The Expiration of Respiration

Oxygen—the missing ingredient in many bodies of water

By TINA ADLER

When the fish, crabs, and shrimp in Alabama's Mobile Bay practically walk ashore, residents of the nearby town call it a jubilee. Someone spots the arrival, and phones start ringing. Soon, people gather at the water's edge to collect baskets of live fish right off the beach, often in the dead of night. Few, if any, other communities in the world ever enjoy such a carefree catch—but Mobile does several times a year.

Newspapers first reported fish coming ashore in July 1867. In 1912, they published a local theory on why jubilees occur. A sudden influx of saltwater from the Gulf of Mexico brings fish into the bay. "When [saltwater] fish are plunged unexpectedly into a muddy fresh-water bath, they appear to lose their heads entirely and make their way posthaste to shore," explained the July 29 Daily Register: Mobile.

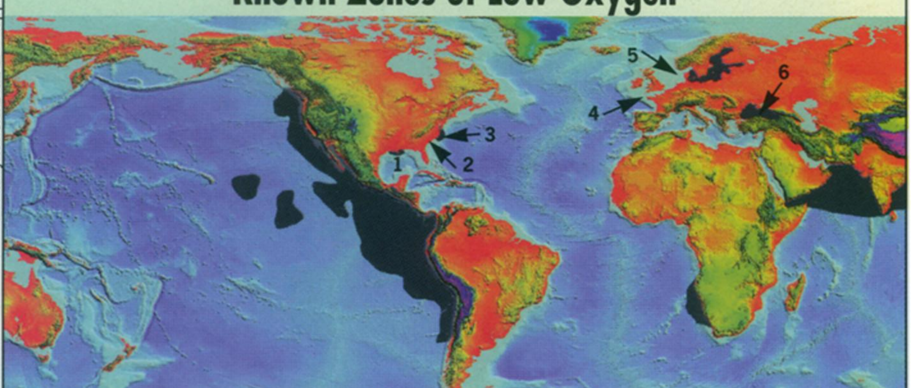
Today, scientists know that the fish don't lose their heads—until they get into human hands, anyway. Instead, their behavior makes sense.

On warm, still nights, little oxygen gets added to the bottom of the bay. Fish move closer to the surface, in search of oxygen. When a rising tide carries low-oxygen water from deep in the bay toward shore, the fish swim ahead of it to shallower waters, explains Jonathan R. Pennock of the Dauphin Island (Ala.) Sea Lab. By the time the fish sense their dangerous proximity to land, they can't turn around.

The number of jubilees occurring each year has remained fairly steady, locals say. The bay's oxygen readings have too, at least since scientists began taking them 25 years ago, Pennock says.

That consistency makes Mobile Bay unique in another way.

Known Zones of Low Oxygen



D. Kamykowski/Diaz/ER Mapper 5.0

Gray areas show hypoxic waters around the world.

1. More than any other area in the United States, the Gulf Coast faces the risk of developing hypoxia severe enough to wipe out the commercial fishery, Diaz says.
2. In June 1995, 25.8 million gallons of hog feces and urine spilled into a narrow stream feeding North Carolina's New River estuary. Eight miles of the stream became anoxic; oxygen concentrations returned to normal in July. About 4,000 fish died, in part from the anoxia, says JoAnn M. Burkholder of North Carolina State University in Raleigh.
3. Much of the Chesapeake Bay remains hypoxic from spring until autumn.
4. Hypoxia contributed to the collapse of the cockle fishery in Sommone Bay, France.
5. The commercially valuable lobster, *Nephrops norvegicus*, no longer lives in the hypoxic waters of Kattegat, an arm of the North Sea. *N. norvegicus* became famous when researchers found on its lips an animal so unusual it appears to represent a new phylum (SN: 12/16/95, p. 404).
6. As a result of both human and natural causes, the Black Sea has more anoxic water than any other area of the world.

Many bodies of water have become much more hypoxic, or low in oxygen, as pollution has worsened, researchers say. That's because pollutants such as fertilizers and sewage enter the world's oceans, bays, and fjords carrying phosphorus and nitrogen, which nourish the phytoplankton. Bacteria thrive on nutrients from dead phytoplankton and eventually use up the water's oxygen. Soon, when anoxia sets in, only animals that don't require oxygen manage to thrive.

More bodies of water now suffer from such ills than ever before. Indeed, low oxygen ranks as a greater environmental threat than most people realize, researchers say. It's also more complicated. When oxygen supplies decrease, the concentration of carbon dioxide in water usually increases, yet many studies overlook this effect.

"There is no other [international] environmental variable of such ecological importance to coastal marine ecosystems that has changed so drastically in such a short period as dissolved oxygen," assert Robert J. Diaz of the College of William and Mary's School of Marine Science in Gloucester Point, Va., and Rutger Rosenberg of Göteborg University in Fiskebäckskil, Sweden.

Low oxygen now causes more mass fish deaths than any other single agent, including oil spills, and it ranks as a leading threat to commercial fisheries and the marine environment in general, they argue. Hypoxic water has less than 2 milliliters of oxygen per liter of water. It can occur seasonally or sporadically, or it can persist for a year or more.

Diaz and Rosenberg came to their conclusions after reviewing some 250 studies, most done in the field, on low oxygen in the marine environment, they report in OCEANOGRAPHY AND MARINE BIOLOGY: AN ANNUAL REVIEW, released in December 1995. No one had ever reviewed the complete literature on marine hypoxia before, Diaz says.

Their analysis suggests that it affects every continent, even though many scientists studying low oxygen fail to see it as a global issue. Most of the papers they reviewed discuss only particular hypoxia problems and don't refer to a worldwide dilemma, they report.

Diaz and Rosenberg's overall findings are "pretty striking to me and most of my colleagues . . . the changes [they] saw in water oxygen were quite profound," as were the effects of those changes on fish populations, says Louis E. Burnett of the University of Charleston (S.C.) Grice Marine Biological Laboratory.

The concentration of oxygen in polluted water tends to decline gradually over the years and then drop dramatically, Diaz and Rosenberg find. Before-and-after studies of hypoxia reveal that many bottom-dwelling, or benthic, ani-

G. Riekerk and G. Steele

mals leave or die when oxygen supplies get low; animals that can tolerate such conditions then move in, they report.

After oxygen concentrations go back up, benthic communities take at least 2 years to return to normal. Seasonal hypoxia often temporarily eliminates much animal life, but about 80 percent of the time, the populations rebound to normal.

No large body of water has ever recovered completely from a yearlong lack of oxygen, which can ruin commercial fisheries, they warn. Most areas with such persistent hypoxia have a stable, but not very diverse, animal community.

The salt marshes around Charleston, S.C., become hypoxic daily, but some fish and shrimp thrive there nevertheless.

Difficulty with respiration is only one of the problems that animals face in hypoxic waters. When oxygen concentrations drop, the bacteria that metabolize sulfates move up from their home deep in the sediment to the surface of the ocean floor. There, they expose fish and other invertebrates to potentially lethal amounts of hydrogen sulfide, studies have shown.

Burnett and his colleagues are investigating the effects of the high concentration of carbon dioxide that accompanies low oxygen. Carbon dioxide makes water and the body fluids and tissues of marine animals more acidic. "But people who have looked at low oxygen have virtually ignored the acidification part of the story," Burnett says.

The tidal salt marshes near Charleston Harbor become hypoxic twice a day. As a result, the hemolymph, or bloodlike fluid, of local oysters is acidic. This acidity makes the oysters less resistant to dermo (*Perkinsus marinus*), a common, deadly parasite, suggest studies by Burnett and his colleagues.

The researchers kept eastern oysters (*Crassostrea virginica*) in tanks under normal or hypoxic conditions for 2 days. They then measured the animals' production of reactive oxygen intermediates, which attack invaders such as dermo. The oysters from the hypoxic tank had acidic hemolymph and produced almost none of these intermediates. The others looked normal in all regards, Burnett says.

Moreover, dermo seems to prefer acidic environments, since it appears to acidify oyster hemolymph, report Burnett and John J. Dwyer III, also of Grice, in the February BIOLOGICAL BULLETIN.

Some animals tolerate hypoxic conditions much longer than others do. Certain clams survive low oxygen by simply stretching their siphons farther, to reach water higher in oxygen. Because its mouth is located on the back of its flat head, the killifish (*Fundulus heteroclitus*) can respire the small amount of oxygen found at the surface of water.

Some survivors switch temporarily from aerobic to anaerobic metabolism. This feat requires them to make use of different chemicals in their bodies to produce energy. They also make and use less energy, studies show. One priapulid worm can survive for 90 days by switching to anaerobic metabolism.

Long-time marine residents of Charleston Bay switch to anaerobic metabolism when the water becomes hypoxic, report Burnett and Richard E. Cochran of Grice in an upcoming JOURNAL OF EXPERIMENTAL MARINE BIOLOGY AND ECOLOGY. They exposed grass shrimp (*Palaemonetes pugio*), spot fish (*Leiostomus xanthurus*), and killifish to various concentrations of oxygen and carbon dioxide.

Blue crabs take a different approach to surviving hypoxia. Their hemolymph becomes more alkaline. An ongoing study by Burnett and Peter L. deFur of the Environmental Defense Fund in Washington, D.C., indicates that this change improves the ability of blue pigment in the hemolymph to take up oxygen.

People in Mobile Bay, who are enjoying the ones that didn't get away, rejoice that some marine animals lack such escape techniques. Diaz and Rosenberg, meanwhile, are wondering whether countries will ever take pollution-abatement steps to make sure that fewer fish need them. □