National Estuarine Inventory

The Quality of Shellfish Growing Waters in the Gulf of Mexico

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Introduction

This report examines the quality of shellfish growing waters in the Gulf of Mexico. Information is presented on the administration of state programs, status of classified waters, sources of pollution affecting harvest-limited waters, and trends in classification between 1971 and 1985. Data were collected by site visits to the five Gulf states, through interviews with state personnel, and by reference to written materials. Data were compiled for 27 estuaries identified in NOAA's *National Estuarine Inventory* (NOAA, Strategic Assessment Branch, 1985) and four additional estuaries included for this analysis.

This project expands upon the *1985 National Shellfish Register of Classified Estuarine Waters* (Register), a joint publication of the U.S. Food and Drug Administration (FDA) and NOAA (1985), that summarizes acreages of shellfish growing waters by classification type and state. The additional information improves the utility of the data for national and regional decisionmaking by aggregating the information by estuary, clarifying classifications, and relating them to water quality. This report is the first of a series on the quality of shellfish growing waters on the Gulf, northeast, southeast, and west coasts.

Waters are classified for the commercial harvest of oysters, clams, and mussels based upon public health concerns. These molluscan shellfish are filter feeders, capable of pumping large volumes of water through their systems and accumulating particles or pollutants present in water. Bacterial or viral pathogens that accumulate in shellfish tissue and digestive systems may be passed to humans who consume partially cooked or raw shellfish. To protect public health, harvest is not allowed in waters that are near potential pollution sources or that contain high levels of fecal coliform bacteria. Gastroenteritis and infectious hepatitis are diseases associated with the consumption of contaminated shellfish.

Results of this work show that: 1) most waters in the Gulf of Mexico do not meet standards for approved waters at all times; 2) the majority of approved waters are in the outer bays of Louisiana where salinities are high and oyster productivity low; 3) harvest is prohibited in 29 percent of waters around developed areas; and 4) an additional 27 percent of waters may not be harvested after heavy rainfall or when river stages are high. These conditionally approved waters are the most productive in the Gulf.

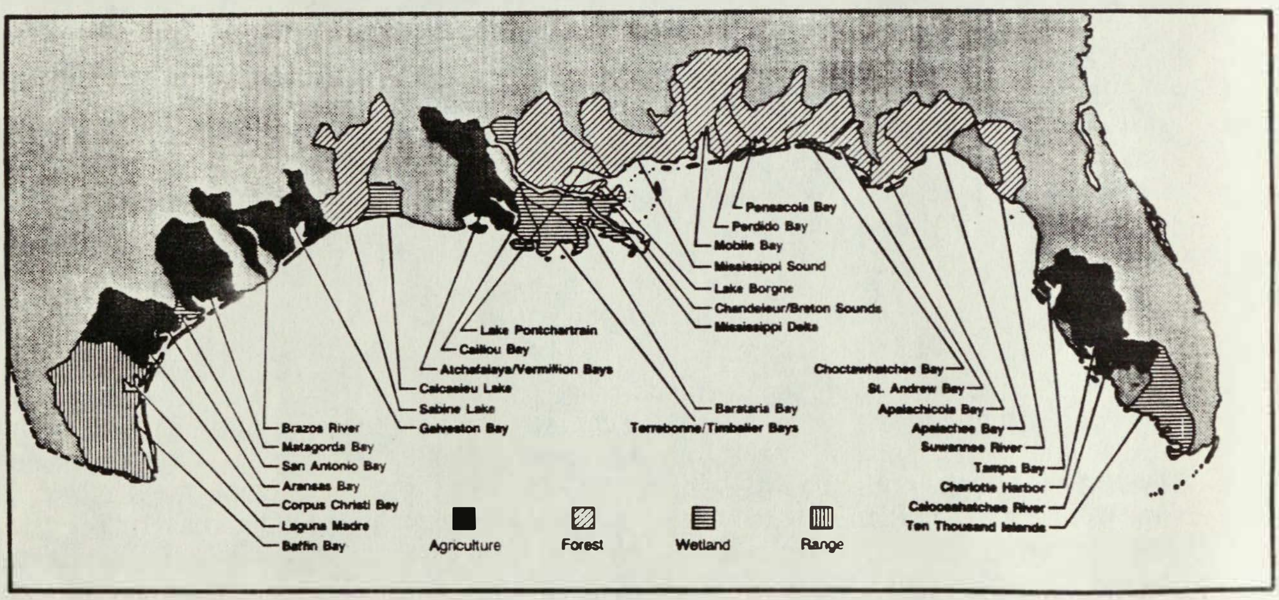
The Region

The Gulf of Mexico region extends from the southern tip of Florida west to the Mexican border. The 31 estuaries included in this report (Figure 1), represent approximately 90 percent of the total estuarine water area along the Gulf of Mexico (NOAA, Strategic Assessment Branch, 1985a). Major features include the Mississippi and Atchafalaya deltas, where large amounts of sediments contained in runoff from development, mining, and agricultural activities have been deposited in shallow coastal waters. These deltaic environments form a complex network of channels and coastal wetlands that provide the habitat for estuarine-dependent recreational and commercial fisheries. Gulf of Mexico estuaries produce most of the oysters harvested in the United States -- 26,509 pounds in 1985 -- valued at over $40 million and representing 60 percent of the total U.S. catch (National Marine Fisheries Service, 1986).

The Gulf of Mexico is the fastest growing coastal region in the Nation, with an increase in population of 30 percent from 1970 to 1980. A large percentage of the population has settled in urban complexes that have developed around the port cities of New Orleans, Houston, and Tampa. A major increase has occurred in second-home development and hotel and resort centers. This increasing development has placed pressure on the Gulf estuaries from sewage disposal, industrial activities, increased runoff from urban areas, and agricultural and livestock activities.

Figure 1 also shows the distribution of land uses in the Gulf of Mexico region (NOAA, Strategic Assessments Branch, 1985b). Urban areas account for less than 30 percent of land use, even in the most urbanized drainage basins. Dense forests, prevalent from northern Florida to the Mississippi River, are a source of pulpwood for paper products. Agriculture is the next major land use, with citrus production dominant on the west coast of Florida and irrigation crops and rangeland dominating the Texas coast and western Louisiana. The greatest number of coastal wetlands in the Nation occurs in the Gulf of Mexico, with most located in the Mississippi Delta and Barataria, Atchafalaya, and Vermilion bays. An estimated 50 square miles of wetlands are lost each year due to rising sea level, land subsidence, and human alterations, such as channelization of estuaries and canal dredging through wetlands to accommodate oil and gas production. The loss of wetlands is critically important to shellfish production since wetlands provide valuable habitat and process and filter domestic, agricultural, and industrial wastes. This report will demonstrate relationships between land uses and the classification of shellfish growing waters.

Figure 1. Dominant Land Use in Gulf of Mexico Estuarine Drainage Areas



The National Shellfish Sanitation Program

The National Shellfish Sanitation Program (NSSP), a cooperative program of the U.S. Food and Drug Administration, the shellfish-producing states, and the shellfish industry, was established in 1925 after an outbreak of typhoid was traced to raw oysters. Its purpose is to ensure the safety of shellfish for human consumption by preventing harvest from sewage contaminated waters that may contain pathogenic organisms. Under NSSP guidelines, waters are classified for harvest based on the presence of actual or potential pollution sources, and fecal coliform bacteria levels in surface waters. Waters are classified by states into one of four categories:

- o *Approved* — Waters may be harvested for the direct marketing of shellfish at all times;
- o *Conditionally Approved* — Waters do not meet the criteria for approved waters at all times, but may be harvested when criteria are met;
- o *Restricted* — Shellfish may be harvested from restricted waters if subjected to a suitable purification process; and
- o *Prohibited* — Harvest cannot occur at any time.

For this report, the term *"harvest-limited"* will be used to refer to conditionally approved, restricted, or prohibited waters.

Waters are classified by each state based upon sanitary surveys that: (1) identify actual or potential pollution sources that may affect shellfish growing waters -- a "shoreline survey"; (2) evaluate hydrologic and meteorological conditions affecting pollutant transport; and (3) sample waters for bacteriological quality.

The NSSP standard for approved waters is a total coliform bacteria concentration of less than 70 Most Probable Number (MPN) per 100 milliliters (ml), with no more than 10 percent of the samples exceeding 230 MPN per 100 ml. Over the past fifteen years most states, including all Gulf of Mexico states, began using a fecal coliform standard of 14 MPN per 100 ml, with no more than 10 percent of the samples exceeding 43 MPN per 100 ml (ISSC, 1986). The newer standard more specifically indicates the presence of microorganisms of fecal origin.

The conditionally approved classification is most often used in waters that are affected by nonpoint sources. Throughout the Gulf of Mexico, many areas do not meet the approved standard after heavy rainfall or at high river stages when large numbers of fecal coliform bacteria are transported from land to the estuary. Use of the conditionally approved classification requires the development of a management plan that clearly defines the conditions under that the waters will be opened and closed. The additional resources necessary to manage conditionally approved waters has limited the use of this classification.

A 1986 revision of the NSSP Manual of Operations (Interstate Shellfish Sanitation Conference,1986) redefined restricted waters to include the relay of shellfish, formerly allowed from prohibited waters. The manual requires that shellfish be relayed to approved waters for at least fifteen days before harvesting for direct market. Prior to 1986, the restricted classification was used only for those areas from which harvested shellfish required depuration, a 48-hour controlled purification process. In 1985, no waters in the Gulf of Mexico study area were classified as restricted, and relaying occured out of prohibited waters.

The NSSP was developed to protect the public from disease caused by pathogens in sewage. However, major shellfish-borne disease outbreaks are also caused by marine biotoxins and *vibrio* bacteria. These diseases are not associated with sewage contaminated waters. The classification system, based on the fecal coliform standard, does not apply to waters closed to harvest because of these public health concerns.

Marine Biotoxins. A separate management approach is used to prevent harvest of shellfish contaminated from marine biotoxins. In Gulf of Mexico waters, toxins produced by the dinoflagellate, *Ptychodiscus brevis,* cause fish kills and neurotoxic shellfish poisoning from consumption of shellfish. Blooms of *P. brevis* and associated chromogenic phytoplanktons are commonly known as "red tides." The occurrences of red tides in the Gulf have not been related to specific pollution sources or weather events.

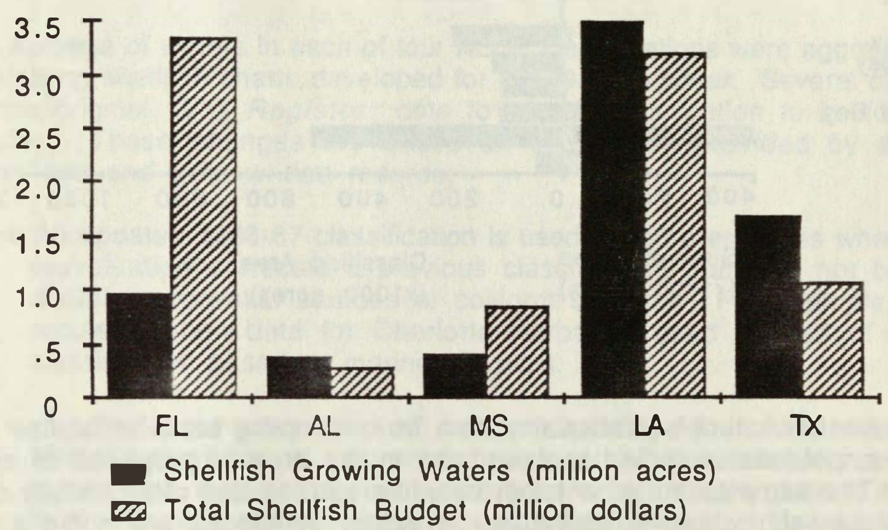
Red tide blooms have occurred more than 30 times on Florida's west coast since 1844. Charlotte Harbor has been closed to shellfish harvest as a result of red tide at least once a year. Although most blooms have occurred in Gulf waters between Tampa Bay and Charlotte Harbor, six incidents north of Tampa Bay have been documented since 1964. A major bloom of *P. brevis* closed Texas shellfish waters for most of the 1986 season, causing a major economic loss to the State. Although the visible red tide ended in mid-November 1986, the toxin remained in the shellfish through September 1987 (R. Thompson, personal communication). Florida, and more recently, Texas have developed management plans to monitor all occurrences and close shellfish growing waters until all shellfish are free of dangerous levels of toxin.

Vibrio Bacteria. Recent outbreaks of shellfish-borne diseases have been associated with the bacteria *vibrio cholerae, vibrio vulnificus,* and *vibrio parahaemolyticus.* Consumption of shellfish contaminated with *vibrio* has caused gastroenteritis and several deaths (seven in 1987), particularly in patients who were already compromised. A study conducted in Apalachicola Bay (Blake, *et al.*, 1983) found *vibrio cholera* in waters classified as approved as well as prohibited, with no correlation between coliform bacteria levels and *vibrio.* This and other studies indicate that *vibrios* are indigenous to marine waters and are not related to the presence of sewage. Most deaths have been linked to shellfish shipped out of state, suggesting that handling and time of transport may affect the pathogenicity of the organisms. This is referred to as "time and temperature abuse" and is the focus of efforts by the shellfish-producing states and the FDA to reduce the incidence of disease.

Administration of State Shellfish Programs

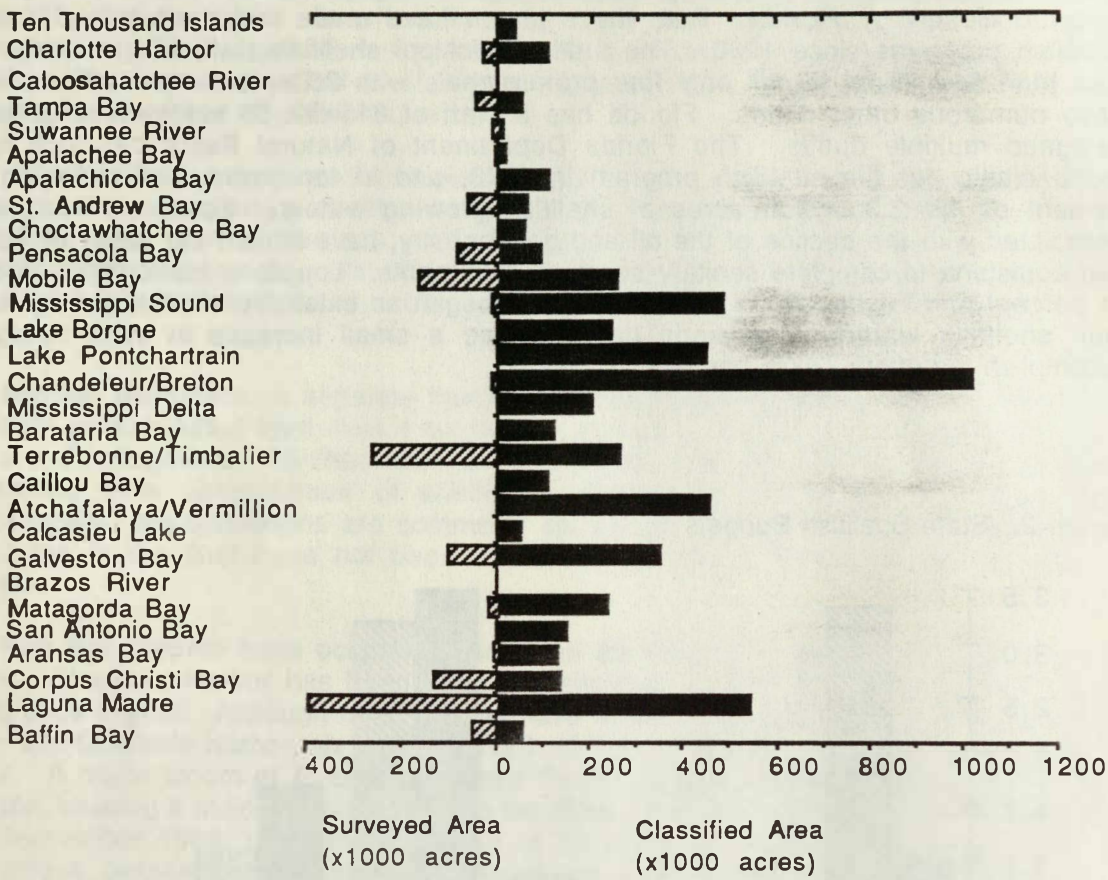
Available resources affect the ability of a state to classify properly shellfish growing waters. Figure 2 shows the distribution of state shellfish budgets and the extent of waters to be classified. Mississippi has the largest budget in relation to classified acres, followed closely by Florida. Both these states have made major advances in their shellfish programs since 1980. The total Mississippi shellfish staff, with a budget of less than $1 million, is still only four professionals with 26 enforcement officers who have numerous other duties. Florida has a staff of 31 with 59 enforcement officers assigned multiple duties. The Florida Department of Natural Resources took over responsibility for the shellfish program in 1978, and in ten years, has surveyed 50 percent of the 2.3 million acres of shellfish growing waters. Economic hardships, associated with the decline of the oil and gas industry, have limited the ability of Texas and Louisiana to complete sanitary survey requirements. Louisiana has completed only 11 percent and Texas 13. In 1987 both states began an extensive effort to survey all of their shellfish waters. Louisiana has received a small increase in state funds to accomplish the effort; Texas has received none.

Figure 2. State Shellfish Budgets



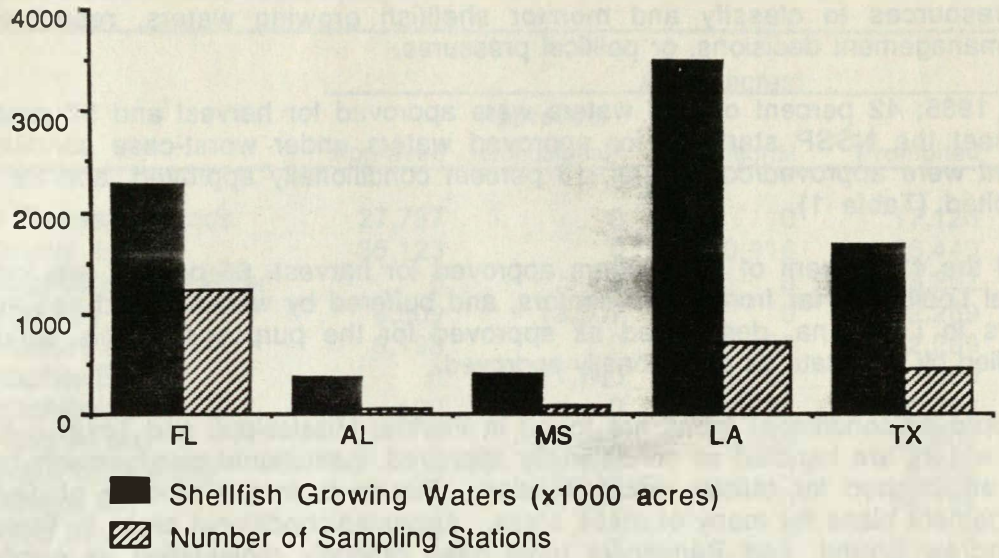
Due to financial limitations, no Gulf state had completed sanitary surveys of all of their growing waters by 1985. Figure 3 illustrates the extent of shellfish growing waters in each state and the percent of surveyed waters. Alabama completed the largest percentage (84 percent) including shellfish waters in lower Mobile Bay and the Alabama portion of the Mississippi Sound. The remaining waters in Mobile Bay do not require a sanitary survey because the area is classified as prohibited. Although Mississippi had not completed any comprehensive surveys prior to 1985, they have now surveyed 100 percent of their shellfish waters.

Figure 3. Surveyed Area by Estuary



Each state collects bacteriological quality data from sampling stations located near freshwater inflows, potential pollution sources, and in the area of proposed or actual shellfish harvest. The samples must be taken near the surface and often include other parameters such as salinity and temperature. Weather conditions are noted as the samples should reflect poorer water quality during heavy rainfall and high river stage. The guidelines suggest that a minimum of five samples be taken annually. In most cases, the states far exceed this requirement, with monthly sampling being the norm. Figure 4 shows the amount of classified shellfish waters and the number of sampling stations in each state. Florida is the exception as large acreages are managed on the basis of rainfall and/or river stage. Management of these conditionally approved areas requires additional sampling stations and samples to verify statistical models and to make decisions to open and close areas to harvest.

Figure 4. Sampling Stations



Classified Acreage by Estuary

Acreage of waters in each of four NSSP classifications were aggregated by estuary by examining shellfish charts developed for the 1985 *Register.* Several changes were made to the original 1985 *Register* data to relate classification to coliform bacteria water quality. These changes are based on information provided by state personnel in interviews and from written records:

- An updated 1986-87 classification is used in some estuaries where a recent reevaluation corrected a previous classification that was not based upon actual or potential sources of coliform bacteria. For example, the 1986 reclassification data for Charlotte Harbor is used instead of the earlier classification based on marine biotoxins.

- A new "approved/conditional" category is defined to include waters that are officially classified as approved, but closed when rainfall is heavy or river stages high. Dates of closure by estuary and by area are given in Appendix A. In most cases, closures were due to rainfall events. However, in a few instances, closure resulted from high counts found during scheduled monitoring. These approved/conditional data exclude closures resulting from hurricanes.

- All waters in Louisiana, officially classified as conditionally approved in 1985, are redefined by examining state charts that designate open and closed areas for four time periods (corresponding to four seasons) for 1986 and 1987. Areas that remained opened during all four time periods are defined as approved, areas that remained closed are designated as prohibited, and areas that were opened and closed over the time period remain conditionally approved. These new designations are for purposes of evaluating regional water quality conditions and do not reflect the official position of the state.

- An administrative closure is defined as waters closed because of insufficient resources to classify and monitor shellfish growing waters, resource management decisions, or political pressures.

In 1985, 42 percent of Gulf waters were approved for harvest and 57 percent did not meet the NSSP standard for approved waters under worst-case conditions; 14 percent were approved/conditional, 13 percent conditionally approved, and 29 percent prohibited (Table 1).

Of the 42 percent of Gulf waters approved for harvest, 66 percent are located in coastal Louisiana, far from urban centers, and buffered by wetlands and salt marshes. Waters in Louisiana, designated as approved for the purposes of this survey, are classified by the State as conditionally approved.

Approved/conditional areas are found in Florida, Mississippi, and Texas. Although these waters are handled as conditionally approved, institutional arrangements have not been established for official reclassification. Florida is in the process of developing management plans for many of these areas. Approved/conditional areas in Tampa Bay, St. Andrew Sound, and Pensacola have been officially reclassified as conditionally approved since 1985.

Texas is in the process of implementing a conditionally approved classification. Several of the most productive shellfish growing areas in the State are currently managed as if conditionally approved. Closures occur in Lavaca Bay (part of Matagorda Bay) after three inches of rain, and in San Antonio Bay if water levels in the Guadalupe River exceed 20 feet at an upstream monitoring station. Galveston Bay is automatically closed after 10 inches of rain and monitored to determine if closure is necessary after rains of 6 to 10 inches.

Perdido Bay and Sabine Lake, comprising one percent of Gulf waters, were classified for administrative reasons. These waters lie within the jurisdiction of two states: Florida and Alabama; and Texas and Louisiana, respectively. Harvest is prohibited by interstate agreement to avoid problems of bistate management. Neither system contains shellfish resources of commercial importance.

Classifications at other state boundaries show inconsistencies. For example, in eastern Mississippi Sound, Mississippi waters are classified as conditionally approved, while Alabama's waters are approved for harvest. In the western sound, Louisiana's waters are approved for harvest while Mississippi's waters are approved/conditional. Beginning in December 1986, high stages of the Pearl River caused Mississippi to close western Mississippi Sound for several months, while Louisiana's waters remained open to harvest.

Landings and Classifications

Over 30 million pounds of oyster meats were landed in Gulf waters in 1985 (National Marine Fisheries Service, 1986). The major species harvested is the American oyster (*Crassostrea virginica*). Commercial harvest occurs throughout the Gulf, from Charlotte Harbor to southern Laguna Madre, and is particularly significant in Apalachicola Bay and Chandeleur and Breton Sounds. Some commercial clam harvest occurs in southern Florida estuaries, but landings are minimal in comparison to oysters.

Table 1. Classification by Estuary in 1985

Estuary	Area (acres)				
	Approved	Approved/ Conditional[a]	Conditional	Prohibited	Administr. Closures[b]
Ten Thousand Islands	27,737	0	0	17,123	0
Charlotte Harbor	55,123	0	20,916	36,449	0
Caloosahatchee River*	0	0	0	3,252	0
Tampa Bay	5,509	18,507	0	32,269	0
Suwannee River	6,193	0	7,982	2,209	0
Apalachee Bay	0	11,740	1,765	7,560	0
Apalachicola Bay	490	0	101,624	10,096	0
St. Andrew Bay	0	31,017	6,335	26,409	0
Choctawhatchee Bay	0	52,725	0	9,659	0
Pensacola Bay	0	39,606	0	54,186	0
Perdido Bay	0	0	0	0	17,452
Mobile Bay	0	0	175,487	84,680	0
Mississippi Sound	76,888	120,083	189,958	96,749	0
Lake Borgne	187,726	0	55,089	7,289	0
Lake Pontchartrain	0	0	0	454,400	0
Chandeleur/Breton Sounds	982,021	0	27,544	9,154	0
Mississippi Delta	13,984	0	5,086	186,963	0
Barataria Bay	101,279	0	23,137	2,712	0
Terrebonne/Timbalier	240,272	0	20,256	2,882	0
Caillou Bay	57,631	0	31,358	20,849	0
Atchafalaya/Vermilion	12,543	0	120,772	326,295	0
Calcasieu Lake	25,002	0	0	31,613	0
Sabine Lake	0	0	0	0	69,183
Galveston Bay	0	170,840	0	179,524	0
Brazos River	0	0	0	1,479	0
Matagorda Bay	0	212,353	0	27,565	0
San Antonio Bay	0	136,849	0	15,521	0
Aransas Bay	63,448	50,003	0	22,134	0
Corpus Christi Bay	109,213	0	0	35,084	0
Laguna Madre	508,159	0	0	34,524	0
Baffin Bay*	47,121	0	0	12,669	0
Gulf of Mexico Total	2,473,218	843,723	787,309	1,735,377	86,635
Percent of Total	42	14	13	29	1

*Estuaries with asterisks are subsystems of larger estuarine systems.

a/ Areas classifed as approved but subject to temporary closure, usually after rainfall.

b/ Not classified on the basis of a sanitary survey.

Figure 5 compares the quantity of oysters landed in 1985 and the acreage of harvestable waters (waters classified as approved, conditionally approved, and approved/conditional). Note that waters may be classified whether or not shellfish are present, in Baffin Bay, for example. However, states limit the use of the conditionally approved classification to areas with significant shellfish resources as they are able to justify additional efforts required to develop a management plan and increase monitoring.

Most of the productive oyster reefs in the Gulf estuaries are in conditionally approved or approved/conditional waters. Freshwater inflow, resulting from highly variable rainfall events, moderates salinity, is unfavorable to predators, and provides nutrients to oyster beds. Unfortunately, the freshwater also carries fecal coliforms.

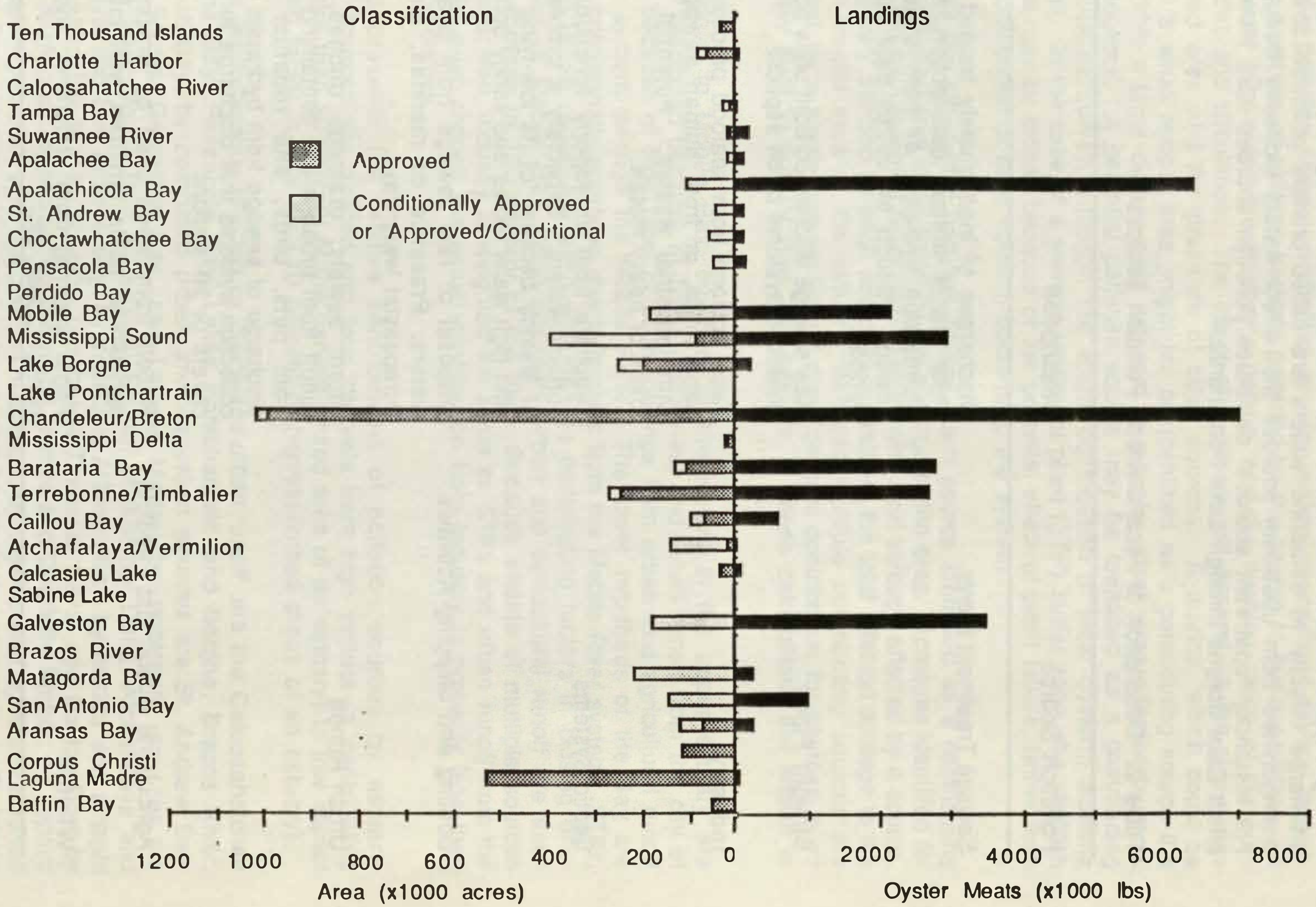
In Louisiana, harvest occurs in both approved and conditionally approved waters. However, over the past 50 to 75 years, productive reefs have moved to upper areas of the bays, closer to pollution sources, because of salinity intrusion (Chatry and Perret, 1987). The salinity intrusion is primarily a result of levees constructed along the Mississippi River, and channels created by the oil and gas industry. The extremely high salinity in much of the approved acreage creates an environment in which disease, such as dermo (*Perkinsus marinum)* and predators, such as the oyster drill, cause high oyster mortality. In the upper bays, salinity is moderated by freshwater inflows. The freshwater input, resulting from highly variable rainfall events, is unfavorable to predators and provides nutrients to the oyster beds. Unfortunately, the freshwater contains runoff from urban and agricultural areas and transports high levels of fecal coliform bacteria.

In Florida, Alabama, Mississippi, and Texas, most of the major harvest areas are in conditionally approved or approved/conditional waters. Nine estuaries with significant landings have only conditional waters; Apalachee, Apalachicola, St. Andrew, Choctawhatchee, Pensacola, Mobile, Galveston, Matagorda, and San Antonio Bays. The Suwannee River, Tampa Bay, Mississippi Sound, and Aransas Bay contain both approved and conditional waters, but harvest occurs primarily in conditional waters. Small harvesting areas are found in the approved waters of Laguna Madre. Ten Thousand Islands, Corpus Christi Bay, and Baffin Bay are totally classified as approved but have no commercially harvested resource.

Pollution Sources

An important part of the study was to compile information on pollution sources that contribute to the permanent or temporary closure of shellfish growing waters. This information was not collected for the *Register*. Sources are identified for each harvest-limited area (prohibited, conditionally approved, and approved/conditional) in the Gulf of Mexico region. Data on pollution sources were obtained from interviews with state personnel, sanitary and shoreline surveys, and other studies. In some cases, sources were inferred from land use.

Figure 5. Classification and Landings by Estuary



Eight types of pollution sources are identified in the region (Table 2). Sources that discharge directly to estuarine waters are called primary pollution sources and are distinguished from upstream sources that affect waters indirectly through tributaries. For instance, "upstream sources" describes pollution sources from New Orleans that affect Lake Borgne through Lake Pontchartrain.

Table 2. Description of Fecal Coliform Pollution Sources

Pollution Source	Description
Sewage Treatment Plants	Discharges of inadequately treated effluent from older plants without disinfection, malfunctioning disinfection systems, or from bypassing of raw sewage through an outfall pipe during overload periods.
Straight Pipes	Raw sewage discharged from units not connected to collection systems or on septics.
Industry	Fecal coliform from seafood processors, pulp and paper mills, or from human sewage discharged with industrial wastes. Potential hazards from toxics or heavy metals.
Septic Systems	Leachate from improperly functioning septics to surface waters. Especially a problem in the Gulf of Mexico because of its low-lying coastal areas with high water tables and sandy soils.
Boating and Shipping Activities	Disposal of raw sewage from boats to surface waters. Presence of marinas, shipping lanes, intracoastal waterways.
Urban Runoff	Storm sewers, drainage ditches, or overland runoff from urban areas containing fecal material from pets, birds, and rodents. Inadvertent discharge of sewage from hydraulic overloading of collection systems that discharge through manhole covers or lift stations.
Agricultural Runoff and Feedlots	Runoff from lands used by grazing animals or agricultural fields fertilized with manure.
Wildlife	Fecal material from waterfowl, rodents, rabbits, beavers, deer, etc.

Only those sources that are significant factors in classifying the area were identified. The effect of a pollution source on shellfish growing waters depends on several factors, including the numbers of coliform bacteria provided by the source to surface waters, the volume of water into which the discharge occurs, and the flushing ability of the area related to tides and circulation. The effect of a source will depend on the size of the harvest-limited area and the presence of other sources. A marina, which could be significant in a small remote area, might not be identified as a contributing source if it is located within a large closure area adjacent to a major urban area affected by more significant sources. A potential pollution source may be identified as a contributing factor in shoreline survey, although the actual contribution of fecal coliform bacteria may be small. In the case of a sewage treatment plant (STP) buffer zone, the shellfish growing area may be closed because of the potential effect of plant failure, rather than the actual contribution of fecal coliform bacteria to the system.

To assess the effect of a pollution source, each source identified as a contributing factor for a classified area is weighted by the acreage of the area. Acreages identified for each source are then summed by estuary to determine total acreage affected by a source. Percent of estuary affected by each source is the ratio of the total affected acreage to the total harvest-limited area of the estuary. Because multiple contributing sources are often identified for a single harvest-limited area, percent contribution for sources in an estuary usually sum to greater than 100 percent. These calculations are shown in Appendix B.

For example, in Mobile Bay, one-third of the waters in the upper estuary are classified as prohibited because of STPs, industries, and urban runoff from the city of Mobile, and because of high fecal coliform loadings from urban and agricultural runoff entering the system through the Mobile River. The lower two-thirds of the Bay are classified as conditionally approved due to impacts from the Mobile River system. STPs, industry, and urban runoff are each weighted as contributing factors in closing one-third of waters in Mobile Bay, while upstream urban and agricultural runoff are each contributing sources in 100 percent of the bay. Because effects of multiple sources cannot be separated, industry is weighted the same as STPs and urban runoff from the city of Mobile, even though the actual contribution from industry is probably less than the other two sources.

Figure 6 presents the relative contributions of pollution sources by estuary. Contributing sources are divided into four intervals from high impact (a contributing source in more than 90 percent of the harvest-limited area of an estuary) to low impact (a contributing factor in less than 10 percent of harvest-limited areas of an estuary).

Estuaries predominantly affected by *STPs and urban runoff* are the Caloosahatchee River, Tampa Bay, Pensacola Bay, Lakes Pontchartrain and Borgne, Brazos River, Corpus Christi Bay; by *combined urban and nonurban sources* are St. Andrew Bay, Mississippi Sound, Galveston Bay, and Laguna Madre; by *upstream sources* are Apalachicola Bay, Mobile Bay, Mississippi Sound, Mississippi Delta, Atchafalaya and Vermilion Bays, and San Antonio Bay; by *septics* is Aransas Bay; by *septics and straight pipes* are Chandeleur/Breton Sounds, Terrebonne/Timbalier Bays, and Caillou Bay; by *septics and boating activities* are Ten Thousand Islands and Charlotte Harbor; by *septics and wildlife* are Apalachee and Choctawhatchee Bays; by *septics and agricultural runoff* is Matagorda Bay; *wildlife* is Suwannee River; and by *agricultural runoff* is Barataria Bay.

Figure 6. Harvest-Limited Area by Estuary, for which a Pollution Source was Identified as a Contributing Cause

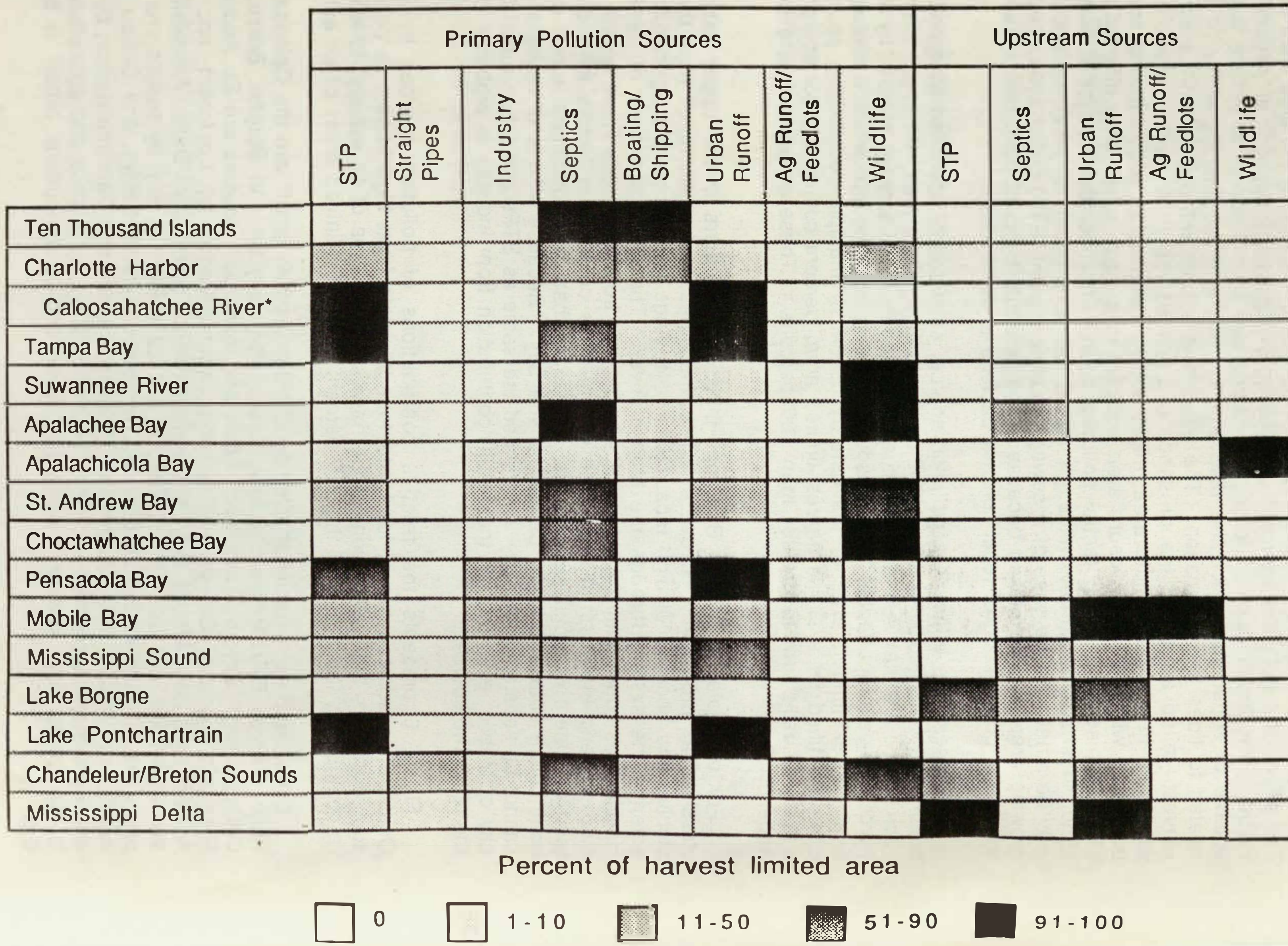
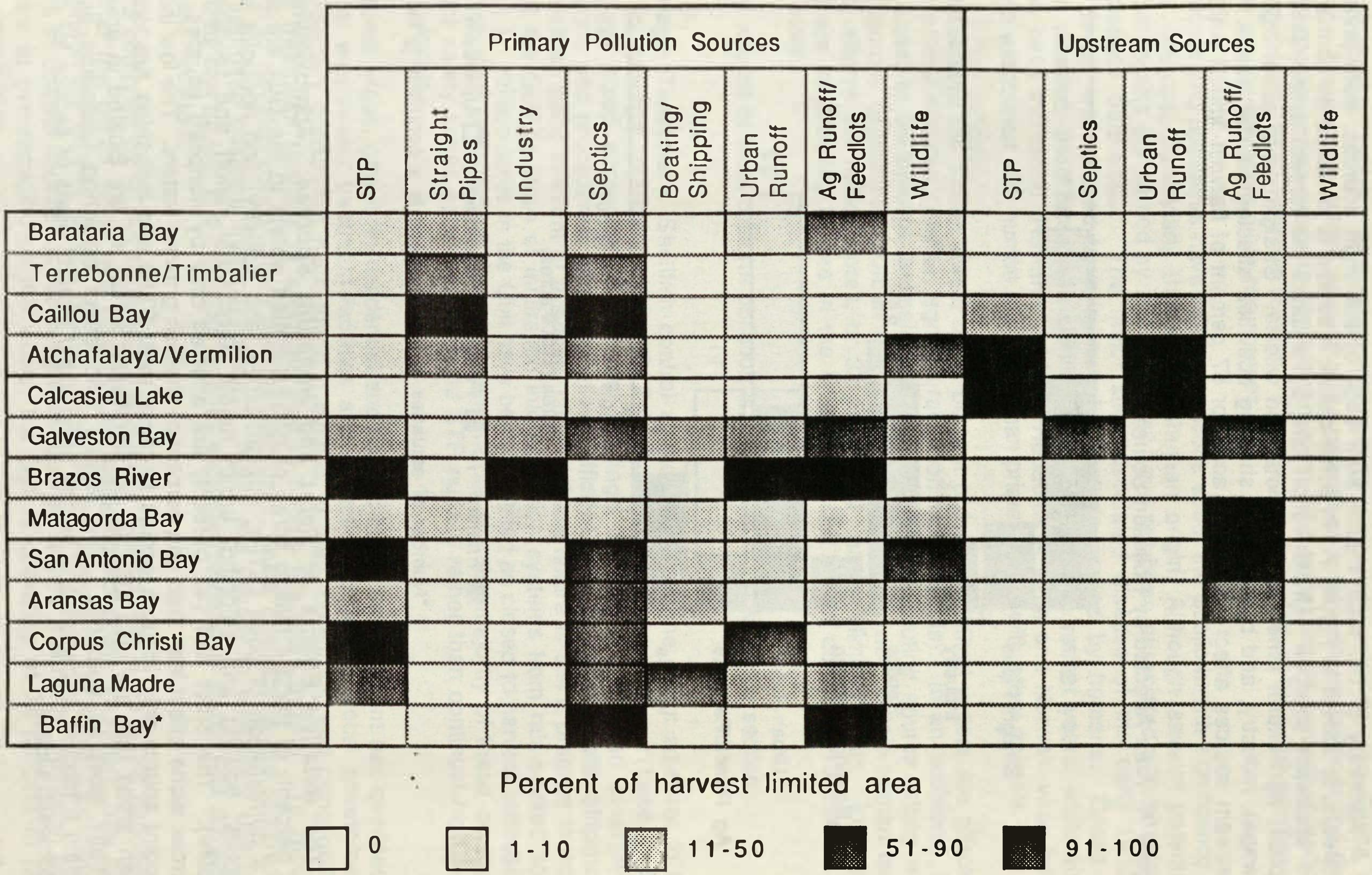


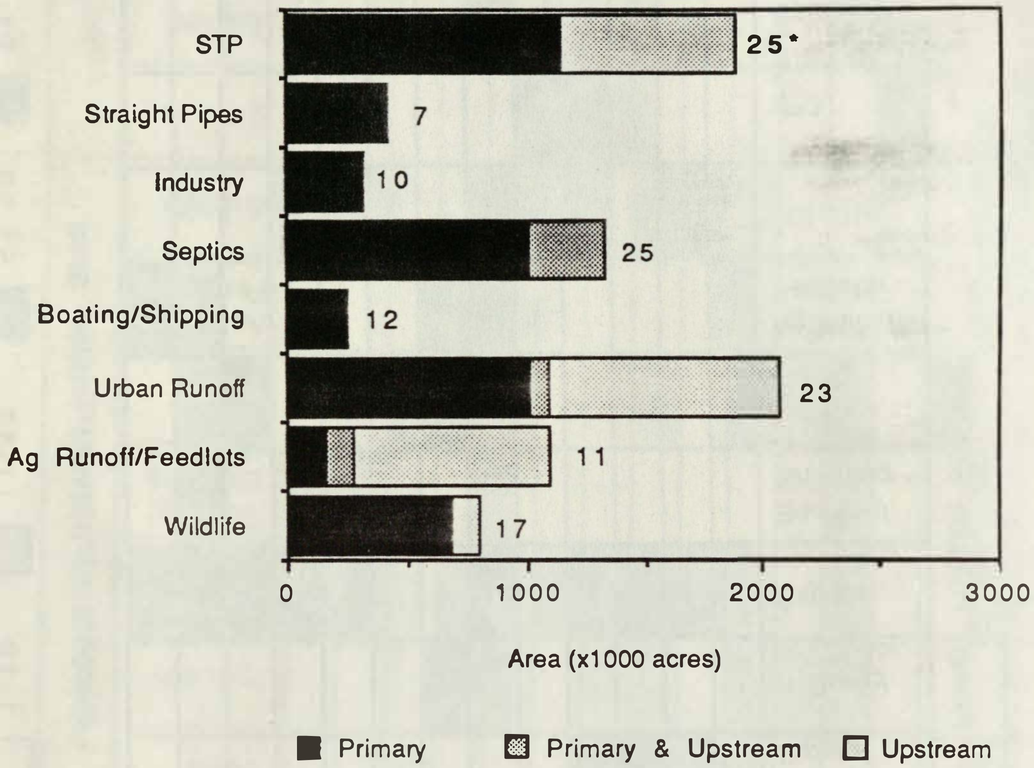
Figure 6. (Continued)



* Subsystem

A summary of the total impact from each of the eight sources, both primary and upstream, is shown in Figure 7. In some cases, a source is identified as both a primary and upstream source. Urban runoff and STPs affect the largest areas, followed by septics, agricultural runoff and feedlots, and wildlife. Straight pipes (discharge of raw sewage), industry, and boating and shipping activities affected smaller areas. Overall, upstream sources affect 1.9 million acres or 57 percent of harvest-limited waters.

Figure 7. Area Affected by Pollution Sources



*Number of estuaries in which source is a contributing factor.

The Relative Effects of Point and Nonpoint Sources. Approximately half (53 percent) of the 3.4 million acres of harvest-limited waters in the Gulf are affected by a combination of point (STPs, straight pipes, and industry) and nonpoint sources (septics, boating and shipping, urban runoff, agricultural runoff and feedlots, and wildlife). The other half (47 percent) are affected only by nonpoint sources. Point sources alone affect less than one percent of shellfish growing waters. The low incidence of point source-only impacts occurs because most STPs and industries are located in urban areas that are also affected by stormwater runoff, or are located in areas only partially sewered (septics). The remote land areas bordering Louisiana estuaries contain a mixture of camps and homes using either straight pipes or septics for disposal of domestic wastes.

Other studies have identified nonpoint sources as a major contributor of fecal coliform bacteria. NOAA estimates reported in a recent report by the Office of Technology Assessment (1987) show that 84 percent of fecal coliform loads in the Gulf of Mexico coastal region are from nonpoint sources. The remaining 16 percent of loading is from municipal point sources (STPs). The loading from industrial point sources is negligible compared to the other two sources.

Scientists and regulators have raised questions about the public health significance of nonpoint sources, particularly those of nonhuman origin. Although several potential human pathogens are carried by animals, most have not been associated with shellfish-borne disease outbreaks. The major shellfish-related disease of the early 1900s, typhoid fever, was caused by a salmonella bacteria carried by humans. Cases of bacterial disease, associated with shellfish, have declined in recent years, while viral diseases have increased (Richards, 1985). Hepatitus A virus and Norwalk virus have only been associated with human and subhuman primates, not with other animals.

An estimated 0.4 million acres, or 11 percent of harvest-limited waters are affected only by animal sources (wildlife, agricultural runoff and feedlots). In an additional 1.1 million acres, or 34 percent, animals are a significant contributing source, along with human sources of pollution. Urban runoff, which may or may not contain human fecal material, affects 1.1 million acres, or 33 percent of harvest-limited acres. Industrial sources are contributing factors in the closures of 0.3 million acres, or 10 percent of these waters.

Each source of fecal coliform pollution is discussed in the following sections.

Sewage Treatment. Shellfish control agencies classify the areas adjacent to the outfalls of sewage treatment plants (STPs) as prohibited for harvest. These "buffer zones" are sized according to pollutant loadings, hydrodynamics, and emergency installations and procedures, and must allow sufficient time for public health officials to close shellfish beds in event of a system failure. Plant failure is still a problem in many areas of the Gulf because of infiltration into collection systems from rain-soaked soils. Although 1.1 million acres in the Gulf have been identified as closed to harvest because of the contribution of municipal sewage treatment plants, the majority of these acreages represent safety zones established around STP outfalls rather than continual high fecal coliform levels.

In some areas, growth in residential and second-home development has overloaded municipal wastewater treatment facilities and collection systems. Local governments with budgetary constraints have found it difficult to plan, construct, and bring on-line sewage treatment facilities of adequate size to handle the rapid growth. To receive approval to develop condominium and planned units, some contractors are required to install approved package treatment plants. These are usually in temporary use until sewer lines can be laid and municipal facilities expanded to regional plants with advanced treatment facilities.

Data compiled by NOAA (Strategic Assessment Branch, 1987) on STPs nationwide show that the Clean Water Act objective of providing adequate treatment has been successful in the Gulf of Mexico region. Gulfwide, 94 percent of the effluent discharged by STPs in coastal counties is receiving secondary or tertiary treatment. Although some STPs are at overcapacity, on the whole, the Gulf is operating at 74 percent of plant design capabilities.

Septic Systems. The rapid residential growth in the region, particularly in second-home development, has outdistanced the ability of local governments to build STPs. Therefore, many smaller communities are still using septic systems for waste disposal. Treatment provided by septic tanks is minimal. Septic systems work well in rural, low density areas with suitable soil and a deep water table. However, these conditions seldom exist in coastal areas. Often, wastes leach into estuarine waters when septic tanks and leach fields are located too close to the shore, when tidally-induced high water tables flush drainfields, and when inadequate drainfields or poor soil absorption cause tanks to overflow. These conditions are worsened by heavy rainfall. When porous coastal soils allow wastes to leach rapidly, the effluent reaches the estuarine waters virtually untreated, polluting the waters with bacteria. Faulty septic systems are a contributing pollution factor in 39 percent of harvest-limited waters in Gulf estuaries.

Straight Pipes. The contribution of raw sewage to surface waters is referred to as "straight pipes". In many of the sparsely populated areas of Louisiana, small camps accomodate hunting and fishing activities. These small camps, often located on remote bays or bayous, are generally rustic and without facilities, either potable water or sewage disposal. Unfortunately, these discharges of raw sewage into the poorly flushed bayous and bays can have a major affect on shellfish growing waters. Because of poor mixing and dispersion, the fecal coliform pollution may persist even though the occupants of the camps have left the area. Large areas of coastal Louisiana are limited to shellfish harvest (13 percent) because of fishing camps located along the bayous. The same situation exists to a lesser degree in Texas.

Studies in Terrebonne and Barataria Bays estimated that camps were used an average of 57 days a year by an average of 2.5 persons a day, for a total of 142.5 person-days per camp per year. Approximately 3,000 housing structures were identified from aerial photography, but these could be either camps or homes on septics (Gulf South Research Institute, 1985).

Industry. Industrial growth has had little effect on the pollutant loadings to municipal sewage treatment plants in the region. Most industrial wastes are treated by the industry and discharged directly to waterbodies. In 1984, direct industrial discharges exceeded municipally discharged effluents in all coastal regions of the Gulf except Texas (NOAA, Strategic Assessment Branch, 1987). With a few exceptions, these discharges have very little affect on fecal coliform levels in Gulf estuaries.

Seafood processing plants located in coastal areas may discharge both processing and sanitary wastes into sewage treatment facilities, or in some cases, directly into receiving waters. Numerous processors with inadequate treatment facilities were identified as sources of excessive coliform concentrations along Grand Caillou and Petit Caillou bayous in Terrebonne Bay and Bayou Coden in Mississippi Sound. Apalachicola Bay also contains large numbers of processors, although the specific effect has not been studied. Fish meal plants along the Pascagoula River were identified as sources of salmonella in a 1960s Bureau of Commercial Fisheries (DOI, 1960) sampling program. *Salmonella sp.* was isolated from the soil, plant equipment, and river water.

Large pulp and paper mills discharge pollutants into receiving streams and bays along the Gulf coast, particularly in Florida. The discharge contains *Klebsiella*, a fecal coliform bacteria found in cellulose wastes and infrequently present in human feces. In some cases, wastewaters include sanitary wastes containing fecal matter. No pulp and paper mills were specifically identified as contributing causes in Gulf waters, although they are identified in shoreline surveys as potential pollution sources.

Industrial discharges to shellfish growing waters concern public health officials despite the limited identified affects. The major concerns are toxics and heavy metals. Waters in Lavaca Bay were closed in 1970 due to mercury released from an ALCOA chemical plant. Waters were reopened in 1971 when monitoring data showed mercury levels in oysters were below FDA guidelines (Texas Department of Health, 1978). This is the only chemical closure that has occurred in molluscan shellfish growing waters in the Gulf. Several Gulf states monitor for heavy metals or other toxics in shellfish meats or waters, and have not found elevated levels.

Boating and Shipping Activities. The significance of sewage discharge from boats has been controversial nationwide, with boaters generally arguing that their discharges are insignificant and Federal and state regulators arguing for stronger controls. Studies by Udell in the 1950s and 1960s showed that sampling stations associated with heavy boat use had higher levels of fecal coliform than stations outside anchorage areas. However, where tidal exchanges were large, no detectable increases in pollution levels attributable to boats were apparent. Further, the degree of fecal pollution in confined coves was directly proportional to the number of boats anchored or docked (Puget Sound Water Quality Authority, 1986). A positive correlation between the number of boats in the Rhodes River estuary (Chesapeake Bay) and fecal coliform concentrations was reported by Faust (1982). Other problems associated with recreational boating are cited, such as operations of marinas, fueling facilities, and boatyards.

To protect the public health from the effect of boat wastes, the Interstate Shellfish Sanitation Committee has developed a marina policy that requires states to establish buffer zones around marinas and canals. The area within the marina proper must be classified as prohibited or restricted. An additional closed restricted area beyond the marina may be required. Many shellfish producing states are conducting studies to develop uniform techniques for closing areas based on dilution, dispersion, die-off or residence time, hydrodynamics, and marina design, quality, and usage.

Similar concerns are raised concerning discharges in shipping channels and major ports. Some states prohibit shellfish harvest in all ship channels, although no official policy has been adopted as has been for marinas. Buffer zones around shipping channels in Mississippi Sound are a contributing factor in the closure of 20 percent of harvest-limited waters. Waters within the channels are classified as prohibited, while most waters in the outer sound are classified as approved or conditionally approved. Other states have closed areas in the intracoastal waterway because of high concentrations of boats and limited circulation. Artificial canals, included within this category, are prohibited to shellfish harvest because of limited circulation, high concentrations of boats, runoff from lawns, and malfunctioning septics.

Gulfwide, boating and shipping activities affect about seven percent of harvest-limited waters. In many cases, marinas and ports are not considered major contributing factors because they are located in major urban areas where waters are already closed to harvest because of STPs and urban runoff. Effects from marinas and boating activities are major in less populated estuaries, a contributing factor in 100 percent of harvest-limited waters in Ten Thousand Islands and 75 percent in Charlotte Harbor. Recreational boats and large concentrations of commercial oyster vessels contribute to the fecal coliform pollution in seven percent of waters in Apalachicola Bay.

Urban Runoff. Many studies have shown that stormwater runoff from urban areas contains high concentrations of fecal coliform. The 1983 EPA report, *Results of the Nationwide Urban Runoff Program (NURP)*, attributes high bacteria levels in urban runoff to heavy loads of animal wastes, particularly pets and rodents. The NURP study found that runoff exceeded recommended bacterial counts at virtually every one of the 28 urban study sites during heavy rainfall. Fecal coliform counts in urban runoff are typically tens to hundreds of thousands per 100 ml during warm weather conditions, with the median for all sites being around 21,000/100 ml. The study also indicated that use of coliforms as an indicator of human health risk, when the sole source of contamination is urban runoff, warrants further investigation. This criticism of the indicator for stormwater runoff is echoed by Wheater, *et. al.* (1979) in a report attributing fecal coliform pollution in urban runoff to humans, farm animals, pets, and rodents.

Urban runoff may also contain human waste from malfunctioning sewage collection and treatment systems. These systems are heavily stressed after storm events. For example, the communities of Gulfport and d'Iberville on Mississippi Sound have experienced pollution affects from malfunctioning lift stations, designed to carry the sewage from coastal commercial and residential developments to the regional treatment plant. A buffer zone has been delineated along the beaches in Mississippi Sound due to high fecal coliform levels found during bathing beach studies. Sewer lines in cities near Apalachicola Bay suffer from infiltration and breakage problems, especially after heavy rains. In March and April 1984, sewage discharges from manhole covers occured three times during two weeks of heavy rains. Raw sewage was released to surface streets and ditches, or pumped to nearby wetlands. Earlier that year, an estimated 5,000 gallons of raw sewage from a sewer line break were pumped into stormwater drains that discharge to Apalachicola Bay (Florida Department of Natural Resources, 1984a, 1984b).

A report by the Gulf Coast Research Institute (1985), attributes bacterial pollution to drainage water from densely populated areas along the descending bank of the Mississippi River and to effluent from community sewer systems. Under average conditions, the treated effluent is discharged to the Mississippi. However, during heavy rainfall events, many of the sewer systems overflow to the drainage systems, and eventually into a 20-mile wide area of marshland, ponds, bayous, and canals.

The urban centers in the Gulf region show major effects on shellfish waters from runoff, a contributing factor in 97 percent of harvest-limited waters in Tampa Bay, 91 percent in Pensacola Bay, 100 percent in Mobile Bay, 55 percent in Mississippi Sound, 100 percent in Lake Pontchartrain, and 36 percent in Galveston Bay.

Agricultural Runoff. Runoff from cropland fertilized with manure or land used by grazing animals contributes fecal coliform bacteria to surface waters. Studies show that the fecal coliform is five to 10 times higher from grazed land than from ungrazed areas and that there is significant bacterial contamination where high-density livestock activities are allowed adjacent to a stream (Milne, 1976). Faust and Goff (1978) estimate that in systems where sanitary effluents are controlled by use of septic tanks, the fecal coliform contribution of one livestock unit is equal to the contribution of 60-70 persons .

Along the western Gulf Coast, shellfish growing waters are affected by livestock operations, a contributing factor in eight percent from primary sources and 27 percent from upstream sources. For example, a major cattle operation on lands adjacent to Barataria Bay is the probable source of coliform pollution affecting 70 percent of harvest-limited waters in the estuary. Cattle, grazing on the levees, were identified as one of several sources affecting the Quarantine Bay area of Chandeleur and Breton Sounds. In Texas, many of the agricultural effects are from upstream sources. The Texas Water Commisssion (1986) identifies nonconfined livestock as the source of coliform bacteria in upstream segments of the Guadalupe (San Antonio Bay) and Lavaca (Matagorda Bay) Rivers.

Wildlife. Wildlife has been identified as a probable source of fecal coliform bacteria in areas with minimal human populations. Presnell and Miescier (1971) identify mammal and bird populations as the source of coliform and fecal coliform organisms isolated from soil and water samples in a Mississippi bayou. Study results demonstrate the varying coliform and fecal coliform contributing potential of different species of birds and mammals (i.e., lowest density from nutria and highest from raccoons, rabbits, muskrats and field mice). The study was requested by the Mississippi Board of Health because high coliform levels in some areas along the Gulf Coast could not be attributed to humans or domestic animals. However, later studies suggested that the fecal coliform were actually from Pascagoula Bay, and were transported to the bayou by tides (Gaines, personal communication). A study by the State of Florida (Williams, 1981) concluded that in developed areas of low density, the fecal coliform contribution from wildlife may equal or exceed that of humans.

Many Florida estuaries are affected by wildlife. The sanitary survey of Myakka River (Florida Department of Natural Resources,1984), identifies egrets and other species of shore birds as the major contributors of fecal coliform in the area. In 1985, classified waters in the Suwannee River estuary were located at the outer limits of the estuary, far from the river. These remote areas do not meet shellfish growing water standards because of fecal pollution from wildlife. The sanitary survey (Florida Department of Natural Resources, 1987) indicated that fecal coliform levels are elevated when wintering fowl arrive, and identified deer, rabbits, mice, opossum, raccoon and mink as minor contributors.

The sanitary survey of Ochlockonee Bay (Florida Department of Natural Resources, 1982) identifies major wildlife populations protected within St. Mark's Refuge and Apalachicola National Forest as potential or actual sources of fecal coliform bacteria. The data list 53 mammalian species, 313 bird species, and 106 species of amphibians and reptiles. The U.S. Fish and Wildlife Service estimated that 300 gulls, shorebirds, cormorants, and scaup feed on exposed oyster bars at the east end of the bay. A wintering population of 300-500 ducks resides near the mouth of the bay, all contributing (100 percent) to the fecal coliform pollution of the Apalachee Bay system. Wildlife is also a contributing factor in St. Andrew (51 percent), Choctawhatchee (100 percent) and Apalachicola Bays (99 percent from upstream sources).

Louisiana identifies wildlife populations as a contributing factor in fecal coliform pollution in several estuarine systems; 76 percent in Chandeleur and Breton Sounds; 58 percent in Atchafalaya and Vermilion Bays; 10 percent in Terrebonne and Timbalier Bays; and 9 percent in Barataria Bay. A Gulf South Research Institute report (1980) identifies the highly productive wildlife populations in Louisiana as a major nonpoint source of fecal coliform pollution. It also reported that nine out of ten bird species in

North America spend part of their life time in Louisiana coastal marshes, with over six million ducks and geese wintering annually. Approximately 80 percent of the world's nutria pelts and 25 percent of the muskrat pelts come from these coastal marshes. The report estimates that the muskrat population of the Barataria Basin may be as high as one million. Texas also experiences some effects from wildlife in Galveston and San Antonio Bays and to a lesser extent, in Matagorda and Aransas Bays.

Upstream Sources. Pollution sources that affect shellfish growing waters through river systems are identified in a separate upstream sources category. Most sanitary surveys identify rivers as sources but do not identify pollution sources in the upstream drainage basin. The upstream sources, identified in this study, have been derived from studies or inferred from land use.

Rivers have a profound effect on classified waters. As a river enters a bay system, salinities in the bay decrease and coliform bacteria levels rise. Thus, higher fecal coliform levels are associated with low salinity. Early studies suggest that die-off rates are higher as salinity increases. However, more recent studies suggest that the organisms may actually go into a dormant stage during periods of high salinity (Office of Technology Assessment, 1987). As the river stage increases, the effects of the river extend further into the estuary. High stages in the Apalachicola and Mobile Rivers will drop salinities to freshwater levels and increase coliform bacteria above approved standards throughout entire estuarine systems.

Monitoring and modeling studies conducted by the South Alabama Regional Planning Commission (Brady, 1979) show that the fecal coliform contamination in the lower Mobile Bay is from nonpoint runoff from the Mobile River system. Loadings from municipal point sources and urban runoff from the city of Mobile were small in comparison to loadings from the Mobile River and were not significant contributing factors to the lower bay pollution problem. A combination of urban and agricultural runoff in the upper watershed were suggested as the probable source of fecal coliform bacteria.

Waters managed on the basis of river stage, or a combination of river stage and rainfall, are found in Apalachicola Bay, Mobile Bay, Mississippi Sound, Atchafalaya and Vermilion Bays, and Galveston, Matagorda, and San Antonio Bays.

Trends in Classification, 1971 to 1985

An attempt was made to identify trends in classified waters, as this information is sought by researchers and decisionmakers. However, only in 3,800 acres could changes in classification could be related to changes in pollution sources (Table 4). The predominant change to occur in the Gulf is the reclassification of over 700,000 acres from approved to conditionally approved or approved/conditional, a result of improvements in monitoring practices and increased awareness of nonpoint sources.

Classification of waters in 1971 was determined from the charts and data sheets produced for the *1971 National Shellfish Register of Classified Estuarine Waters* (FDA, 1971). Each 1971 chart was examined in conjunction with the corresponding 1985 chart. Changes were evaluated on an area-by-area basis. State personnel were asked if changes between classifications or from unclassified to conditionally approved or prohibited resulted from a change in pollution sources.

Table 3. Pollution Related Changes in Classification

Estuary	Area	Acres	Classification 1971	1985	Reason for change
Mississippi Sound	Dauphin Island	774	Prohibited	Conditional	STP construction
	Bayou La Batre	144	Approved	Prohibited	STP expansion
Matagorda Bay	Indianola	600	Approved	Prohibited	Development
	Magnolia Beach	561	Approved	Prohibited	Development
	Old Town Lake	64	Approved	Prohibited	Development
	Port O'Connor	439	Approved	Prohibited	Development
	Ditch	20	Approved	Prohibited	Development
	Noble Point	30	Approved	Prohibited	Development
	Carancahua	1051	Approved	Prohibited	Development
Aransas Bay	St. Charles Bay	184	Approved	Prohibited	moved STP outfall
Total		3,867			

In Alabama, Mississippi, Louisiana, and Texas, an additional two million acres of estuarine waters were classified between 1971 and 1985. In Florida, 0.8 million acres less were classified in 1985 than in 1971. All five Gulf states changed from the total coliform to the fecal coliform standard between 1971 and 1985. This change had no effect on the classification of shellfish growing waters in any of the states.

Changes were noted in over 800,000 acres in 45 areas. Greater than 90 percent of these changes are from approved to conditionally approved or approved/conditional. Approximately 50,000 acres were downgraded in classification from approved to prohibited. Upgrades occured in about 16,000 acres, of which 6,000 went from prohibited to conditonally approved, and 10,000 acres became approved from prohibited or conditionally approved. Some change in classification occurred in all but five of the estuaries: Ten Thousand Islands; Caloosahatchee River; Perdido Bay; Mobile Bay; and Sabine Lake.

Waters changed from approved to conditionally approved or approved/conditional due to improved monitoring, increased awareness of the effect of nonpoint sources, and the technical ability to develop and implement management plans. Although the states provided numerous examples of improvements in sewage treatment, these efforts have not opened up waters to harvest because: 1) other pollution sources keep waters above coliform standards; 2) reductions in coliform bacteria are not enough to meet standards; 3) closure lines remain as buffer zones in case of failure of the improved facility; or 4) improvements were made so recently that effects have not yet been determined.

This report establishes a baseline of information from which future *Registers* will evaluate classification changes. It will now be possible to estimate changes that result from differences in water quality or pollution sources separately from administrative changes.

Florida. In Florida, the responsibility for the shellfish program was transferred in 1978 from the public health agency to the Department of Natural Resources. Prior to 1978, sanitary surveys were conducted by individual county health departments and varied in quality. Many of the surveys conducted in the early 1970s were "sunny day" surveys, i.e., surveys conducted under best rather than worst conditions. Trends are not available for Florida waters for the past ten years because most waters were evaluated only once during that period.

Since 1978, Florida has adopted the conditionally approved classification for many areas that were previously approved. This change occured as the administrative and technical capabilities to manage conditional waters were developed, including the development of a model for relating rainfall, river stage, and fecal coliform levels. The nonpoint sources affecting these conditionally approved areas have existed for many years. In Apalachicola Bay, for example, FDA recommended a conditionally approved classification as early as 1972, and again in 1975, after analyzing monitoring data. Waters were finally classified conditionally approved in 1985.

The state of Florida has removed many outfalls that discharged directly to estuarine waters. When the STP outfall in Apalachicola was moved from direct-bay discharge to a marshy creek, the buffer zone around the original outfall remained and was eventually expanded due to high coliform loadings from the Apalachicola River. After the Lynn Haven STP in St. Andrew Bay went from a discharge outfall to spray irrigation, the buffer zone remained as a buffer to the STP at neighboring Military Point.

Alabama. Between 1971 and 1985, approved waters of Portersville Bay and lower Heron Bay were classified as conditionally approved because they are affected by the Mobile River at high river stage. At Dauphin Island, 774 acres were upgraded from prohibited to conditionally approved after the installation of a new wastewater treatment plant replaced septic systems. Enlargement of an STP at Bayou La Batre increased an existing buffer zone by 144 acres.

The current classification boundaries of Mobile Bay were delineated in the 1950s, and have not changed since that time. However, conditionally approved waters in Mobile Bay remain open for longer periods since the state changed from the total to the fecal coliform standard.

Mississippi. The major changes to occur in Mississippi between 1971 and 1985 are the designation of ship channels as prohibited, and the addition of conditional areas. The inner bays have been closed to harvest for many years. The first closure line in Biloxi Bay was established in 1945. The line gradually advanced outward toward the sound until the entire bay was closed in 1967. Pascagoula Bay was closed in 1936 after oysters harvested at the mouth of the Pascagoula River caused an outbreak of hepatitis. Development in the unsewered community of Mallini Bayou at the western end of the sound is currently threatening to close additional harvest areas due to increasing levels of pollution.

Although studies of fecal coliform levels along the Mississippi coast show great reductions as a result of improvements in STPs, collection systems, and storm drainage, levels are still above shellfish growing water standards. Data collected at bathing beaches during summer months from 1976 to 1986 showed improved water quality at eight of the ten stations. Fecal coliform levels in Biloxi Bay declined by as much as 95 percent after a new regional STP at Ocean Springs replaced an older, overloaded facility. A study was conducted in the summer of 1987 to determine if prohibited shellfish waters in Biloxi Bay could be opened to harvest on a conditional basis as a result of the Ocean Springs STP upgrade (Biloxi and Back Bay Comprehensive Sanitary Survey, June 5-19, 1987). Preliminary results suggest that waters are not suitable for conditional harvest but may be used for relaying or depuration (Gaines, personal communication).

Louisiana. Trends in Louisiana were not evaluated because all 1985 waters were officially classified as conditionally approved, and seasonal openings and closings were calculated from the averages of five to ten years of monitoring data.

Since 1982, Louisiana has made significant improvements in the STPs and collection systems for the cities of Houma along Bayou Chauvin (Terrebonne Bay) and Morgan City along the Atchafalaya River. In Houma, the STP was upgraded from two inadequate oxidation ponds with no chlorination to a 16 MGD plant with full chlorination capabilities. Coliform levels at the outfall dropped from 3.5 million to below 200 MPN. In addition, bypassing was stopped at 26 known discharge points that had been releasing raw sewage into storm drains after each significant rainfall. Morgan City has a new STP providing secondary treatment. The city previously had a collection system but no treatment (St. Pe, 1985). The impact of these changes on downstream shellfish growing waters has not yet been evaluated by the State.

Texas. Little information is available on changes in sources because comprehensive shoreline surveys have not been conducted or re-evaluated in most areas since 1972. Recently the State of Texas was found "out of compliance" with the NSSP for classifying waters on the basis of monitoring data alone, without the supporting shoreline survey information. In Matagorda Bay, 2,800 acres changed from approved to prohibited as a result of increased coastal population and shoreline development. A new buffer zone of 184 acres was created in Aransas Bay when the outfall from an STP was moved to a new location. In several cases, closure lines around harvest-limited waters were moved to provide more visible markers and to enhance enforcement capabilities.

Concluding Comments

Although shellfish growing waters in the Gulf of Mexico are among the most productive in the USA, they are also among the most sensitive to changes in land use and weather conditions. The majority of shellfish growing waters in the Gulf of Mexico do not meet the fecal coliform standards for approved harvest. Twenty-nine percent of waters are classified as prohibited. These are waters adjacent to urban areas and smaller shoreline developments. An additional 27 percent of waters are managed as conditionally approved. These areas are further from developed shorelines, have harvestable resources, and are heavily affected by freshwater inflows from heavy rainfall or high river stages. Elevated fecal coliform levels are associated with freshwater inflows, regardless of the land use of the surrounding area. There is an immediate effect as the runoff from urban areas, agricultural lands, woodlands, and marshes flows into estuarine waters. When heavy rainfalls occur further up in the watersheds, high river flows transport coliforms, often with minimal dilution, into estuarine waters.

As the fastest growing coastal region in the USA, the Gulf has had to assimilate the wastes generated by large population centers, resort communities, and industrial complexes. Concurrent with this growth has been a decline in the availability of molluscan shellfish resources throughout the region. During 1987, production was severely curtailed in Florida, Alabama, Mississippi, and Texas. Only Louisiana continued a high level of production, assisted by shellplanting programs and successful spat (larval oyster) set. Although Louisiana has the highest percentage of approved waters (55 percent), these are in areas of extremely high salinity where disease and predators cause high oyster mortality. The most productive oyster reefs are located in conditionally approved areas closer to populated areas where heavy rains and high river stages can close waters to harvest for lengthy periods. Oystermen manage the resource by transplanting seed oysters from the public seed grounds located in reef areas (most of which lie east of the Mississippi River far from pollution sources) to private bedding grounds, where they complete the growth cycle. The process is labor intensive and results in the harvest of 50 percent or less of the relayed product.

Across the Gulf of Mexico, the predominant sources of fecal coliform are sewage treatment and collection systems (a contributing factor in the closure of 34 percent of harvest-limited waters from primary sources and 22 percent from upstream sources), septic systems that do not function properly in coastal areas because of poor soils and high groundwater tables (39 percent and 10 percent upstream), and stormwater runoff from urban areas (33 percent and 32 percent upstream). Overall, upstream sources affect 57 percent of harvest-limited areas. Contributions from wildlife are significant in rural estuaries (21 percent and 3 percent upstream). Runoff from pasturelands affects estuaries in Louisiana and Texas (8 percent and 27 percent upstream). Straight pipes are a problem in coastal Louisiana (13 percent). Actual effects from industry (10 percent) and boating and shipping activities (7 percent) are minimal compared to other sources.

The heavy impact of nonpoint sources is also evident in the minimal trends data that could be compiled. Despite numerous examples of improvements in point sources, e.g.; construction, upgrades and expansions of STPs, only one area of 774 acres has been upgraded in classification because of a newly constructed STP that replaced septics in the area. Although much of the trends data are lost to administrative changes, the primary changes that have occurred in the Gulf have been increases in conditional areas due to a heightened awareness of the effects of nonpoint sources.

The results of the shellfish project may provide guidance to national and regional decisionmakers in the development of policies and implementation strategies to maintain and, in some cases, improve estuarine water quality. The Strategic Assessment Branch is continuing work on quality of shellfish growing waters nationwide. Information is currently being compiled on the administration of state programs, status of classified waters, sources of pollution, and classification trends for 14 east coast states and 52 estuaries. Following the production of the east coast report, data collection will begin for the west coast. The resultant data base will be used as a baseline for future data collection efforts. The 1990 and subsequent editions of the *National Shellfish Register of Classified Estuarine Waters* will be expanded to provide additional information and will better reflect estuarine water quality in the nation.

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Appendices

Temporary Closures of Approved Waters in the Gulf of Mexico

Pollution Sources by Area

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Appendix A. Temporary Closures of Approved Waters in the Gulf of Mexico

Estuary	Area	Dates of Closure
Tampa Bay	Cockroach Bay	Aug-84, Feb-83, Feb-80
	Lower Tampa Bay	Nov-83, Aug-83
Apalachee Bay	Wakulla County Waters	Dec-85, Nov-85, Apr-84, Mar-83, Feb-82, Jan-82, Feb-81, Nov-80, May-80, Mar-80, Feb-80, Nov-79
St. Andrew Bay	East Bay	Dec-85, Apr-84, Mar-84
	West Bay	Dec-85, Mar-84, Apr-83
	all	Oct-85
Choctawhatchee	all	Dec-85, Mar-84
Pensacola Bay	all	Dec-85
	Escambia and East Bays	Apr-84, Mar-84
Mississippi Sound	All Mississippi Waters	Dec-87, Feb-83
	Western Mississippi Sound	Dec-82
Galveston Bay	All	Nov-86, Mar-85, Nov-84, Oct-84, Jul-79, Apr-73, Mar-73
	Galveston and Trinity Bays	Feb-87, Nov-86, Jul-81, Jun-81, Jun-76, Jan-74
	East Galveston Bay	Jan-87, Nov-86, Jul-81, Jun-76, Jan-74
	West Galveston Bay	Jan-83, Jun-81
Matagorda Bay	all	Mar-85, Nov-84
	Lavaca, Cox, and Keller Bays	Dec-85, Nov-85,Nov-84, Mar-84, Nov-83, Feb-83, Nov-82, Mar-82, Nov-81
	Lavaca Bay	Feb-87, Jan-85
	East Matagorda Bay	Feb-87, Jan-87, Nov-84
	Tres Palacios, Carancahua Bay	Feb-87, Apr-85, Nov-84, Feb-83
	Oyster and Powderhorn Lakes	Mar-85, Mar-82
San Antonio Bay	all	Dec-86,Dec-85, Apr-85, Mar-85, Nov-81
	portion	Apr-85, Jan-79
Aransas Bay	Copano Bay	Feb-87
	Mission, Copano, Port Bays	Apr-85, Mar-85

Appendix B. Pollution Sources by Area

Estuary	Area	1985 Acreage: Approved/ Conditional	1985 Acreage: Conditional	1985 Acreage: Prohibited	Primary Pollution Sources for 1985 Harvest Limited Classification: STP	Straight Pipes	Industry	Septics	Boating/ Shipping	Urban Runoff	Ag Runoff/ Feedlots	Wildlife	Upstream Sources: STP	Septics	Urban Runoff	Ag Runoff/ Feedlots	Wildlife
Ten Thousand Islands	Total			17,123				17,123	17,123								
	% of Total							100	100								
Charlotte Harbor	Pine Island Wildlife Refuge			2,712								2,712					
	Pine Island Creek			561				561	561								
	Safety Harbor			51					51								
	Chadwick Bayou			678				678									
	Wulfert Channel			254				254									
	Clam Bayou			85				85									
	Old Blind Pass			34				34									
	York Island			42				42									
	Matlacha Pass			1,173				1,173	1,173								
	Sanibel Island			22,756				22,765	22,756								
	Boca Grande			469	469			469	469								
	Myakka			3,143				3,143				3,143					
	Tippecanoe Bay		3,561					3,561				3,561					
	Muddy Cove			316				316				316					
	Bokeelia			918				918	918								
	Gasparilla Sound		17,355		17,355			17,355	17,355								
	Gasparilla Pass			5					5								
	Caloosahatchee River*			3,252	3,252					3,252							
	Total		20,916	36,449	21,076			51,354	43,288	3,252		9,732					
	% of Total				37			90	75	6		17					
Caloosahatchee River*	Total			3,252	3,252					3,252							
	% of Total			100	100					100							
Tampa Bay	Old Tampa Bay			27,466	27,466					27,466							
	Weedon Island			602	602					602							
	Cockroach Bay	4,355						4,355									
	Northwest Channel	14,152						14,152									
	Miguel Bay			82				82	82								
	Terra Ceia Island			72				72				72					
	Bishop Harbor			102				102	102			102					
	Terra Ceia River			41				41				41					
	Mallet Key Bayou			51	51												
	Madelaine Key			561	561												
	Indian Key			3,292	3,292					3,292							
	Total	18,507		32,289	31,972			18,804	184	31,360		215					
	% of Total				99			58	1	97		1					
Suwannee River	Horseshoe Cove			1,583								1,583					
	Suwannee Reef		7,982.									7,982					
	Cedar Key			599	599			599		599							
	Horseshoe Point			27				27				27					
	Total		7,982	2,209	599			626		599		9,592					
	% of Total				6			6		6		94					

Continued.

Estuary	Area	1985 ACREAGE Approved/ Conditional	Conditional	Prohibited	PRIMARY POLLUTION SOURCES FOR 1985 HARVEST LIMITED CLASSIFICATION STP	Straight Pipes	Industry	Septics	Boating/ Shipping	Urban Runoff	Ag Runoff/ Feedlots	Wildlife	UPSTREAM SOURCES STP	Septics	Urban Runoff	Ag Runoff/ Feedlots	Wildlife
Apalachee Bay	Ochlockonee Bay		1,765	5,143				6,906				6,906		6,906			
	Walker Creek			1,010				1,010	1,010			1,010					
	Oyster Bay	11,740						11,740				11,740					
	Dickerson Bay			367				367				367					
	Old Creek			673								673					
	Spring Creek			367				367				367					
	Total	11,740	1,765	7,560				20,392	1,010			21,065		6,906			
	% of Total							97	5			100		33			
Apalachicola Bay	St. Vincent			133													
	Apalachicola			7,453	7,453		7,453	7,453	7,453	7,453							7,453
	Apalachicola Bay		101,624														101,624
	Green Point			2,041				2,041		2,041							2,041
	East Point			469	469		469			469							
	Total		101,624	10,096	7,922		7,922	9,494	7,453	9,963							111,118
	% of Total				7		7	8	7	9							99
St. Andrew Bay	St. Andrew Bay			23,440	23,440		23,440			23,440							
	Wetappo Creek			255								255					
	East Bay	14,361						14,361				14,361					
	Lynn Haven			612						612							
	North Bay		6,335					6,335		6,335							
	West Bay	16,656		745	745			16,656				16,656					
	West Bay Creek			490				490				490					
	Crooked Creek			520								520					
	Burnt Mill Creek			347								347					
	Total	31,017	6,335	26,409	24,185		23,440	37,842		30,387		32,629					
	% of Total				38		37	59		46		51					
Choctawhatchee Bay	Choctawhatchee	52,725						52,725				52,725					
	Alaqua, LaGrange Bayous			3,417				3,417				3,417					
	Lower Bay			6,242								6,242					
	Total	52,725		9,659				56,142				62,384					
	% of Total							90				100					
Pensacola Bay	Entrance Pensacola Bay			149	149					149							
	Pensacola Bay	39,606		45,683	45,883		45,683			65,289							
	East Bay			7,232	7,232			7,232				7,232					
	East Bay River			1,122				1,122				1,122					
	Total	39,606	•	54,186	53,064		45,683	6,354		85,438		8,354					
	% of Total				57		49	9		91		9					
Mobile Bay	Upper Mobile Bay			84,282	84,282		84,282			84,282					84,282	84,282	
	Bon Secour River			398	398			398			398						
	Lower Mobile Bay		175,487												175,603	175,603	
	Total	• 0	175,487	84,680	84,680		84,282	398		84,282	398				260,085	260,085	
	% of Total				33		32	0		32	0				100	100	

Continued.

Estuary	Area	1985 ACREAGE Approved/ Conditional	Conditional	Prohibited	PRIMARY POLLUTION SOURCES FOR 1985 HARVEST LIMITED CLASSIFICATION STP	Straight Pipes	Industry	Septics	Boating/ Shipping	Urban Runoff	Ag Runoff/ Feedlots	Wildlife	UPSTREAM SOURCES STP	Septics	Urban Runoff	Ag Runoff/ Feedlots	Wildlife
Mississippi Sound	Upper bay			31	31		31			31		31					
(AL)	Bayou La Batre			372	372		372		372								
	Dauphin Island Bay		774		774				774								
	Ft. Gaines spoil area			50					50								
	Portersville Bay		7,452												7,452	7,452	
	Lower Heron Bay		10,343												10,343	10,343	
	Mobile Bay		176		176												
	Grand Bay, etc.			307	307												
(MS)	MS Sound/Petit Bois Island		27,438												27,438	27,438	
	Gulfport Channel			20,828					20,828	20,828							
	MS Sound off Biloxi		92,704							92,704							
	Biloxi Channel			24,735	24,735				24,735	24,735							
	Graveline Bayou			224				224				224					
	MS Sound/Bellefontaine Pt		51,071							51,071							
	Pascagoula			35,563	35,563		35,563		35,563	35,563							
	Bayou Cumbest			20				20				20					
	St. Louis Bay			11,569	11,569		11,569	11,569									
	Clermont Harbor			19				19									
	Bayou Caddy			83				83									
	Pass Christian			2,501	2,501												
	Gulf Hills			20				20		20							
	D'Iberville			18				18		18							
	Biloxi/Tchoutacabouffa R.			377								377					
	Magnolia Bend			32								32					
	Western MS Sound	120,083						120,083						120,083			
	Total	120,083	169,958	96,749	76,026		47,535	132,038	82,322	224,970		684		120,083	45,233	45,233	
	% of Total				19		12	32	20	55		0		30	11	11	
Lake Borgne	Little Lake			1,865										1,865			
	Eastern Lake Borgne		783									783					
	Antonios Lagoon		85										85		85		
	Western Lake Borgne		51,105	3,814									54,919		54,919		
	Pearl River			1,610										1,610			
	Half Moon Island		3,136											3,136			
	Total		55,089	7,289								783	55,004	6,611	55,004		
	% of Total											1	88	11	88		
Lake Pontchartrain	Lake Pontchartrain			444,853	444,653					444,853							
	Lake St. Catherine			5,933	5,933					5,933							
	The Rigolets			3,136	3,136					3,136							
	Chef Menteur Pass			678	678					678							
	Total			454,400	454,400					454,400							
	% of Total			100	100					100							

Continued.

		1985 ACREAGE			PRIMARY POLLUTION SOURCES FOR 1985 HARVEST LIMITED CLASSIFICATION								UPSTREAM SOURCES				
Estuary	Area	Approved/ Conditional	Conditional	Prohibited	STP	Straight Pipes	Industry	Septics	Boating/ Shipping	Urban Runoff	Ag Runoff/ Feedlots	Wildlife	STP	Septics	Urban Runoff	Ag Runoff/ Feedlots	Wildlife
Chandeleur and Breton Sounds	Bay Boudreau		4,830	1,441								6,271					
	Old Stump Lake			339				339									
	Stump Lagoon		339			339		339				339	339		339		
	Grand Coquille Bay		424					424			424		424		424		
	Grand Bay			1,780				1,780					1,780		1,780		
	Long Lagoon		763			763		763				783					
	California Bay		8,984					8,984			8,984	8,984					
	Lake Almeda,Hopedale Lagoon		254	763	1,017	1,017	1,017	1,017									
	Bayou Fongera		1,102			1,102		1,102									
	Bakers Bay		424			424		424									
	Little Crevasse			678	678			678									
	American Bay		2,882			2,882		2,882				2,882					
	Little Coquille Bay			593				593			593		593		593		
	Cox,Mud,Long,Uhlan Bays			1,780				1,780					1,780		1,780		
	Bay Denesse			678		678		678	678		678		878		678		
	Quarantine Bay		7,543	1,102		1,102			1,102		1,102	1,102	8,645		8,645		
	Total		27,544	9.154	1,695	8,307	1,017	21,783	1,780		11,781	20,341	14,239		14,239		
	% of Total				5	23	3	59	5		32	55	39		39		
Mississippi Delta	Bird's Foot			179,674									179,874		179,874		
	Bays Lanaux,de la Cheniere		932	848	1,780												
	Adams Bay		254		254												
	Bay Pomme D'Or		170	1,356	1,358			1,526			1,528						
	Grand Bay		509	4.322									4,831		4,831		
	Drakes Bay			254	254						254						
	Bay Tambour		3,221	509		3,221		3,221					3,730		3,730		
	Total		5,086	186,963	3,644	3,221		4,747			1,780		188,235		188,235		
	% of Total				2	2		2			1		98		98		
Barataria Bay	Round Lake		2,034			2.034		2,034									
	Bay Dosgris,Bayou Dosgris		1,187		1,187			1,187									
	Bayou St. Denis,Mud Lake		9,153	1,187							10,340						
	Grand Bayou		2,373					2,373		2,373							
	Wilkinson Bay			932							932						
	Bay Chene Fleur		848								848						
	Bay Batiste,Bay Sans Bois		5,255	593							5,848						
	Lake Grand Ecaille		848			848		848				848					
	Lake Washington,Lake Robinson		1,441			1,441		1,441				1,441					
	Total		23,137	2,712	1,187	4,323		7,883		2,373	17,988	2,289					
	% of Total				5	17		30		9	70	9					

Continued.

		1985 ACREAGE			PRIMARY POLLUTION SOURCES FOR 1985 HARVEST LIMITED CLASSIFICATION								UPSTREAM SOURCES				
Estuary	Area	Approved/ Conditional	Conditional	Prohibited	STP	Straight Pipes	Industry	Septics	Boating/ Shipping	Urban Runoff	Ag Runoff/ Feedlots	Wildlife	STP	Septics	Urban Runoff	Ag Runoff/ Feedlots	Wildlife
Terrebonne and Timbalier Bays	Bay Chaland		5,339			5,339		5,339									
	Deep Saline			339								339					
	Bayou LaForche			593		593		593									
	Bay Long			932		932		932									
	Laurier Bay			170		170		170									
	Little Lake,Hackberry Bay		3,305			3,305		3,305									
	La Croix Bay		424			424		424									
	Bay Courant		678									678					
	Lake Jesse		170			170		170									
	Lake Chien		678			678		678									
	Bay La Fleur		3,051			3,051		3,051									
	Bay Negress		424			424		424									
	Tambour Bay		593			593		593									
	Deer, Sale, Touch Me Not Bays		932			932		932									
	Moss Bay		593	85		678		678									
	Alligator Bayou		932	763		1,695		1,695									
	Bay Cocodrie		339			339		339									
	Dog Lake		593									593					
	Bayou Grand Caillou		1,441		1,441	1,441		1,441									
	Quitman Bayou		763									763					
	Total		20,255	2,882	1,441	20,764		20,764				2,373					
	% of Total		86	12	6	90		90				10					
Caillou Bay	Fourleague Bay		3,814	19,323		23,137		23,137					23,137		23,137		
	Blue Hammock Bayou,Fiddlers Lake		1,865			1,865		1,865									
	Caillou Lake,Lake Mechant		25,680	339		26019		26019									
	Lost Lake			1,187		1187		1187									
	Total		31,356	20,649		52,206		52,206					23,137		23,137		
	% of Total		60	40		100		100					44		44		
Atchafalaya and Vermilion Bays	Atchafalaya Bay		97,889	102,719		102,719		102,719				102,719	200,608		200,608		
	Atchafalaya River			10,170	10,170		10,170						10,170		10,170		
	Bayou Shaffer			1,271	1,271		1,271						1,271		1,271		
	Shell Island Pass			254									254		254		
	Wax Lake, Big Wax Bayou			4,322		4,322		4,322					4,322		4,322		
	East Cote Blanche			28,138		28,138		28,138				28,138	28,138		28,138		
	West Cote Blanche			61,954		61,954		61,954					61,954		61,954		
	Vermilion Bay		22,883	103,228		126,111		126,111				126,111	126,111		126,111		
	Weeks Bay			12,967		12,967		12,967					12,967		12,967		
	Intracoastal Waterway			593					593								
	Vermilion River			678		678		678									
	Total		120,772.	326,295	11,441	336,889	11,441	336,889	593			256,968	445,795		445,795		
	% of Total		27	73	3	75	3	75	0			57	100		100		
Calcasieu Lake	Calcasieu Lake			30,172									30,172		30,172		
	Ship channel			1,441				1,441			1,441						
	Total			31,613				1,441			1,441		30,172		30,172		
	% of Total			100				5			5		95		95		

Continued.

Estuary	Area	1985 ACREAGE Approved/ Conditional	Conditional	Prohibited	PRIMARY POLLUTION SOURCES FOR 1985 HARVEST LIMITED CLASSIFICATION STP	Straight Pipes	Industry	Septics	Boating/ Shipping	Urban Runoff	Ag Runoff/ Feedlots	Wildlife	UPSTREAM SOURCES STP	Septics	Urban Runoff	Ag Runoff/ Feedlots	Wildlife
Galveston Bay	West Bay	40,657		15,066	55,743			55,743	55,743								
	Chocolate Bay			5,304				5,304									
	Lower Galveston Bay			31,333	31,333		31,333			31,333							
	Trinity Bay	34,210		59,580				93,790			93,790	93,790		93,790		93,790	
	Intracoastal Wat rway			1,207					1,207								
	East Bay			8,956				6,956			8,958	8,956					
	Galveston Bay	95,973		55,406	55,408		55,406	95,973		95,973	95,973			95,973		95,973	
	Smith Point			2,652				2,652			2,652						
	Total	170,840		179,524	142,482		86,739	262,418	56,950	127,308	201,371	102,746		189,763		189,763	
	% of Total	49		51	41		25	75	16	36	57	29		54		54	
Brazos River	Total			1,479	1,479		1,479			1,479	1,479						
	% of Total			100	100		100			100	100						
Matagorda Bay	Port O'Conner			412	412			412									
	Maxwell Ditch			20				20									
	Turtle Bay			1,234		1,234		1,234									
	Lavaca Bay			8,446			8,446	8,446			8,446	8,448				8,446	
	Indianola			600				600									
	Port Lavaca			5,284	5,284		5,284	5,284		5,284							
	Matagorda Bay	212,353														212,353	
	Old Town Lake			64				64									
	Tres Palacios			4,457	4,457				4,457		4,457					4,457	
	Carancahua			8,457				6,457									
	Noble Point			30				30									
	Magnolia Beach			581				581									
	Total	212,353		27,585	10,153	1,234	13,730	23,108	4,457	5,284	12,903	8,448				225,258	
	% of Total				4	1	6	10	2	2	5	4				94	
San Antonio Bay	Port O'Connor			27	27			27									
	Hynes Bay			15,494	15,494											15,494	
	Upper Esperito Santo	3,807							3,807	3,807						3,807	
	San Antonio Bay	133,042			133,042			133,042				133,042				133,042	
	Total	138,849		15,521	148,538			133,069	3,807	3,807		133,042				152,343	
	% of Total				97			87	2	2		87				100	
Aransas Bay	Bayside			1,265				1,285								1,265	
	Port Bay			541							541	541					
	West Live Oak			980				980									
	Redfish-Rockport			10,230	10,230			10,230	10,230			10,230					
	St. Charles Bay			388	388				388			388					
	Salt Lake			571				571	571								
	Redfish Bay			7,649	7,649							7,649					
	Copano Bay	50,003						50,003								50,003	
	Shell Point			510				510									
	Total	50,003		22,134	18,267			63,559	11,189		541	18,808				51,268	
	% of Total				25			88	16		1	26				71	

Continued.

Estuary	Area	1985 ACREAGE Approved/ Conditional	Conditional	Prohibited	PRIMARY POLLUTION SOURCES FOR 1985 HARVEST LIMITED CLASSIFICATION STP	Straight Pipes	Industry	Septics	Boating/ Shipping	Urban Runoff	Ag Runoff/ Feedlots	Wildlife	UPSTREAM SOURCES STP	Septics	Urban Runoff	Ag Runoff/ Feedlots	Wildlife
Corpus Christi Bay	Corpus Christi			768	768					768							
	Oso Bay			4,794	4,794												
	Corpus Christi Bay			17,270	17,270			17,270		17,270							
	Portland			663	663												
	Laguna Madre North			5,510	5,510			5,510									
	University Heights			6,079	6.079					6,079							
	Total			35,084	35,084			22,780		24,117							
	% of Total				100			65		69							
Laguna Madre	South Laguna Madre			653	653												
	Laguna Heights			1,326				1,326									
	Laguna Madre North			11,899	11,899			11,899									
	Port Isabel			7,977	7,977				7,977	7,977							
	Baffin Bay*			12,669				12,669	12,669		12,669						
	Total			34,524	20,529			25,894	20,646	7,977	12,669						
	% of Total				59			75	60	23	37						
Baffin Bay*	Total			12,669				12,669			12,669						
	% of Total			100				100			100						
GULF OF MEXICO	Total	843,723	787,309	1,735,377	1,149.864	426.946	323.268	1,329,108	250.802	1,096,994	262,331	690.431	756,582	323,365	1,061,900	923,948	111.118
	% of Total				34	13	10	39	7	33	8	21	22	10	32	27	3

*Subsystem

National Estuarine Atlas

PHYSICAL AND HYDROLOGIC CHARACTERISTICS

PHYSICAL

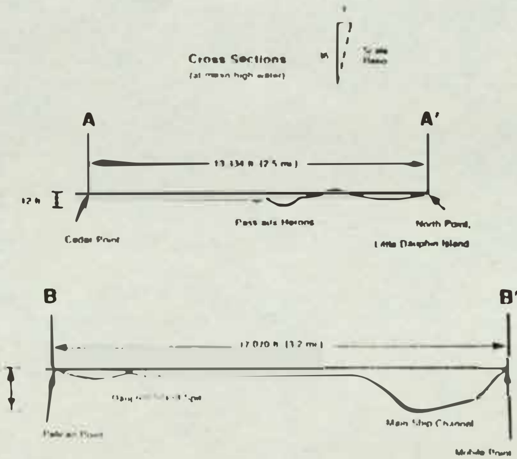
Surface Areas (mi²)	
Fluvial Drainage	[illegible]
Estuarine Drainage	[illegible]
Estuarine Zones	
Tidal Fresh	[illegible]
Mixing Zone	[illegible]
Seawater	[illegible]
Total	[illegible]
Dimensions	
Length (mi)	[illegible]
Width (mi) Average	[illegible]
Minimum	[illegible]
Maximum	[illegible]
Average Depth (ft)	[illegible]
Average Depth at Water Table	[illegible]
Stratification Classification	
3 Month High Flow	[illegible]
3 Month Low Flow	[illegible]

FRESHWATER INFLOW

Flow Rates (1000 cfs)		
Period of Record		1975 1982
Long Term Average Daily		[illegible]
Long Term Average Monthly	J [illegible]	J [illegible]
	F [illegible]	A [illegible]
	M [illegible]	S [illegible]
	A [illegible]	O [illegible]
	M [illegible]	N [illegible]
	J [illegible]	D [illegible]
7 Day 10 Year Low Flow		7.6
50 Year Flood		[illegible]
100 Year Flood		[illegible]
Flow Ratios		
Average Annual		0.449
High Flow Period		0.870
Low Flow Period		0.171

TIDAL DATA

Prevailing Tide Channel		
Tidal Prism (ft³)		[illegible]
Phase Range of Tide (ft)		
Map Key	Station	Range
A	[illegible]	[illegible]
B	[illegible]	[illegible]
C	[illegible]	[illegible]
D	[illegible]	[illegible]

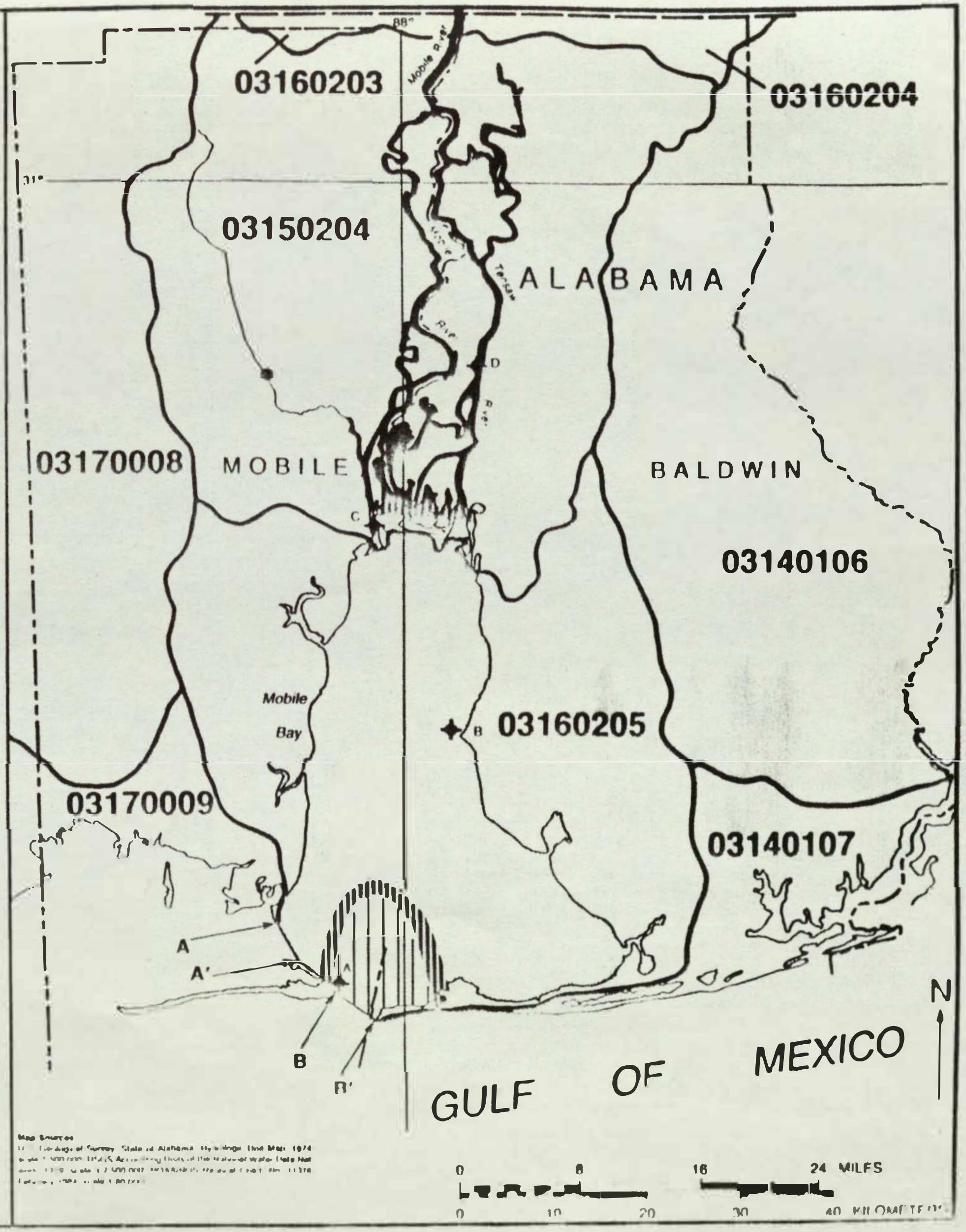


Notes

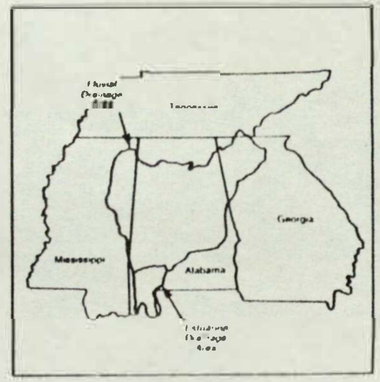
Approximately 40% of Estuarine Drainage Area is shown on map

References

April et al. 1976, April and Lancey 1979, Bault, 1972, Bingham 1982, Crane 1971, Hollins et al. 1981, Schroeder ... U.S. Department of Commerce ...



Mobile Bay
AL



- Tide Gage
- Flow Gage
- Head of Tide
- Estuarine Drainage Area (EDA)
- Tidal Fresh Zone
- Mixing Zone
- Seawater Zone
- Hydrologic Cataloging Unit Boundary
- County Boundary
- Salinity Zone Boundary - Low Variability
- Salinity Zone Boundary - Moderate Variability
- Salinity Zone Boundary - High Variability