogen is the nutrient that drives hypoxia," says Don Scavia of NOAA, who is coordinating the White House Committee on the Environment and Natural Resources Research's (CENR's) Gulf of Mexico Hypoxia Assessment. "The controversy," he says, is "trying to figure out where it is coming from and how to reduce it."

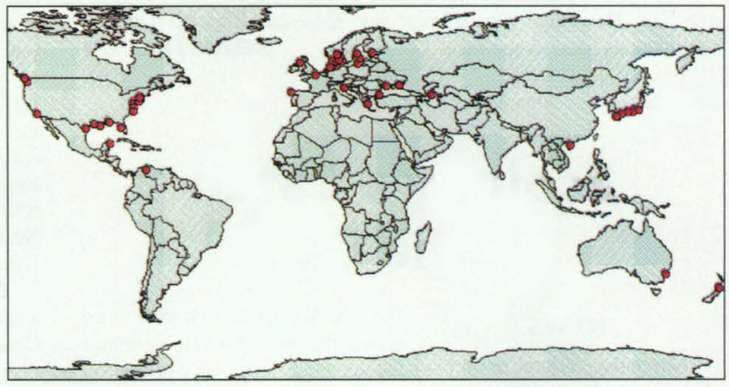
According to Scavia, the CENR effort "boils down to figuring out whose nitrogen it is that is feeding the hypoxic zone." Scientists do know that an awesome mass of nitrogen moves down the Mississippi: About 1.82 million metric tons of it reaches the gulf each year, almost triple the amount 40 years ago, estimates Cornell University biogeochemist Robert Howarth. The nutrient comes from a variety of sources, says Don Goolsby, a hydrologist at the U.S. Geological Survey (USGS) in Denver, who leads the CENR team assessing the river basin's nitrogen discharge hot spots. By far the leading culprit, Goolsby and others believe, is nitrogen fertilizer leaching from the basin's croplands—particularly those planted with corn. Other sources include livestock manure, nitrogen-fixing legumes such as soybeans, sewage treatment plants, nitrogen-rich soils in drained wetlands, and airborne nitrogen oxides from fossil-fuel burning.

More than half the 11 million metric tons of nitrogen added to the basin each year comes from fertilizer, according to the USGS. Iowa farmers, for instance, applied on average 130 kilograms of nitrogen per hectare of corn in 1996, according to state records. Up to half this fertilizer may find its way into ground and surface waters as nitrate, or into the air as nitrogen oxides, estimates a team led by Stanford University's Peter Vitousek. USGS studies suggest that over 60% of the Mississippi's nitrate originates in the Corn Belt north of the Ohio River. Such calculations, which Goolsby cautions are based on sketchy data, raise hackles in farm country. "The agriculture community is being forced to take a defensive posture, even before the actual source of the hypoxia problem is determined," says C. David Kelly of the American Farm Bureau Federation in Chicago.

But other experts say that farmers don't have to wait for further studies to justify actions that could benefit both the gulf and their bottom line. "Have we traced a nitrogen atom from a farm field to the gulf? No," admits ecologist John Downing of Iowa State University in Ames. "But if you cost out the excess nitrogen we know is flowing down the Mississippi each year, it is worth something like $750 million. On economic grounds alone, I think you can convince farmers to take steps to keep nitrogen on their fields." Downing knows, however, that educating the region's farmers about nutrient management—which he hopes to do through a new $4 million grassroots outreach program—is an uphill battle: Just 11% of about 500 rural Mississippi Basin residents recently surveyed by his group were even aware the dead zone exists. Laments Downing, "We realized we were asking them how they would help solve a problem that they did not know they had!"

Another headache for those who want to curtail the dead zone is how to assess its economic threat. It's hard to weigh the benefit of protecting the gulf's $3 billion fishing industry, which supports at least 40,000 jobs, against costs incurred by the $98 billion Mississippi Basin farm economy, which supports almost a million farmers. "Trying to prove the economic benefits of reducing the hypoxic zone is going to be extremely difficult: We don't have the data," says Walter Keithley Jr. of Louisiana State.

Part of the problem is that biologists so far have been unable to link serious declines in a gulf fishery to the transient hypoxic zone. There are, however, some warning signs: Evidence suggests that the dead zone may corral fish and shrimp into areas near shore, blocking them from spawning areas. And some studies show that sea-



Life-taking waters. Oxygen-starved coastal "dead zones" spawned by human activity, shown above as red dots, have tripled in number worldwide in the last 30 years.

DIAZ AND ROSENBERG, SOURCE: *OCEANOGRAPHY AND MARINE BIOLOGY: AN ANNUAL REVIEW* **33**, 245 (1995)

floor communities in hypoxic areas tend to be impoverished—younger, sparser, and home to fewer species. Ironically, increased nutrients may be nourishing some of the gulf's fisheries. Annual catches of menhaden, a fish used for its oil and for aquaculture feed, have skyrocketed since the 1930s, to almost 550,000 metric tons a year in the 1990s. Although the link is fuzzy, the boom may be fueled by the nitrogen-fed algae blooms, which are a major food source for young menhaden and other fish, says Churchill Grimes of NOAA's fisheries research lab in Santa Cruz, California. To assess these conflicting signals, this summer the Louisiana Department of Wildlife and Fisheries is beginning a 3-year study of hypoxia's impact on commercial fisheries.

Before that study can reach any conclusions, however, it appears likely that government officials will forge ahead with programs to slash the Mississippi's nitrogen loads. The Clinton Administration, for instance, has proposed spending $322 million over the next 5 years on reducing hypoxia. The money, which would be funneled through several agencies, would go to research and to implement so-called "win-win, no regrets" measures unlikely to anger the powerful farm lobby. Indeed, even the Fertilizer Institute, the industry's Washington, D.C.–based trade group, supports one such measure: voluntary incentives for creating 2 million miles of nitrogen-trapping vegetation buffers along farm fields. Administration officials say other initiatives could include building wetlands and helping farmers buy computers and equipment that would enable them to apply fertilizer more efficiently.

But even if all these steps are taken, hypoxia researchers say it could be decades before they yield meaningful results—and in the short term, the gulf's ecological health could even worsen. Studies in watersheds around the Chesapeake Bay and elsewhere, for instance, have shown that after years of effort to reduce nitrogen leaching, levels of the nutrient in streams and rivers can remain stable or even rise slightly. The problem, says Goolsby, is that "these systems have been saturated with so much nitrogen for so long that there is a very long lag time in cycling it out"—a discouraging prospect for lawmakers who may need to show quick results for expensive and controversial restoration projects. And if

remediation efforts do succeed in reducing nitrogen levels, a shifting nutrient balance could shake up the gulf's phytoplankton community in unpredictable ways that abet hypoxia or even lead to blooms of toxic dinoflagellates, such as those found in red tide, warns Quay Dortch of the Louisiana Universities Marine Consortium. "We could see some unintended consequences in getting to where we want to be," she says.

As scientists hash out the best strategy for battling the dead zone, gulf fishers like Darda and midwestern farmers like Sievers are beginning to appreciate how tightly bound their livelihoods are to the mighty Mississippi and the dissolved nitrogen it sweeps into the sea. "Never before," says Downing, "has the interconnectedness of life in distant rural communities been so apparent." **–DAVID MALAKOFF**

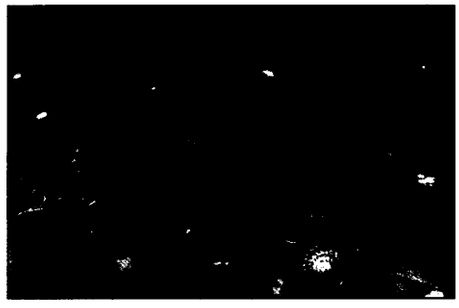
David Malakoff is a writer in Bar Harbor, Maine.

Ecology's Catch of the Day

NEWS

A massive federal undertaking to learn where fish live in the ocean could lead to major changes in the way the United States manages its fisheries

Dave Packer probably knows more about the mid-Atlantic summer flounder than any other person on the planet. The marine ecologist has spent a year scouring journals, digging up graduate theses, and tracking down survey data to assemble a picture of exactly where off the U.S. eastern seaboard the fish spend their lives. Packer's daunting task—as he describes it, to find out "everything you've always wanted to know" about the flounder's habitat, from Maine to Georgia—involved sorting through more than 250 papers and sometimes conflicting accounts on, among other things, the fish's preferred water temperatures, bottom types, and food. The grueling exercise has yielded an "incredible overview of the species," says Packer, who works for the National Marine Fisheries Service (NMFS) in Highlands, New Jersey.



Flounder's flat. A painstaking effort is under way to define and protect the summer flounder's habitat.

HERB SEGARS / ANIMALS ANIMALS

Packer's labors are part of a sea change in the way the U.S. government hopes to manage increasingly fragile ocean fisheries. His flounder opus is one of hundreds of similar studies spawned by a federal effort to force fishery managers to take into account the health of a fish's habitat—and not simply its population size—in setting restrictions on fishing. This move to give ecologists a greater voice in the management of commercial fish stocks comes courtesy of the 1996 Magnuson-Stevens Fishery Conservation and Management Act. "For the first time, people who manage fisheries must consider habitat, and that is an overdue and giant leap forward," says Elliott Norse, president of the Marine Conservation Biology Institute in Redmond, Washington. The law mandates that by 11 October, eight fishery management councils around the country must have finished mapping out "essential fish habitat" for more than 600 species, from groupers off Florida to salmon off Alaska.

Industries that operate along the coast are anxiously awaiting the results: Areas designated as essential habitat should gain protection under the act, and harmful commercial activities—including some fishing practices—could be curtailed. But specific repercussions are still unknown. For instance, East Coast councils haven't tipped their hands yet on whether Packer's findings might help trigger restrictions on activities such as dredging in estuaries or waste discharges. That the law might wrap a protective cocoon around coastal nurseries delights the fishing industry. "We hope [implementing the law] will unlock fish stocks that we currently cannot use because they are contaminated by pollution or harmful algae blooms," says Richard Gutting of the National Fisheries Institute, an industry lobby group.

In a rare show of solidarity, scientists, conservationists, and fishing industry officials agree that safeguarding habitat is a key to restoring beleaguered fish stocks. But the effort faces a big obstacle: Scientists know so little about the habitat needs of many fish species that they are starting virtually from scratch. Indeed, some observers argue that, in the face of this yawning knowledge gap, the federal effort to define essential habitats is badly underfunded. Others worry that the program could be politically vulnerable if it leads to tighter regulations. Still, scientists are thrilled about the prospect that ecology could soon help underpin fishing regulations. The act and its "far-reaching implications," predicts Jim Murray, a fisheries biologist at North Carolina State University in Raleigh, "will be a cornerstone of fishery management for years to come."

Essentially black boxes. The effort to define essential habitats is aimed at remedying a key shortcoming of the Magnuson Fishery Conservation and Management Act of 1976, landmark legislation that laid the groundwork for regulating where, when, and how many fish can be caught in a season. "Right now, the fishery management models assume that habitat is stable, but that's not the case," says Jim Burgess, director of the National Oceanic and Atmospheric Administration's (NOAA's) habitat restoration center, who until May directed NMFS's habitat conservation office. Habitat for commercial species is being degraded by a host of factors, Burgess says. They include pollution from oil spills, urban and agricultural runoff (see story on p. 190), dredging, damming coastal rivers needed for spawning, and filling or draining salt marshes. Fishing methods that disturb the seabed, such as trawling, also alter fish habitat, although the damage they inflict is still hotly debated.

But, although experts say it's clear that human activities are degrading fish habitat, it's still uncertain how much the intrusions contribute to declines in fish stocks. That's why environmentalists and commercial fishers joined forces and lobbied Senator Ted Stevens (R–AK) 2 years ago to include a provision in a new version of the law—the Magnuson-Stevens Act—requiring that each of the eight regional fishery management councils identify essential habitats, and threats to those habitats, for each species in its jurisdiction. The act defines essential habitat as "waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity." NMFS has instructed the councils to use survey data on a species at a given location to map habitats used by fish, from birth to death. For overfished species that now occupy reduced ranges, the councils can consider historical data.

For most species, there are major knowledge gaps. "We tend to know where the adults are but not the juveniles," explains Burgess, who says the missing data present "a major obstacle" to implementing the law. In many cases, fishery managers infer likely habitat based on notions about a species' needs at various stages in its life cycle. But that requires knowledge—such as where kelp forests and rocky bottoms are located—that too is often lacking, Burgess says.

Even when there's good information about a species' geographic range, it's not easy to determine which areas are truly essential. That will require data on a species' reproductive and growth rates in different geographic areas—information that is scarce for any fish, says Paul Brouha, executive director of the American Fisheries Society (AFS). "We don't know enough by orders of magnitude" for