The Consequenc

of Hypoxia and Nutrient Over-Enrichment

The consequences of hypoxia in the Gulf of Mexico are not fully known. This chapter examines what is known about hypoxia's direct effects on fisheries and on the structure of the marine ecosystem in the Gulf. It also describes the consequences of excess nutrients—the probable primary cause of hypoxia—for water quality and ecosystem functioning within the Mississippi–Atchafalaya River Basin (MARB).

Consequences in the Gulf

The shallow continental shelf area in the Gulf of Mexico that is affected by hypoxia shows signs of hypoxia-related stress—low abundance of fish and shrimp and distinctly different benthic communities. While current ecological conditions are a response to a variety of stressors, the most obvious effects of hypoxia are that many bottom-dwelling, or benthic, organisms die; larger, long-lived species are eliminated; and productivity is shifted to nonhypoxic periods (energy pulsing).

The effects of hypoxia on fishery resources could include direct mortality of both fish and their food base, as well as such indirect effects as altered migration patterns, reduction in suitable habitats, increased susceptibility to predation and disease, and disruption of spawning and recruitment.

Trawl data from the fishery-independent SEAMAP database showed a very consistent pattern that whenever dissolved oxygen approached 1–3 mg/l, catch of shrimp and fish rapidly declined to zero. Laboratory experiments have shown that both white and brown shrimp are able to detect and attempt to avoid hypoxic waters. Both abundance and biomass of fish and shrimp are significantly lower where bottom-water concentrations of oxygen decline below 2 mg/l. Geographic comparisons of the distribution of fishing effort around the Gulf show that the industry has shifted shrimping efforts away from hypoxic zones (Downing et al. 1999).

Overall, fisheries landings statistics for at least the last few decades have been relatively constant. However, the brown shrimp catch—the most important commercial fishery (by dollar value) in the Gulf—declined from a record high in 1990 to below average during 1992–97, coinciding with years of greatly increased hypoxia (see Figure 3.1). Catch per unit effort for brown shrimp, while variable, has trended down since the late 1970s. Near-shore zones, away from hypoxic waters, are the usual habitat for white shrimp, which have not shown as great a decline.

An economic analysis sought to examine the relationship between the estimates of the hypoxic area and available fisheries data, primarily on the two main shrimp species in the Gulf because they are part of the benthic community and are commercially important. Since data on the area of the hypoxic zone are only single annual estimates and are not available before 1985, the time series was judged too short to establish a credible relationship, and the analysis resorted to an extrapolation back to 1960 (see the Topic 2 report, pp. 7–8, for details). Fisheries variables examined included catch per unit effort, depth of landings, and shrimp size. This economic assessment based on fisheries data failed to detect effects attributable to hypoxia (i.e., correlations between the extrapolated time series and fisheries data were below levels usually considered statistically significant). However, this failure does not necessarily mean that hypoxic effects are absent; it only means that the data available for analysis were inadequate to identify the reasons for variability.

> The shallow continental shelf area in the Gulf shows signs of hypoxia-related stress—low abundance of fish and shrimp and distinctly different benthic communities.

Fisheries data are highly variable and affected by many factors. Fisheries productivity, particularly in pelagic (or near-surface) species, may increase as a result of nutrient enrichment, but enrichment can fuel bottom hypoxia, thereby decreasing the productivity of benthic (or bottom-dwelling) species. In the food web, the documented responses of zooplankton to hypoxia include direct mortality, avoidance behavior in adults, interference with vertical migration, and changes in species composition toward smaller species that carry their eggs. Copepods, the dominant zooplankton in the northern Gulf of Mexico, are lower in abundance or absent when dissolved oxygen is less than 1 mg/l.

Comparison of benthic communities in the area affected by hypoxia with those unaffected in nearby Mississippi Sound reveals distinct differences. On the Louisiana continental shelf, benthic communities consist of disturbance-adapted populations. In contrast, the Mississippi Sound contains more fully developed, late-successional stage, "equilibrium"-type communities.

In addition to destroying bottom and near-bottom habitat, hypoxia alters energy flows in the ecosystem. During hypoxia, significant amounts of the system's energy are diverted from invertebrates to microbial decomposition. Energy flows through the ecosystem in pulses, favoring opportunistic species with shorter life cycles that can take advantage of the abbreviated time bottom habitats are available. A reduction in overall biodiversity, abundance, and biomass of the ecosystem is associated with pulsed energy systems, since longer-lived species tend to be eliminated.

Consequences in the Mississippi–Atchafalaya River Basin

Nutrient concentrations affect many aspects of ecosystem and water quality in the Basin, including plankton composition and production, nuisance algal blooms, macrophyte communities and fish communities, as well as the suitability of waters for swimming and drinking and, ultimately, may lead to violations of water quality standards.

Review of state assessments submitted to the U.S. Environmental Protection Agency under section 305b of the Clean Water Act indicates that most states in the MARB have substantial numbers of river miles impaired by high nutrient conditions. This means that those areas are not fully supporting one or more resource uses, including aquatic life, fish consumption, and swimming. Elevated nutrient concentrations, primarily nitrogen and phosphorus, can result in excessive growth of algae and other nuisance aquatic plants, disrupting the ecological balance, clogging pipes, and interfering with recreational activities. Subsequent decay of algae can result in foul odors, bad taste, and further ecological disruption through oxygen depletion.

Legally binding numeric standards have not been established in any state for nutrients in flowing- water systems or lakes, but efforts have been directed toward the development of such standards for many years. At present, many states have a non-numeric (narrative) standard that in essence says nutrients must not be

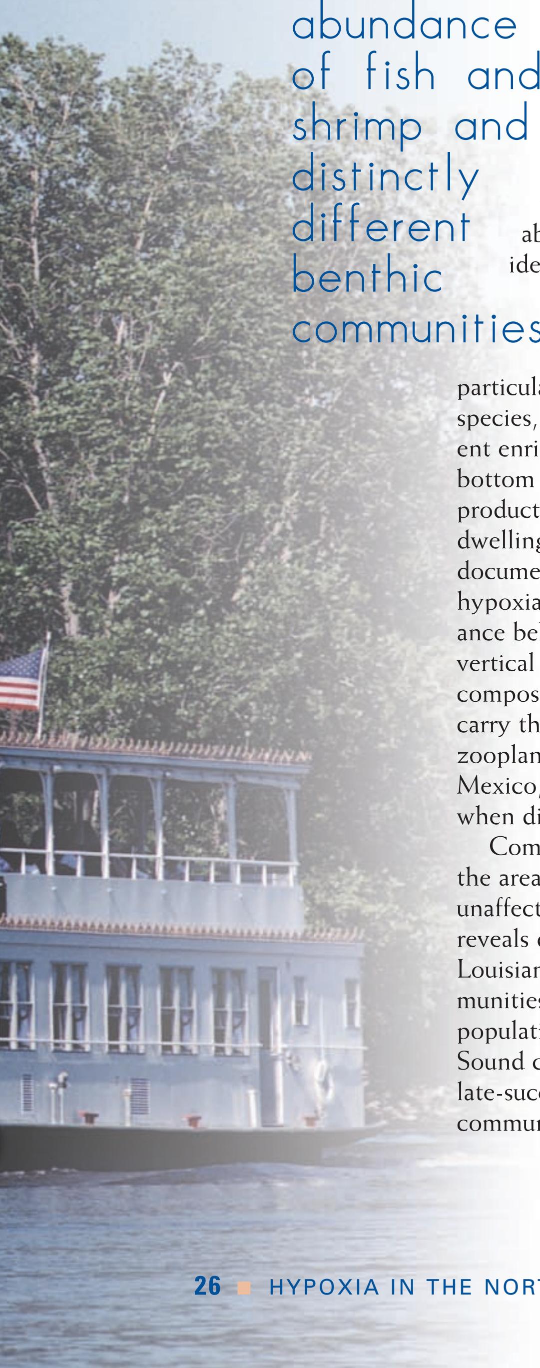
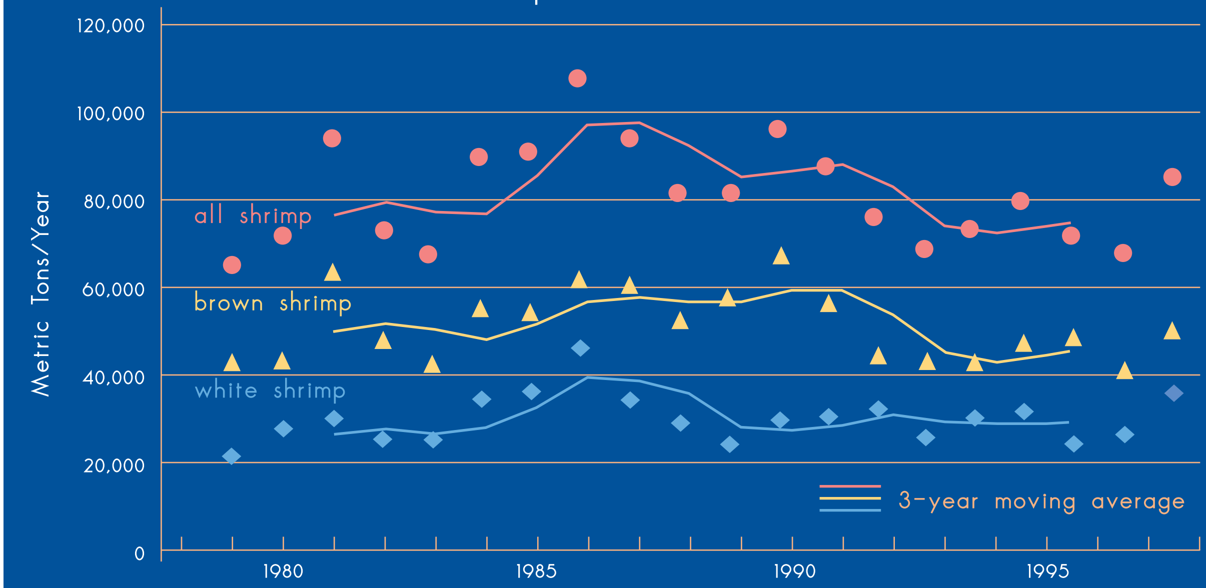


FIG. 3.1 Trends in Annual Shrimp Yield: 1979–98



Source: NOAA National Marine Fisheries Service, www.sf.nmfs.gov/st1/commercial/landings/index.html

While variable, catch per unit of effort for brown shrimp off Louisiana and Texas has trended down since the late 1970s. In contrast, white shrimp haven't shown as great a decline, perhaps because they inhabit near-shore zones away from hypoxic waters.

added to a water body to the extent that they cause an imbalance in the natural flora and fauna. Although science-based numerical criteria for nutrient concentrations to classify lake ecosystems according to trophic state have been available for many years, few classification methods exist in the literature to evaluate the trophic status of stream ecosystems in quantitative terms. One simple classification scheme developed by researchers (Dodds et al. 1998) for streams would use nutrient concentrations at the boundary approximately defining mesotrophic and eutrophic conditions, which is 1.5 mg/l for total nitrogen and 0.075 mg/l for total phosphorus. Under this scheme, about 30–55 percent of the hydrologic cataloging units (HCUs) of the Ohio, Lower Mississippi, and Tennessee subbasins exceed this eutrophic threshold boundary for total phosphorus in flowing waters, and 16–40 percent of the HCUs in these regions exceed the threshold for total nitrogen in flowing waters. Higher exceedance frequencies were found in the Missouri, Upper Mississippi, and Arkansas–Red sub-basins (~80 percent of the HCUs for total phosphorus and 70–75 percent for total nitrogen) (see the Topic 4 report for details).

Excessive nitrate in drinking water can result in "blue baby syndrome" (methemoglobinemia), which causes oxygen levels in the blood of infants to be low—sometimes fatally. About 15 percent of all shallow ground water beneath agricultural and urban areas that has been sampled by the U.S. Geological Survey exceeded the 10 mg/l drinking-water standard for nitrate (USGS 1999). Contamination of shallow ground water may be a warning to alert populations to potential future risks from consumption of water from deeper wells in these aquifers.