Annotated Bibliography on Hypoxia and its Effects on Marine Life, With Emphasis on the Gulf of Mexico

Maurice L. Renaud

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ABSTRACT

This bibliography contains 73 annotated references from publications and reports concerning hypoxia, ≤ 2.0 ppm dissolved oxygen concentration, in the Gulf of Mexico. Instances of hypoxia from similar habitats and the effects of low oxygen levels on marine or estuarine organisms are also included.

INTRODUCTION

Marine and aquatic organisms require various levels of dissolved oxygen to maintain normal growth and activity. Hypoxia, ≤ 2.0 ppm dissolved oxygen concentration, occurs naturally in several regions of the world and creates a stressful condition for most organisms subjected to it. A variety of environmental variables are associated with the formation of oxygen-depleted water. Freshwater runoff, water column stratification, biological processes, and weather conditions appear to play major roles in hypoxia formation. The extent to which any single factor is involved is unknown.

During the past 10 yr, hypoxia has become a major concern to scientists and commercial fishermen in the Gulf of Mexico. Hypoxic or anoxic conditions have been reported annually in the Gulf of Mexico since 1972. They have been concentrated along the Louisiana coastline between the Mississippi River Delta and Marsh Island, LA. More recently, hypoxia was noted off western Louisiana and the upper Texas coast.

The full effect of hypoxia on the commercial fish and shrimp industries is unknown. Although hypoxia has not been directly linked to temporary changes in migratory patterns or in the decline of annual shrimp catch, its presence during portions of a shrimp’s life cycle implicate it as a possible source of variation in annual yields.

This paper contains 73 annotated references that document the occurrence of hypoxia in the Gulf of Mexico and similar coastal habitats, or address the effects of oxygen depletion on marine life. References were obtained through a computer survey of Biological Abstracts, Aquatic Sciences and Fisheries Abstracts, National Technical Information Service, and library research. All articles in this bibliography were reviewed by the author. Users are encouraged to alert the author of any omissions so that addenda can be produced.

ACKNOWLEDGMENTS

I would like to thank Beatrice Richardson for typing the manuscript; the librarian, Pat Torrefranca, for the acquisition of several articles not present in our library; and Lorna Kent for the computer literature survey.

ANNOTATED BIBLIOGRAPHY

Adams, J. K.

Summarization topics include 1) the occurrence of hypoxia in the Gulf of Mexico, 2) factors influencing hypoxia, 3) characterization of Mississippi River water, 4) sources of oxygen-demanding material, 5) areal extent of hypoxic bottom water, 6) research needs concerning the prediction of hypoxia, and 7) understanding the processes in the ecosystem controlling hypoxia.


Discusses the effect of hypoxic conditions on the embryological development, i.e., fertilization through hatching, of the salmon eggs. Mortality and hatching success are noted.


Dissolved oxygen concentration, turbidity, nitrates, nitrites, inorganic and total phosphates were measured at 82 stations in Louisiana estuaries from Sabine Lake to the Pearl River, from April 1968 to March 1969. Seasonal and geographic variation of data are discussed.

1981. Pollution fate and effect studies. In C. A. Bedinger (editor), Ecological investigations of petroleum production platforms in the central Gulf of Mexico, Vol. 1, part 1, 53
Review of the geology and physical oceanography on the outer continental shelf of the Gulf of Mexico, i.e., advective processes, Louisiana shelf circulation, dissolved oxygen levels, water column stratification, photosynthesis, and estimates of petroleum hydrocarbons in the Mississippi River discharge. An examination of hypoxic occurrences is included. Cause and effect relationships are discussed.

Boesch, D. F.

A concise review of documented hypoxia in the Gulf of Mexico. The severity, potential causes, and consequences of hypoxia are evaluated.

Brongersma-Sanders, M.

Classifies mass mortality in the sea into general categories, i.e., catastrophe, sudden changes in environmental parameters (temperature, dissolved oxygen concentration, salinity, and currents), phytoplankton blooms, etc. A catalog of worldwide mass mortalities in the sea is presented. Biological and physical processes resulting in the depletion of oxygen on the ocean floor are discussed.

Bulloch, D. K.

Presents the chronological reporting of the fish and invertebrate kill. Information was collected from commercial and sport fishermen and scuba divers. A low dissolved oxygen concentration in the bottom water of the New York Bight was identified as the cause of the mortalities. Possible sources of the low oxygen levels are discussed.


Atlantic menhaden, Brevoortia tyrannus, and spot, Leiostomus xanthurus, were examined. Relationships between the mean lethal concentration of oxygen and the rate of reduction of dissolved oxygen that induces a fish kill were determined.

Carpenter, J. H., and D. G. Cargo.

Discusses blue crab mortalities in Chesapeake Bay from 1951 to 1953. Dissolved oxygen concentration and water circulation in the Bay are examined. Resistance times to varying degrees of hypoxic water are calculated. Wind direction and speed, tidal velocity, and air and water temperatures are considered.

Childress, J. J.

The oxygen consumption rate of G. ingens was measured in water with a dissolved oxygen concentration ranging from 0.0 to 0.3 ppm. The ability of G. ingens to function under anoxic conditions, and the production and maintenance of the oxygen minimum layer in the deep sea are discussed.


Reports on temporal fluctuations of oxygen levels in Offatts Bayou with respect to Gonyaulax sp. activity and fish kills.

Conseil Permanent International Pour l'Exploration de la Mer.

Provides oxygen, phosphate, and nitrate profiles at numerous locations in the Gulf of Mexico during 1935.


Experimental evidence suggests that minor changes in dissolved oxygen concentration severely affects the swimming behavior of the chinook, Oncorhynchus tshawytscha, and coho, O. kisutch, salmon. This could impact food gathering, predation, and escape behavior, i.e., survival of fish in the wild. May be applicable to Gulf species as well.

Deubler, E. E., Jr., and G. S. Posner.

Examines behavior of postlarval flounders in oxygen-depleted water.

Characterizes oxygenation and reoxyxygenation in the lower Mississippi River. Examines historical and future trends and describes the effects of dredging in the river. Discusses future dredging planned by the Corps of Engineers at Southwest Pass, LA, and the need for future studies.


Describes changes in the burrowing behavior of the “Kuruma” prawn with respect to changes in dissolved oxygen concentration.


Water chemistry was evaluated in the vicinity of a proposed single-point mooring terminal and offshore oil pipeline. Temperature, pH, salinity, BOD-COD, organic matter, inorganic nutrients, and selected heavy metal data were collected monthly during 1973 and 1974. Temporal variations of these data and a large anoxic area discovered during the study were described. Numerous raw data are available in this report.


Summarizes the occurrence of hypoxia off Louisiana from 1978 to 1982. Describes the relationship of hypoxia with catches of demersal fish, plankton, and epibenthos. Provides a correlation of environmental parameters with hypoxia.


Factors affecting the formation of hypoxic bottom water and the assessment of major impacts of oxygen depletion in Louisiana nearshore waters are discussed. Water temperature, salinity, current velocity, and water chemistry are mentioned. Temporal changes in density and vitality of macrofauna with respect to the presence of oxygen-depleted water are noted.


Considered an overview of the Texas-Louisiana shelf ecosystem. Water currents, salinity, turbidity, dissolved oxygen concentration, bottom topography, and sediments are discussed. Zoogeographic faunal assemblages are presented and temporal variations are discussed. The effects of drilling structures, fluids, and oil spills on the above biological and physical data were investigated.


Presents historical data associated with changes in Mississippi River waters, summarizes reports of hypoxia and major biological changes in Gulf water, and suggests the development of assimilative models for the Texas-Louisiana shelf ecosystem.


Reports on the impact of brine disposal from the Bryan Mound disposal site off Texas. Data were collected at one offshore and two nearshore sites in order to determine the presence and magnitude of brown and white shrimp spawning. Hydrographic data (including dissolved oxygen concentration), sediment TOC and grain size, meristic notes on fish and shrimp catch, biochemical analyses of benthic infauna, and histological information on various shrimp tissues were gathered.


A mass mortality of marine organisms in the presence of hypoxic bottom water is described. Benthic infauna and epifauna, fouling organisms, and fishes were affected. Abnormal seasonal variation of several environmental parameters is discussed with respect to the formation of hypoxic bottom water.

A description of marine chemistry and biology in the vicinity of a proposed offshore pipeline and mooring terminal. Plankton, demersal nekton, benthos, avifauna, mammal, sediment, and hydrological data were recorded in and around the study area. Hypoxia documented during this study was the most widespread and severe in present day records.

Gunter, G.

Fish and invertebrate kill in Offatts Bayou, from 1936 to 1941, are described. Dredging, the presence of hydrogen sulfide, oxygen depletion, salinity, water column stratification, and minimal tidal exchange with Offatts Bayou and West Galveston Bay are discussed in relationship to the mass mortalities.

Hagerman, L., and R. F. Uglow.

Monitors haemolymph chloride, magnesium, and calcium ions at various salinities (10, 15, and 20%) and oxygen levels (PO₂ = 10-60 mm Hg). Discusses avoidance behavior of *C. crangon* to hypoxic water and chemical changes in its blood chemistry under hypoxic conditions which may increase the animal’s ability to remove oxygen from water with a low PO₂.

Hann, R. W., and R. E. Randall (editors).

An indepth report containing information on various hydrological parameters, water and sediment quality, nekton, plankton, and benthos. Data were collected before, during, and after brine diffuser operation. Hypoxic bottom water was present in 1979.


Reports on the first documented occurrence of widespread hypoxia in Texas waters. Variation in environmental parameters; species diversity; and species density before, during, and after the event is presented. Provides an understanding of the formation of hypoxic bottom water and contains a brief review of hypoxia in the Gulf of Mexico.


Discusses the formation of hypoxic water and its effect on commercial shrimp, fish, and other forms of marine life. Numerous environmental and biological data are provided. A baseline of normal environmental conditions versus hypoxic and anoxic conditions is presented.

Hochachka, P. W.

Presents biochemical aspects of anaerobic metabolism in parasitic helminths, bivalve mollusks, cephalopods, fish, and diving mammals. Adaptations of organisms that normally live in an anoxic or hypoxic environment are discussed.

Imabayashi, H.

Describes the effect of oxygen-depleted water on species composition, species diversity, and the number of individuals in a benthic community.

Ingham, M.

Provides a list of signs that suggest a worsening of environmental conditions is proceeding in the north central Gulf of Mexico. Discusses man-made versus natural causes of hypoxia using the New York Bight incident as an example.

Kramer, G. L.

Brown shrimp tolerance to sudden salinity changes and varying rates of reduction of dissolved oxygen are described. Behavioral responses are recorded and analyzed with respect to shrimp size and sex. Avoidance of oxygen-depleted water by brown shrimp is hypothesized.

Provides seasonal variation in shrimp and finfish catch data, benthic community structure and sediment types at two study sites off Louisiana. Environmental data, including dissolved oxygen concentration, are presented.


Brief summary of the role of satellite sensing with regard to discovering hypoxic water off Louisiana in 1982.


Discusses the anomalous crowding of fish and invertebrates into the shallow waters of Mobile Bay, i.e., “jubilees.” The recorded history of “jubilees” is presented. Temperature, salinity, and dissolved oxygen data are examined. Climatological data are also reported.


Widespread hypoxia is documented in Mobile Bay, AL, in 1971. Historical references of resultant “jubilees,” the shoreward movement of demersal fish and crustaceans are discussed. Causes and effects of hypoxia are mentioned.


Survivorship in all possible combinations of salinity (20, 25, and 30 ppt), temperature (5°, 15°, and 25°C), and dissolved oxygen concentration (2.9, 4.3, and 6.4 mg/l) were tested on acclimated and nonacclimated lobsters. Size differences, molting stage, starved and fed lobsters were considered. Resistance times are also identified.


Reports on anoxia in the Middle Atlantic Bight in 1976. Physical and chemical aspects of the water, demersal fish, and benthic invertebrates affected by the low oxygen levels are discussed. Similar data collected from 1972 and 1975 are compared with the 1976 findings. Plausible causes and consequences of the kill are presented. Some raw data are included. Finally, the chronological reporting of the hypoxic occurrence is provided.


Reports on a series of workshops covering hypoxia and its consequences in the New York Bight. Climatic, oceanographic, and biological data are presented.


Reviews hypotheses explaining the effects of oxygen stress on community diversity, species diversity, the number of species present, and their numerical composition. Special reference is made to marine invertebrate communities in a stable oxygen stress environment.


Dissolved oxygen concentration, temperature, salinity, transmissivity, water mixing, and photosynthesis are among several hydrographic parameters recorded during this study. Seasonal trends and interrelationships are discussed. Numerous raw data are available.


Reviews history of anoxia in Chesapeake Bay. Temporal enhancement during the past 50 yr was investigated. Typical onset of annual hypoxia is described. Ecological and economic impacts and the magnitude of these impacts are discussed. Although this paper does not refer directly to the Gulf of Mexico, its findings may parallel those in the Gulf in the near future.
Ogren, L., and J. Chess.

Reports on a fish kill off New Jersey in the fall of 1968. A list of dead and moribund fish and invertebrates is provided. Environmental anomalies preceding the kill are discussed. Scant hydrographic data are available. Recolonization of a wreck after 8 mo is described.

O'Reilly, J.

Brief summary on hypoxic water noted off the New Jersey coast in 1983, its effect on bottomfish and accumulation of organic detritus on the ocean floor.


A baseline survey of the benthic communities near two proposed brine diffuser sites. Geographic and temporal variation in community structure is described. A large anoxic region in the Gulf of Mexico is reported.

Ragan, J. G.

Variability in the density of macroinvertebrates is discussed with respect to bottom depth, season, salinity, distance from shore, and bottom water dissolved oxygen concentration. Comparisons are made by species as well as with total number of species of invertebrates. Community composition and the number of organisms per species are presented.


A baseline study south of Belle Pass, LA, in a proposed area for an offshore oil pipeline. Provides estimates of relative abundance of fish and invertebrates and lists natural variation in species number and weight. Correlations between water quality and species diversity and abundance were determined. Temporal variation is included in these analyses.

Ragan, J. G., A. H. Harris, and J. H. Green.

Ocean temperature, salinity, dissolved oxygen concentration, and monthly river discharge rates are presented. Seasonal analyses of these and additional data from 1973-74 are presented. Raw data are provided.

Ray, S. M.

Synopsis of historical references to hypoxia on the inner continental shelf of the Gulf of Mexico and its apparent causes.

Reitsema, L. A.

Temporal and geographic variation in zooplankton are discussed. Species diversity, species density, and dominant taxa are listed. Locations of hypoxic bottom water discovered during the study are noted.


Brown shrimp, Penaeus aztecus, and white shrimp, P. setiferus, abundance and spawning activity off the upper Texas and Louisiana coasts were investigated at four inshore and three offshore regions. Notes on the occurrence of hypoxic bottom water during this study are included. Hydrographic data, substrate characterization, meristic notes on fish and shrimp catch, biochemical analyses of shrimp and benthic infauna, and histological information on various shrimp tissues were also gathered.
Renaud, M.


Brief summary of the hypoxic conditions off Louisiana in 1983. "Typical" sequence of events leading to the formation of hypoxia is described. An editing error in the last sentence of the second paragraph occurs. It should read "The offshore migrations of shrimp and fish may be affected by hypoxic bottom water."

Savage, N. B.


Discusses the ability of the hard shell clam and the surf clam to burrow when exposed to extreme temperatures and low dissolved oxygen concentrations (<1.0 ppm). Habitat and geographic distribution of these clams are discussed with respect to temperature and oxygen tolerances.


Oxygen and carbon dioxide cycles are examined. Major sources of oxygen demand are identified. The history of low dissolved oxygen in the New York Bight is reviewed. Primary production and nutrient sources are considered. The consequences of discontinuing sewage and spoil dumping are hypothesized.

Seki, H., T. Tsuji, and A. Hattori.


The effect of fecal pellet production by herbivorous copepods on the onset of anoxia is discussed. The relationship between phytoplankton density and the formation of phytodetritus and fecal pellets is analyzed.

Shepard, M. P.


The tolerance of juvenile speckled trout to oxygen-depleted water was determined. Avoidance behavior, resistance time, and acclimation times were investigated. An empirical method for describing the ability of fish to withstand hypoxia is presented.

Shick, J. M.


Resistance of the starfish, Cenodiscus crispatus, to hypoxia is noted. The compound effect of hydrogen sulfide in the presence of hypoxia is discussed. Behavioral responses, including morphological changes, to hypoxia are examined.


Reports on hypoxic bottom water in the Mississippi River Delta Bight, in 1982, and the shrimp and fish associated with these areas. Remote satellite sensing of hypoxia is also discussed.

Swanson, R. L., and C. J. Sindermann (editors).


An in-depth review of bottom water hypoxia and its effects on the commercial fisheries of the New York Bight in 1976. A compilation of papers covering physical characteristics, atmospheric conditions, chemical factors, bottom dissolved oxygen concentrations, water column stratification, water and oxygen transport, plankton dynamics, and biological processes before, during, and after the onset of hypoxia. The socioeconomic impacts and a perspective on natural and human factors are also presented.

Theede, H.


Survivorship of several marine benthic invertebrates, from the North and Baltic Seas, was measured in oxygen-deficient (<0.2 ppm) water. The additive effects of hydrogen sulfide, pH, salinity, and temperature were also considered. Tissue samples from these organisms were also...
tested in a similar manner. In addition, the oxygen consumption of invertebrates at different oxygen tensions was measured.


Survivorship of 14 marine benthic invertebrates, from the North and Baltic Seas, was measured in oxygen-deficient (<0.2 ppm) water. The additive effects of hydrogen sulfide, pH, salinity, and temperature were also considered. Tissue samples from these organisms were also tested in a similar manner.


Describes geographic and seasonal variation of bottom water dissolved oxygen concentrations from south of Mobile Bay, AL, to south of Atchafalaya Bay, LA, from 1975 to 1980. Historic references to hypoxic water masses in the Gulf of Mexico are provided.


Discusses community plankton respiration (CPR) rates and oxygen depletion times in bottom waters of the Mississippi River Delta Bight during July and November 1976. Describes the relationship of CPR with suspended sediments, chlorophyll concentrations, and bottom water dissolved oxygen concentrations.

Vetter, R. D., and R. E. Hodson.

Investigates the effect of hypoxic conditions on estuarine fish. Concentrations of ATP and total adenylates in white muscle are used as indicators of environmental stress.

1972. Effects of dissolved oxygen on two life stages of the mummichog. Prog. Fish-Cult. 34:222-225.

Dissolved oxygen tolerance limits and percent mortality of adult and embryonic mummichogs are compared and contrasted. Hatching rates at various dissolved oxygen levels are discussed. The tolerance of juvenile menhaden, Atlantic silversides, and embryonic oysters to low oxygen concentrations is also mentioned.

Waddell, E., and P. Hamilton.

Monthly water temperature, salinity, dissolved oxygen concentration, and current speed and direction were among several physical data collected near the proposed Texoma brine disposal site from 1977 and 1978. Factors controlling nearshore currents, water column stratification, and sediment TOC and grain size are discussed. Plankton, demersal nekton, and benthos were characterized for each site. Geographic and seasonal variation in the data are presented.

Ward, C. H., M. E. Bender, and D. J. Reish (editors).

A compilation of papers on the physical and biological oceanography of Timbalier Bay and the offshore waters of Louisiana. Seasonal variation in the hydrographic parameters, sediment characters, fish and benthos community composition, and nutrient concentrations are described. The effects of oil production platforms on the above are considered.

Whitmore, C. M., C. E. Warren, and P. Duodoroff.

Avoidance of oxygen depleted water (1.5-6.0 ppm dissolved oxygen concentration) by juvenile coho salmon, bluegills, largemouth bass, and chinook salmon is discussed. Seasonal variation in their responses is noted.

Wiebe, P. H.

Examines the formation and separation of eddy currents from the Gulf Stream. Changes in physical and biological properties of these rings are discussed. Their role in the formation of regions of hypoxic water masses is hypothesized.

Wiseman, W. J.

Mississippi River flow into the Gulf of Mexico, water column stratification, and the intrusion of high salinity water from offshore are discussed with respect to the
formation of hypoxic bottom water in the Mississippi River Bight.

Young, J. S.

Mortality of the American lobster, Homarus americanus, on ship wrecks off the New Jersey coast is discussed. Oxygen depletion is considered as a possible cause of mortality. Minimal data are available.