p with detailed "nutrient management plans"
e, and hopefully prevent, nutrient runoff.
hite suggested that farmers will follow these
/ out of economic self-interest. Fertilizer is
s money. "If you're looking for someone who
you're talking to the wrong guy," he said.
nent at Michigan State University's Kellogg
ıggests that economic self-interest alone can
n. The experiment, which has been studying
f different farming practices for the past
ble to dramatically reduce nutrient releases
ıs to require farmers to scale back their
han pursuing the highest yields of the most

ist for the University of Maryland, says get-
ly under control will take many years. "It's
/ent in a wrong direction incrementally, and
ementally. It's not going to give us the water
But it's all moving in the right direction."

fertilizer wisely?
ıtlined in this article between watersheds
er?
roblem of fertilizer polluting our coastal

'economic self-interest alone can actually
experiment, which has been studying the
lifferent farming practices for the past
ossible to dramatically reduce nutrient
: it seems to require farmers to scale back
rather than pursuing the highest yields of
ich is corn." Discuss as a class what this
solution. How do you think a farmer

might respond to the idea of a fertilizer diet? And, if "economic self-interest alone" is not enough, what more may be needed to make solutions like this a reality?

2. Combining what you learned in this article and in "Good Old Dirt," write a newspaper article that describes the delicate relationship between the problems of nutrient runoff and soil degradation. Be sure to include the ways that the solutions to each of these problems might affect the other. Conclude with a suggestion of how these issues may be addressed simultaneously.
3. Use the concept of ecosystem services from the previous reading to construct an argument for putting farmland on a fertilizer diet.

Louisiana Universities Marine Consortium
"About Hypoxia"

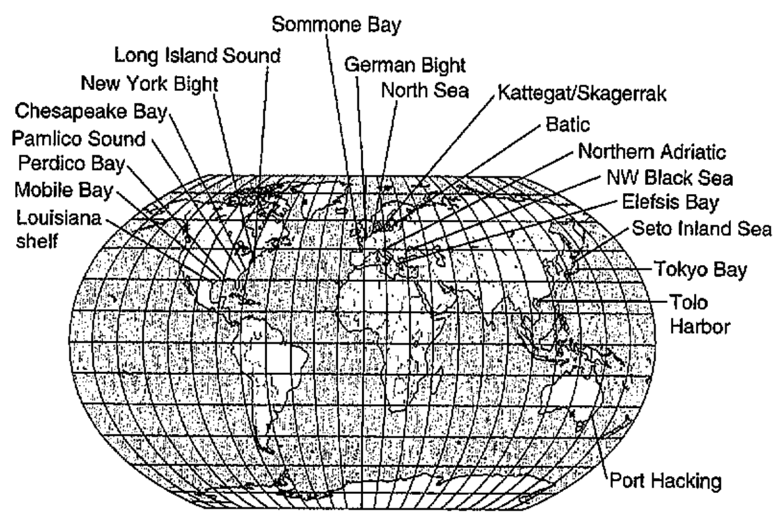
This introductory overview of hypoxia appears on the website of the Louisiana Universities Marine Consortium (LUMCON), directed by Dr. Nancy Rabalais. The hypoxia research team at LUMCON has 4 researchers and 10 collaborators at university research centers across Louisiana. LUMCON researchers have published 45 papers or book chapters, 3 books, and 6 reports concerning hypoxia in the Gulf of Mexico. This website offers a clear and accurate definition of hypoxia and a careful explanation of its causes and describes the history of hypoxia research. While this is not a research publication in a scientific journal, the language and style are carefully qualified and the document does not make strong, unsupported claims. As you read, think about whether you trust these writers or not, and how they explain difficult concepts in ways that you can understand.

Hypoxia, or oxygen depletion, is an environmental phenomenon where the concentration of dissolved oxygen in the water column decreases to a level that can no longer support living aquatic organisms.

Hypoxia in the northern Gulf of Mexico is defined as a concentration of dissolved oxygen less than 2 mg/L (2 ppm). This figure is based on observational data that fish and shrimp species normally present on the sea floor are not captured in bottom-dragging trawls at oxygen levels <2 mg/L. In other oceans of the world, the upper limit for hypoxia may be as high as 3–5 mg/L.

Hypoxia occurs naturally in many of the world's marine environments, such as fjords, deep basins, open ocean oxygen minimum zones, and oxygen minimum zones associated with western boundary upwelling systems. Hypoxic and anoxic (no oxygen) waters have existed throughout geologic time, but their occurrence in shallow coastal and estuarine areas appears to be increasing as a result of human activities (Diaz and Rosenberg, 1995). The largest hypoxic zone currently affecting the United States, and the second largest hypoxic zone worldwide, occurs in the northern Gulf of Mexico adjacent to the Mississippi River on the Louisiana/Texas continental shelf. The maximum areal extent of this hypoxic zone was measured at 22,000 km^2 during the summer of 2002; this is approximately the same size as the state of Massachusetts.

The average size of the hypoxic zone in the northern Gulf of Mexico over the past five years (2004–2008) is about 17,000 km^2, the size of Lake Ontario. For comparison, the entire surface area of the Chesapeake Bay and its major tributaries measures about 11,000 km^2.



Anthropogenically Influenced Estuarine and Coastal Hypoxia

Figure 6.1 Hypoxia, a worldwide problem: areas of anthropogenically-influenced estuarine and coastal hypoxia worldwide.

What Causes Hypoxia?

Major events leading to the formation of hypoxia in the Gulf of Mexico include: 5

- Freshwater discharge and nutrient loading of the Mississippi River
- Nutrient-enhanced primary production, or eutrophication
- Decomposition of biomass by bacteria on the ocean floor
- Depletion of oxygen due to stratification

The Mississippi River basin drains approximately 41% of the land area of the conterminous United States, ranging as far west as Idaho, north to Canada, and east to Massachusetts.

The Mississippi River system is the dominant source of freshwater and nutrients to the northern Gulf of Mexico. The discharge of the Mississippi River system is controlled so that 30% flows seaward through the Atchafalaya River delta and 70% flows through the Mississippi River bird-foot delta. About 53% of the Mississippi River delta discharge flows westward onto the Louisiana shelf.

Mississippi River nutrient concentrations and loading to the adjacent continental shelf have greatly changed in the last half of the 20th century.

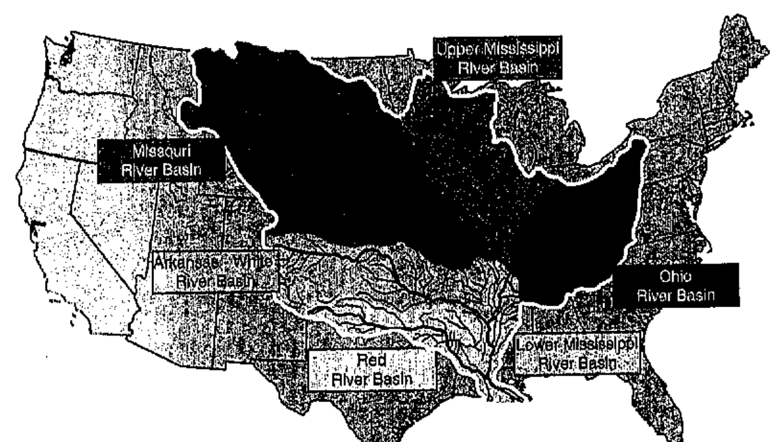


Figure 6.2 The Mississippi River Basin: The Mississippi River Basin is divided into six sub-basins.

During this time there has been a marked increase in the concentration of nitrogen and phosphorous in the Lower Mississippi River. This increase has been attributed to the increased use of nitrogen and phosphorous fertilizers, nitrogen fixation by leguminous crops, and atmospheric deposition of oxidized nitrogen from the combustion of fossil fuels. Nitrogen and phosphorous occur in four inorganic forms in the river: nitrate (NO_3^-), nitrite (NO_2^-), ammonium (NH_4^+), and orthophosphate (PO_4^{-3}). Many of these nutrients enter the river from non-point sources like runoff, which are much more difficult and complex to control and monitor than point sources of pollution.

Eutrophication follows when ocean systems are over enriched with nutrients beyond natural levels, causing significant increases in primary production, or growth of algae in marine systems. In the same way that nitrogen and phosphorous fertilize human crops, they also fertilize plants in the ocean. The spring delivery of nutrients initiates a seasonal progression of biological processes that ultimately leads to the depletion of oxygen in the bottom water.

10 In the northern Gulf of Mexico, eutrophication initiates a massive growth of phytoplankton on the water's surface. The size of this plankton population is well beyond the natural capacity of predators or consumers to graze it down to a balanced level. Phytoplankton have a relatively short life span, and after dying sink down to the bottom waters where they await decomposition by bacteria.

During this time of year, the water column is also stratified, meaning that environmental factors like temperature and salinity are not uniform from top to bottom. Freshwater flowing from the river, and seasonally warmed surface water, has low density and forms a layer above the saltier, cooler and more dense water masses near the bottom. This stratification leaves the bottom layer isolated from the surface layer and cut off from a normal resupply of oxygen from the atmosphere.

As bacteria on the ocean floor decompose the abundant carbon in the phytoplankton that sinks down, oxygen is consumed. Because of water column stratification, oxygen consumption rates at the bottom of the ocean easily exceed those of resupply and the result is hypoxia, or low dissolved oxygen. Organisms capable of swimming (i.e., fish, shrimp, and crabs) evacuate the area, but less motile fauna experience stress or die as a result of low oxygen. Hypoxia has the potential to damage important commercial fisheries in the Gulf of Mexico over the long term as food webs become disrupted and organisms at all trophic levels are impacted.

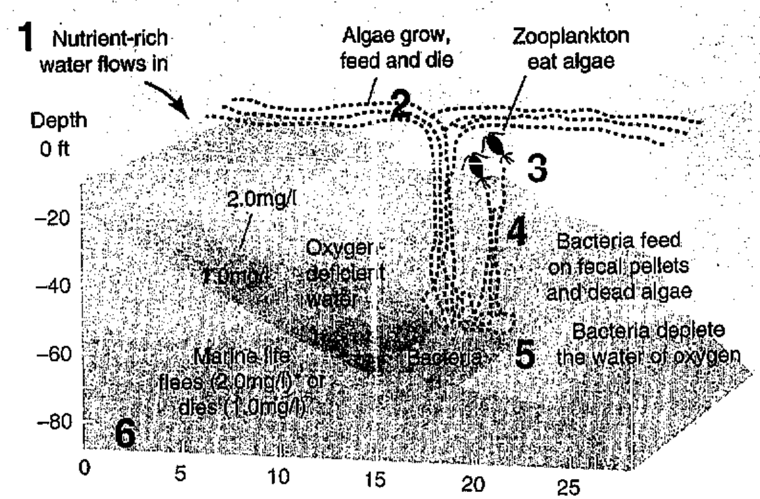


Figure 6.3 Nutrient-based hypoxia formation: 1) nutrient-rich water flows in; 2) algae grow, feed, and die; 3) zooplankton eat the algae; 4) bacteria feed on fecal pellets and dead algae; 5) bacteria deplete the water of oxygen; 6) marine life flees or dies.

Hypoxia can persist several months until there is strong mixing of the ocean waters, which can come from a hurricane or cold fronts in the fall and winter.

History of Hypoxia Research in the Northern Gulf of Mexico

Hypoxia was first documented in the northern Gulf of Mexico off the Louisiana coast in 1972. Sporadic occurrences were observed in subsequent years. In 1975 and 1976, two cruises were conducted specifically to map a suspected area of low oxygen along the Louisiana coast. These maps indicated small, disjunct areas of hypoxia. With an increase in oceanographic research in the Gulf of Mexico, more reports of hypoxia emerged. The first concerted, continuous, and consistent documentation of the temporal and spatial extent of hypoxia on the Louisiana and Texas continental shelf began in 1985 with funding from the National Oceanic and Atmospheric Administration, National Ocean Service. Dr. Don Boesch, then Director of Louisiana Universities Marine Consortium (LUMCON), initiated the study, which was led by Dr. Nancy N. Rabalais of LUMCON and Drs. R. Eugene Turner and William J. Wiseman, Jr. of Louisiana State University.

15 Over the next 25 years, the research team expanded their studies, included more components and collaborators, and began unraveling the dynamics of hypoxia in this river-dominated coastal ecosystem. For more information, and to read about current research efforts, please visit the Research and Resources sections of our website.

Analyze

1. Nitrogen and phosphorus are nutrients. Farmers put nitrogen and phosphorus on their fields to make them more productive. So, why is nitrogen a problem in the Gulf of Mexico?
2. This article suggests that hypoxia is both a natural phenomenon as well as a human-induced phenomenon. Succinctly describe why that is. Why, if hypoxia occurs naturally, does this article suggest it is a problem?
3. Pick a paragraph you understand but had trouble reading and rewrite it so that it is easier to understand.

Explore

1. Who do you think is affected by hypoxia? An immediate and correct answer might be "fishermen," but as this book suggests over and over again, consequences can be complicated and far-ranging. In a group, thinking on as wide a scale as you can, make a list of all of the people or groups that you can imagine might be affected by hypoxia and why. Bonus: Who affects hypoxia? Is it just farmers? Or can you think of any other groups of people whose actions or choices may have an indirect effect on hypoxic conditions as well?
2. Hypoxia is a major problem, but not the only significant problem with water and ecosystems we face in America. Do some research to identify the critical water sources and issues in your state, county, or town. You might begin with the notion of the watershed, the area that drains into a single river, lake, or estuary. Create a poster or digital map that represents the whole system and explains how the pieces of the problem are connected to each other.
3. Using the third visual, "Nutrient-based Hypoxia Formation," create a larger visual or map that integrates additional systems in play that contribute to or result from hypoxia, based on your knowledge from

the readings in this chapter. For example, the current st with "Nutrient-rich water flows in." But what caus the map both from the beginning of the cycle and the end porating some ideas about what might occur after "M or dies."

Cynthia Barnett
"The Illusion of Water Abundance"

Cynthia Barnett in a journalist who has written about the water supply, use, and scarcity in America for 25 years. She has a degree in journalism and a master's degree in environmental the University of Florida. Her writing has won many awards, inc 2007 Florida nonfiction book award for *Mirage: Florida and the Water of the Eastern U.S.* The essay reprinted here comes from he book, *Blue Revolution: Unmaking America's Water Crisis*, in which that our false sense of a never-ending supply of water is leading t areas in America. Echoing Aldo Leopold's earlier call for a "la Barnett calls for a "water ethic" to inspire a "blue revolution" in whi careful attention to our cheapest necessity—water. As you read, why Barnett includes stories of how citizens and local governme changed their water management practices.

During America's retreat to the suburbs in the 1950s, large disposable incomes, and a nifty concrete spray called gunit lies a new marker of success: the backyard swimming pool. For the twentieth century, residential pools symbolized upward m offered a sense of seclusion not possible at city pools or even p The following decades redefined our relationship with water essence of life to emblem of luxury. By the time of the twenty-fi housing run-up, even the plain blue pool had lost its luster. A were needed. Aquatic affluence meant floating fire pits, glass pool vanishing edges, which create the illusion of never-ending wate