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The Effect of the Clean Water Act on Shellfish Growing Waters in the Gulf of Mexico

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by

Marlene A. Broutman

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Broutman, Marlene A., D.Env.

University of California, Los Angeles, 1988

U·M·I
300 N. Zeeb Rd.
Ann Arbor, MI 48106

The final report of Marlene A. Broutman is approved.

Charles Bennet

David Chapman

Doug McKay

Richard L. Perrine

Michael K. Stenstrom, Committee Chair

University of California, Los Angeles

1988

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VITA

June 22, 1956 Born, Akron, Ohio

1978 B.S., Biochemistry
University of California
Angeles, California

1980 M.S., Biochemistry
University of California
Angeles, California

1983 - present Environmental Engineer
National Oceanic and Atmospheric Administration
Rockville, Maryland

1982 - 1983 Postgraduate Researcher
Department of Environmental Science and Engineering
University of California, Los Angeles

1980 - 1982 Staff Research Associate, II
Department of Engineering
University of California, Los Angeles

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ABSTRACT OF THE FINAL REPORT

The Effect of the Clean Water Act on
Shellfish Growing Waters in the Gulf of Mexico

by

Marlene A. Broutman
Doctor of Environmental Science and Engineering
University of California, Los Angeles, 1988
Michael K. Stenstrom, Chair

This report examines the classification of shellfish growing waters in the Gulf of Mexico as an indicator of bacterial water quality. Information presented includes the status of classified waters, sources of pollution affecting waters that are not classified as approved, and trends in classification between 1971 and 1985. Data were collected by site visits to the five Gulf states, interviews with state personnel, and reference to written materials.

Data are used to assess the effectiveness of national efforts to improve bacterial water quality in the past fifteen years since passage of the Clean Water Act. The hypothesis to be tested is that these efforts have not succeeded in reducing fecal coliform concentrations to levels required for approved harvest of shellfish, as established by the National Shellfish Sanitation Program.

Results of this work show that: 1) an upgrade in classification resulting from improved sewage treatment occured in only one area of less than 1,000 acres; 2) most waters in the Gulf of Mexico do not meet the standard for approved waters; 3) waters that meet approved standards are not highly productive because of high salinity and low freshwater inflow; 4) areas around sewage treatment plants are closed to harvest because of the potential for plant failure; 5) other areas do not meet the standard for approved harvest because of nonpoint sources; and 6) elevated fecal coliform bacteria levels are associated with freshwater inflow entering estuaries as runoff or river flow, even from undeveloped watersheds.

1.0 Introduction

In the past 15 years since passage of the Clean Water Act, many Federal programs have been directed toward improving water quality in the nation's waterways and providing fishable and swimmable waters. Some of these programs have focused on reducing bacterial pollution in marine and estuarine environments, particularly through reductions in municipal point sources. In the Gulf of Mexico, more than one billion dollars have been given to coastal counties through the Construction Grants Program, for constructing, expanding, or upgrading municipal sewage treatment facilities. Effluent standards, developed under the National Pollutant Discharge Elimination System, have limited pollutant loadings discharged from municipal and industrial point sources. The goal of this project is to examine the effectiveness of these programs using classified shellfish growing waters as an indicator of bacterial pollution in estuarine waters. Classification provides a consistent data base that is available for a fifteen year period during which Clean Water Act programs were implemented. Effectiveness of these programs is examined by assessing status, pollution sources, and trends in classified waters. The hypothesis to be tested is that these efforts have not succeeded in reducing fecal coliform bacteria concentrations to levels required for approved harvest of molluscan shellfish, as established by the National Shellfish Sanitation Program.

Waters are classified for the commercial harvest of edible species of oysters, clams, and mussels in order to protect public health from consumption of shellfish contaminated by sewage that may contain pathogenic bacteria or viruses. As filter feeders, these molluscan shellfish pump large volumes of water through their systems and accumulate particles or pollutants that are present in the water. Pathogens that are picked up by the shellfish are a potential health hazard to humans who consume the shellfish, especially if consumed raw. Gastroenteritis and hepatitis are currently the major diseases associated with the consumption of sewage contaminated shellfish. Typhoid had been the major shellfish-borne disease, but no cases have been reported since the mid-1950s.

Guidelines for classifying waters are established by the National Shellfish Sanitation Program (NSSP), a cooperative program of the U.S. Food and Drug Administration, shellfish producing states, and the shellfish industry. Classification is based on presence of actual or potential pollution sources or coliform bacteria levels in surface waters.

Few studies have successfully documented the effectiveness of these programs, especially at a regional or national level. Vast data collected by various federal, state, or local groups is difficult to compare because it is collected using different techniques and for different purposes.

A recent study by U.S. Geological Survey (Smith, 1987) reported trends in water quality parameters consistently measured at last downstream monitoring stations that are part of the National Stream Water Quality Network (NASQAN). Results of

this seven year sampling program show reductions in bacteria concentrations in rivers entering the coastal zone, especially in the Gulf of Mexico. Through inferential evidence, these reductions are attributed to improvements in point source control. The NASQAN data do not, however, assess if these reductions are enough for waters to meet designated uses.

In *America's Clean Water,* the Association of State and Interstate Water Pollution Control Administrators (1985) report that water quality throughout the Nation was maintained between 1972 and 1982, even with substantial increases in population, industry, and development. The study, based on state responses to a questionnaire, also reported great improvements in treatment of municipal and industrial wastes over the ten year period.

This study examines classified shellfish growing waters as another source of information for measuring national progress toward improving water quality because: 1) data for classification are collected by all 22 coastal states, for most estuarine waters, for the same purposes, and using standardized techniques; 2) the system for classifying waters has been in existence since 1925; and 3) classification of waters were consistently documented in 1971, 1974, 1980, and 1985 as part of a series entitled *The National Shellfish Register of Classified Waters* (FDA and NOAA, 1985).

Nationwide, there have been several reported cases of improved water quality conditions in shellfish growing waters. In Tillamook Bay, Oregon, EPA's Rural Clean Water Program assisted dairy farmers in controlling runoff from manure piles (Jackson and Glendening, 1982). In the *National Water Quality Inventory, 1984 Report to Congress* (EPA, 1985), Connecticut, Rhode Island, and Maryland reported opening shellfish growing waters as a result of improvements in wastewater treatment. In Virginia, five sanitation projects opened over 800 acres of growing waters (EPA, 1987).

This project grew out of the *1985 National Shellfish Register of Classified Estuarine Waters*, a joint publication of FDA and NOAA (1985) that summarizes acreages of shellfish growing waters by classification type and by state. To make the information more useful, this project compiles classified data by estuary as part of NOAA's National Estuarine Inventory (NOAA, 1985). The Inventory provides consistent information on physical and hydrologic characteristics, land use, and habitats for approximately 100 estuaries on the east, west, and gulf coasts. Data on classified shellfish waters will eventually be collected for all estuaries in the Inventory. This information will be used by environmental managers and decisionmakers at the regional and national level.

2.0 Background

Information is provided on the study area, methods of classification, and Clean Water Act programs affecting shellfish growing waters.

2.1 The Region

Data were compiled for 29 Gulf estuaries identified in NOAA's National Estuarine Inventory (NOAA, 1985). The Inventory provides a consistent data base on estuarine resources in the U.S., and contains information on land use, habitats, and physical, hydrologic, and biological characteristics. Total surface area of Gulf estuaries in the Inventory is 6.2 million acres, or about 90 percent of the total estuarine surface area in the Gulf.

Shellfish growing waters in the Gulf of Mexico are among the most productive in the Nation, providing approximately 60 percent of the domestic oyster supply in 1985, and valued at over $40 million (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 sourthern Laguna Madre.

Predominant land uses in the region are shown in figure 1. Forest land predominates along the Florida panhandle and into Alabama and Mississippi, a prime resource for a thriving pulp and paper mill industry. Agriculture and rangeland are found in Texas and parts of southern Florida, and wetland in coastal Louisiana and southern Florida. Urban areas account for less than 30 percent of land use, even in the most populated drainage basins.

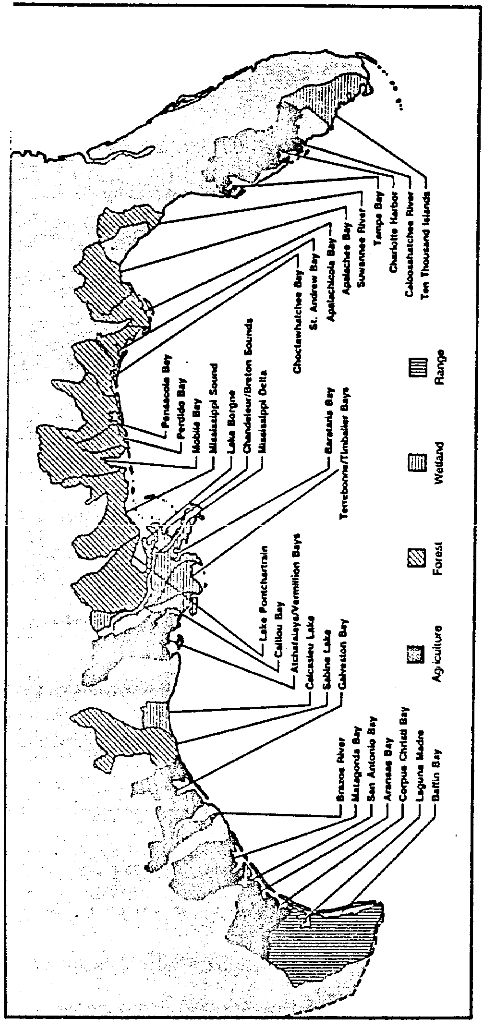


Figure 1. Land Use in the Gulf of Mexico Coastal Region

Between 1970 and 1980, popultaion in the Gulf of Mexico region grew by 30 percent, faster than any other region in the country. Much of this growth is in large urban complexes surrounding existing cities, such as Tampa, New Orleans, and Galveston. In Tampa, for example, city population has not increased significantly over the past twenty years, but the population of Hillsborough County has increased substantially and the urban core is expanding into unincorporated areas. Discovery of petroleum and natural gas, the expansion of agricultural activities, and the growth of tourism, second-home, and retirement communities are the primary reasons for population shifts into the Gulf region.

2.2 The National Shellfish Sanitation Program

The National Shellfish Sanitation Program (NSSP), is a cooperative program comprised of the U.S. Food and Drug Administration (FDA), shellfish producing states, and the shellfish industry. The program was established in 1925, after an outbreak of hepatitis was traced to consumption of raw oysters. FDA assumed federal responsibility for the program in 1968, replacing the Public Health Service. In 1982, the Interstate Shellfish Sanitation Conference (ISSC) was formed by FDA and the shellfish-producing states to strengthen and eventually supercede the NSSP. Participation in the NSSP and ISSC is voluntary, although states must participate in the programs and be certified by FDA in order to ship product across state lines.

Shellfish growing waters are classified by states into one of four categories in accordance with guidelines established under the NSSP. These classifications are defined as:

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 at those times when these criteria are met.
o *Restricted*	Shellfish may be harvested from restricted waters if subjected to a suitable purification process.
o *Prohibited*	Harvest cannot occur at any time.

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

Waters are classified by each state after sanitary surveys that: 1) identify actual or potential pollution sources that may affect shellfish growing waters -- a "shoreline survey"; 2) evaluate hydrolographic and meteorological conditions effecting pollutant transport; and 3) sample waters for bacteriological quality. Limitations on harvest may result from presence of actual or potential pollution sources as identified in the shoreline survey, or from sampling data that do not meet the NSSP standard.

Sanitary surveys are to be updated annually, reviewed every three years, and completely redone every twelve years.

Minimum requirements for shoreline surveys were recently defined by the ISSC and are presented in Appendix A. The requirements include the identification and evaluation of all sanitary, industrial, and agricultural pollution sources, animal farms, marinas, drainage ditches, and populations of wildlife within the survey area.

Waters may also be closed to harvest if the sanitary survey indicates presence of poisonous or deleterious substances or radionuclides. No waters are currently closed for these reasons.

The standard for approved waters is a total coliform bacteria concentration of less than 70 Most Probable Number (MPN) per 100 milliliters (ml), and not more than 10 percent of the samples may exceed 230 MPN per 100 ml. Over the past fifteen years most states, including all five Gulf states, began using a fecal coliform standard of 14 MPN per 100 ml, and not more than 10 percent of the samples may exceed 43 MPN per 100 ml (ISSC, 1986). The newer standard more specifically indicates 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 via runoff. Under these conditions, areas are closed for a minimun of one week, and may be closed much longer if rainfall or high river stage persists. Use of the conditionally approved classification requires the development of a management plan that clearly defines the conditions under that the waters will be closed and reopened. The additional efforts required to determine these conditions and to actually manage waters have prevented many states from using the conditionally approved classification.

In 1985, shellfish taken from restricted waters required depuration, a costly process in which shellfish pump purified water in specially designed tanks for 48 hours. To date, depuration has only been economically successful for clams, not oysters. Because oysters are the predominant harvest in the Gulf, no depuration occurs, and no waters were classified as restricted.

Each state defines its own set of classifications, often using different terminology than the NSSP definitions. In Texas, for example, only two classifications are used: approved and polluted. The definition of polluted allows for relaying, and is therefore the equivalent of prohibited by 1985 NSSP definitions and restricted by 1986 definitions.

Waters classified under the NSSP include all interior waters in the state from which commercial harvest of molluscan shellfish does or may occur. These waters are identified by the state. Many areas that are classified under the NSSP actually contain no molluscan shellfish resources.

2.3 Shellfish-Borne Diseases

The predominant diseases associated with consumption of shellfish out of sewage contaminated waters are hepatitis A, Norwalk illness, and nonspecific gastroenteritis. Nationwide, reported incidence of these illnesses, which are caused by viruses, have increased in recent years, while bacterial diseases have declined (Richards, 1986).

National attention focused on shellfish-related diseases after 1982, when outbreaks of gastroenteritis associated with eating raw clams and oysters reached epidemic proportions in New York state. According to Morse (1986), there were 103 well documented outbreaks in which 1,017 people became ill. Symptoms of diarrhea, nausea, abdominal cramps, and vomiting began one to two days after consumption and the duration of illness was one to two days. Norwalk virus was identified as the predominant etiologic agent. The shellfish were traced to coastal waters of several northeastern states, suggesting that the problem is widespread (Morse, 1986).

Morse's results were published the New England Journal of Medicine. In the same issue, an editorial by Dupont (1986) commented that "people who have become accustomed to eating raw shellfish may need to reconsider this practice in view of new medical evidence", and that "eating poorly cooked shellfish is currently a high-risk venture at best". The editorial concludes that the current methods for protecting public health, including the system of classifying waters based on fecal coliform bacteria, are not adequate.

Outbreaks of the predominant shellfish-borne disease in the early 1900s, typhoid fever, have not been reported since 1954. The disappearance of this disease is attributed to improvements in sewage treatment practices, prevention of harvest from sewage contaminated waters, and a reduction of the causative bacteria, *Salmonella typhi*, in the population.

From 1961 to 1985, 1,075 reported cases of hepatitis and gastroenteritis have been associated with shellfish harvested from waters in the Gulf of Mexico (Table 1). The actual number of disease cases is probably much higher, since only a small percentage of cases are reported. Current detection methods can identify only a few of the numerous viruses that can cause gastroenteritis. Becaues of this, the disease agent is often unknown, or viruses are implicated because bacteriological tests fail to identify bacteria as the causative agent.

In addition to hepatits and gastroenteritis, two types of diseases transmitted by shellfish harvested from Gulf waters arise from organisms that are not associated with sewage. These diseases are caused by marine biotoxins and the bacteria group *vibrio*. The classification system, based on the fecal coliform standard does not apply to these problems.

A separate system is used to prevent harvest of shellfish contaminated from naturally occuring marine biotoxins. In Gulf of Mexico waters, toxins produced by the dinoflagellate *Ptychodiscus*

brevis causes fish kills, neurotoxic shellfish poisoning from consumption of shellfish, and an airborne-irritant in sea spray that can cause human respiratory discomfort. Shellfish become toxic to humans and other consumers by filter feeding the dinoflagellates and absorbing the toxin into their digestive tissues. The dinoflagellate is related to *Gonyaulax tamarensis vs breve*, the dinoflagellate found in colder Northeast Atlantic and Northwest Pacific waters and causing paralytic shellfish poisoning (PSP).

Table 1. Shellfish-borne Diseases Reported in the Gulf of Mexico

Type of Disease	No. of Cases	State of Harvest	Year
Hepatitis A	84	AL,MS	1961
	31	AL	1961
	13	FL	1969
	2	FL	1972
	293	LA	1973
	10	FL	1979
Gastroenteritis	6*	FL	1980
	46	FL	1980
	472**	LA	1982
	15	FL	1982
	9	FL	1982
	93	FL	1984
	6	AL	1985
total	1,075		

*Norwalk virus
**Norwalk-like virus
Source: Richards, 1985

Blooms of *P. brevis* and associated chromogenic phytoplanktons are commonly known as "red tides". 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 bloom 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 most of the 1986 season causing a major economic loss to the state. Longshore currents carried the toxic dinoflagellates south, encompassing all coastal embayments from West Bay in the Galveston complex to the Rio Grande River. Although the visible red tide ended in mid-November 1986, the toxin remained in the shellfish through September 1987 (Thompson, 1987).

The occurrences of the red tide in the Gulf have not been related to specific pollution sources or weather events. Therefore, the affected states cannot predict the blooms, but must react quickly to monitor shellfish for toxic levels. A management plan is developed to monitor all occurrences and close shellfish growing waters until all shellfish are free of dangerous levels of toxin. Florida and Texas are the only states in the Gulf experienced in the management of marine biotoxins.

Recent outbreaks of shellfish-borne diseases have been associated with the bacteria *vibrio cholerae, vibrio vulnificus,* and *vibrio parahemolyticus.* Consumption of shellfish contaminated

with *vibrio* has caused gastroenteritis and several deaths (seven in 1987), especially in patients that are already compromised. A study conducted in Apalachicola Bay found *vibrio cholera* in waters classified as approved as well as prohibited, and no correlation between coliform bacteria levels and *vibrio* could be found (Blake and Rodrick, 1983). This and other studies indicate that vibrios are indegenous to marine waters and are not related to presence of sewage (Cabelli *et al.*, 1979; Blake *et al.*, 1982). Studies in Texas, after a cholera outbreak, showed that the organisms persisted in the marine environment for at least five years (Office of Technology Assessment, 1987).

2.4 Coliform Bacteria as an Indicator

The coliform indicator has been criticized by researchers, regulators, and the commercial shellfish industry for several reasons. The primary criticism is that the relationship between coliform bacteria and public health risk associated with consumption of raw shellfish has never been clearly established. Todays standards are based on methods developed in the early 1900s, and the value of these bacterial indicators for predicting viral contamination is in question.

That coliform bacteria occur in association with sewage has been known since the early 1900s. The original total coliform standard, adopted by the Public Health Service in 1939, defined waters as unsatisfactory for harvesting if 50 percent of one milliliter water samples were positive for coliform. Some studies had shown correlations between coliform levels and *salmonella typhi*, the bacteria that caused the predominant shellfish-borne disease of the day, typhoid fever. Later the standard was changed to the Most Probable Number equivalent of the original standard. The fecal coliform standard was developed from the MPN total coliform standard, but the number used for the standard, 14 MPN, was chosen as a compromise between several proposed numbers. Relationships between total and fecal coliforms in samples taken from all over the country had a very wide range, but averaged out to roughly a 1 to 5 ratio.

The total coliform standard, along with improvements in sanitation practices may be partially responsible for eliminating typhoid fever. A case of shellfish-borne typhoid has not been reported since 1954. But while the incidence of bacterial disease has declined in recent years, viral diseases have increased (Richards, 1985). The utility of the coliform bacteria standard for predicing risk from virus-contaminated shellfish is questionable because viruses may be less sensitive to chlorination and more persistent in the marine environment (Office of Technology Assessment, 1987).

Recent work by Grimes, *et al.* (1986) challenges the long accepted theory that bacterial indicators and pathogens die off in the marine environment. These studies suggest that enteric bacteria enter a dormant stage, during which they remain viable and potentially virulent. Dormant bacteria may be detected by

direct cell counting procedures, but not by indirect tests such as the MPN enumeration method.

Current detection methods for viruses are costly and cumbersome, limiting the amount of research that has been conducted on viruses in the marine environment. In a Galveston Bay study, 50 percent of water samples and 20 percent of the oysters from approved shellfish waters tested positive for viruses. Results from prohibited waters were 63 percent and 40 percent, respectively. Although presence does not necessarily equate to disease, these results do suggest a potential problem with current classifications.

Other problems with the fecal coliform standard are:

- o The coliform standard does not distinguish between human and animal sources of fecal contamination. Hepatitis A virus and Norwalk virus are carried by humans and subhuman primates, but have not been found in other animals. If this is the case, then waters contaminated by animal sources of fecal material are less of a public health risk.
- o Both the total and fecal coliform groups contain some organisms that are not of fecal origin. The most common example is *Klebsiella*, a fecal coliform bacteria associated with pulp and paper mill wastes but infrequently found in the intestinal tract of warm-blooded animals.
- o Under certain conditions, some fecal coliform bacteria may actually multiply in the environment.

o The Most Probable Number (MPN) method provides an estimate of the number of organisms present in a sample, but this estimate can range from 30% to 300% of the true value. So, for example, a sample containing 100 organisms per 100 ml may produce an MPN value from 30 to 300. This large range makes it difficult to distinguish between clean waters and moderately contaminated waters (Dufour and White, 1985).

Recent work by Cabelli (1983) examined the relationships between several indicator organisms and incidence of gastroenteritis contracted while swimming at bathing beaches. Total and fecal coliform, *E. coli*, and enterococcus were among the potential indicators investigated. As a result of these studies, EPA changed the indicator for recreational waters from coliform bacteria to enterococcus, the organism that was most closely related to disease incidence. Neither total nor the fecal coliform correlated well with disease.

An epidemiologic study, currently being conducted by EPA and NOAA, is assessing the relationships between shellfish-borne diseases and indicator levels by feeding clams and oysters from pristine and potentially polluted waters in Virginia to volunteers at the University of North Carolina. For legal reasons, the shellfish are always taken from approved waters. But the potentially polluted shellfish are taken from approved waters just outside of a prohibited zone surrounding an urban area.

Researchers, regulators, and the shellfish industry have called for a nationwide study to relate indicators to disease potential associated with consumption of sewage contaminated shellfish. Using the current EPA, NOAA feeding study as a model, the proposed national study would evaluate oysters and clams from 10 to 15 approved areas around the country that are downstream from point, nonpoint, animal, and human pollution sources. It is hoped that a better indicator will be identified, as happened in the case of recreational waters.

2.5 The National Shellfish Register

The *1985 National Shellfish Register of Classified Estuarine Waters* was produced cooperatively by FDA and NOAA (1985). The 1985 *Register* and earlier versions published in 1966, 1971, 1974, and 1980 summarize acreage of waters in the four NSSP classifications by state. Data were collected by site visit to shellfish program offices in 22 states. Waters within each of the four classifications were outlined on approximately 250 NOAA nautical charts per year. Acreage of each outlined area was determined by planimetry. Some are as small as one acre. Nationwide, there are approximately 2,000 discreet areas in the *Register* database.

The utility of the *Register* as a national water quality indicator is limited because the relationship between classification and water quality is never established. Waters classified on the basis of actual or potential bacterial water quality problems are not distinguished from waters classified for other reasons. Each Register reported changes that occured since the previous Register, but large changes in classification are often administrative in nature. For example, Louisiana reclassified all waters as conditionally approved in 1985, causing an apparent six percent decline in approved waters nationwide since 1980. The reclassification resulted from new management procedures and does not reflect an environmental trend. Smaller changes that may be related to water quality changes are imperceptible when data are aggregated by state.

2.6 The Clean Water Act

The major piece of federal legislation that has affected water quality conditions in shellfish growing waters is the Federal Water Pollution Control Act Amendments of 1972, otherwise known as the Clean Water Act. The Clean Water Act established national goals to eliminate all discharges of pollutants to the nation's waterways by 1985, achieve fishable and swimmable waters by 1983, to restore and maintain physical, chemical, and biological integrity of waters, and to upgrade municipal sewage treatment facilities to secondary treatment. Goals and deadlines were modified in amendments in 1977, in 1981, and again in the Water Quality Act of 1987.

Clean Water Act programs specifically address water quality through a series of effluent and ambient water quality standards that pertain to many types of pollutants, including

microorganisms. Programs established under the Clean Water Act that most effect shellfish growing waters are the Construction Grants Program and the National Pollutant Discharge Elimination System.

A major goal of the Clean Water Act is for the nation to achieve secondary treatment levels at all sewage treatment facilities. To help meet this goal, the Construction Grants Program provides money to states for the planning, construction, expansion, or upgrade of sewage treatment and collection systems. Until 1985, the Program provided 75 percent of the cost of the improvement, with the state or local community assuming the remaining 25 percent of cost.

The National Pollutant Discharge Elimination System (NPDES) was created under Section 402 of the Act. Permits that specify effluent limitations, process requirements, schedule of compliance, and monitoring requirements must be obtained by all point source dischargers in the nation. In addition to industrial and municipal point source dischargers, NPDES permits are issued for some agricultural activities, including feedlots. The permit system also provides a data base on numbers and types of dischargers.

Problems with noncompliance and enforcement have reduced the effectiveness of the NPDES program. Enforcement actions by EPA have declined from 1,500 in 1977 to 400 in 1982, as greater emphasis has been placed on voluntary compliance (Office of Technology Assessment, 1987).

Section 303 of the Clean Water Act provides for the establishment of national water quality standards for receiving waters. These standards are based on the intended use of the waters. The standard for waters from which shellfish may be harvested is, for example, more stringent than standards for recreation or propogation of aquatic life. If waters are designated for more than one use, standards will reflect the most stringent requirements of the multiple uses. The establishment of national standards for harvest of shellfish from growing waters had little affect on shellfish producing states because the same standards were already in use as part of the NSSP.

In addition, Section 303 contains an antidegredation clause. If the intended use is established as the harvest of shellfish, then water quality may not be degraded below this level. Antidegredation may be used to stop siting of a pollution source, such as a sewage treatment plant outfall or marina in approved shellfish growing waters if these sources would result in the closure of those waters.

The Clean Water Act also provides grants for prevention, reduction and elimination of pollution (Section 106), and developing and operating areawide waste treatment and nonpoint source pollution management processes (Section 208). Initial efforts to develop areawide plans under Section 208 focused primarily on point sources because these problems are easier to identify and correct.

The Water Quality Act of 1987 is a reauthorization and amendment to the Clean Water Act. The Water Quality Act provides $18 billion for construction of sewage treatment facilities through 1994, $60 million to address pollution problems in estuaries under a National Estuary Program, and $400 million in grants to states to control nonpoint source pollution (Office of Technology Assessment, 1987).

Little information is available to assess the affectiveness of these efforts nationwide. This project examines bacterial water quality in estuarine waters in the Gulf of Mexico to determine if these waters are currently meeting standards for harvet of shellfish and if effluent limitations and improvements in sewage treatment that resulted from the Clean Water Act have opened up waters to harvest. Similar information is being collected for the east and west coasts.

3.0 Methods

A data base on classified estuarine waters was developed for the Gulf of Mexico region and includes: 1) classification of waters by individually classified areas and by estuary; 2) acreage of each classified area; 3) sources of pollution for all harvest-limited areas; and 4) changes in classification for each area from 1971 to 1985. Raw data were taken from the *National Shellfish Register of Classified Estuarine Waters* (FDA and NOAA, 1985). Additional information was obtained by questionnaire, interviews, and reference to written materials. Pilot information was collected for six east coast states before beginning work in the Gulf of Mexico.

A questionnaire was used to obtain information about each state program. This information was collected to assure that waters were classified in a comparable manner by all of the Gulf states. In addition to information on state classification programs, the questionnaire addressed resource management, seafood plant inspection, bottom leasing, disease outbreaks, and other aspects of state shellfish programs. A copy of a questionnaire is provided in Appendix B.

Individual shellfish growing areas, ranging in size from one to several hundred thousand acres, are outlined on nautical charts and catalogued on data sheets that are part of the *National Shellfish Register of Classified Estuarine Waters*. Areas from these charts were assigned to estuaries using the boundaries developed by NOAA's *National Estuarine Inventory* (NOAA, 1985).

The data base created contains the classification and acreage of all areas within each estuary.

Data on trends in classification were developed by examining the charts and data sheets from the 1971 Register in conjunction with the set from 1985 and noting changes in each specific area.

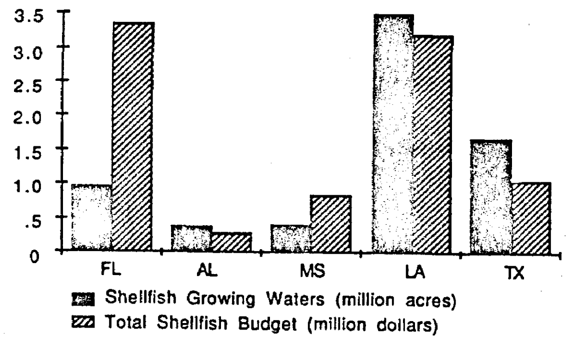
Data sheets of classified areas by estuary and 1985 *Register* charts were taken to each of the five Gulf of Mexico states. Each chart was examined with state personnel responsible for classifying waters, who were asked to identify any areas that are not classified on the basis of a sanitary survey and pollution sources for each harvest-limited area. Areas that had changed classification between 1971 and 1985 were identified for state personnel, and they were asked to provide reasons for the change.

The data collection process included interviews with over 50 people in Federal and state agencies, the shellfish industry, and academia (Appendix C). Additional information was provided by sanitary surveys (Appendix D) and other studies. Some historic information was found in state memoranda, on file at the FDA regional office in Atlanta.

4.0 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. 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.

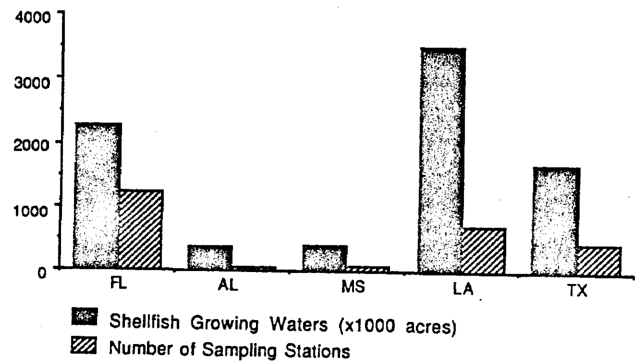
Figure 2. State Shellfish Budgets



The resources required to properly classify waters depends on several factors including acreage of waters, shoreline miles, location of pollution sources, and hydrographic conditions. In

examining the number of sampling stations, for example, Florida appears to have a disproportionately large number of sampling stations per area classified compared to the other Gulf states (Figure 3). This is due to the number of small estuaries in Florida, where the amount of shoreline in relation to the number of acres is high, and to the many conditional areas that require additional sampling stations and monitoring efforts.

Figure 3. Sampling Stations



In general, approved waters are sampled once every one to six months, while conditional areas are sampled on a more frequent weekly or monthly basis. Florida and Louisiana sample monthly or quarterly in prohibited waters, although this is not required by the NSSP. Mississippi and Texas monitor prohibited waters occasionally, primarily when waters are used for relaying. Relaying occurs in 43,000 acres in Florida, 175,000 acres in

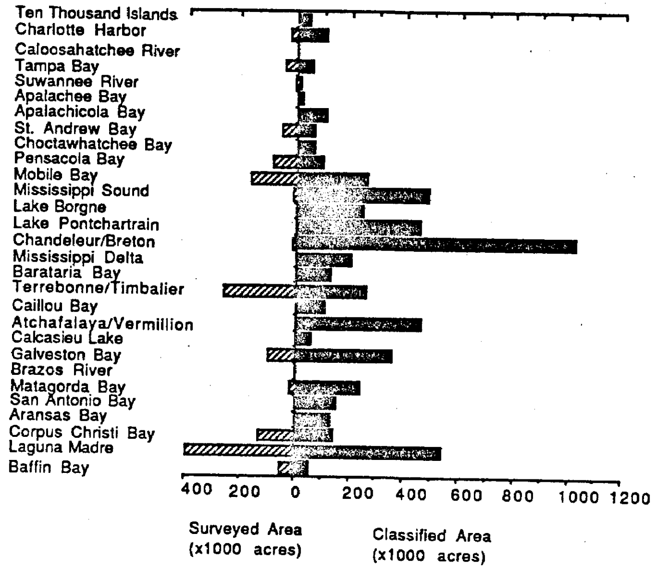
Texas, and unknown acreages in Alabama, Mississippi, and Louisiana.

All states except Alabama reported that financial limitations hampered their ability to strictly comply with all requirements of the NSSP manual. Most problems with noncompliance were related to shoreline surveys and to sampling under worst conditions. The area covered by written sanitary surveys is shown in figure 4. Alabama had complete written sanitary surveys for all approved and conditionally approved shellfish growing waters in the state. Mississippi recently completed a sanitary survey of all shellfish growing waters, but the draft was undergoing review and was not available. In Florida, written sanitary surveys were complete for Suwannee River, and St. Andrew and Pensacola Bays, and complete for portions of Charlotte Harbor, Tampa, and Apalachee Bays. Results of monitoring data were available for Apalachicola Bay, but not a shoreline survey. No current information was available for Ten Thousand Islands or Choctawhatchee Bay, although these areas are classified.

In Louisiana, shoreline survey information is shown on maps but not described in written form. Exceptions are a pollution source survey of Terrebonne Bay conducted by local universities (Louisiana University Marine Consortium, 1985), a pollution source survey of Terrebonne and Barataria Bays conducted by contractor (Gulf South Research Institute, 1985), and a sanitary survey of

Quarantine Bay (an area managed on rainfall and river stage) conducted by the adjacent county, Plaquemines Parish (1986).

Figure 4. Surveyed Area by Estuary



Texas has not conducted complete comprehensive shoreline surveys of shellfish growing waters since 1972. About two-thirds of waters in the State are classified solely on the basis of monitoring data. Seven areas have been newly classified or reappraised since 1978, and only these areas have completed sanitary surveys, including shoreline surveys.

5.0 Status of Classified Shellfish Growing Waters

Acreage of waters in each of four NSSP classifications are presented by estuary in Table 2. Several changes were made to the original 1985 *Register* data to better reflect coliform bacteria water quality:

- o 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 are used instead of the earlier classification that was based on marine biotoxins.

- o 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 E. In most cases, closures were a result of rainfall events. However, in a few instances closure resulted from high counts found during scheduled monitoring. This approved/conditional data excludes closures resulting from hurricanes.

- o 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 state personnel.

- o An administrative classification category is defined as waters closed for management reasons rather than on the basis of a sanitary survey.

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.

Of the 42 percent of approved waters, 66 percent were in coastal Louisiana, far from urban centers, and buffered by wetlands. Waters in Louisiana, designated as approved for this survey, were classified by the State as conditionally approved.

Approved/conditional areas were found in Florida, Mississippi, and Texas. These waters were managed as conditionally approved, although institutional arrangements have not been established to officially reclassify. Florida is developing management plans for many of these areas. Approved/conditional areas in Tampa Bay and St. Andrew Sound have been officially reclassified as conditionally approved since 1985.

Texas is implementing a conditionally approved classification. The most productive waters in the state were managed as if conditionally approved. Closures occured in Lavaca Bay (Matagorda Bay) after 3 inches of rain, and in San Antonio Bay if water levels in the Guadalupe River exceeded 20 feet at an upstream monitoring station. Galveston Bay was closed after 10 inches of rain, and monitored for closure after 6 to 10 inch rains.

Table 2. 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
b/ Not classified on the basis of a sanitary survey.

Perdido Bay and Sabine Lake lie within the jurisdiction of Florida and Alabama; and Lousisiana and Texas, respectively. Harvest was prohibited by interstate agreement to avoid problems of bistate management. Neither contains shellfish resources of commercial importance.

Classifications at other state boundaries showed inconsistencies. In Mississippi Sound, Mississippi waters were conditionally approved, while Alabama's waters were approved for harvest. In the western sound, a high Pearl River in December 1986 caused Mississippi to close western Mississippi Sound for months, while Louisiana's waters remained open to harvest.

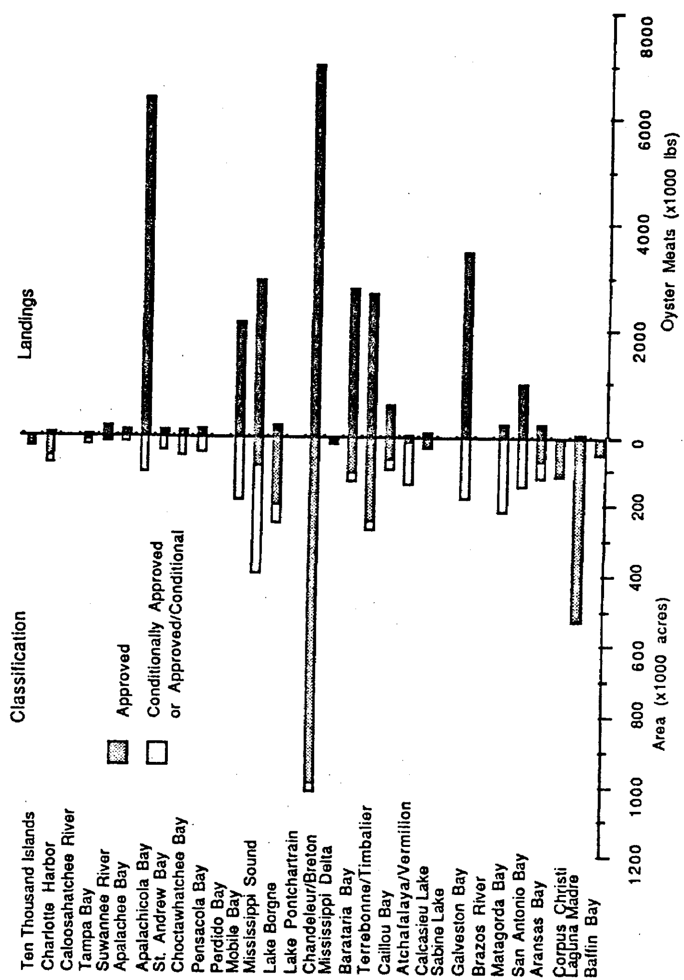
5.1 Landings and Classifications

Over 30 million pounds of oyster meats were landed in Gulf waters in 1985 (National Marine Fisheries Service, 1986). 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.

Oysters survive optimally in a narrow salinity range between freshwater and seawater, about 10 to 20 parts per thousand (U.S. Fish and Wildlife Service, 1983). Lower salinities inhibit spawning and reduce larval survival. Higher salinities favor predators and fouling organisms that reduce survival of mature oysters. Because of this, oysters are generally found in areas that are highly influenced by freshwater inflow.

Figure 5 compares quantity of oysters landed in 1985 to acreage of harvestable waters (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 the additional efforts required to develop a management plan and increase monitoring.

Figure 5. Classification and Landings by Estuary



In Louisiana, harvest occurs in both approved and conditionally approved waters. However, over the past 50 to 75 years, many of the productive reefs in the approved waters in the lower bays have been destroyed by salinity intrusion caused by the creation of levees along the Mississippi River, increased channelization in the outer marshes by the oil and gas industry, and natural processes. Salinity intrusion has shifted optimal habitats toward the upper reaches of the bays, causing a number of problems: appropriate substrate for setting of oyster larvae is lacking; potential for oyster mortality from freshwater inundation is greater; and human development and pollution prevents harvest from waters (Chatry and Perret, 1987; Chatry, Dugas, and Easley,1983).

This relationship between freshwater inflow and productive oyster beds also occurs in Florida, Alabama, Mississippi, and Texas, where 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. 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 have approved but not conditional waters, and have no commercially harvested resource.

5.2 Pollution Sources

Pollution sources that contribute to the permanent or temporary closure of shellfish growing waters were identified for each harvest limited area (prohibited, conditionally approved, and approved/ conditional). 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, the volume of water into which the discharge occurs, and the flushing ability of the area. The effect of a source will also depend on the size of the harvest limited area and the presence of other sources. A marina, significant in a small remote area, may not be 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 a contributing factor,

Eight types of pollution sources are identified in the region (Table 3). 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 3. Description of Fecal Coliform Pollution Sources

Pollution Source	Description
Sewage Treatment Plants	Discharges of inadequately treated effluent either from older plants without disinfection, malfunctioning disinfection systems, or from by-passing of raw sewage through an outfall pipe during overload periods.
Direct discharge	Raw sewage discharged from units that are not connected to collection systems or on septic systems.
Industry	Fecal coliform from seafood processors, pulp and paper mills, or from human sewage contamination of industrial wastes. Potential hazards from toxics.
Septic Systems	Leachate from improperly functioning septic systems 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.
Shipping and Boating 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.

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

For example, in Mobile Bay, one-third of the waters are classified as prohibited because of STPs, industries, and urban runoff from the city of Mobile, and upstream urban and agricultural runoff that enter the Bay via the Mobile River. Two-thirds of the Bay are classified as conditionally approved because of the Mobile River. STPs, industry, and urban runoff are each weighted as contributing factors in one-third of waters in Mobile Bay, while upstream urban and agricultural runoff are 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 contribution from industry is probably less than these two sources.

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

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

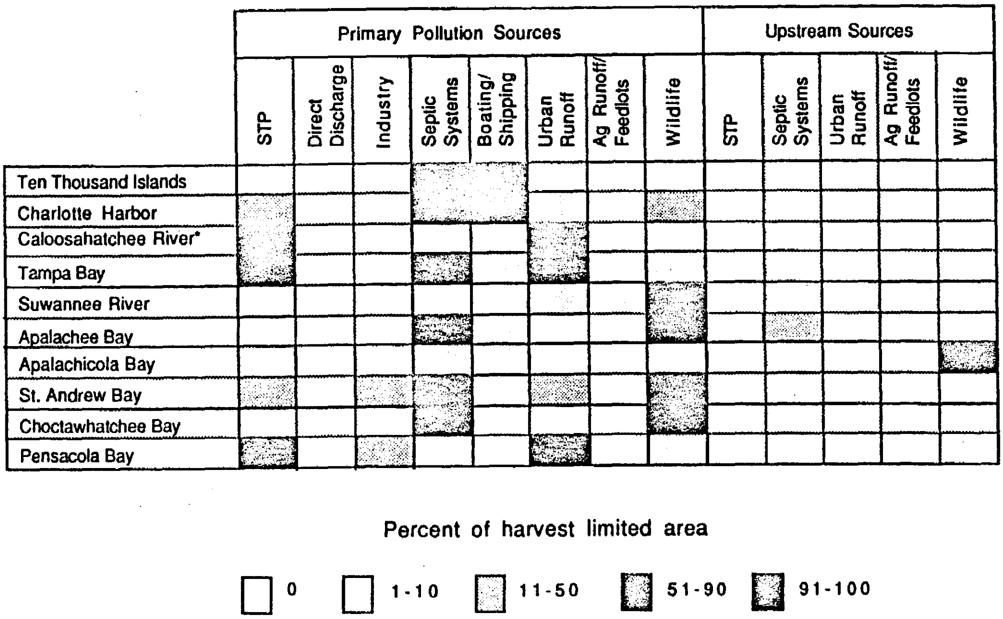


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Figure 6. (Continued)

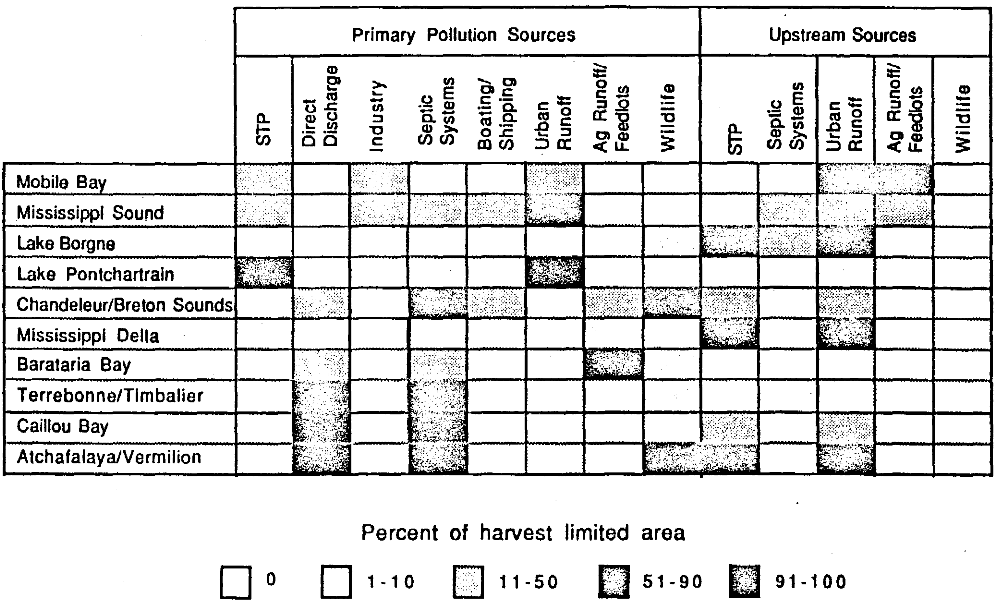

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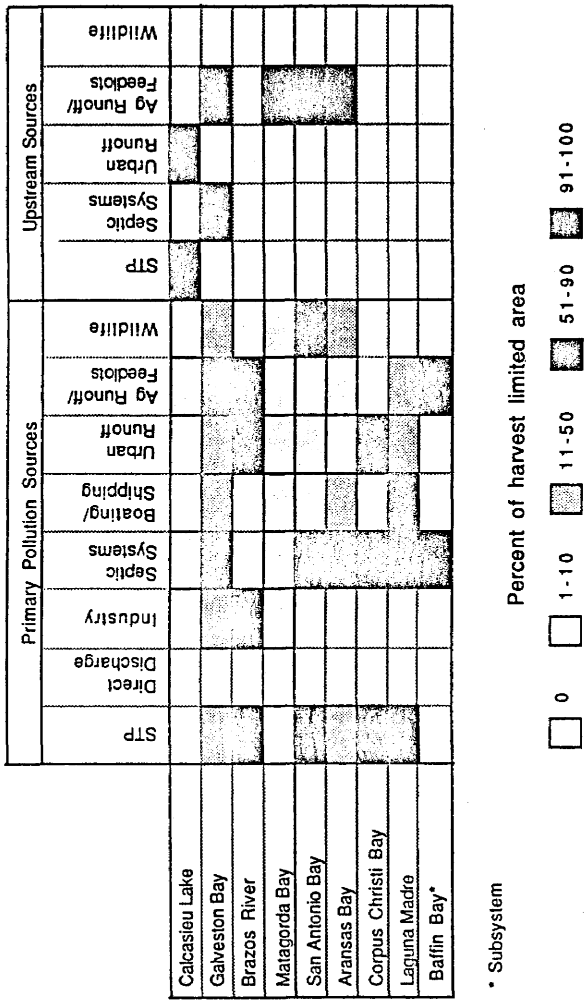
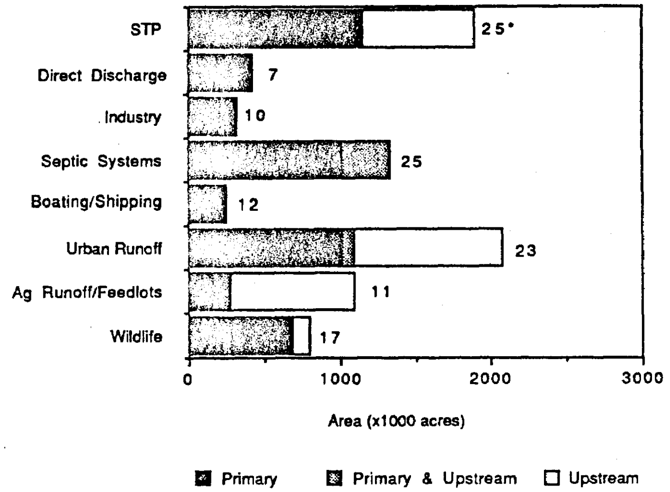
Figure 6. (Continued)



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

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 septic systems, agricultural runoff or feedlots and wildlife. Direct discharge, industry and boating and shipping activities affected smaller areas. Overall, upstream sources affect 1.9 million or 57 percent of harvest limited waters. Pollution sources are discussed individually in the following sections.

Figure 7. Area Affected by Pollution Sources



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

5.21 Sewage Treatment

Shellfish control agencies prohibit shellfish harvesting in areas adjacent to the outfalls of sewage treatment plants. The buffer zones are sized according to pollutant loadings, hydrographics, 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 in wet weather conditions. Although 1.1

million acres in the Gulf of Mexico are closed to shellfish harvest because of the contribution of municipal wastewater treatment plants (Appendix F), the majority of these acreages represent safety zones established around sewage treatment plant outfalls rather than continual high fecal coliform levels. In addition, much of this area is also affected by urban runoff.

Gulfwide, it is estimated that 94 percent of the effluent discharged by STPs in coastal counties is receiving secondary or tertiary treatment. Although some POTWs are at overcapacity, on the whole the Gulf is operating at 74 percent of plant design capabilities (NOAA, 1987).

In some areas of the Gulf coast, growth in residential and second-home development has overloaded municipal wastewater treatment facilities, resulting in the installation of smaller 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.

Studies conducted by Cabelli (1982) at nine STPs in Rhode Island examine the effect of level of treatment on fecal coliform densities. On average, primary treatment did not change densities. Levels were reduced from 8.7 million to 330,000 per 100 ml after secondary treatment (a 96 percent reduction), and to 32,000 after tertiary treatment (a 99.6 percent reduction). After secondary or tertiary treatment and chlorination, fecal coliform densities averaged 52 per 100 ml, and ranged from zero to 170 per 100 ml.

Because secondary treatment alone does not reduce coliform levels to within standards, disinfection is required. In 1974, EPA defined STP design requirements for protection of shellfish growing waters to include: 1) chlorinator and capacity to continuously maintain adequate disinfection when the largest unit is not functioning; 2) continuous disinfection during container or chlorinator changeover; 3) chlorine contact time of at least 30 minutes; 4) effluent chlorine residual to be continouosly recorded; and 5) an alarm for low chlorine residual in affluent and/or backup increased capacity components such as pumps, sedimentation basins trickling filters, aerators, mixers, and flocculation basins (Florida Department of Natural Resources, 1986).

More recent work by Cabelli (1988a, 1988b) investigated levels of indicators and pathogens in sewage and surface waters. Norwalk virus was simulated by monitoring F-2 male-specific bacteriophage (f phage). Overall, average levels of f phage were 1.5 times less than average fecal coliform levels in prechlorinated sewage effluent, as much as 3 times greater than fecal coliform in surface waters, and even greater in shellfish. The differences were greater in winter than in summer. These results suggest that f-phage survive treatment, chlorination, and transport in the marine environment better than fecal coliform. Cabelli questions certifying waters for harvest of shellfish where disinfection is used to meet water quality standards.

6.3 Direct discharge

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 geneally rustic and without facilities, either potable water or sewage disposal. 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. Because of the threat to public health, large areas of coastal Louisiana are limited to shellfish harvest (13 percent) because of fishing camps located along the bayous.

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 septic systems (Gulf South Research Institute, 1985).

6.4 Industry

Most industrial wastes in the Gulf region are treated by the industry and discharged directly to the waterbody. In 1984 direct industrial discharges exceeded municipal discharges in all coastal regions of the Gulf except Texas (NOAA, 1987b). Of the major industries in the Gulf, oil and gas, petrochemicals, seafood processing, and the pulp and paper inudstry, only the latter two have the potential to elevate fecal coliform levels in shellfish growing waters.

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.

Large pulp and paper mills discharge wastes into receiving streams and bays along the Gulf coast, particularly in Florida. The discharge may contain *Klebsiella*, a fecal coliform bacteria found in cellulose wastes and infrequently present in human feces. In some cases, wastewaters may be contaminated with sewage.

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 as a result of 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 shellfish growing waters in the Gulf. Several states monitor for heavy metals or other toxics in shellfish meats or waters, and have not found elevated levels.

6.5 Septic Systems

The rapid residential growth in the Gulf region, particularly in second home development, has outdistanced the ability of local governments to build treatment plants. Therefore many smaller communities still use septic systems for waste disposal. Septic systems work well in rural, low density areas with suitable soil and a deep water table, conditions that are not characterisitc of the Gulf coast. Often wastes leach into estuarine waters when septic tanks and leach fields are located too close to the shore, tidally-induced high water tables flush drainfields, and inadequate drainfields or poor soil absorption cause tanks to overflow. These conditions are worsened by heavy rainfall. Faulty septic systems were identified as a contributing factor in 39 percent of harvest limited areas in the Gulf estuaries (Appendix F).

6.6 Boating and Shipping Activities

The significance of sewage discharge from boats has been controversial nationwide, with boaters arguing that their contribution to pollutant loading is insignificant and regulators arguing for stronger controls. Studies 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 as operations of marinas, fueling facilities, and boatyards.

To protect the public health from the effects of boat wastes, state and federal regulators developed a marina policy that requires states to establish buffer zones around marinas. Many shellfish producing States are conducting studies to establish uniform techniques for determining closed areas based on dilution, dispersion, die-off , hydrography, marina design 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. 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 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 the limited circulation within the waterway.

Gulfwide, boating and shipping activities affect about seven percent of harvest limited waters (Appendix F). 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. In the entire state of Texas, for example, there is only one marina buffer zone. All other marinas lie within existing closed areas.

Marinas and boating activities affect less populated estuaries such as Ten Thousand Islands (100 percent) and Charlotte Harbor (75 percent). Recreational boats and large concentrations of commercial oyster vessels contribute to the fecal coliform pollution in Apalachicola Bay (seven percent).

6.7 Urban Runoff

Runoff from urban areas is greater than that of undeveloped watersheds because of an increase in impervious surfaces such as paved roads, sidewalks, and parking lots, and because of simplified drainage networks such as drainage ditches or storm drainage systems. Many studies have shown that stormwater runoff from urban areas contains high concentrations of fecal coliform.

The Nationwide Urban Runoff Program (NURP), conducted by EPA (1983), measured levels of pollutants in urban runoff from 28 cities nationwide. High bacteria levels in urban runoff were attributed to heavy loads of animal wastes, particularly pets and rodents. Runoff exceeded recommended bacterial counts at virtually every one of the 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 per 100 ml. The study also suggests that the use of coliforms as an indicator of human health risk when the sole source of contamination is urban runoff warrants further investigation.

Studies by Olivieri (1981) on storm drains and urban streams in Baltimore showed mean fecal coliform levels of 1,100 to 15,000 per 100 ml in dry conditions. Values were an order of magnitude higher in storm conditions. Values below 200 per 100 ml were extremely rare. Pathogens such as *Salmonella* were found in all stormwater samples and most urban stream samples, but correlations between pathogens and indicator organisms were poor, and Olivieri questioned the health significance of these organisms given the low reported incidence of disease from contact with stormwater.

Urban runoff may also contain human waste from malfunctioning collection systems. These systems are particularly stressed after storm events. The communities of Gulfport and d'Iberville on Mississippi Sound, for example, have experienced pollution affects from malfunctioning lift stations. A buffer zone has been delineated along the beaches as a result of high fecal coliforms. Sewer lines in cities near Apalachicola Bay suffer from infiltration and breakage problems. 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 (Florida Department of Natural Resources, 1984b). Earlier in that year, 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).

The *Pollution Source Survey, Terrebonne and Barataria Bay, Louisiana* (Gulf Coast Research Institute, 1985), attributes bacterial pollution to drainage water from densely populated areas along the descending bank of the Mississippi River and 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 of Mexico region show major affects 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 (Appendix F).

6.8 Agricultural Runoff

Runoff from land used by grazing animals or manured cropland contributes fecal coliform bacteria to surface waters. Milne (1976) has shown that the fecal coliform was 5 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. Faust and Goff (1978) estimated that in systems where the sanitary effluents are controlled by the use of septic tanks, the fecal coliform contribution of one livestock unit is equal to the contribution of 60 to 70 persons.

Along the western Gulf coast, shellfish growing waters are affected by livestock operations. 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 (Appendix F). Cattle grazing on the levees were identified as one of several potential 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 Quality Inventory (1986) identifies nonconfined livestock as the source of coliform bacteria in upstream segments of the Guadalupe (San Antonio Bay) and Lavaca (Matagorda Bay) Rivers.

6.9 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. study by the State of Florida (Williams, 1981) concluded that developed areas of low density, the fecal coliform contributi from wildlife may equal or exceed that of humans.

Many Florida estuaries are affected by wildlife. The sanita survey of Myakka River (Appendix D), identifies egrets and oth species of shore birds as the major contributors of fecal colifor in the area. In 1985, classified waters in the Suwannee Riv estuary were located at the outer limits of the estuary, far fro the river. These remote areas do not meet shellfish growing wat standards because of fecal pollution from wildlife. The sanita survey (Appendix D) indicated that fecal coliform levels a elevated when wintering fowl arrive, and identified deer, rabbit mice, opossum, raccoon and mink as minor contributors.

The sanitary survey of Ochlockonee Bay (Appendix [identifies major wildlife populations protected within St. Mark Refuge and Apalachicola National Forest as potential or actu sources of fecal coliform bacteria. The data list 53 mammalia species, 313 bird species, and 106 species of amphibians an reptiles. The U.S. Fish and Wildlife Service estimated that 30 gulls, shorebirds, cormorants, and scaup feed on exposed oyste bars at the east end of the bay. A wintering population of 300-50 ducks resides near the mouth of the bay, all contributing (10 percent) to the fecal coliform pollution of the Apalachee Ba system. Wildlife is also a contributing factor in St. Andrew (5 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.

4.39 Upstream Sources

Pollution sources that affect shellfish growing waters through river systems are identified in a separate upstream source 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. Rivers entering bays tend to dilute the salinity and increase the coliform concentration. Early studies suggested that die-off rates are higher as salinity increases. However, more recent studies on enteric pathogens suggest that bacteria may actually go into a dormant stage that is not detectable using standard tests (Grimes, 1987). As the river stage increases, the effects of the river extend further into the estuary. High flow rates in the Apalachicola and Mobile Rivers will drop salinities to freshwater levels and increase coliform bacteria above approved standards throughout both 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, Galveston, and San Antonio Bays.

5.3 Point and Nonpoint Source Impacts

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, direct discharge and industry) and nonpoint sources (septic systems, 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 affects occurs because most STPs and industries are located in urban areas that are also affected by stormwater runoff or in areas that are only partially sewered (septic systems). The remote land areas bordering Louisiana estuaries contain a mixture of camps (direct discharge) and homes on septic systems.

Other studies have identified nonpoint sources as a major contributor of fecal coliform bacteria. NOAA estimates reported recently by the Office of Technology Assessment (1987) showed that 84 percent of fecal coliform loads in the Gulf of Mexico coastal region are from nonpoint sources. The remaining 16 percent loading is from municipal point sources (STPs), and 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 (Olivieri, 1981; Wheater, *et. al.*, 1979). Although several potential human pathogens are carried by

animals, most have not been associated with shellfish-born disease outbreaks. Cases of bacterial disease associated wit shellfish have declined in recent years, while viral diseases hav increased. Hepatitus A virus and Norwalk virus have only bee associated with human and subhuman primates, not with othe animals.

An estimated 0.4 million acres, or 11 percent of harves limited waters are affected only by animal sources (wildlife agricultural runoff and feedlots). In an additional 1.1 millio acres or 34 percent, animals are a significant contributing source along with human sources of pollution. Urban runoff, that may o may not contain human fecal material, affects 1.1 million acres o 33 percent of harvest limited acres. Industrial sources are contributing factors in the closures of 0.3 million acres or 1(percent of these waters.

6.0 Trends in Classifcation, 1971 to 1985

Trends in classification were examined to determine if improvements in wastewater treatment had opened waters to harvest. Trends could not be evaluated in many areas that were classified in 1985 but not in 1971. In Alabama, Mississippi, Louisiana, and Texas, an additional two million acres of estuarine waters were classified between 1971 and 1985. One-half of waters in Louisiana and one-third of waters in Texas (mostly in Laguna Madre) were not classified in 1980. Three-forths of waters in Mississippi were unclassified in 1974 (FDA and NOAA, 1985). In Florida, 800,000 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.

Areas that changed classification between 1971 and 1985, as identified from Register charts, are listed in Appendix G. 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. Changes in classification occurred in all but five of the estuaries:

Ten Thousand Islands; Caloosahatchee River; Perdido Bay; Mobile Bay; and Sabine Lake.

However, only in 3,867 acres could changes in classification be related to changes in pollution sources (Table 4). Most of this area is in Matagorda Bay, where shoreline development resulted in closures. Dauphin Island (in Mobile Bay) provided the only case where an improvement in sewage treatment resulted in an upgraded classification. Installation of the Dauphin Island STP removed septic systems from the area, allowing 774 acres to be reclassified from prohibited to conditionally approved.

Table 4. 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	1,051	Approved	Prohibited	Development
Aransas Bay	St. Charles Bay	184	Approved	Prohibited	moved STP outfall
TOTAL		3,867			

Most classification changes occured for reasons other than changes in sources. Waters that were approved became conditionally approved or approved/conditional due to improved monitoring, increased awareness of nonpoint sources, and the technical ability to implement management plans. Nonpoint sources affecting these waters have been present for many years.

In earlier years, monitoring was conducted in areas where there were known pollution sources, especially point sources. Because the total coliform standard was a less specific indicator of fecal pollution, greater emphasis was placed on the shoreline survey, and less emphasis on the bacteriological standard. As one shellfish sanitarian described it in the late 1960s:

> "It is important to understand that if the sanitary reconnaissance *[shoreline survey]* of the watershed shows no significant fecal pollution sources, the coliform standard need not be followed. It is well established that southen Mississippi's natural surface waters, i.e., receiving no human or industrial wates, are exceedingly high in coliform and fecal coliform densities. There is no explanation why such high values occur in these natural surface waters... Until better parameters are available to classify shellfish growing waters, a great reliance must neccessarily be placed on the sanitary reconnaissance and continued surveillance of pollution the sources" (Clem, 1969).

The states provided numerous examples of improvements in sewage treatment. New disposal methods such as deep well injection (Tampa Bay) and spray irrigation (Charlotte Harbor and Tampa and St. Andrews Bays) were implemented where plant effluent had an adverse affect on receiving waters. Outfalls were moved from direct bay discharge to upstream creeks or marsh

areas (Apalachicola Bay and Mississippi Sound). Treatment was begun in areas that proviously had only collection systems (Atchafalaya Bay). Chlorination was added (Terrebonne Bay). By-passes were eliminated (St. Andrew and Terrebonne Bays). Large regional STPs replaced older overloaded facilities (Mississippi Sound). Expanded collection systems eliminated septic systems and package plants (St. Andrew Bay, Mississippi Sound, and Galveston Bay).

These efforts have not opened up waters to harvest for two major reasons. First, waters remain closed as a buffer zone in case of plant failure. Overloading and py-passing are still a problem in most areas, even after STP improvements are made. Second, other sources keep waters above approved standards. Impact from nonpoint sources, especially urban runoff and inflow from large river systems, still affect areas that have improved sewage treatment. In some cases, STP upgrades were made recently, and impacts have not yet been evaluated. Examples of changes that have occured in state programs and pollution sources are provided below by state.

6.1 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 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 conditonally approved classification for many previously approved areas. 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 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 (FDA, 1972, 1975). Waters were finally classified conditionally approved in 1985.

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

6.2 Alabama

Between 1971 and 1985, approved waters of Portersville and lower Heron Bays became 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 of Mobile Bay was delineated in the 1950s, and has not changed since that time. However, conditionally approved waters remain open for longer periods since changing from the total to the fecal coliform standard.

6.3 Mississippi

The major changes to occur in Mississippi are the designation of ship channels as prohibited, and 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 currently threatens to close additional harvest areas.

Although studies show reduced fecal coliform levels as a result of improvements in STPs and storm drainage, levels are still above growing water standards. Data collected at bathing beaches during summers from 1976 to 1986 showed improvements in coliform water quality at eight of the ten stations.

In Biloxi Bay, fecal coliform levels declined by as much as 95 percent near the Ocean Springs STP outfall after a new regional plant replaced an older, overloaded facility. An FDA study (1987) to determine if the prohibited shellfish waters in Biloxi Bay could be opened to harvest on a conditional basis as a result of the Ocean Springs STP upgrade, concluded that "in spite of enormous improvements in physical wastewater treatment facilities, the rapid growth of residential and commercial development was still overwhelming the treatment systems."

6.4 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 (St. Pe', 1987). 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. The impact of these changes on downstream shellfish growing waters has not yet been evaluated by the State.

6.5 Texas

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

7.0 Conclusion

Results of this work show that Clean Water Act efforts have not been successful in opening shellfish growing waters to harvest. Less than half of all growing waters in the Gulf of Mexico met standards for approved harvest in 1985. Sewage treatment plants, septic systems and nonpoint runoff were identified as the major pollution sources affecting waters. Despite numerous examples of improvements in sewage treatment, only in one case did this result in an upgrade in classification.

Overall, 42 percent of waters were classified as approved in 1985. Twenty-nine percent of waters were classified as prohibited. These were waters adjacent to urban areas and smaller shoreline developments. An additional 27 percent of waters were managed as conditionally approved. These areas were further from developed shorelines, had harvestable resources, and were affected by freshwater inflows from heavy rainfall or high river stages.

Most of the oyster harvest in the Gulf occurs out of waters that are managed as conditionally approved. Freshwater inflow from rainfall and river flow optimize habitat by providing nutrients and moderating salinities, but also provide a major source of coliform bacteria. Fecal coliform in rivers is mainly fron nonpoint sources, although point sources are important in some river systems such as the Mississippi River. Stormwater runoff from lands adjacent to the estuary contains fecal coliform

from failing STPs and septic systems, urban runoff, and from fecal material from wild or domestic animals. Runoff is high in fecal coliform regardless of land use: urban, agricultural, forest, or marshland. In a wet year, the impacts of freshwater inflow can be great, closing growing waters for weeks or months at a time.

Gulfwide, the predominant sources of fecal coliform were identified as: failing 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, contributing 39 percent and 10 percent upstream; and stormwater runoft from urban areas, contributing 33 percent and 32 percent upstream (Appendix F). Overall, upstream sources affect 57 percent of harvest-limited waters. 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). Direct discharges are a problem in coastal Louisiana (13 percent). Effects from industry (ten percent) and boating and shipping activities (seven percent) are minimal compared to other sources (Appendix F).

Scientists and regulators have questioned the public health significance of several of these sources. Animals do not appear to transmit human enteric viruses, the major pathogens related to current shellfish-borne diseases. If this is the case, then closure of growing waters on the basis of high fecal coliform levels when the pollution source is urban runoff, agricultural runoff, or wildlife may be overly restrictive. Conversely, viruses may survive sewage treatment and chlorination better than fecal coliform bacteria. Waters opened to harvest where disinfection of sewage is used to reduce fecal coliform levels may endanger public health. Buffer zones may be effective in reducing this risk.

Since passage of the Clean Water Act, coastal counties in the five Gulf states have received more than $1 billion in Construction Grants monies to construct and improve sewage treatment facilities and collection systems. In addition, states have limited point source discharges to estuarine waters through effluent limitations under the NPDES program. Although there are many examples of improved sewage treatment and controlled point sources throughout the Gulf, only one upgrade in classification occured as a result of these efforts: 774 acres were upgraded from prohibited to conditionally approved as a result of a newly constructed STP that replaced septic systems at Dauphin Island (Mobile Bay). Clean Water Act programs have not increased approved areas because:

- o Although municipal point source discharges have been reduced, many sewage treatment facilities and collection systems still have problems with by-passes and system failures that result in occasional raw sewage discharges to surface waters. System failures usually occur after heavy rains, as a result of infiltration problems. Because

of this, buffer zones are required around all sewage treatment plants. Even if Clean Water Act programs were completely successful in reducing fecal coliform levels to within standards, some area would remain closed to harvest as buffer zones as long as the potential for failure exists.

- o Many areas along the Gulf coast are still unsewered, relying primarily on septic systems or small package sewage treatment plants for sewage disposal. These systems are not adequately regulated by federal or state programs. Efforts to manage septic systems by some states, such as Florida, have been ineffective because the regulations do not seem to be enforced.
- o Nonpoint runoff from urban areas, pasturelands, and forests, either in the immediate drainage basin or upstream of the estuary, keep shellfish growing waters from meeting standards. In Apalachicola and Tampa Bays, for example, nonpoint sources kept areas closed after STP outfalls were removed.

Since 1971, the major trend to occur in classified shellfish growing waters in the Gulf is an increase in waters managed as conditionally approved. This increase in conditional waters resulted from improved monitoring efforts, changes in the use of the indicator standard, and heightened awareness of nonpoint sources, due in part to reductions in point sources. The nonpoint sources that provide fecal coliform to the Gulf estuaries have existed for many years, but were not monitored as much in earlier years. As regulators have placed greater reliance on the fecal coliform standard and improved monitoring efforts by increasing sampling after rainfall events, waters have changed from approved to conditionally approved.

The increase in condtionally approved waters, particularly in highly productive growing areas such as Apalachicola Bay, has alarmed the shellfish industry. Oyster harvests have declined in recent years for several reasons including pollution, diseases, predators, and overfishing. In 1986, red tides closed many oyster areas along the Texas coast. Because of overfishing in areas that remained open, the Texas Department of Marine Fisheries cancelled the 1987 oyster season completely to protect scarce remaining resources. In Alabama, dwindling resources have resulted from overfishing and poor resource management. Louisiana is the only Gulf state that has maintained high harvest levels, although not without problems: salinity intrusion has shifted shellfish beds higher up into the estuaries, closer to pollution sources; and oystermen and researchers estimate that predators destroy as much as 50 percent of oysters in the higher saline waters.

Industry, regulators, and scientists have questioned the validity of the fecal coliform standard, particularly as more waters failed to meet approved water standards. These groups have called for a national study to examine the relationship between shellfish-borne disease and indicators, including fecal

coliform, total coliform, enterococcus, *E. coli*, and others. The objective of the study is to establish a new standard. Feeding studies would relate indicators to disease risk. The study would examine sites from different regions of the country that are affected by human, animal, point, and nonpoint sources of pollution.

A new indicator system could potentially allow harvest from vast acreages that are affected by nonpoint sources of animal origin. Nonpoint sources alone affect 47 percent of harvest-limited waters in the Gulf of Mexico, while a combination of point and nonpoint sources affect 53 percent. An estimated 0.4 million acres, or 11 percent, of harvest-limited waters are affected only by animal sources. In an additional 1.1 million acres, animals are significant contributors of fecal coliform. Runoff from urban areas affects 1.1 million acres from primary sources and another 1.0 million acres from upstream sources.

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Appendix A. Minimum Requirements for Performing Shoreline Surveys in Shellfish Growing Areas

1. Survey Assignment
   A. Each survey area is determined and assigned by the shellfish control agency. Each survey area is identified by a unique designation. All survey data must be identified by this unique designation which allows for tracking of all forms used in the survey. All shoreline survey data shall be documented and filed promptly.

2. Examination of Individual Properties for Pollution Sources

   A. The boundaries of the shoreline survey area will be determined by an in-field investigation of the area topography and the proximity of individual properties to the growing area which identifies only those properties with the potential to impact growing water quality. Once the boundaries of the shoreline survey have been determined, all businesses and residences must be examined and all potential discharges of wastes (raw sewage, kitchen wastes, laundry wastes, agricultural wastes, etc.) must be evaluated.

   B. The location of each property with a pollution source adversely impacting the growing area shall be provided.

   C. If the property has a pollution source adversely impacting a growing area one of two notations listed below shall be made concerning its impact on water quality.

      1) Direct Impact
         a. A pollution source haveing direct impact is defined as any waste discharge which has immediate impact on the growing area.
         b. An attempt should be made to quantify the volume of the discharge.

      2) Indirect Impact
         a. A pollution source having indirect impact is defined as any waste discharged which reaches the growing area in a roundabout way.

b. An attempt should be made to quantify the volume of the discharge.

D. All samitary, industrial, or agricultural pollution sources are to be located on a map of the survey area.

E. All animal farms shall be evaluated. Evaluation shall include the number and type of animals.

F. All marinas shall be evaluated in accordance with the ISSC Marina Policy.

G. Notations shall be made of any flocks of waterfowl and an estimation of their number given. Populations of wild animals such as deer and muskrat should be noted and where possible and estimation of their number given.

H. Drainage ditches shall be evaluated.

I. Any other potential sources of pollution which in the surveyor's opinion might influence water quality shall be noted.

J. At the end of each shoreline survey the surveyor shall write a summation. The surveor must also provide a comprehensive map of the survey area identifying the location of each pollution source found.

Appendix B. Shellfish Management Survey Questionnaire

I. State Shellfish Sanitation Program

A. Which state agencies are responsible for shellfish control functions?

1. **Shellfish Growing Waters** ____________
   - Contact Person ____________
   - Address ____________
   - ____________
   - ____________
   - Phone ____________
   - a. 1985 Shellfish Expenditures $ ____________
   - b. 1985 Shellfish Staff ____________
2. **Plant Inspections** ____________
   - Contact Person ____________
   - Address ____________
   - ____________
   - ____________
   - Phone ____________
   - a. 1985 Shellfish Expenditures $ ____________
   - b. 1985 Shellfish Staff ____________
3. **Enforcement** ____________
   - Contact Person ____________
   - Address ____________
   - ____________
   - ____________
   - Phone ____________
   - a. 1985 Shellfish Expenditures $ ____________
   - b. 1985 Shellfish Staff ____________
4. **Laboratories** ____________
   - Contact Person ____________
   - Address ____________
   - ____________
   - ____________
   - Phone ____________
   - a. 1985 Shellfish Expenditures $ ____________
   - b. 1985 Shellfish Staff ____________
   - c. Number of laboratories ____________
5. **Resource Management** ____________
   - Contact Person ____________
   - Address ____________
   - ____________
   - ____________
   - Phone ____________
   - a. 1985 Shellfish Expenditures $ ____________
   - b. 1985 Shellfish Staff ____________

II. Role of County and Municipal Government in Shellfish Control

Function	Responsibility County	Responsibility Municipal
Shellfish Growing Waters	______	______
Plant Inspection	______	______
Enforcement	______	______
Laboratories	______	______
Resource Management	______	______

III. Classification of Shellfish Growing Waters

A. Standard (total or fecal coliform)

1. Which standard is used?
   total coliform____
   fecal coliform____

2. When did you change from total to fecal standard? _____
3. Did the change in standard open or close more areas?
   open____
   close____

B. Do you use the following classifications?

Classification	check if used
Approved	______
Open	______
Conditionally Approved	______
Seasonally Approved	______
Restricted	______
Conditionally Restricted	______
Seasonally Restricted	______
Condemned	______
Prohibited	______
Closed	______
Nonshellfish/Nonproductive	______

IV. Sanitary Surveys

A. Shoreline Surveys
1. Has 100% of the state shoreline been surveyed?
   yes_____ no____

2. Frequency and Method of Shoreline Surveys

	Yearly	2yrs	3yrs	4yrs	5yrs	over 5 yrs
Field	____	____	____	____	____	____
Desktop	____	____	____	____	____	____

3. Pollution Source Survey
   Check off those sources reviewed in your most recent shoreline surveys:

<u>Point Sources</u>

municipal wastewater treatment facilities ____
  design capacity vs. actual loading ____
  type, strength of pollutants ____
  type of treatment ____
  emergency procedures ____

industrial facilities ____
combined storm / wastewater discharges ____
illegal tieins to storm sewers ____
privately-operated wastewater treatment facilities ____

<u>Nonpoint Sources</u>

malfunctioning septic tanks ____
marinas ____
agricultural operations ____
storm water runoff ____
constuction sites ____
waste disposal sites ____
extraction and mining activities ____
dredge and fill operations ____

B. Evaluation of Meteorologic and Hydrologic Effects
Check off each factor considered.

1. Tidal amplitude ______
2. Circulation studies;
   dye studies ______
   drogue studies ______
3. Water depth ______
4. Salinity ______
5. Stratification characteristics ______
6. Turbidity ______
7. Temperature ______
8. Rainfall patterns and intensity ______
9. Prevailing winds ______
10. Tides ______
11. Do you use modeling to manage conditional areas
    yes_____ no_____

C. Sampling Program

1. Consituents regularly sampled.

a. Ambient Water
   1) Total coliform ______
   2) Fecal coliform ______

b. Shellfish Tissues
   1) Heavy metals ______
   2) Petroleum hydrocarbons ______
   3) Chlorinated hydrocarbons ______

c. Sediments
   1) Heavy metals ______
   2) Petroleum hydrocarbons ______
   3) Chlorinated hydrocarbons ______

2. Sampling Stations

CLASSIFICATION OF AREAS	# OF STATIONS	# OF SAMPLES	FREQUENCY OF SAMPLING	TISSUES SAMPLED

D. Buffer Zones

1. How are buffer zones delineated for sewage treatment plants?
   a. Dye studies ______
   b. Based on monitoring data ______
   c. Other (specify)______________________

2. How large are STP buffer zones?

acres	minimum	maximum
<50	______	______
50-100	______	______
100-200	______	______
>200(specify)	______	______

3. How large are marina buffer zones?

   a. Restricted to immediate area of boats ______
   b. Based on monitoring data ______
   c. Other(specify)______________________
   d. Do not use marina buffer zones ______

4. Minimum number of slips necessary for boating activity to be considered a marina ______

V. Management of Molluscan Shellfish

How many acres were:

A. in private leases in 1985? ________

B. in public harvest areas in 1985? ________

C. set aside for recreational harvest in 1985? ______

D. Controlled Relaying
1. How many acres were set aside for relaying of shellfish from restricted or prohibited areas in 1985? ________

VI. Purification of Molluscan Shellfish
A. Depuration

1. How many depuration plants are in operation?

a. Ultraviolet ________
b. Ozone ________

2. Quantity of shellfish depurated in 1985?

a. clams ________
b. oysters ________

3. Inspection
a. Which agency is responsible________

b. How often are the depuration plants inspected?
daily ________
weekly ________
monthly ________
spot checked ________

VII. Marketing and Landings Information

A. Does the State keep records of landings
yes_____
no_____

1985 Data:

a. Oysters ________
b. Clams ________
c. Mussels ________

VIII. Does the state have a PSP Monitoring Program?
yes_____
no_____

A. PSP closures based on presence of toxic dinoflagellates

1. When did toxic levels first cause closures of shellfish waters?

____

2. Were closures made in 1985? (please outline on charts)
yes_____
no_____

B. Has DSP been recorded as a shellfish-related disease in your state?
yes_____
no_____

C. Have outbreaks been traced to state harvested shellfish?
yes_____
no_____

Specific area________________

Classification________________

Appendix C. Personal Communications

Andrews, R.H. Public Health Laboratories, Mississippi State Department of Health. Jackson, MS.

Bastian, M. Gulf Initiative, Environmental Protection Agency, Region VI. Dallas, TX.

Berrigan, M. Environmental Administrator. Bureau of Marine Resource Regulation and Development, Florida Department of Natural Resources. Tallahassee, FL.

Boesch, D. Executive Director. Louisiana Universities Marine Consortium. Chauvin, LA.

Bowles, E. Milk and Shellfish Sanitation Branch, Mississippi State Department of Health. Jackson, MS.

Branche, J. Bureau of Marine Resource Regulation and Development, Florida Department of Natural Resources. Tallahassee, FL.

Bryan, C.E., Texas Parks & Wildlife Commission. Austin, TX.

Burnside, F. Gulf Initiative, Environmental Protection Agency, Region VI. Dallas, TX.

Byrd, L. Environmental Health Administration, Alabama Department of Public Health. Mobile, AL.

Chatry, M.F. Louisiana Deaprtment of Wildlife and Fisheries, Lyle S. St. Amant Marine Laboratory. Grand Isle, LA.

Cirino, J. Gulf Coast Research Laboratory. Ocean Springs, MS.

Cook, D. Gulf Coast Research Laboratory. Ocean Springs, MS.

Cosgrove, J.A. Regulatory Services, Office of Preventive and Public Health, Louisiana Department of Health and Human Services. New Orleans, LA.

Covert, C. Enforcement Division, Texas Parks & Wildlife Commission. Austin, TX.

Crocker, P. Gulf Initiative, Environmental Protection Agency, Region VI. Dallas, TX.

Davenport, G. Fishery Statistics, National Marine Fisheries Service. Miami, FL.

Davenport, J. Permitting and Enforcement Office, Texas Water Commission. Austin, TX.

Demoran, W. Gulf Coast Research Laboratory. Ocean Springs, MS.

Dugas, R. Louisiana Department of Wildlife and Fisheries. New Orleans, LA.

Ellingsen, Col. D.N. Director, Division of Law Enforcement, Florida Department of Natural Resources. Tallahassee, FL.

Elliott, B. Gulf Initiative. Environmental Protection Agency, Region VI. Dallas, TX.

Futch, C.R. Bureau of Marine Resource Regulation and Development, Florida Department of Natural Resources. Tallahassee, FL.

Gallott G. Chief of Enforcement, Bureau of Marine Resources, Mississippi Department of Wildlife Conservation. Gulfport, MS.

Garrett, S. Director. Seafood Surveillance Program, National Marine Fisheries Service. Pascagoula, MS.

Glatzer, M. Milk and Shellfish Sanitation Branch, Mississippi State Department of Health. Gulfport, MS.

Handley, L.R. National Wetlands Research Center, U.S. Fish & Wildlife Service. Slidell, LA.

Heil, D.C. Environmental Administrator, Bureau of Marine Resource Regulation and Development, Florida Department of Natural Resources. Tallahassee, FL.

Herrington, T. Shellfish Specialist, Food and Drug Administration, Region IV. Atlanta, GA.

Hoffman, M. Office of Habitat Conservation, National Marine Fisheries Service. Panama City, FL.

Kilgen, M. Department of Biological Sciences, Nicholls State University. Thibodaux, LA.

Kraemer, D. Shellfish Specialist, Food and Drug Administration, Region VI. New Orleans, LA.

Kutzman, J. Marine Protection Section, Environmental Protection Agency, Region IV. Atlanta, GA.

Leard, R. Bureau of Marine Resources, Mississippi Department of Wildlife Conservation. Longbeach, MS.

Lertjerapresert, T. Regulatory Services, Office of Preventive and Public Health, Louisiana Department of Health and Human Services. New Orleans, LA.

MacLondon, M. Milk and Shellfish Sanitation Branch, Mississippi State Department of Health. Gulfport, MS.

Morris, D. Bureau of Marine Resource Regulation and Development, Florida Department of Natural Resources. Tallahassee, FL.

Neleigh, D. Gulf Initiative, Environmental Protection Agency, Region VI. Dallas, TX.

Olmstead, R. Shellfish Specialist, Food and Drug Administration, Region IV. Atlanta, GA.

Otto, C. Environmental Health Administration, Alabama Department of Public Health. Mobile, AL.

Pendleton, E.C. Branch Chief, National Wetlands Research Center, U.S. Fish & Wildlife Service. Slidell, LA.

Perkins, R. Environmental Health Administration, Alabama Department of Public Health. Mobile, AL.

Perret, W.S. Assistant Secretary for Coastal and Marine Resources, Louisiana Department of Wildlife and Fisheries. Baton Rouge, LA.

Robertson, N.A., Jr. Milk and Shellfish Sanitation Branch, Mississippi State Department of Health. Jackson, MS.

Savoie, B.G. Environmental Consultant, Office of the Secretary, Louisiana Department of Health and Human Services. Baton Rouge, LA.

Schneider, J.W. Chief, Bureau of Marine Resource Regulation and Development, Florida Department of Natural Resources. Tallahassee, FL.

Sharp, L. Mississippi Bureau of Pollution Control, Gulf Coast Research Laboratory. Ocean Springs, MS.

St. Pe, K.M. Water Quality Specialist, Office of Water Resources, Louisiana Department of Environmental Quality. Lockport, LA.

Sweet, C. Division of Shellfish Sanitation Control, Texas Department of Health. Austin TX.

Swingle, H. Director, Marine Resources Division, Alabama Department of Conservation and Natural Resources. Dauphin Island, AL

Taylor, J. Director of Laboratories Bureau of Marine Resource Regulation and Development, Florida Department of Natural Resources. Tallahassee, FL.

Thompson, R.E. Director, Division of Shellfish Sanitation Control, Texas Department of Health. Austin TX.

Turner, S. Chief, Marine Protection Section, Environmental Protection Agency, Region IV. Atlanta, GA.

VanHoose, M.S. Marine Resources Division, Alabama Department of Conservation and Natural Resources, Dauphin Island, AL.

Voisin, M. Motavatit Seafoods, Inc., Houma, LA.

Wiles, K. Division of Shellfish Sanitation Control, Texas Department of Health, Austin TX.

Young, K. Gulf Initiative, Environmental Protection Agency, Region VI. Dallas, TX.

Appendix D. Sanitary Surveys

Alabama

Alabama Environmental Health Administration, 1985. *Sanitary Survey of Grand Bay Area.* Mobile, AL.

1986a. *Sanitary Survey of Aloe Bay Area.*

1986b. *Sanitary Survey of Bayou La Batre - Coden Area.*

1986c. *Sanitary Survey of Dauphin Island Bay (Northern Portion).*

1986d. *Sanitary Survey of Dauphin Island Bay (Southern Portion).*

1986e. *Sanitary Survey of Oyster Bay, Bon Secour River System.*

1986f. *Sanitary Survey of Portersville Bay.*

1986g. *Sanitary Survey of South Mobile Bay.*

Florida

Florida Department of Natural Resources. 1979. *Comprehensive Sanitary Survey. Lower Tampa Bay, Manatee Co, Florida.* Tallahassee, FL.

1982. *Comprehensive Shellfish Growing Area Survey, Ochlocknee Bay, Florida.*

1983. *Comprehensive Shellfish Growing Area Survey for Gasparilla Sound, Charlotte and Lee Counties, Florida.*

1984a. *Comprehensive Shellfish Growing Area Survey, Cedar Key, Florida.*

1984b. *Comprehensive Shellfish Growing Area Survey, Horseshoe Beach, Dixie County, Florida.*

1984c. *Comprehensive Shellfish Growing Area Survey, Myakka River, Charlotte County, Florida.*

1984d. *Shellfish Growing Area Reappraisal for Old Tampa Bay, Hillsborough and Pinellas Counties, Florida.*

1985. *Comprehensive Shellfish Growing Area Survey, Pensacola Bay System, Pensacola, Florida.*

1986a. *Comprehensive Shellfish Harvesting Area Survey for East Bay, Bay County, Florida.*

1986b. *Comprehensive Shellfish Harvesting Area Survey for North Bay, Bay County, Florida.*

1986c. *Comprehensive Shellfish Harvesting Area Survey for West Bay, Bay County, Florida.*

1987. *Comprehensive Shellfish Growing Area Survey, Suwannee Sound, Dixie and Levy Counties, Florida.*

Louisiana

Gulf South Reseach Institute. 1985. *Pollution Source Suvey, Terrebonne and Barataria Bays, Louisiana.* Baton Rouge, LA. 32 pp.

Plaquemines Parish Environmental Services. 1986. *A Preliminary Report of the Quarantine Bay Area Sanitary Survey.* Pointe-a-la-Hache, LA. 41 pp.

Texas

Texas Department of Health, 1978a. *Pollution Potential Survey of Trinity Bay Watershed and East Bay Watershed.* Austin, TX.

1978b. *Report of a Reappraisal of Aransas Bay.*

1981a. *Carancahua Bay Survey.* Inter-office memo.

1981b. *Report of a Reappraisal of Tres Palacios Bay.*

1981c. *Report of Shellfish Growing Waters of the Laguna Madre.*

1982. *Freeport Area Survey Report.*

1985. *Sanitary Survey of the Shellfish Producing Waters of Lavaca Bay.*

Appendix E. Temporary Closure of Approved Areas

Estuary	Date	Area
Tampa Bay	Aug-84	Cockroach Bay
	Nov-83	Lower Tampa Bay
	Aug-83	Lower Tampa Bay
	Feb-83	Cockrouch Bay
	Feb-80	Cockrouch Bay
Apalachee Bay	Dec-85	Wakulla County
	Nov-85	Wakulla County
	Apr-84	Wakulla County
	Mar-83	Wakulla County
	Feb-82	Wakulla County
	Jan-82	Wakulla County
	Feb-81	Wakulla County
	Nov-80	Wakulla County
	May-80	Wakulla County
	Mar-80	Wakulla County
	Feb-80	Wakulla County
	Nov-79	Wakulla County
St. Andrew Bay	Dec-85	East and West Bays
	Oct-85	all
	Apr-84	East Bay
	Mar-84	East and West Bays
	Apr-83	West Bay
Choctawhatchee Bay	Dec-85	all
	Mar-84	all
Pensacola Bay	Dec-85	all
	Dec-85	Escambia and East Bays
	Apr-84	Escambia and East Bays
	Mar-84	Escambia and East Bays

Continued.

Estuary	Date	Area
Mississippi Sound	Dec-87	All Mississippi waters
	Feb-83	All Mississippi Waters
	Dec-82	Western Mississippi Sound
Galveston Bay	Feb-87	Trinity Bay, Galveston Bay
	Jan-87	East Galveston Bay
	Nov-86	all
	Nov-86	Galveston, Trinity, and East Galveston Bays
	Mar-85	all
	Nov-84	all
	Oct-84	all
	Jan-83	West Galveston Bay
	Jul-81	Trinity, Galveston, and East Bays
	Jun-81	Trinity, Galveston,and West Bays
	Jul-79	all
	Jun-76	Trinity, Galveston, and East Bays
	Jan-74	Trinity, Galveston, and East Bays
	Apr-73	all
	Mar-73	all
Matagorda Bay	Feb-87	E. Matagorda, Carancahua, Tres Palacios Bays
	Feb-87	Lavaca Bay
	Jan-87	East Matagorda Bay
	Dec-85	Lavaca, Cox, Keller Bays
	Nov-85	Lavaca, Cox, Keller Bays
	Apr-85	Tres Palacios, Carancahua
	Mar-85	Oyster and Powderhorn Lakes
	Mar-85	all
	Jan-85	portion of Lavaca Bay
	Nov-84	all
	Nov-84	E. Matagorda, Tres Palacios, Lavaca, Cox, Keller, Carancahua Bays, and Matagorda Bay east of Matagorda ship channel
	Mar-84	Lavaca, Cox, and Keller Bays
	Nov-83	Lavaca, Cox, and Keller Bays
	Oct-83	portion of Lavaca Bay
	Feb-83	Carancahua Bay
	Feb-83	Lavaca, Cox, and Keller Bays
	Nov-82	Lavaca, Cox, and Keller Bays
	Mar-82	Lavaca, Cox, Keller Bays, Powderhorn Lake
	Nov-81	Lavaca, Cox, and Keller Bays

Continued.

Estuary	Date	Area
San Antonio Bay	Dec-86	all
	Dec-85	all
	Apr-85	southeast portion
	Apr-85	all
	Mar-85	all
	Nov-81	all
	Jan-79	portion
Aransas Bay	Feb-87	Copano Bay
	Apr-85	Mission, Copano, and Port Bays
	Mar-85	Mission, Copano, and Port Bays

Appendix F. 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					
	Mudov 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	27,468					27,468							
	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					
	Mullet Key Bayou			51	51												
	Madelaine Key			561	561												
	Indian Key			3,292	3,292					3,292							
	Total	18,507		32,269	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	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
Apalachee Bay	Ochlockonee Bay		1,765	5,143				6,908				6,908		6,908			
	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			21,085		6,908			
	% 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		48		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	45,683		45,683			85,289							
	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	8,354		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												175,803	175,803	
	Total	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]				[illegible]	[illegible]	

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 (AL)	Upper bay			31	31		31			31		31					
	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	189,958	96,749	76,028		47,535	132,036	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		763									763					
	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								763	55,004	6,611	55,004		
	% of Total											1	88	11	88		
Lake Pontchartrain	Lake Pontchartrain			444,653	444,653					444,653							
	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.

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
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				763					
	California Bay		8,984					8,984			8,984	8,984					
	Lake Aimeda, Hopedale Lagoon		254	763	1,017	1,017	1,017	1,017									
	Bayou Fongere		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, Uhlen Bays			1,780				1,780					1,780		1,780		
	Bay Denesse			678		678		678	678		678		678		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									179,674		179,674		
	Bays Laneaux, de la Chenière		932	848	1,780												
	Adams Bay		254		254												
	Bay Pomme D'Or		170	1,356	1,356			1,526			1,526						
	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	17,968	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 Negresa		424			424		424									
	Tambour Bay		593			593		593									
	Deer, Sale, Touch Me Not Bays		932			932		932									
	Moss Bay		593	65		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		88	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		31,358	20,849		52,208		52,208					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

		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
Galveston Bay	West Bay	40,657		15,086	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 Waterway			1,207					1,207								
	East Bay			8,956				8,956			8,956	8,956					
	Galveston Bay	95,973		55,406	55,406		55,406	95,973		95,973	95,973			95,973		95,973	
	Smith Point			2,652				2,652			2,652						
	Total	170,840		170,524	142,482		86,739	262,418	56,950	127,306	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	8,446				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			6,457				6,457									
	Noble Point			30				30									
	Magnolia Beach			561				561									
	Total	212,353		27,565	10,153	1,234	13,730	23,108	4,457	5,284	12,903	8,446				225,256	
	% 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	136,849		15,521	148,536			133,069	3,807	3,807		133,042				152,343	
	% of Total				97			87	2	2		87				100	
Aransas Bay	Bayside			1,265				1,265								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	

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	1,329,106	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

Appendix G. Changes in Classification, 1971 to 1985

Estuary	Area	Acres Lost	Acres Gained	Classification 1971	1985
Charlotte Harbor	Myakka		3,561	P	C
Tampa Bay	Old Tampa Bay	-17,544		A	P
	Weedon Island	-602		A	P
	Indian Key	-303		A	P
	Lower Tampa Bay	-18,507		A	A/C
Suwannee River	Horseshoe Cove	-7,776		A	P+C
	Suwannee Reef	-7,982		A	C
Apalachee Bay	Ochlocknee Bay		1,765	P	C
	Oyster Bay	-255		A	P
	Old Creek	-673		A	P
	Apalachee Bay	-11,740		A	A/C
Apalachicola Bay	St. Vincent	-133		A	P
	Apalachicola	-84,191		A	C
	Green Point	-2,041		A	P
St. Andrew Bay	North Bay	-1,826		A	C
	St. Andrew Bay	-31,017		A	A/C
Choctawhatchee Bay	Choctawhatchee Bay	-52,725		A	A/C
Pensacola Bay	Pensacola Bay	-39,506		A	A/C
Mississippi Sound	West Fork River	-31		A	P
	Bayou La Batre	-535		A	P
	Dauphin Island		774	P	C
	Portersville Bay	-7,452		A	C
	Graveline Bayou	-224		A	P
	St. Louis Bay	-395		A	P
	West Mississippi Sound	-120,083		A	A/C
	Pass Christian	-2,224		A	P
Galveston Bay	West Bay	-296		A	P
	West Pass		7,936	C	A

Continued...

Estuary	Area	Acres Lost	Acres Gained	Classification 1971	1985
Matagorda Bay	Indianola	-600		A	P
	Magnolia Beach	-561		A	P
	Old Town Lake	-64		A	P
	Port O'Connor	-412		A	P
	Ditch	-20		A	P
	Noble Point	-30		A	P
	Carancahua Bay	-1,051		A	P
	Turtle Bay	-1,234		A	P
	Matagorda Bay	-212,353		A	A/C
San Antonio Bay	San Antonio Bay	-357		C	P
	San Antonio Bay	-133,534		A	A/C
Aransas	St. Charles Bay	-184		A	P
	Shell Point	-510		A	P
	Redfish-Rockport		1,714	P	A
	Aransas Bay	-50,003		A	A/C
Corpus Christi	Aransas Pass	-1,020		A	P
	Laguna Madre North	-8,435		A	P
Laguna Madre	Southern Laguna Madre	-1,879		A	P
	TOTAL	-820,408	15,750		

"Abbreviations: A, Approved; A/C, Approved/Conditional; C, Conditionally Approved; P, Prohibited."