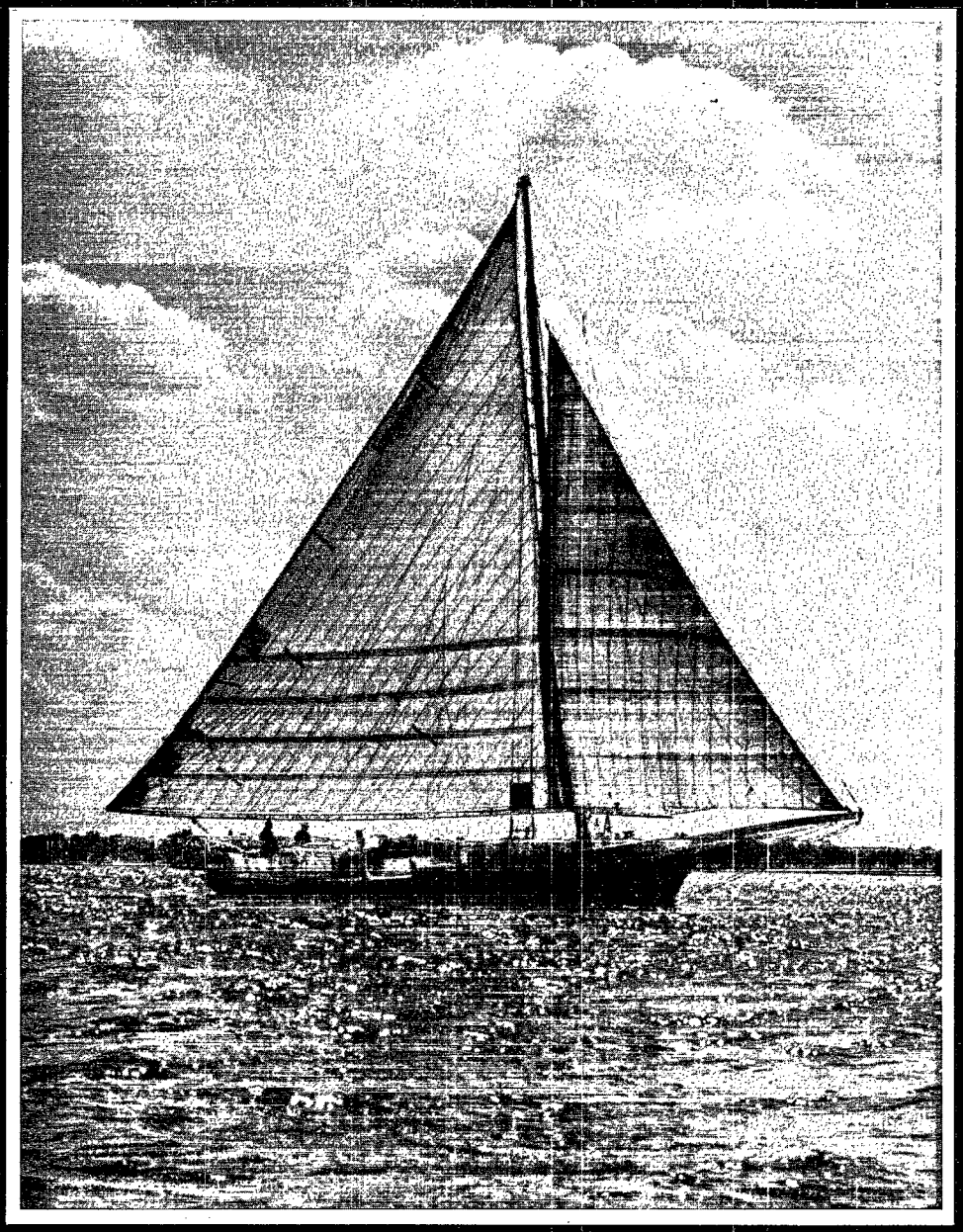
United States Environmental Protection Agency
Office of Water (WH-556F)
EPA 503/2-91-004
June 1991

EPA

# Portraits of Our Coastal Waters - Supplement to the National Water Quality Inventory

## Report from the EPA Regions



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# Portraits of Our Coastal Waters — Supplement to the National Water Quality Inventory

## Introduction

This report contains eight descriptive narratives highlighting coastal and estuarine environmental problems for unique geographic areas. These localities have been selected to show a sampling from diverse ecosystems and regions across the country. The locations described in the eight narratives are:

- Great Bay, New Hampshire
- Mid-Atlantic Bight
- Eastern Gulf of Mexico
- Texas and Louisiana Near Coastal Waters
- Barataria Basin, Louisiana
- Port Townsend Bay, Washington
- San Diego Bay, California
- Green Bay/Fox River, Wisconsin

The water quality problems described are diverse and have significant impacts on the coastal natural resources and human populations. Coastal economies and human health are adversely affected by coastal and marine environmental pollution. The problems being addressed at these localities include pathogen and toxics contamination, red tide blooms, floatable marine debris, and significant wetlands loss, among others; all are harmful to the marine and estuarine ecosystems in which they occur.

Over the past several years, while implementing the Near Coastal Waters Strategy, staff in the U.S. EPA regions and the states began to recognize the need for more information and better understanding of coastal environmental problems. This document is a

result of the commitment by the states and U.S. EPA regions to share some of their "stories." They share recent water quality monitoring and research activities undertaken to mitigate water quality problems and protect coastal resources. The narratives also describe planned management and research activities to solve coastal water quality problems well into the future.

## Background — the Inventory

This report was written as a supplement to the National Water Quality Inventory, 1988 Report to Congress. As required by Section 305(b) of the Clean Water Act, states collect water quality monitoring data and compile that data for U.S. EPA, reporting the extent to which goals in the Clean Water Act have been met. After receiving the state reports, U.S. EPA analyzed and compiled the data in the final National Water Quality Inventory.

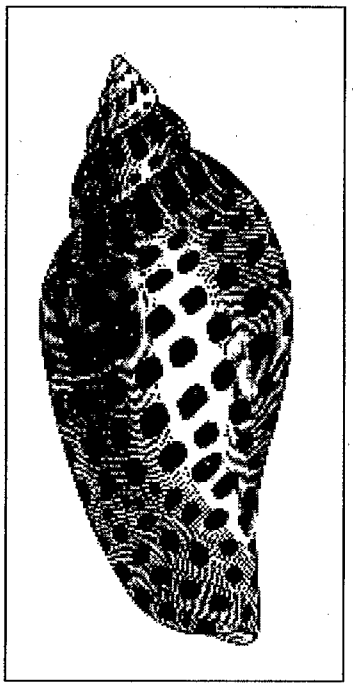
The National Water Quality Inventory includes an assessment of the condition of the nation's coastal waters. The states reported whether the waters were acceptable for designated uses including drinking water supply, contact recreation, and warm and cold water fisheries. For the 1988 Inventory, nearly 3,800 coastal shoreline miles were assessed by 12 states and Territories. Unfortunately, this represents only 20 percent of the total coastal shoreline. Insufficient data are available to assess and document the causes of impairment and sources of pollution. The states and U.S. EPA recognize the need for increased monitoring and research efforts to more accurately evaluate the quality of the nation's coastal waters.

This report was initiated in response to the need for improved coastal water quality information. Although this report does not provide a quantitative or comprehensive assessment of coastal waters it does provide an assessment of the diverse and complex environmental problems encountered in these areas. The Office of Wetlands, Oceans, and Watersheds hopes that this report will contribute to a broader understanding of the current status and future for our nation's coastal waters.

## Sharing Coastal Information

This report targets specific geographic areas consistent with the geographic approach to environmental management established by U.S. EPA 's Office of Water. This approach establishes that environmental problems should be addressed on a local or regional basis, recognizing that the problems and best solutions may be unique. For example, the salmon mortalities in Port Townsend Bay, Washington are not an issue in Green Bay, Wisconsin. However, the Port Townsend Bay research studies may result in findings and management approaches which can be more broadly applied to address fish mortalities at other locations. Sharing research information and management strategies, as presented in this report, will improve our ability to address environmental problems today and in the future.

Communication and coordination between federal, state, and local governments is critical if we are to minimize duplication of efforts to manage near coastal waters and prevent their degradation. Significant contributions are being made by the U.S. EPA regions and states to research and monitor coastal waters, and to develop management strategies that incorporate other groups involved in protecting and restoring coastal waters. For example, the state of New Hampshire has established an interagency Shellfish Committee to address environmental problems in Great Bay. Similar efforts have been initiated in other coastal areas; some of these are shared in this report.



## Summary of Report Findings

*Resources at Risk*

The estuaries, embayments, wetlands and coastal shoreline identified in this report provide habitat for an abundance of wildlife species. They provide critical spawning grounds for diverse species of fish and shellfish and nesting habitat for seabirds and other waterfowl. In some cases, the wildlife is threatened or endangered. For example, San Diego Bay is home for at least seven endangered species including the California brown pelican, the peregrine falcon, and the green sea turtle.

The coastal areas support a variety of human activities, including both recreational and commercial fishing, shellfish harvesting, hunting, and boating. Commercial fishing and tourism are essential to the health of many local and regional economies. Barataria Basin provides a significant share of Louisiana's multi-million dollar commercial fishery harvest. Toxic contamination or floatable debris may devastate local economies when beaches close and tourism declines. In addition, human health problems may result when individuals are exposed to the toxicants or ingest contaminated seafood.

*Water Quality Problems*

The water quality problems encountered in the coastal areas include floatable debris, nonpoint source pollution, saltwater intrusion into freshwater marshes, hypoxic or oxygen-depleted conditions, and toxic and pathogen contamination.

Red tide, a pathogen contaminant, has impacted the eastern coastal zones. Red tide is caused by periodic blooms of a single-cell algae that produces potent toxins harmful to marine organisms and humans. Blooms of the species, *Gonyaulax spp.* have led to the closure of shellfish beds in Great Bay, New Hampshire. Other species affect the Gulf Coast areas of Florida, Texas, and Mexico. Blooms may be transported great distances by winds and tides impacting nearshore and estuarine areas. In documented cases, blooms in southwest Florida have been transported by currents to Florida's east coast and to North Carolina. The narrative, *Red Tide in the Eastern Gulf of Mexico*, describes the effects and implications of the red tide phenomenon. The narratives on Great Bay, New Hampshire and the Middle Atlantic Bight also discuss the problems associated with another species of red tide.

*Monitoring, Management, and Research Activities*

Significant activities are underway to research and monitor pollutant impacts on marine organisms, coastal ecosystems, and human populations. Region III has initiated baseline monitoring activities conducting water and sediment sampling, public health surveys, and undertaking marine mammal watches. The Florida Department of Natural Resources monitors red tide concentrations and oversees shellfish bed closures. Other coastal states actively monitor coastal water quality. U.S. EPA 's Great Lakes National Program Office is a key participant in the comprehensive research study of toxic contaminants in the Green Bay ecosystem. Monitoring and research efforts, such as those described in the narratives, provide the critical data necessary to make informed management decisions and direct future program efforts.

The states, U.S. EPA, and other agencies, such as the National Oceanic and Atmospheric Administration, play a vital role, directing and participating in management efforts to better define coastal problems and update state and Federal programs and policies. The National Estuary Program (NEP) and the Near Coastal Waters (NCW) Strategies are

mechanisms for directing and improving the management of coastal and estuarine waters. Within the NEP, Comprehensive Conservation and Management Plans (CCMP) are developed for the targeted estuaries. The regional Near Coastal Water strategies enhance and improve existing water quality-based programs. Many additional management actions have taken place and are planned for the future. For additional information, contact the Office of Wetlands, Oceans and Watersheds, U. S. Environmental Protection Agency, Washington, DC 20460, FTS/202-475-7102.

This report provides a descriptive portrait of the many programs and initiatives designed to improve and protect our nation's coastal waters.

The Office of Wetlands, Oceans and Watersheds would like to recognize contributors from the regions and states who have played a vital role in developing this report. Some have written a significant portion of these narratives and others have provided valuable comments and sources of information. The contributors to the Report include:

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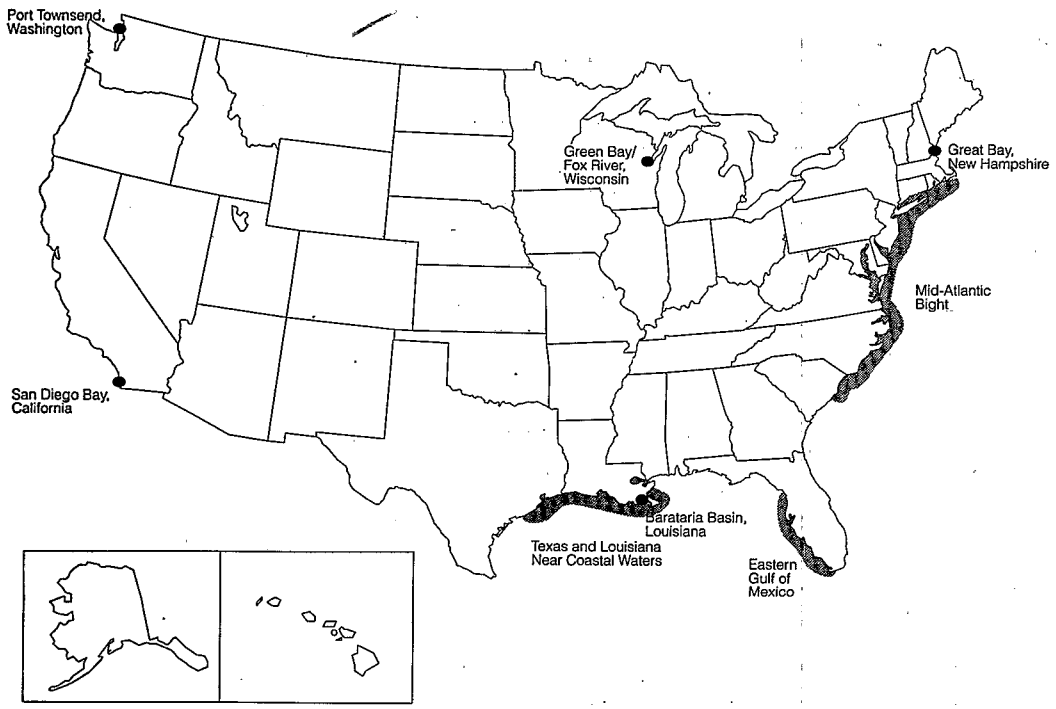


# Pathogen Contamination in Great Bay, New Hampshire

## Description of Geographic Area

Great Bay is located in the southeastern corner of the state of New Hampshire. Compared to many other estuaries throughout the country, Great Bay is in a relatively undeveloped, pristine area. It is part of the Piscataqua River Basin and has a drainage area of 930 square miles, of which two-thirds is in New Hampshire and one-third is in Maine. Great Bay is described as containing 4,471 acres of tidal water, 800 acres of ecologically important upland areas, 502 acres of tidal wetlands, and 456 acres of freshwater wetlands.

The Piscataqua River is formed by the confluence of two rivers after which it flows thirteen miles to its mouth at the Atlantic Ocean. Nine miles upstream from the mouth, the Piscataqua receives flow from the tidal areas of Little and Great Bays. The principal tributaries to Great Bay are the Lamprey, Oyster, and Exeter (Squamscott) rivers. While the riverine flow entering the Bay varies seasonally, the ratio of fresh to salt water in the estuary is less than one percent for most of the year. Water flows from Great Bay into Little Bay and subsequently the Piscataqua River. Tidal flow is the dominant hydrologic influence in Great Bay.

## Resources at Risk

The Great Bay system provides habitat for an abundance of species of vegetation, fish, and wildlife. Lobsters and rock crab are harvested commercially. There are periodic restrictions on the harvesting of soft shell clams, mussels, oysters, and sea scallops in this area due to bacteriologic exceedances. These restrictions may be removed upon review by regulatory agencies (NH Fish and Game, NH

Department of Public Health, and NH Department of Environmental Services). Over 71 species of sea birds, waterfowl, wading, terrestrial, and shore birds are found at Great Bay as well as numerous mammalian species. More than 50 species of fish make Great Bay their habitat. The Bay is an important breeding ground for many finfish, as well. This abundance of wildlife in turn attracts the human activities of fishing, shellfish harvesting, hunting, boating, and bird watching.

## Water Quality Problems

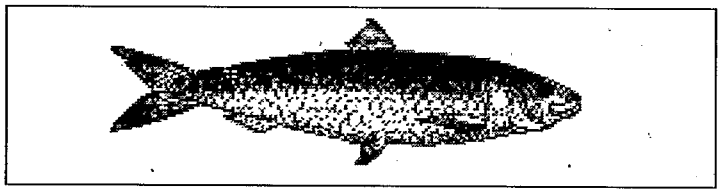
Great Bay is threatened by water quality problems that occur upstream where there has been significant pathogen contamination. To date, 4,120 acres of the Great Bay/Little Bay system have been documented as severely impacted by pathogen contamination and another 3,741 are threatened. There have been many instances where pathogen contamination and oxygen levels in various segments of the tributaries and Great Bay do not meet water quality standards set as part of their designated use classification. These problems have been primarily caused by combined sewer overflows (CSOs) and publicly owned treatment works (POTWs) and secondarily by on-site septic systems. Upgrades at the Exeter, Durham, Dover, and Portsmouth wastewater treatment facilities have been undertaken to alleviate the problem.

In addition to pathogen contamination, blooms of red tide (*Alexandrium spp.*) have been occurring on a regular basis and are responsible for annual closures of the Great Bay and Little Bay shellfish beds for the past seven years. Red tides are a natural phenomenon caused by periodic blooms of single-celled algae. Shellfish draw the red tide organism from overlying water and accumulate it in their gut. Eating as little as 100 grams of shellfish infected with *Alexandrium spp.* may result in paralytic shellfish poisoning (PSP). Nonpoint runoff from urbanized areas has been postulated as causing or exacerbating these blooms. Red tide occurs periodically along the eastern coast of the U.S. and in the Gulf of Mexico. The effects of red tide are described in the section, *Red Tide in the Eastern Gulf of Mexico.*

The state of New Hampshire has identified and evaluated the significance of 22 nonpoint sources of pollutants that may have a potential impact on the Great Bay system. Pollutants from these sources may cause the destruction of ecologically important eel grass beds by erosion, sedimentation, and nutrient enrichment. Pollutant loading of metal and organic contaminants in urban stormwater runoff negatively impact the ecosystem of the Bay and are related to land use patterns in the drainage basin.

## Land Use Management

The shoreline of Great Bay is primarily a mixture of large-lot residential properties, agricultural land and woodlands, with seasonal homes in some areas. Eighty-five percent of the drainage basin is open space composed of forests, fields, farms,



marshes, and bogs. While relatively undeveloped compared to other East Coast estuaries, the population of the Great Bay area is growing rapidly and projected to increase 22 percent in the next 30 years. Urban centers are located in the southeastern portion of the basin and urbanization is increasing along the tributaries to the Bay. Water quality problems have been linked to the presence of the higher population densities along these tributaries.

Increasing development along the shoreline has brought new awareness of the need for resource protection. In addition to the point sources of pollution from POTWs, industrial facilities, and CSOs, many nonpoint sources are presently being studied and may be the focus of future control efforts. The most significant nonpoint source problem in the Basin is on-site septic systems (OSSS). Urban runoff, erosion and sedimentation from construction and agricultural activities, boating wastes, and road salting are other types of nonpoint sources under study in the basin. Future management actions should include development of regulations on septage management and septic system maintenance, and enforcement of Water Quality Standards for combined sewer overflows (CSOs).

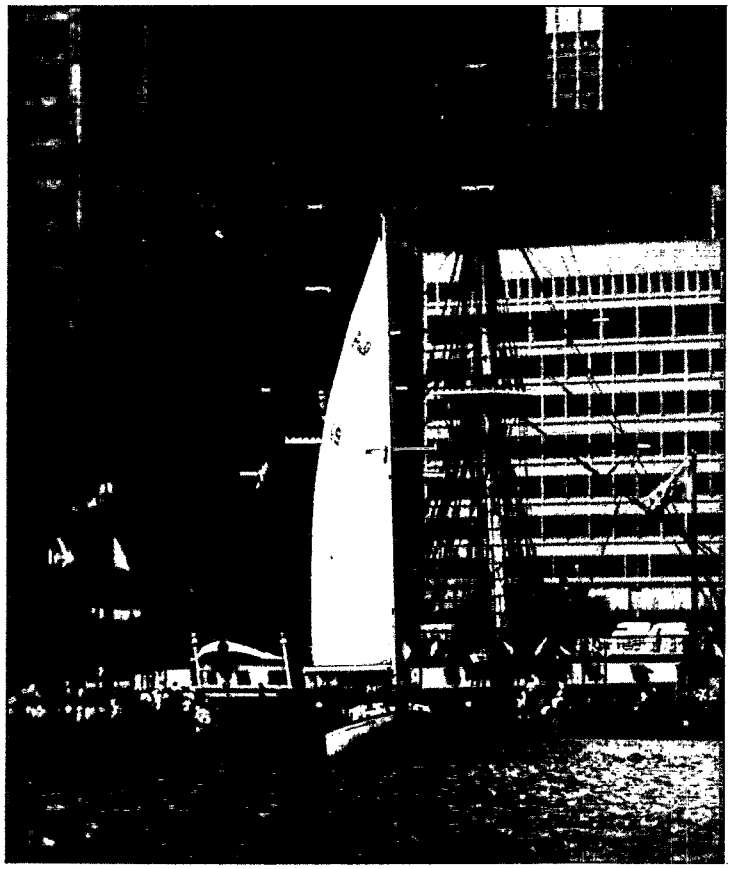
## Management Actions

The U.S. EPA approved Nonpoint Source Management Plan for New Hampshire proposed technical guidelines for stormwater runoff, fertilizer/pesticide use, erosion/sedimentation control, and dredging and filling of wetlands. These proposals could be implemented upon availability of funds from federal, state and other independent sources.

The state of New Hampshire has established an interagency Shellfish Committee to address restoration of contaminated portions of the Bay and protection of presently threatened areas. The goals of the Committee include determining sources and impacts of water quality problems, and responding to issues raised by the public. The Committee consists of representatives from the New Hampshire Department of Health, the New Hampshire Fish and Game Commission, and the Division of Water Supply and Pollution Control of the Department of Environmental Services. Recently, the Committee has been involved in the completion of the shellfish study report for the state of New Hampshire.

In order to help protect Great Bay from the expected increases in development pressure, Great Bay has been designated as a National Estuarine Research Reserve by the National Oceanic and Atmospheric Administration. To better quantify the extent to which existing pollutant sources may impact the Great Bay system, the state has identified goals and research priorities as part of the Research Reserve charter. One of the major goals of this project is to protect existing resources within Great Bay and maintain a balance between existing uses and increasing urbanization. Research on the red tide problem and how human activity may contribute to it is also proposed as part of the Reserve charter. In addition, programs and activities are planned to focus public attention on the estuarine reserve as a valuable estuarine resource and ecosystem worth protecting.

# Water Quality Problems in the Middle Atlantic Bight



## Description of Geographic Area

The Mid-Atlantic Bight includes the coastal and continental shelf areas from Nantucket Shoals off the southern Massachusetts coast, to Cape Hatteras, North Carolina. The coastal zone varies from a glaciated and rugged coastline in the north to low relief further south to the New York Bight. South of New York, the coast is bordered by a 100-mile wide coastal plain. The Continental Shelf ranges in width from 70 to more than 100 miles.

The beaches of the Northern area of the Bight are narrow, and inshore waters drop steeply. Along the coastal plain to the south, the beaches of the outer banks and barrier islands are wide, gently sloped, and sandy. Estuarine features include Narragansett Bay, Long Island Sound, Hudson River Estuary, Delaware and Chesapeake Bays, and the nearly continuous band of estuaries behind the outer banks and barrier islands along southern Long Island, New Jersey, Delaware, Maryland, and Virginia. Also included are the estuaries of Currituck, Albemarle, and Pamlico Sounds located behind the Outer Banks of Cape Hatteras.

## Water Quality Problems

In the summer of 1988, unprecedented public attention focused on ocean pollution problems plaguing the mid-Atlantic coastline as noxious debris, including potentially hazardous hospital wastes, washed ashore. Beach closures and the death of over 700 dolphins along the coastline from Maine to Florida received widespread attention. Each year fish diseases and mortality along the Mid-Atlantic Bight cost the commercial fishing industry millions of dollars in loss of potential catch. Thousands of acres of shellfish beds are closed because of pathogen contamination or contamination by toxin-producing algal blooms such as red tides. Beach closures due to pathogen contamination or floatable debris affect the economic and recreational value of coastal areas and have become a common occurrence.

## Historical Background

During the 1960's and the 1970's, a variety of industrial and municipal wastes were dumped in the ocean on the mid-continental shelf bordering Maryland and Delaware. U.S. EPA Region III (which includes the mid-Atlantic states from Pennsylvania to Virginia) managed four disposal sites in this area between 1972 and 1980.

With the passage of the Marine Protection, Research, and Sanctuaries Act of 1972 and subsequent regulations, U.S. EPA began a systematic review of the need for ocean dumping, the feasible alternatives to ocean disposal, and the impacts of dumping on the marine environment. As a result, all four disposal sites were successfully phased out and replaced by environmentally acceptable land-based alternatives.

U.S. EPA Region III conducted baseline surveys in and around the dumpsite used for disposal of sewage sludge from Philadelphia and Camden. A variety of impacts on the marine environment were found. These impacts included accumulations of heavy metals in organisms and sediments, the appearance of sludge deposits on the ocean bottom, the presence of sewage bacteria, changes in the benthic community with the loss of sensitive species, and the occurrence of necrotic lesions and melanization of gills in rock crab. After closure of the disposal sites, follow up monitoring revealed systematic recovery of the benthic and fish species and improvements in water and sediment quality.

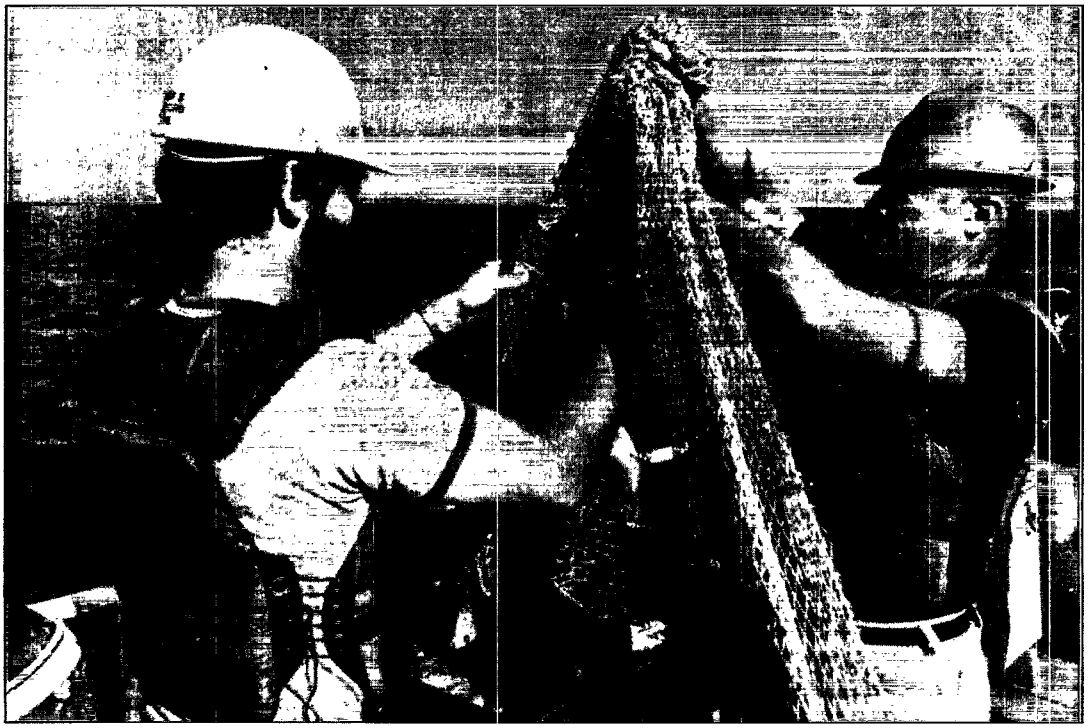
## Monitoring Program

There are no active ocean dumpsites for industrial or sludge wastes in U.S. EPA Region III. As a result, monitoring programs have been modified over the years to reflect changing utilization and stresses on the living resources in the area. In 1987, U.S. EPA's regional monitoring activities were again expanded in response to new concerns: dolphin mortality, atypical algal blooms, fish diseases, and floatable debris.

U.S. EPA Region III is pursuing additional strategies to better understand coastal pollution problems and take a more proactive approach to coastal protection. Baseline monitoring and surveillance work has been expanding. This includes coastal eutrophication and public health surveys at locations along the Delmarva Peninsula to the Virginia coast south of the Chesapeake Bay. In addition to water and sediment sampling, a marine mammal watch and floatable or plastic pollution watch are included as part of routine surveillance activities.

## Environmental Rapid Deployment Team

In 1991, U.S. EPA Region III is continuing efforts to respond quickly to coastal environmental crises and public health problems. The Environmental Rapid Deployment Team plays a critical role in these efforts and is effective, in part, due to active participation by



State and Federal agencies such as the U.S. Coast Guard, U.S. Fish and Wildlife Service, National Marine Fisheries Service, National Park Service, and the States of Maryland, Virginia, and Delaware. Local governments and citizens who have timely information on current or abnormal environmental conditions in their coastal communities are encouraged to take part in these activities.

*Mid-Atlantic Initiative*

Recognizing that ocean pollution problems are seldom localized, U.S. EPA Region III initiated an effort to develop a broad-based Mid-Atlantic Initiative that would address coastal problems as a whole rather than from a regional or state-level perspective.

The Mid-Atlantic Initiative is a first step toward addressing common concerns in the Mid-Atlantic Bight and near coastal waters. The purpose of the initiative is to better define coastal problems, reorient existing U.S. EPA and state programs to more effectively address common high priority problems, provide suggestions for solving these problems, and implement consistent ocean and estuarine policies where they are lacking in major regulatory areas.

As part of this initiative, Region III sponsored a one-day workshop on monitoring in the Middle Atlantic Bight. Representatives from U.S. EPA, NOAA, state and local governments, and research and academic organizations described their monitoring programs in the middle Atlantic coastal waters and participated in discussions on toxics, public health, and eutrophication issues as they relate to monitoring in the Middle Atlantic Bight. In 1990, the region also conducted several coastal state workshops, to bring state and local interests into the initiative. During 1991, the region intends to establish a coastal forum of all the mid-Atlantic states.

# Red Tide in the Eastern Gulf of Mexico

## Description of Geographic Area

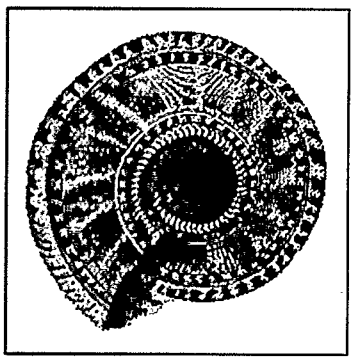
The west coast of Florida from the Florida Keys to Cedar Key, is characterized by mangrove and barrier islands to the south and extensive mangrove swamps and spartina marshes to the north. The nearshore area is characterized by extensive shallows with seagrass beds and hard bottom communities. In addition to numerous smaller embayments and estuaries, the west coast includes Tampa Bay and Charlotte Harbor, the two largest open water estuaries in the state.

The southwest coast of Florida is not as developed as the east coast. Population centers include Fort Myers/Cape Coral, Sarasota/Bradenton, and Tampa/St. Petersburg. The barrier islands and coastal areas, from Naples to Clearwater, have undergone extensive residential and commercial development in the past 30 years, but inland areas have, to a large extent, remained in pastureland, citrus production, and pine/palmetto cover. Industrial development has been confined mostly to Tampa Bay and Charlotte Harbor.

## Water Quality Problems

Red tides are a natural phenomenon in the eastern Gulf of Mexico caused by periodic blooms of single-celled algae, such as the species *Gymnodinium breve*. Red tide derives its name from the red-brown water color that occurs during an intensive bloom of these dinoflagellates. Between 1975 and 1990, red tides in the eastern Gulf of Mexico generally occurred in the fall and winter and were most prevalent in the area between Tampa Bay and Charlotte Harbor. Red tide also occurs in northern coastal areas, as described in the section on Great Bay, New Hampshire. These outbreaks and subsequent closure of shellfish beds, were caused by blooms of the species *Alexandrium spp.*

The red tide algae *G. breve* produces potent toxins that are released to the water



when the cell membrane is ruptured. Release of toxins in high concentrations causes fish kills, contaminates shellfishing areas, and can cause respiratory irritation in humans when aerosols are blown ashore. Red tides can result in severe economic and public health problems for coastal communities and significantly affect the marine and estuarine ecosystems in which they occur.

## Public Health Impact

The *G. breve* algae produces several neurotoxins that accumulate in filter feeding shellfish, causing neurotoxic shellfish poisoning (NSP) when consumed. Symptoms of NSP include central nervous system effects such as tingling of the face, throat, and extremities (with temporary paralysis in extreme cases), burning mucous membranes, and reversal of hot-cold temperature sensations as well as somatic motor nervous system effects including loss of coordination, dizziness, headaches, and convulsions. Human intoxication has resulted after ingestion of both raw and cooked contaminated shellfish, indicating that the toxins are not destroyed by heat.

Unlike most toxic dinoflagellates, which are armored with a hard cell wall, *G. breve* cells are unarmored and thus easily ruptured, releasing their toxins into the surrounding water. When incorporated into the surf, the toxins become associated with salt spray and aerosols, causing severe respiratory irritation, burning of the nose and throat, coughing, and choking. Although respiratory irritations usually subside when the victim is removed from the affected environment, the long-term effects of exposure are not known.

## Ecological Impact

Red tides have been associated with mortalities of marine fish and invertebrates in the eastern Gulf of Mexico. Most of these events are caused by neurotoxins that kill the animal directly or indirectly via ingestion of toxin contaminated organisms. In other cases, oxygen depletion caused by community respiration may cause mortalities. Ducks and shorebirds feeding on contaminated mollusks or fish are also at risk. In addition, it has been reported that manatees feeding on seagrasses during red tide events inadvertently consume contaminated tunicates and benthic invertebrates and are affected by disorientation and other symptoms of NSP.

## Economic Impact

Fish kills and NSP in Florida have caused economic stress to local communities and a number of industries. The 1971 red tide caused an estimated economic loss of $20 million dollars to the tourist industry alone, and a 1973-1974 red tide caused an estimated $15 million dollar loss to that industry. Sportfishing, wholesale, and retail seafood sales, and real estate sales were also affected. An "economic halo" effect occurs because public concern can lead to buyer resistance to all seafood products, even if they are safe to eat. For example, during outbreaks of *G. breve*, only bivalves such as oysters and clams should not be consumed. The halo effect can extend far beyond the county or state involved, so that total economic impact is very difficult to measure.

## Dynamics and Extent of the Red Tide

Although early investigators thought that blooms originated near shore and were linked to nutrient enrichment, further investigation found that *G. breve* blooms begin in an "initiation zone" 28 to 74 kilometers offshore. Within this zone, it is speculated that benthic cysts for *G. breve* exist in seed beds. This dormant resting stage can

accumulate in localized areas and reinoculate the overlying water column. When the Gulf Loop current meanders and eddies through these seed beds, cysts can be carried up to areas with more favorable growth conditions of more light, warmth, and nutrient supply. As the algal population increases under these favorable conditions, the organisms can be concentrated into blooms by currents and winds.

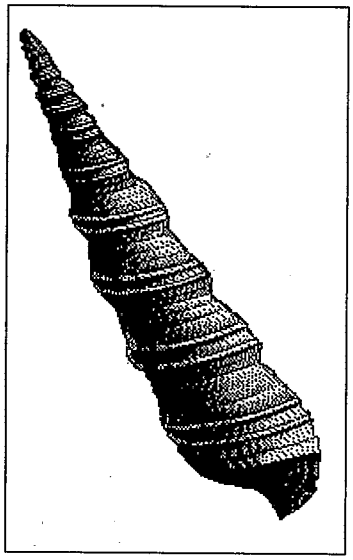
Winds, currents, and tides move *G. breve* blooms to coastal areas. In the eastern Gulf of Mexico, red tides usually move southward after reaching nearshore waters, and in some cases are transported around the Florida peninsula and then northward by Gulf Stream currents. The first documented occurrence of *G. breve* red tide on the east coast of Florida was in 1972, although it is likely that there were occasional events before that time.

In the fall of 1987, an extensive red tide (identified as *G. breve*) occurred in coastal and inshore waters of North Carolina. This bloom had a serious impact on shellfisheries in the area resulting in scallop mortalities and closed oyster harvesting areas. This was the first time a red tide had been documented in North Carolina waters. It was presumed that the Gulf Stream had transported the red tide north from south Florida. Satellite imagery from the NOAA weather service supported this hypothesis with evidence of a warm mass of Gulf Stream water moving into the North Carolina coastal area at the same time the red tide occurred.

## Monitoring and Research Activities

The Florida Department of Natural Resources (DNR) is responsible for monitoring *G. breve* concentrations in near shore waters to determine locale and duration of shellfish bed closures. Shellfish beds are closed to commercial harvesting when *G. breve* concentrations in the water column exceed 5,000 cells per liter. At this concentration the bloom is not detectable to the naked eye and would be unlikely to cause mass fish mortality. However, shellfish can concentrate the toxins in a low magnitude bloom and present a risk of NSP to consumers.

Research is being conducted on the life history of *G. breve* and environmental factors that lead to bloom formation. The goals are to establish the basic biology of the organism and provide better management of red tide events. Control is not generally considered feasible. However, if benthic cyst accumulations indeed are precursors of red tides and can be located in well-defined and limited areas, control methods might be developed and evaluated. Also under study is the question of whether or not human activity, which has increased the load of nutrients in coastal waters, contributes to the intensity of red tides.



# Oxygen Depleted Coastal and Estuarine Waters in Louisiana and Texas

## Description of Geographic Area

The northern Gulf of Mexico, off the Louisiana and Texas coast, is a shallow subtropical sea rich with marine life. Many of those species migrate between estuarine embayments and the inner continental shelf. The Mississippi River outflow has a dominant influence on biological productivity on the inner shelf off Louisiana's coastal marshes. The freshened Gulf waters ride over the denser, saline waters of the Gulf. Depending on various physical conditions, this phenomenon can extend along the coast from the Mississippi River delta as far west as Texas. This area is also one of the most well-documented locations of oxygen-depleted (hypoxic) bottom waters. The hypoxic zone has been recorded as covering an area as large as 1200 square kilometers. It can occur in waters from five to fifty meters deep, from two to twenty-five kilometers offshore, and up to twenty meters above the bottom.

The hypoxic conditions that occur above the inner continental shelf of the Gulf of Mexico have also been documented in Lake Pontchartrain and Lake Calcasieu, Louisiana and Galveston Bay, Texas. In these estuaries, the extent of the hypoxic zone is more limited than the area above the shelf, and is generally confined to dredged navigation channels, where reduced tidal flushing causes poor water quality, and to sites adjacent to industrialized urban areas.

## Water Quality Problems

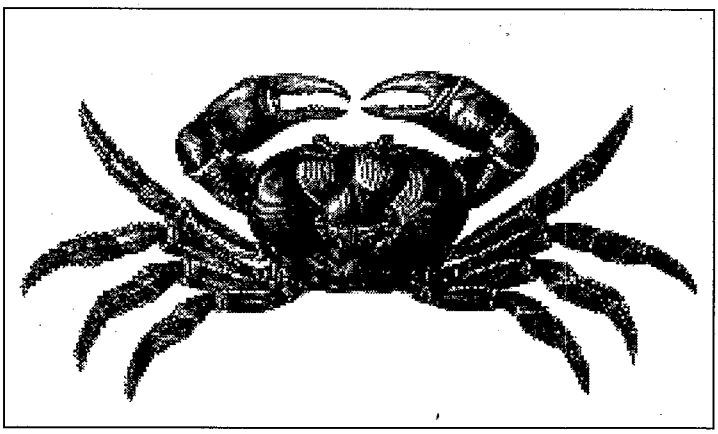
Hypoxic, or oxygen-depleted, bottom waters contain levels of dissolved oxygen so low (less than 2.0 mg/l) that biological productivity is impeded. Although limited historic data are

available regarding the occurrence of waters with extremely low-levels of oxygen, some general trends have been observed. The phenomenon occurs at varying intensities, mainly during the months of June, July, and August, and is associated with strong thermohaline stratification and a significant source of oxidizable organic material.

Hypoxic conditions can affect both the mortality and redistribution of fish and shellfish populations. Commercial fisheries of national significance have been affected by oxygen deficient waters. Virtually no shrimp or bottom-dwelling fish are caught in hypoxic areas. Reduced catches by commercial fish and shellfish industries are difficult to estimate since mobile species can move out of hypoxic areas and be caught elsewhere and the overall impact of hypoxia on productivity is not well understood.

Hypoxic zones can act as a barrier to the migration of adult organisms to coastal estuaries that serve as nurseries or transitory feeding grounds. Additionally, the phenomenon may act as a herding force, which results in mass movements of fish and shellfish, known as jubilees, away from hypoxic zones toward oxygen-rich waters.

Originally estimated at approximately 1,200 square kilometers, recent research has documented the area affected by hypoxia in recent years to be much greater. From 1985 to 1987, over 8,000 square kilometers of bottom waters off the Louisiana inner continental shelf was found to be hypoxic. In 1988, based on limited data, this area was estimated to be much reduced (2,000 square kilometers). The drought of 1988 caused a 52 year record low flow of the Mississippi River Delta. With such a low input of fresh water into the system, salinity increased and stratification did not remain stable, a necessary condition under which hypoxia occurs.



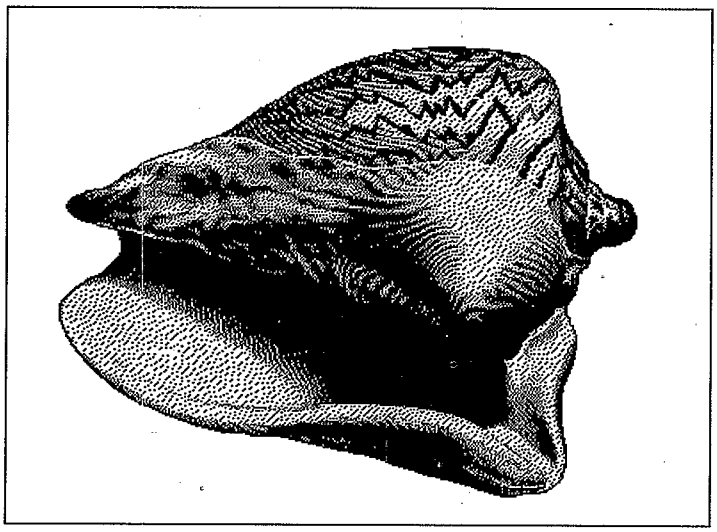
## Causes of Hypoxia

Severe oxygen depletion of bottom waters occurs when the re-aeration rate is low in comparison to the oxygen consumption rate. Re-aeration rates can be low because of the strong thermohaline stratification that occurs in the warm summer months when winds are lightest and frontal passages are less frequent. This stratification occurs above the Louisiana shelf and in areas that are affected by the massive freshwater contributions from the Mississippi and Atchafalaya Rivers. High oxygen consumption rates in bottom waters are generated by the decomposition of settled organic material. The source of this organic material appears to be the highly productive phytoplankton population in surface waters.

Despite a lack of comprehensive historical data, researchers have expressed concern that the occurrence of the hypoxic zone along the Louisiana inner continental shelf may be increasing in frequency, intensity, and area. It is proposed that human activities have contributed to the occurrence

of the hypoxic zone. A definite cause-effect relationship, however, is difficult to establish.

The nutrients carried into the Gulf by the Mississippi River have contributed to the enormous productivity of these waters which, in turn, has directly benefited the commercial fish and shellfish industries by providing a rich harvest. And yet, an increase in the level of inorganic nutrients (especially nitrates) from runoff carried by the river has been cited as one of the major causes of hypoxia. Other human activities, such as altering freshwater dispersal patterns by confining the Mississippi River flows, are also thought to have contributed to the hypoxic conditions.



## Current Monitoring and Research

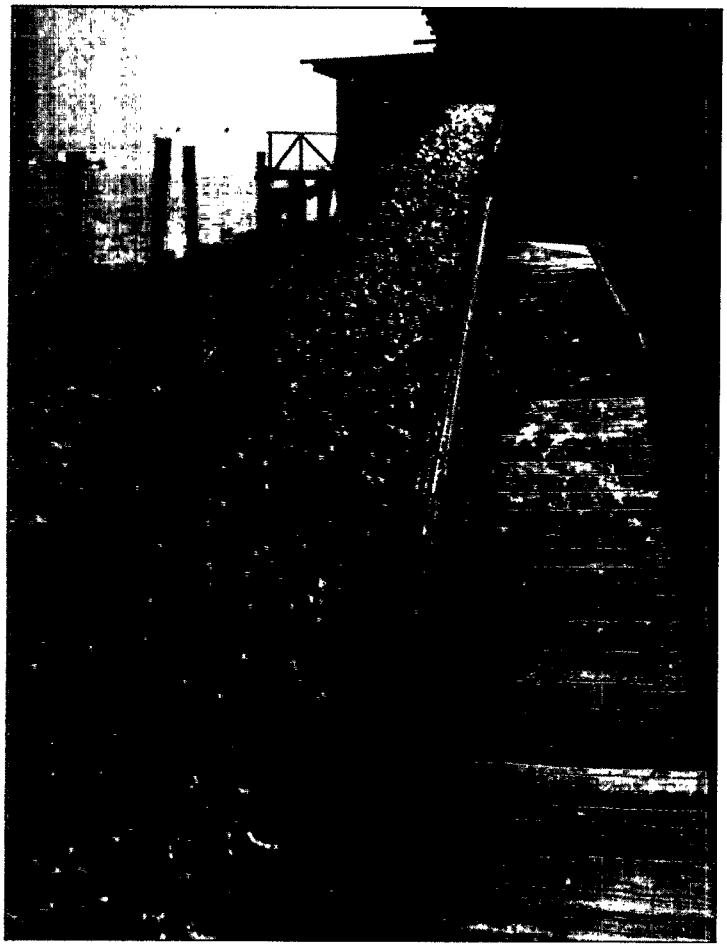
Studies of the occurrence of hypoxic bottom waters in the northern Gulf of Mexico have only been conducted recently. One of the first studies was a dissolved oxygen sampling program conducted from 1975 to 1980. During that period, samples were collected from Mobile Bay in Alabama to the Atchafalaya River in Louisiana. The Coastal Zone Color Scanner was used in 1982 and 1983 to examine the relationship between hypoxic bottom waters and high surface temperatures and chlorophyll levels in waters off the Louisiana coast. In 1985, the National Oceanic and Atmospheric Administration, the Louisiana Universities Marine Consortium, and Louisiana State University conducted a data collection and analysis program specifically designed to assess the extent, duration, and intensity of oxygen depletion in the northern Gulf of Mexico. In Lake Pontchartrain, the Louisiana Department of Environmental Quality monitors for dissolved oxygen as part of its fixed benchmark monitoring network in operation for 21 years. The network consists of twenty stations in the Lake Pontchartrain Basin and nine stations in the Calcasieu River Basin. In recent years wastewater treatment plant and stormwater discharges have been reduced by relocating the greater New Orleans treatment plant outfall to the Mississippi River. The lake still receives significant nonpoint source loading from the north shore area as a result of runoff and forced drainage.

Similarly, the Texas Water Commission conducts ambient water quality monitoring which includes dissolved oxygen. Stations are located in the Galveston Bay system and in the Gulf of Mexico off the Texas coast. The Texas Water Commission's predecessor agency, the Texas Department of Water Resources, initiated several comprehensive studies of the Houston Ship Channel, its tributaries and side bays, and the upper Galveston Bay in 1982. As a result of these studies more

stringent wastewater permit requirements were implemented, self-reporting requirements were expanded, and additional routine stream monitoring stations were established.

While both states conduct routine water quality monitoring which includes dissolved oxygen analysis, most of the specific studies focused on hypoxic conditions in coastal waters are conducted by the Louisiana Universities Marine Consortium and Texas A&M University. In addition, dissolved oxygen measurements have been collected by the cooperative Southeast Area Monitoring and Assessment Program (SEAMAP) which is a federal and state biological resource sampling effort. Information gained from these research efforts and monitoring programs are important for improving and managing a coastal area that is considered one of the nation's most valuable fisheries.

# Sediment Deficit and Saltwater Intrusion in Barataria Basin, Louisiana



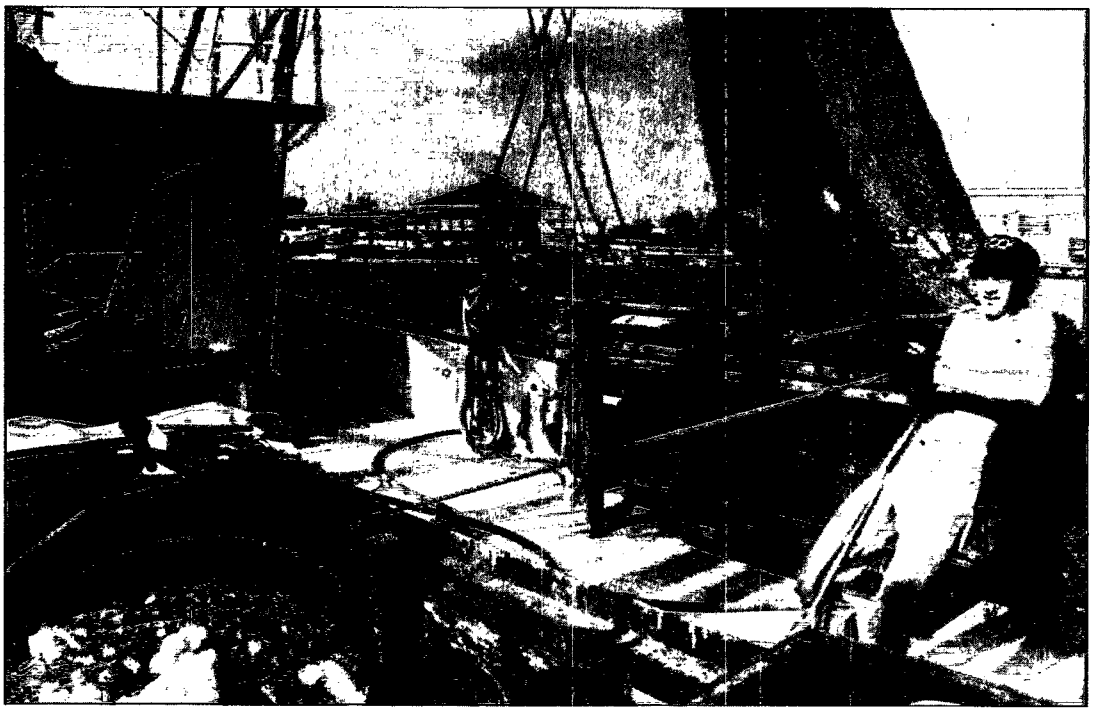
## Description of Geographic Area

The Barataria Basin and Bay estuarine system in Louisiana is one of the most productive estuaries in the nation. Its cypress swamps, grassy marshes, and shallow lakes and bays are the basis for significant ecological, recreational, and economic resources of national scope. The 2,350 square mile ecosystem is predominantly characterized by water, which covers approximately 400,000 acres. About 80 percent of the total basin is comprised of periodically flooded marsh and swamp. The wetlands of the upper basin are predominantly composed of bald cypress/water tupelo stands and flotant marsh. Twenty-two percent of the central basin is characterized by brackish and intermediate marshes. As the salinity of the water increases, the dominant plant in this area changes from saltmeadow cordgrass to oyster grass, which characterizes the salt marsh area surrounding the bay system.

Protected areas represent a small but significant type of land use. Approximately 8,600 acres of swamp, marsh, and bottomland hardwood forest lands are protected from development and are open for public recreation in the Jean Lafitte National Historical Park. In addition, approximately 3,000 acres of adjacent Bayou aux Carpes wetlands have been afforded federal protection from dredge and fill activities. Two State Wildlife Management Areas encompass 52,757 acres of coastal marsh and swamp forest.

## Biologic Resources

The Barataria wetlands and bays together provide vital nursery grounds for many estuarine dependent species of recreational and commercial value. The Barataria Basin is responsible for a large share of Louisiana's $200 million commercial fishery harvest, which is the largest in the U.S. The basin also provides valuable habitat for a diversity of wildlife species including commercially important furbearers, eight threatened or endangered wildlife species, and an abundance of



waterfowl that utilize the Mississippi Flyway migratory route.

## Water Quality Problems and Wetland Loss

The estuarine habitat supporting this productivity is degrading at a very rapid rate. Coastal Louisiana wetlands were vanishing at a rate of 60 square miles per year by the mid-1980's, although the rate of loss may have slowed to approximately 32 square miles toward the end of that decade. The losses arise from a combination of natural processes such as channelization, subsidence, erosion, sea level rise, and human activities which include flood control practices, impoundment, and dredging.

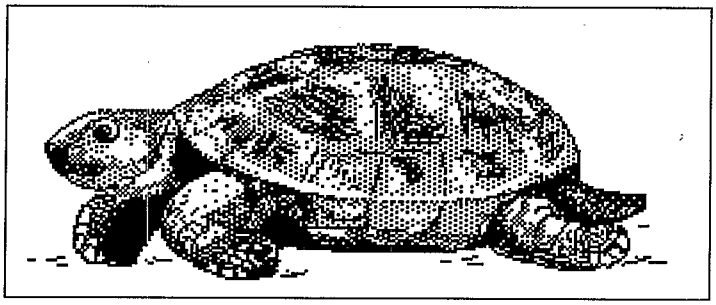
The result of these compounding influences has been a great reduction of sediment and freshwater allocations to Barataria Basin. The freshwater is largely being channeled through the Mississippi River passes, which carry the river's heavy load of sediments into deep waters of the Gulf of Mexico. As a result, the swamps and marshes in the delta plain are experiencing a sediment deficit and pathways are opened for the inland advance of saline waters. As the substrate subsides and the vegetation is stressed, wetlands are converted to open water.

The overbank flooding that typically feeds the delta marshes has been eliminated by construction of the Mississippi River levees below New Orleans. The levees eliminated both the seasonal overbank flows and the long term delta shifts. The only place along the Louisiana coast where major delta building is occurring today is at the Atchafalaya Delta, west of Barataria Bay. The projected emergence of 120,000 acres of Atchafalaya Delta marsh in the next 30 to 50 years will not, however, offset the geometrically increasing rate of land loss that is occurring along the entire Louisiana coast.

Activities within the Barataria Basin itself are also contributing to the sediment deficit. The major influence in this category is canal dredging and leveeing, which is generally done for navigation and mineral extraction. Because the canals are deeper than the natural watercourses, they cut off the sediment supply to the marshes by channeling the water flow through the system at a much faster rate. Also, because the canals are lined by levees or spoil banks, the overbank sheet flow of water through the marshes is reduced or eliminated. This effect is often magnified when the spoil banks of canals, which are dredged at different times for various purposes, end up interconnecting to form impoundments.

In addition to effects on sediment supplies, leveeing and canal dredging of the Mississippi River have had profound effects on freshwater inflow and saltwater intrusion. Control of the Mississippi River has minimized the introduction of freshwater into the upper basin, while canals have lessened freshwater retention time and allowed greater inland intrusion of saltwater.

Scientists have proposed several mechanisms by which saltwater intrusion and reduced sedimentation may contribute to the loss of wetlands. The first mechanism points to increased salinity, or saltwater intrusion, as the primary cause. When water of greater salinity penetrates the intermediate and freshwater marshes of the central and upper basin, the vegetation is stressed. This may result in the die-off of marsh plants, which are not replaced. Such a situation may occur when the rate of salinity change exceeds the rate of succession toward a more salt-tolerant species, causing the underlying peat to erode. In this way, large, shallow ponds and lakes may be created where the vegetation once occurred. The problem of vegetation loss can be compounded by the formation of larger areas of open water, since the increase in the interface between water and marsh, in turn, leads to a greater rate of erosion.

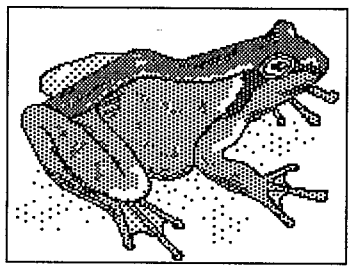


More recently, a number of scientists have proposed that increases in salinity alone do not cause the loss of wetland vegetation. Instead, it is suggested that submergence of marsh plants and accumulation of hydrogen sulfide in the soil is the mortality agent. As hydrogen sulfide accumulates in the soils of submerged wetlands, it prevents the plants from taking up nitrogen and growth is thereby retarded. The issue of whether marsh loss in this area is more a function of reduced sedimentation or increased salinity has become an important management issue.

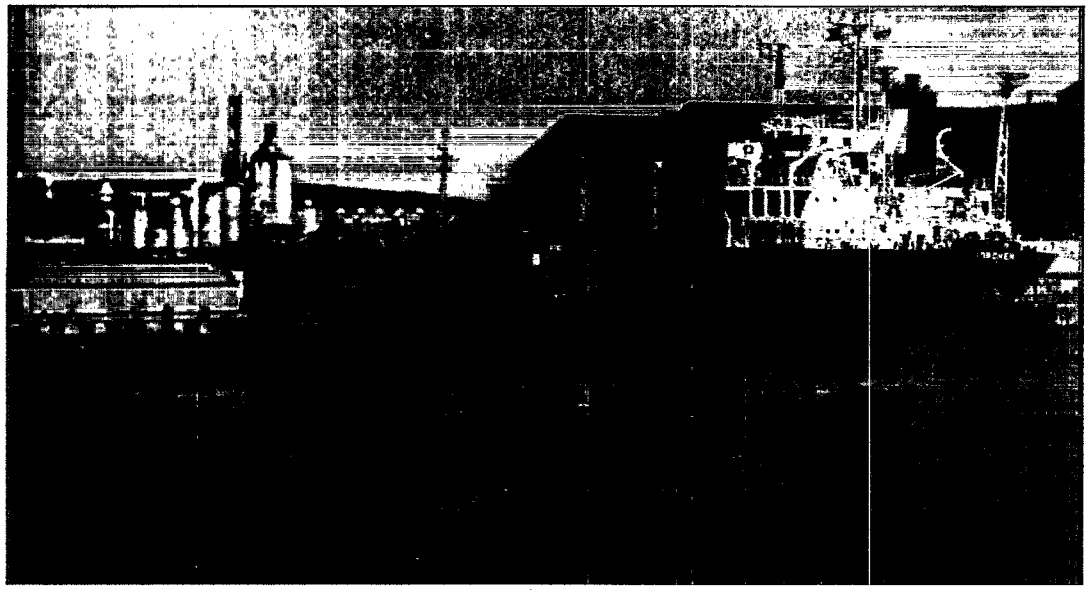
## Future Directions and Strategies

As discussed, two of the predominant causes of habitat degradation in the Barataria estuary are saltwater intrusion and reduced sediment input and retention. A new plan for future management of the Mississippi River would affect both of those factors. The plan is to divert a portion of the Mississippi River flow into Barataria Basin in an attempt to re-establish a more balanced overbank flow regime.

The traditional goals of managing the flow of the Mississippi River have been maintaining navigation, providing flood control, and developing fossil fuels. In response to a better understanding of the role and value of wetlands and the impact of man's activities on them, a new goal has emerged for managing the water flow in this area: to revitalize one of the nation's most unique natural resources. As the new management strategy develops, the focus will be on reversing the pattern of wetland loss and maintaining the ecological diversity which defines a healthy and productive estuary. Two of the key tactics for implementing the strategy will revolve around the goals of restoring a more supportive hydrologic system and sedimentation process. Management alternatives being considered range from restoration planning for individual access canals to developing a comprehensive master plan for the entire Louisiana coast. Also, a comprehensive interagency planning effort has begun for the Barataria-Terrebonne estuarine complex as part of the National Estuary Program administered by the U.S. Environmental Protection Agency.



# Toxic Contamination in San Diego Bay, California



## Description of Geographic Area

Approximately 10 miles from the U.S.-Mexican border, San Diego Bay is the southernmost embayment on the United States' western coast. Fifteen miles in length, the arc-shaped bay varies in width from 1/3 mile to 2 1/4 miles, and in depth from over 40 feet in the channel to only a few feet in many areas of the South Bay. Fresh water input to the bay is predominantly from periodic surface runoff via storm drains, and from four small rivers during periods of rainfall. Two of these, the Otay and Sweetwater Rivers, flow through an ecologically important marsh prior to entering the bay.

San Diego Bay is one of the nation's finest natural harbors, and maintains a variety of beneficial uses, including shipping, fishing, industry, contact and non-contact recreation, military use, and habitat for marine life. However, like many other industrialized bays, San Diego bay has had its share of problems. For example, the bay's wetlands, floodplains, and marsh habitats have been reduced by over 90 percent in the last 100 years. Similarly, the Bay has faced a number of water and sediment quality problems.

## Water and Sediment Quality Problems

Pollution problems in San Diego Bay have changed considerably over the past fifty years. In the 1940s and 1950s, biological contamination from the input of sewage was the major problem facing the bay. Untreated wastewaters from several industrial facilities, a Naval facility, and private vessels also contributed to eutrophication of the bay's waters. The initiation of sewage treatment in 1963, along with the removal of most municipal waste dischargers and other point sources of pollution, resulted in a dramatic improvement in the quality of the bay's waters by the early 1970s. During the

1970s, San Diego Bay was considered by many to be significantly cleaner than most other industrialized harbors.

However, the 1980s saw a dramatic shift in the nature of San Diego Bay's pollution problems. While problems associated with eutrophication diminished, other contamination problems in the bay became more visible. As sampling and detection technology improved, previously unseen problems from toxic chemicals began to emerge. The discharge and accumulation of toxic chemical pollutants is now the key issue concerning the health of the bay. Of particular concern are toxic hot spots from chemical contaminants such as polychlorinated biphenyls (PCBs), organotins, and copper.

## Resources at Risk

Habitat reduction and chemical and biological pollution present a potential risk to many of San Diego Bay's beneficial uses. These include commercial and recreational fishing, wildlife habitat, and activities such as swimming, water skiing, rowing, and sailing.

*Commercial and Recreational Fishing*

The San Diego area sport fishery is claimed by the Chamber of Commerce to be the largest in the United States. Dozens of fish species are caught and consumed from the ocean and San Diego Bay each year. The public health significance of water and sediment quality problems in the bay has remained unclear. Because of this, many people have questioned whether it is safe to eat fish from the bay. To address these concerns, the San Diego County Department of Health Services conducted the *San Diego Bay Health Risk Study*, released in April 1990.

Of the chemicals evaluated in the study, only mercury and PCBs were present in high enough concentrations to be considered a threat to human health. Based on the results of the study, some areas were also identified as possibly requiring the collection of additional data. These include an assessment of shellfish consumption patterns in the Bay, and further evaluation of dioxins and furans, specific radioisotopes, and levels of organic vs. inorganic arsenic and mercury in fish from the bay.

*Wildlife Habitat*

San Diego Bay provides habitat for a wide variety of fish, wildlife, and plant species. Many miles of its shoreline contain shallow water eel grass (*Zostera*) habitat for fish, invertebrates, and birds. Commercial salt water evaporation ponds, and associated marshes in the South Bay, attract many species of waterfowl. The bay is also home to at least seven endangered species. These include the California brown pelican, the California least tern, the peregrine falcon, the light-footed clapper rail, the

green sea turtle, the belding savannah sparrow, and the salt marsh bird's-beak. The risk to these species from pollution to the Bay is currently poorly understood. Preservation of these species and the sensitive habitat areas necessary to sustain them is paramount, and will need to be more completely addressed in future research and monitoring efforts.

*Recreational Activities*

Both contact and non-contact recreational activities are pursued in San Diego Bay by residents and visitors to the area. These include swimming at numerous beaches, water skiing, board sailing, rowing, sailing, and fishing. A great deal of economic investment has also been attracted to the area. Shoreline hotels, restaurants, commercial theme malls, and public parks and trails can be found at many locations around the bay. Most of the concern about human health risks in San Diego Bay has centered on the consumption of seafood. However, while it is generally thought that the risks from other recreational activities are minimal, little work has been done to quantify them.

## Sources of Toxic Pollutants

Many chemical and biological contaminants are capable of affecting the beneficial uses of San Diego Bay. Some of the more significant sources of these contaminants are thought to include industries around the Bay, marinas and anchorages, U.S. Naval installations, underwater hull cleaning and vessel antifouling paints, urban runoff, and underground dewatering.

*Industries in the Bay Area*

In general, industries around San Diego Bay have made significant progress in abating the effect of pollutants on the bay. Most industries handling hazardous materials or wastes are required to obtain a permit. Also, the City of San Diego issues permits for industries discharging wastes to sanitary sewers. In spite of these restraints, contamination from industries on the bay does occur. Investigations have shown a source of PCB contamination in the North Bay to be three storm drains that flow from an industrial facility. Additionally, seven boat yards in the North Bay are responsible for high sediment levels of copper, mercury, and tributylin. Cleanup and abatement is currently being negotiated for these sites by the California Regional Water Quality Control Board.

*Marinas and Anchorages*

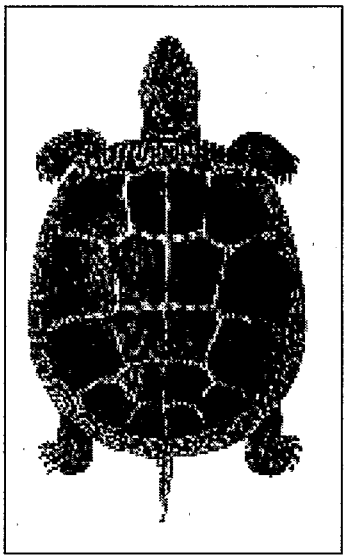
Oil changing, bilge pumping, and sewage released from vessels are all potential sources of contamination to the Bay. Marinas are not currently required to provide facilities for oil and paint storage, recycling, or disposal. Additionally, few sewage holding tank pump out stations are installed or operable, and existing facilities are infrequently used by boaters. It is not known whether illegal releases of sewage from vessels are producing unsafe swimming conditions.

*U.S. Naval Installations*

The U.S. Navy controls much of San Diego Bay's shoreline. Because of security requirements, most available information on water quality near these military areas has been provided by the Navy. Little is known about urban runoff components and the makeup of surface films near Navy fueling facilities. However, sampling programs currently being conducted may provide more information.

*Underwater Hull Cleaning and Vessel Antifouling Paints*

San Diego is home port for up to 8,000 boats and ships, including 100 Navy ships and submarines. The bay is



the site of much vessel maintenance, including hull cleaning and coating with antifouling paints. Studies have found that by-products of vessel maintenance activities have been accumulating in the bay. These by-products include copper, mercury, and tributylin (TBT).

Of major concern in the late 1980s was the accumulation of organotins, especially TBT, in shellfish and sediments. TBT has been shown to be highly toxic to many marine organisms. Recent state legislation has limited the use of TBT in marine applications. New paint formulations are also being developed which may prove to be less toxic than current antifouling paints. In addition, some underwater hull cleaning companies have proposed best management practices to reduce the environmental effects of antifouling paint removal.

*Urban Runoff*

Storm water conveys many materials into the bay from upland areas. These materials can be toxic or contribute to nuisance problems. The potential effects of industrial and household hazardous waste discharges have not been quantified. Under the Clean Water Act, urban runoff was originally considered a non-point source. However, the courts have now required that NPDES permits be issued for urban drains. The permits contain monitoring and reporting requirements that will provide valuable information for understanding the complexity of urban runoff.

*Underground Dewatering*

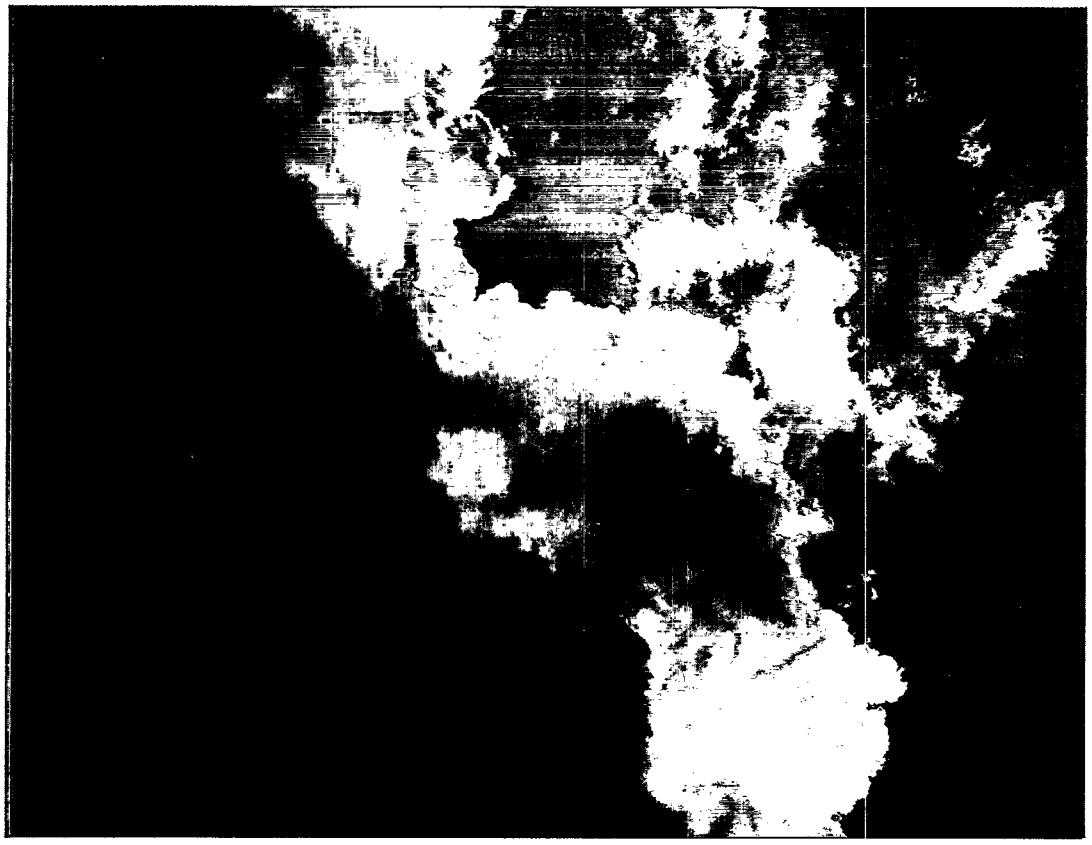
Activities such as construction dewatering and maintenance dewatering of underground structures can provide pathways for the movement of subsurface contamination into the bay. In particular, several underground sites containing petroleum products have leaked their contents into the bay. Because of regulatory efforts currently underway, this problem should lessen over time.

## Current and Planned Activities

The San Diego Regional Board is continuing its studies of the Bay which include the five-year San Diego Bay Cleanup Project, initiated in July 1987. Other agencies, including the California Department of Fish and Game and the U.S. Geological Survey, are working with the San Diego Regional Board on this project. The Project's current focus includes petroleum occurrence, toxics in sediment, tidal circulation, and underwater hull cleaning activities.

Many other agencies and organizations share responsibility for maintaining the health of San Diego Bay. To improve communication between these groups, the San Diego Interagency Water Quality Panel was created in 1987 by the State Legislature. The Panel consists of representatives from 25 organizations including the Regional Water Quality Control Board, San Diego County Department of Health Services, Port of San Diego, California Departments of Health Services, Food and Agriculture, and Fish and Game, and the U.S. Environmental Protection Agency.

# Salmon Mortality Problems in Port Townsend Bay, Washington



## Description of Geographic Area

Port Townsend Bay is an embayment in the northeast corner of the Olympic Peninsula in Washington State. Its large northern outlet opens to Admiralty Inlet, which connects the Strait of Juan de Fuca (and the Pacific Ocean) to Puget Sound. At the southern end, a narrow connection to Puget Sound restricts exchange of water. Between the bay's two islands, Indian and Marrowstone, lies Kilisut Harbor. The bay (excluding Kilisut Harbor) has a surface area of 30 square kilometers and a mean depth of 17.4 meters. Its shoreline is 20 percent urban (Port Townsend), 20 percent county urban/suburban, 30 percent conservancy/natural uses, and 30 percent U.S. Naval Reserve (Indian Island).

A variety of biological resources can be found in and around Port Townsend Bay. The glacous-winged gull, pelagic cormorant, pigeon guillemot, and black oystercatcher use the area for nesting. Commercial fishermen operate just north of the bay in Admiralty Inlet. The bay itself supports sport salmon fishing as well as spawning grounds and holding areas for the Pacific herring and shellfish beds of geoduck, clam, and oyster. Dungeness crab can also be found.

## Water Quality Problems

At two locations in Port Townsend Bay in 1986 and at one location in 1987, commercial attempts to raise Atlantic salmon in pens failed because of a greater than 90 percent mortality. A pathology study concluded

that the salmon mortality was caused by severe liver disease associated with waterborne toxicants.

The Bay is generally considered a nonurban area with little or no previous record of toxic contamination. A preliminary investigation at a proposed pen site in Glen Cove (on the western shore of the bay) found further evidence of an environmental problem: the diversity and numbers of bottom-dwelling and benthic organisms were severely limited.

## Pollutant Sources

The major point source discharger to Port Townsend Bay is an unbleached kraft pulp mill that discharges 12 to 16 million gallons per day into Glen Cove through an outfall 1,800 feet offshore. In addition, the Naval Undersea Warfare Engineering Station (NUWES), Indian Island Annex, is permitted to discharge up to 36,000 gallons per day of treated domestic wastewater to waters off Crane Point on the eastern shore of the Bay.

Other possible pollutant sources include the Navy Munition Steam-out Facility on Indian Island. Conventional explosives have been handled at this site since the mid-1970's. Although a permit exists to allow the discharge of treated "red water" from this facility, these wastes are not discharged at this site. A former ocean disposal area is located just outside the bay and two anchorages for ships carrying explosives are within the bay, one at the mouth and one off Indian Island. It is not known what materials may have been disposed of in the bay, either intentionally or accidentally. Additional problems are caused by nonpoint sources including surface runoff, septic leakage, and boat traffic.

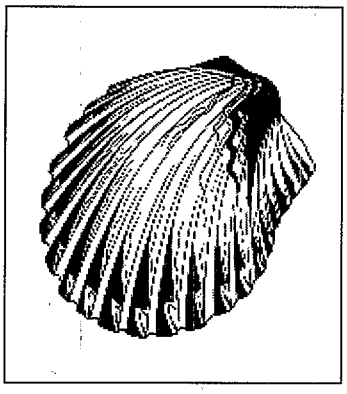
## Continuing Investigation

In October 1987, the Washington Department of Ecology (WDOE) began to investigate the Port Townsend salmon mortality problem. Samples of salmon

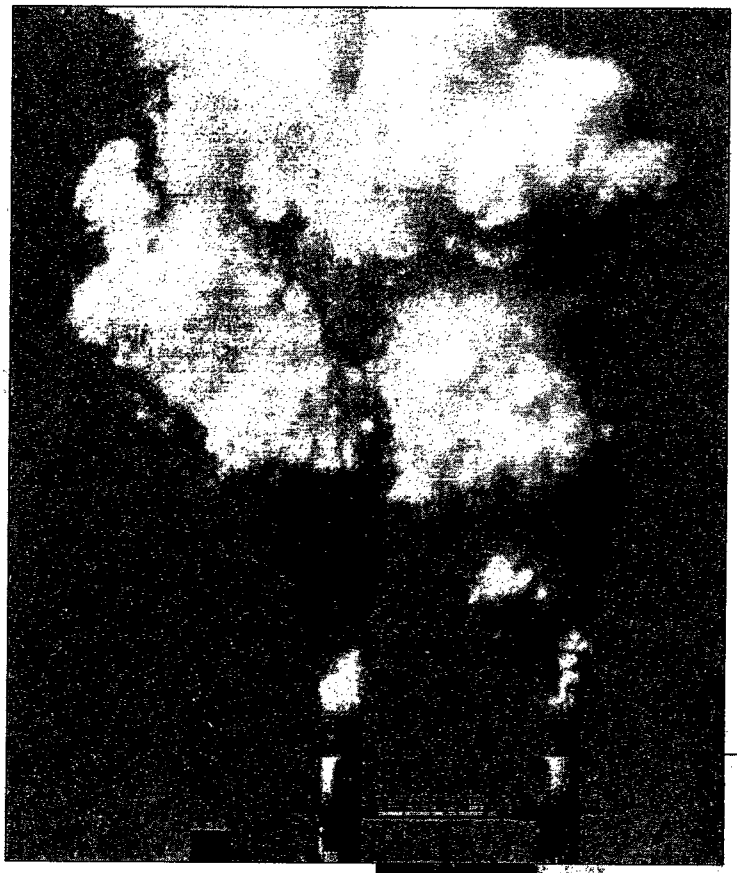
tissues both within and outside the Bay, samples of seawater at the salmon net pens, and bottom sediments of the bay were collected and analyzed for priority pollutants, chlorinated dioxin/furans, selected trace metals, resin acids, and munitions chemicals. A biomonitoring inspection of the Port Townsend Paper Company pulp mill and an inspection of the Navy Indian Island facility were also conducted in late 1987. None of these investigations revealed the source of the waterborne toxicant.

In 1988, further studies were conducted. Long-term bioassay testing of the pulp mill effluent, using Atlantic salmon, resulted in no liver lesions or significant mortality. Atlantic salmon, Chinook salmon, Donaldson trout, and shiner perch were also raised in pens off the Port Townsend marina and at Crane Point. Atlantic salmon suffered high mortality at both sites; young Chinook salmon suffered a significant, but lower, mortality rate at the marina site while no significant mortality was observed among larger Chinook salmon. Donaldson trout displayed liver lesions, but did not suffer mortality. The liver lesions appeared to be similar to those observed in previous years' testing. Additional water sampling conducted in 1988 by WDOE at the pen site off the marina revealed no problems.
at the pen site off the marina revealed no problems.

The liver disease, first observed in Atlantic salmon, has now been observed in other salmonid species in Port Townsend Bay and does not appear to be caused by the pulp mill effluent. Other water and sediment sampling near the fish pens has not revealed any likely sources of the problem. Since Atlantic salmon with similar liver disease have been found in four unpolluted sites in British Columbia, U.S. EPA Region X is now encouraging further research to confirm the hypothesis that a natural algae-produced toxin may be the cause of the problem.



# Multimedia Pollutants Effect Green Bay/Fox River, Wisconsin



## Description of Geographic Area

Green Bay can be characterized as a long, relatively shallow extension of northwestern Lake Michigan. The Green Bay watershed drains land surfaces in both Wisconsin and Michigan, and contains about one-third of the total Lake Michigan drainage basin. The Fox River Valley is heavily industrialized and contains the largest concentration of pulp and paper industries in the world.

## Water Quality Problems

At present, conditions in Green Bay range from hypereutrophic in the southern portion to mesotrophic-oligotrophic near the Lake Michigan interface. The extreme productivity in the southern portion results in deposition of organic material which, in turn, causes hypolimnetic oxygen depletion in the central bay.

The presence of toxic organic materials in the water, sediment, and biota has adversely affected both the

utilization and management of the Bay's fisheries. The commercial fisheries in the Bay, with the exception of yellow perch, are closed due to PCB contamination. Consumption advisories have been issued to sport fishermen. Reproductive failure and increased deformities have been observed in some fish-eating birds and is apparently related to toxic contamination.

The problems with toxic contamination observed in Green Bay are similar to those in other polluted areas of the Great Lakes, and are representative of the problem of bioaccumulation of toxic contaminants in the fish and in the Lakes at large. The lower bay and Fox River have been recognized as a polluted water system, and have been designated by the International Joint Commission as one of the 42 Great Lakes Areas of Concern.

## Green Bay/Fox River Mass Balance Study

EPA's Great Lakes National Program Office (GLNPO) is coordinating and providing major funding for a mass balance study of the toxic contaminants in the Green Bay ecosystem.

The concept of total load management in the Great Lakes Basin is a fundamental element of the Water Quality Agreement between Canada and the United States, of GLNPO's Five-Year Strategy and of the Lake Michigan Toxicant Control Strategy. Great Lakes managers have recognized that addressing toxic contaminants in the Great Lakes system requires a comprehensive multi-media evaluation of the point and nonpoint source loadings to the lakes, including less easily measured sources such as air, precipitation, soil, sediments, and ground water. The mass balance approach, based on the law of conservation of mass, assumes that inputs of toxic contaminants (less quantities stored, transformed, or degraded within the system) must equal outputs. This concept serves as the framework around which data are being gathered to provide a comprehensive picture, an ecosystem model, of contaminant dynamics in Green Bay.

The overall goal of the Green Bay/Fox River Study is to develop a modeling framework to improve our understanding of the sources, transport, and fate of toxic compounds, to evaluate the technological capability to measure multi-media loadings to the system, and ultimately to guide and support regulatory activity.

*Study Scope and Activities*

For the Green Bay/Fox River Mass Balance Study, models will be applied to toxicants of interest. These include PCBs, the pesticide dieldrin, cadmium and lead. Each of these toxicants had been selected as a model for larger groups of chemicals. Physical/chemical models will be coupled with a food chain model to allow estimation of the body burdens in the target species of carp, brown trout, and walleye. The integrated model will then be used to predict concentrations in the water, sediment, and biota in response to differing regulatory and remedial action scenarios. The predictions will include long-term extrapolation from the short-term calibration.

The study is concentrating the research efforts of numerous investigators on Green Bay, in order to gather the data needed to construct and drive the mass balance model. Research vessels will travel the bay to measure contaminant levels in water, sediments, and biota. Projects to quantify sources of toxic contaminants include:

- A first-of-its-kind network of air monitors to measure the introduction of airborne toxicants to Green Bay;
- Sampling programs to measure toxic input from major rivers that enter Green Bay, including the mouth of the Fox River; and

- An in-depth study of the distribution and movement of contaminants from polluted sediments.

These activities will tap the expertise of a number of state and federal agencies. Aside from EPA's GLNPO, participants include the Wisconsin Department of Natural Resources, Wisconsin Sea Grant, the National Oceanic and Atmospheric Administration (NOAA), the U.S. Fish and Wildlife Service, the U.S. Geological Survey, the Michigan Department of Natural Resources, the Green Bay Remedial Action Plan Implementation Committee, EPA labs at Duluth, MN and Grosse Isle, and EPA Region 5 Divisions of Water and Waste Management.

*Study Schedule and 1990 Status*

The study activities were conducted during a four-year period from 1986 to 1990. During 1986-87, a monitoring plan was developed, along with a quality assurance program to be used in evaluating analytical and field methods for the project. Also during this time, modeling tasks were scoped out and assigned to appropriate investigators, and some field reconnaissance was accomplished. Results of the study are expected in 1991.

During 1988, three atmospheric deposition monitoring stations were operating. EPA's research vessel, the R/V Roger Simons, was outfitted with the necessary sampling and laboratory equipment. The field season saw the first shakedown surveys in the bay to test the research equipment while at sea. During the August, October, and November surveys, methods for sampling toxics in bay and tributary waters were tested in preparation for the main field work year of 1989. NOAA deployed wave rider buoys and current meters at strategic locations in the bay. Field work was completed during the 1989-90 field season. Sample analysis and data evaluation was concluded during 1990. Modeling work is underway with results and a final report expected in 1991.

*Significance of the Study to Great Lakes Water Quality Management*

As recommended by the International Joint Commission for all Great Lakes Areas of Concern, Wisconsin's Department of Natural Resources has prepared a Remedial Action Plan for Green Bay and Lower Fox River. This plan outlines actions the state intends to carry out to restore beneficial uses, such as swimming and fishing, of the bay. The plan, however, does point out that the relative importance of some sources of toxic contaminants, such as acid deposition, are not well understood. The results of the Mass Balance Study will aid the state in refinement of their plans to enhance water quality in the bay.

The methods and findings of the study could also have a much wider application. Mass balance modeling has successfully been applied to the regulation of nutrient loads in the Great Lakes during the decade. However, the sources, pathways, and sinks for toxics are less well understood. Under the Water Quality Agreement between the U.S. and Canada, the U.S. EPA and the Great Lakes states have a mandate to manage toxic contamination in the Great Lakes on a lake-wide basis by taking all inputs into account, that is, total load management.

The Green Bay/Fox River Mass Balance Study will test the use of a modeling framework to improve our understanding of the sources, transport and fate of toxic compounds. It will ultimately guide and support regulatory activity. The study is also designed to develop and test methods, such as sampling for airborne toxics, that can later be used for lake-wide investigations of toxic contaminants. In this way, it serves as a pilot for future modeling studies of Great Lakes ecosystems.