

HYPOXIA



Ecological Society of America

WHAT IS HYPOXIA?

Throughout the world, large areas of our coastal waters are becoming so polluted that they lack sufficient oxygen, one of the basic building blocks of life. This condition is called “hypoxia.” Although this is sometimes a natural condition, the increased area of water affected, extended length of each episode, and higher frequency in recent decades are due to human activities. Overenrichment of estuaries and coastal waters with nutrients, especially nitrogen, stimulates outbreaks or “blooms” of algae that consume vital oxygen from the water when they decompose. The effects of hypoxia include fish kills and shellfish bed losses. These losses can have significant detrimental effects on the ecological and economic health and stability of coastal regions.

Hypoxia means “low oxygen.” In aquatic ecosystems, low oxygen usually means a concentration of less than 2-3 milligrams of oxygen per liter of water (mg/l). A complete lack of oxygen (0 mg/L) is called **anoxia**. Since organisms that can live without oxygen (such as some microbes) are the only residents in these areas, they are sometimes called “dead zones”. Hypoxia is primarily a problem in estuaries and coastal waters, although it can also be a problem in freshwater lakes.

WHAT ARE THE EFFECTS OF HYPOXIA?

The direct effects of hypoxia include fish kills, which not only deplete valuable fish stocks and damage the ecosystem, but are unpleasant for local residents and can harm local tourism. Oxygenated water is necessary for aquatic animals to breathe. Mobile animals, such as adult fish, can often survive hypoxia by moving into oxygenated waters. When they cannot, such as when young fish need to spend time in the habitat that has become hypoxic area, the result is a fish kill. Nonmobile animals, such as clams, cannot move into healthier waters and are often killed by hypoxic episodes. This causes a severe reduction of the amount, or in extreme cases the complete loss, of animal life in hypoxic zones.

Because hypoxia often occurs in estuaries or near shore areas where the water is poorly mixed, nursery habitat for fish and shellfish is often affected. Without nursery grounds the young animals cannot find the food or habitat they need to reach adulthood. This causes years of weak recruitment to adult populations and can result in an overall reduction or destabilization of important stocks.

Fish-eating birds and mammals, such as herons or otters, cannot live where there are no fish. Hypoxic areas may also be more susceptible to overfishing, pest outbreaks, storm damage, or other stresses.

What is mixed water?

In poorly mixed water, oxygen or pollutants get trapped in a single water layer (usually the top or the bottom). In well-mixed water, they get dispersed throughout.

Chemical reactions between hypoxic water and bottom sediments can release pollutants stored in the sediments, further fueling the hypoxic conditions or otherwise polluting the ecosystem.

HYPOXIA KILLS FISH

- 15 of the 21 fish kills with identified causes that occurred in the Barataria and Terrebonne Estuarine Complex in 1998, were due to low dissolved oxygen concentrations.
- In North Carolina, two separate hypoxic events in the Neuse River Estuary in 1995 killed millions of fish. Additional events in 1998 and 1999 killed tens of thousands of fish. These fish kills were closely linked to hypoxia in the estuary.
- In the Chesapeake Bay, low oxygen levels have killed many blue crabs, one of the most popular local menu items.

The most serious effects of hypoxia on fisheries are probably:

- longterm weakening of species also stressed by overfishing
- habitat loss
- longterm changes in ecology (e.g. a shift in the dominant species of algae, which can change the dominant fish species)
- economic losses

In the northern Gulf of Mexico, small brown shrimp populations occur in the same years that large hypoxic zones do. In many areas hard hit by hypoxia, fish and shellfish populations are highly variable, an indication they are unstable. Recurrent hypoxic conditions prevent fish and shellfish from recovering from other stresses such as disease, storms, and overfishing and may cause longterm changes in the ecology of the area.

This situation is detrimental not only for ecosystems but for fishermen who rely on these resources for their livelihood and for consumers who look forward to bountiful fish and shellfish harvests.



Dead fish. Photo courtesy of USEPA

WHAT CAUSES HYPOXIA?

Hypoxia is a complex ecological phenomenon that arises from the convergence of several factors, some of which are altered by human activities.

- **Physical environment.** The shape of the water body and the strength and direction of water flow determine how well-mixed the water is and how long it spends in the lake, bay, or estuary. Wind strength and direction and the influence of major storms also affect the rate of mixing. Human activities, such as changing the amount of freshwater entering an estuary, can reduce the amount of mixing. Poorly-mixed water increases the chance hypoxia will develop.
- **Nutrient enrichment.** Nutrients (primarily nitrogen and phosphorus, but sometimes also including silica, iron, zinc, and magnesium) are necessary for plant growth. An overabundance of these nutrients, combined with enough light and warm, slow-moving, and poorly-mixed water, can result in an algae bloom. This is the first step in the chain of reactions that can lead to hypoxia. These overabundant nutrients may come from point sources such as waste water treatment plant discharges and nonpoint sources such as agricultural activities, urban runoff, groundwater, and atmospheric deposition. The amount of pollutants generated and the rate at which they reach rivers, estuaries and coastal waters are increased by human activities such as the destruction of wetlands, grasslands, and forests in favor of urban or suburban landscapes and many agricultural practices.

REDUCING NITROGEN LOADS TO ENCOURAGE HEALTHY ECOSYSTEMS

Tampa Bay has a long history of high nitrogen loadings and hypoxic conditions. Through the Tampa Bay National Estuary Program and other efforts, the community agreed to meet a reduction goal of 17 tons of nitrogen per year for at least five years. This goal will allow for economic growth in the Tampa region without causing additional nutrient enrichment problems.

In general, water that is slow-moving, poorly-mixed, and has abundant nutrients is more likely to become hypoxic. It also tends to stay that way for longer periods of time.

HOW DOES HYPOXIA DEVELOP?

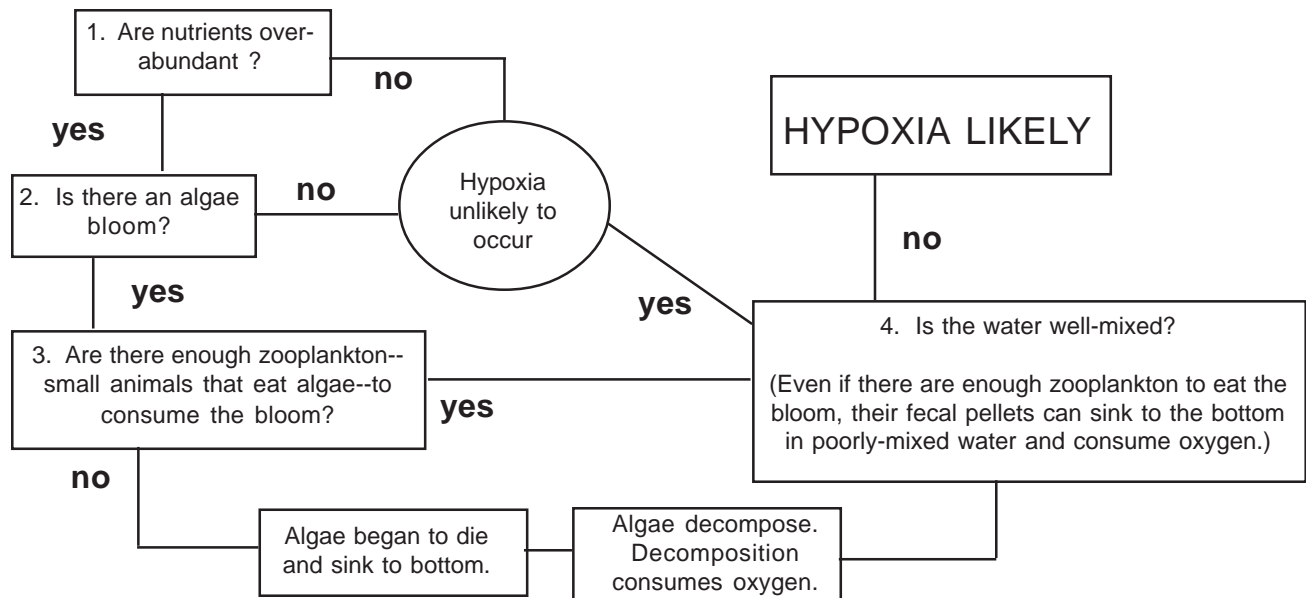
Hypoxia develops when a series of conditions occur together. The diagram below explains how they interact. One of the most important conditions is that there must be a large amount of algae (box 2). These algae have to sink or otherwise end up on the bottom. This happens when the algae die without being eaten, or when they are eaten by small animals (zooplankton) whose fecal pellets sink to the bottom (box 3). On the bottom, the algae or fecal pellets decompose. This process of decomposition consumes oxygen. If the water is not well-mixed, there is no way to replace the oxygen consumed by decomposition (box 4), and hypoxia is likely to occur.

A hypoxic zone is created when there is a large demand for oxygen in bottom waters (which consumes the available oxygen) and few ways for new oxygen to get into those waters.

PROTECTING LONG ISLAND SOUND AND ITS LIVING RESOURCES

Long Island Sound has traditionally suffered from severe hypoxic events, resulting in massive fish kills and other ecological damage. Because of this, a coalition of management agencies and community groups has adopted a target of 58.5% reduction in nitrogen loading to the Sound. Based on extensive modeling of Long Island Sound, it is estimated that this reduction in nitrogen loading will reduce the size of the area that becomes hypoxic by 75%, reduce the length of time the remaining portions of the sound are hypoxic by 85%, and reduce mortality of sensitive larvae by 90%.

FOUR QUESTIONS THAT CAN BE USED TO PREDICT HYPOXIA:



HYPOXIA ON A LARGE SCALE: THE GULF OF MEXICO

The largest hypoxic zone in the United States forms every spring and summer in the Gulf of Mexico just west of the mouth of the Mississippi River. This hypoxic zone has ranged in size from 16,000-20,000 km² since 1993. In 1999, the hypoxic zone was the biggest ever measured at 20,000 km², or roughly the size of the state of New Jersey. For several years before the 1993 Mississippi River Floods it was approximately half of this size. Researchers now agree that the hypoxic zone is the result of the huge loads of nutrients that pour out of the Mississippi and Atchafalaya Rivers every year combined with mixing patterns in the Gulf that separate surface waters from bottom waters. These conditions are optimal for the development of a hypoxic zone. Together, the cities, suburbs, and farms in the Mississippi River watershed contribute an estimated 90% of the nutrient flow into the Gulf of Mexico.

PROTECTING WATERS FROM HYPOXIA

The federal government and many state governments have initiated programs to reduce the amount of nutrients entering our nation's waterbodies. Many other coalitions of citizens, industry, and federal, state, and local governments have formed to develop and implement plans for reducing the amount of nutrients entering coastal waters.

Millions of small actions upstream in places such as Pennsylvania, Minnesota, Vermont, and Colorado, as well as those along the coasts, have large effects—both good and bad—on the health of our nation's coastal waters. Some of the actions that will help keep are coasts healthy are:

- **Minimize use of fertilizers and manage them properly.** Excess fertilizer washes off lawns and farms into streams and eventually rivers, where it travels to the ocean. It can also volatilize from fields or manure lagoons into the atmosphere and be redeposited where it can wash into waterways.
- **Remove nutrients from wastewater and urban runoff before they are discharged.** These sources contribute large amounts of nutrients to areas at risk for hypoxia.
- **Reduce the amount of electricity use and the number of miles driven.** Power generation, either in an electrical power plant or in a car, generates nitrogen oxides (NO_x). NO_x are transformed into nitrates in the air and deposited throughout the country, especially east of the Mississippi River.
- **Practice clean boating.** This includes choosing boat engines that produce the smallest amount of NO_x and using pumpout stations at marinas rather than discharging raw sewage into the water.
- **Preserve land adjoining rivers and streams.** This land, often called a **riparian buffer**, can play a vital role in preventing nutrients that wash off fields and streets from reaching the rivers and coasts. It is also valuable protection against floods, provides habitat for wildlife and migrating birds, and improves the overall health and beauty of the stream or river. Preserving **wetlands** also helps keep nutrients out of rivers, estuaries and coastal waters.



Restored wetland. Photo from USFWS.

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