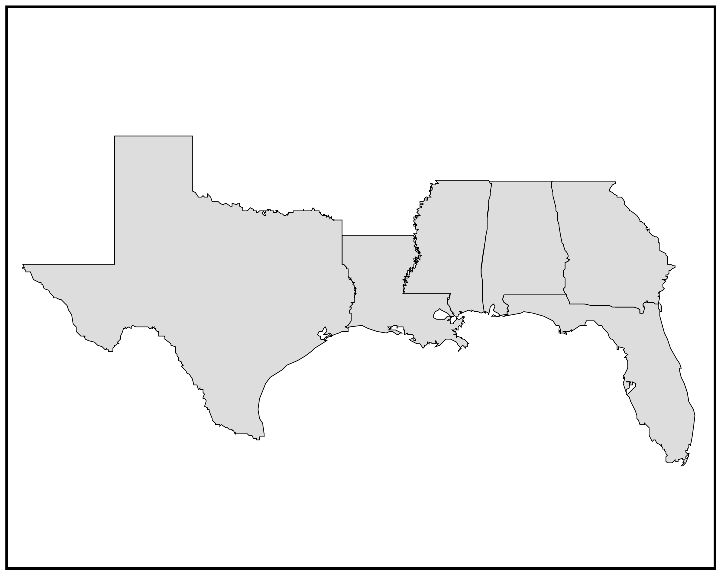
NOAA's Estuarine Eutrophication Survey

Volume 4: Gulf of Mexico Region



November 1997

Office of Ocean Resources Conservation and Assessment
National Ocean Service
National Oceanic and Atmospheric Administration
U.S. Department of Commerce

The National Estuarine Inventory

The National Estuarine Inventory (NEI) represents a series of activities conducted by NOAA's Office of Ocean Resources Conservation and Assessment (ORCA) since the early 1980s to define the nation's estuarine resource base and develop a national assessment capability. Over 120 estuaries are included (Appendix 3), representing over 90 percent of the estuarine surface water and freshwater inflow to the coastal regions of the contiguous United States. Each estuary is defined spatially by an estuarine drainage area (EDA)—the land and water area of a watershed that directly affects the estuary. The EDAs provide a framework for organizing information and for conducting analyses between and among systems.

To date, ORCA has compiled a broad base of descriptive and analytical information for the NEI. Descriptive topics include physical and hydrologic characteristics, distribution and abundance of selected fishes and invertebrates, trends in human population, building permits, coastal recreation, coastal wetlands, classified shellfish growing waters, organic and inorganic pollutants in fish tissues and sediments, point and nonpoint pollution for selected parameters, and pesticide use. Analytical topics include relative susceptibility to nutrient discharges, structure and variability of salinity, habitat suitability modeling, and socioeconomic assessments.

For a list of publications or more information about the NEI, contact C. John Klein, Chief, Physical Environments Characterization Branch, at the address below.

NOAA's Estuarine Eutrophication Survey

ORCA initiated NOAA's Estuarine Eutrophication Survey in October 1992. The goal is to comprehensively assess the scale and scope of nutrient enrichment and eutrophication in the NEI estuaries (see above) and to provide an information base for formulating a national response that may include future research and monitoring. The Survey is based, in part, upon a series of workshops conducted by ORCA in 1991-92 to facilitate the exchange of ideas on eutrophication in U.S. estuaries and to develop recommendations for conducting a nationwide survey. The survey process involves the systematic acquisition of a consistent and detailed set of qualitative data from the existing expert knowledge base (i.e., coastal and estuarine scientists) through a series of surveys, site visits, and regional workshops.

The original survey forms were mailed to over 400 experts in 1993. The methods and initial results were evaluated in May 1994 by a panel of NOAA, state, and academic experts. The panel recommended that ORCA proceed with a regional approach for completing data collection, including site visits with selected experts to fill data gaps, regional workshops to finalize and reach consensus on the responses to each question, and regional reports on the results. The Gulf of Mexico regional workshop was held in July 1996; this document, Volume 4, is the regional report. It was preceeded by the South Atlantic (Volume 1, September 1996), Mid-Atlantic (Volume 2, March 1997), and North Atlantic (Volume 3, July 1997) reports.

A regional report will be completed for the Pacific Coast in the next six months. A national assessment report of the status and health of the nation's estuaries will be developed from the survey results. In addition, an "indicator" of ecosystem health will also be published. Both national products will require one or more workshops to discuss and reach consensus on the methods proposed for conducting these analyses. ORCA also expects to recommend a series of follow-up activities that may include additional and/or improved water quality monitoring, and case studies in specific estuaries for further characterization and analysis.

For publications or additional information, contact Suzanne Bricker, Project Manager, at the address below.

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ORCA Organization

The Office of Ocean Resources Conservation and Assessment (ORCA) is one of four major line offices of the National Oceanic and Atmospheric Administration's (NOAA) National Ocean Service. ORCA provides data, information, and knowledge for decisions that affect the quality of natural resources in the nation's coastal, estuarine, and marine areas. It also manages NOAA's marine pollution programs. ORCA consists of three divisions and a center: the Strategic Environmental Assessments Division (SEA), the Coastal Monitoring and Bioeffects Assessment Division (CMBAD), the Hazardous Materials Response and Assessment Division (HAZMAT), and the Damage Assessment Center (DAC), part of NOAA's Damage Assessment and Restoration Program.

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Acknowledgments

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Contents

Introduction

This section presents an overview of how the Estuarine Eutrophication Survey is being conducted. It includes a statement of the problem, a summary of the project objectives, and a discussion of the project origins and methods. A diagram illustrates the project process and a table details the data being collected. The section closes with a brief description of the remaining tasks. For additional information, please see inside the front cover of this report.

About This Report

This report presents the results of ORCA's Estuarine Eutrophication Survey for 37 estuaries of the Gulf of Mexico region of the United States, plus the Mississippi/Atchafalaya River Plume. It is the fourth in a series of five regional summaries (South Atlantic (NOAA, 1996), Mid-Atlantic (NOAA, 1997), Gulf of Mexico, North Atlantic (NOAA, 1997) and Pacific Coast). A national report on the overall project results is also planned. The Survey is a component of ORCA's National Estuarine Inventory (NEI) – an ongoing series of activities that provide a better understanding of the nation's estuaries and their attendant resources (see inside front cover).

The report is organized into five sections: Introduction, Regional Overview, References, Estuary Summaries and Regional Summary. It also includes three appendices. The Introduction provides background information on project objectives, process, and methods. The Regional Overview presents a summary of findings for each parameter and includes a regional map as well as maps illustrating the results for selected parameters. Next are the Estuary Summaries—one-page summaries of Survey results for each of the 37 Gulf of Mexico estuaries. Each page includes a narrative summary, a salinity map, a table of key physical and hydrologic information, and a matrix summary of data results. The Regional Summary displays existing parameter conditions and their spatial coverage across the region. Appendix 1 lists the regional experts who participated in the survey. Appendix 2 presents the references suggested by workshop participants as useful background material on the status and trends of nutrient enrichment in Gulf of Mexico estuaries. Appendix 3 presents a complete list of NEI estuaries.

The Problem

Between 1960-2010, the U.S. population has increased, and is projected to continue to increase, most significantly in coastal states (Culliton et al., 1990). This influx of people is placing unprecedented stress on the Nation's coasts and estuaries. Ironically, these changes threaten the quality of life that many new coastal residents seek. One of the most prominent barometers of coastal environmental stress is estuarine water quality, particularly with respect to the inputs of nutrients. Coastal and estuarine waters are now among the most heavily fertilized environments in the world (Nixon et al., 1986). Nutrient sources include point (e.g., wastewater treatment plants) and nonpoint (e.g., agriculture, lawns, gardens) discharges. These inputs are known to have direct effects on water quality. For example, in extreme conditions, excess nutrients can stimulate excessive algal blooms that can lead to increased metabolism and turbidity, decreased dissolved oxygen, and changes in community structure—a condition described by ecologists as eutrophication (Day et al., 1989; Nixon, 1995; NOAA, 1989). Indirect effects can include impacts to commercial fisheries, recreation, and even public health (e.g. Boynton et al., 1982; Rabalais and Harper, 1992; Rabalais, 1992; Paerl, 1988; Whitledge and Pulich, 1991; NOAA, 1992; Burkholder et al., 1992; Cooper, 1995; Lowe et al., 1991; Orth and Moore, 1984; Kemp et al., 1983; Stevenson et al., 1993; Burkholder et al., 1992a, Ryther and Dunstan, 1971; Smayda, 1989; Whitledge, 1985; Nixon, 1983).

Reports and papers from workshops, panels and commissions have consistently identified nutrient enrichment and eutrophication as increasingly serious problems in U.S. estuaries (National Academy of Science, 1969; Ryther and Dunstan, 1971; Likens, 1972; NOAA, 1991; Frithsen, 1989; Jaworski, 1981; EPA, 1995). These conclusions are based on numerous local and regional investigations into the location and severity of nutrient problems, and into the specific causes. However, evaluating this problem on a national scale and formulating a meaningful strategy for improvements requires a different approach.

Objectives

The Estuarine Eutrophication Survey will provide the first comprehensive assessment of the temporal scale, scope, and severity of nutrient enrichment and eutrophication-related phenomena in the Nation's major estuaries. The goal is not necessarily to define one or more estuaries as eutrophic. Rather, it is to systematically and accurately characterize the scale and scope of eutrophication-related water-quality parameters in over 100 U.S. estuaries. The project has four specific objectives:

1. To assess the existing conditions and trends, for the base period 1970 to present, of estuarine eutrophication parameters in 129 estuaries of the contiguous United States;

2. To publish results in a series of regional reports and a national assessment report;

3. To formulate a national response to identified problems; and

4. To develop a national "indicator" of estuarine health based upon the survey results.

ORCA also expects to recommend a series of follow-up activities that may include additional and/or improved water-quality monitoring, and case studies in specific estuaries for further characterization and analysis.

Methods

The topic of estuarine eutrophication has been receiving increasing attention recently in both the scientific literature (Nixon, 1995) and in the activities of coastal resource management agencies. In the United States, investigators have generated thousands of data records and dozens of reports over the past decade that document seasonal and annual changes in estuarine water quality, primary productivity and inputs of nutrients. The operative question for this project is how to best use this knowledge and information to characterize these parameters for the contiguous United States.

Preparing for a national survey

To answer this question, ORCA conducted three workshops in 1991-92 with local and regional estuarine scientists and coastal resource managers. Two workshops held at the University of Rhode Island's Graduate School of Oceanography in January 1991 (Hinga et al., 1991) consisted of presentations by invited speakers and discussions of the measures and effects associated with nutrient problems. The purpose was to facilitate the exchange of ideas on how to best characterize eutrophication in U.S. estuaries and to consider suggestions for the design of ORCA's proposed data collection survey. A third workshop, held in April 1992 at the Airlie Conference Center in Virginia, focused specifically on developing recommendations for conducting a nationwide survey.

Given the limited resources available for this project, it was not practical to try to gather and consolidate the existing data records. Even if it were possible to do this, it would be very difficult to merge these data into a comprehensible whole due to incompatible data types, formats, time periods, and methods. Alternatively, ORCA elected to systematically acquire a consistent and detailed set of qualitative data from the existing expert knowledge base (i.e., coastal and estuarine scientists) through a series of surveys, interviews, and regional workshops.

Identifying the Parameters and Parameter Characteristics

To be included in the survey, a parameter had to be (1) essential for accurate characterization of nutrient enrichment; (2) generally available for most estuaries; (3) comparable among estuaries; and (4) based upon existing data and/or knowledge (i.e., no new monitoring or analysis required). Based upon the workshops described above and additional meetings with experts, seventeen parameters were selected (Table 1).

The next step was to establish response ranges to ensure discrete gradients among responses. For example, the survey asks whether nitrogen is high, medium, or low based upon specific thresholds (e.g., high $\geq$ 1 mg/l, medium $\geq$ 0.1 < 1 mg/l, low > 0 <0.1 mg/l, or unknown). The ranges were determined from nationwide data and from discussions with eutrophication experts. The thresholds used to classify ranges are designed to distinguish conditions among estuaries on a national basis and may not distinguish among estuaries within a region.

Temporal Framework: Existing Conditions and Trends

For each parameter, information is requested for existing conditions and recent trends. Existing conditions describe maximum parameter values observed over a typical annual cycle (e.g., normal freshwater inflow, average temperatures, etc.). For instance, for nutrients, ORCA collected information characterizing peak concentrations observed during the annual cycle such as those associated with the spring runoff and/or turnover. For chlorophyll *a*, ORCA collected information on peak concentrations that are typically reached during a bloom period. Ancillary information is also requested to describe the timing and duration of elevated concentrations (or low levels in the case of dissolved oxygen). This information is collected because all regions do not show the same periodicity, and, for some estuaries, high concentrations can occur at any time depending upon estuarine conditions.

For some parameters, such as nuisance and toxic blooms, there is no standard threshold concentration that causes problems. In these cases, a parameter is considered a problem if it causes a detrimental impact on biological resources. Ancillary descriptive information is also collected for these parameters (Table 1).

	PARAMETERS	EXISTING CONDITIONS (maximum values observed over a typical annual cycle)	TRENDS (1970 - 1995)
ALGAL CONDITIONS	**CHLOROPHYLL *A***	• Surface concentrations: Hypereutrophic (>60 µg chl-a/l) High (>20, ≤60 µg chl-a/l) Medium (>5, ≤20 µg chl-a/l) Low (>0, ≤5 µg chl-a/l) • Limiting factors to algal biomass (N, P, Si, light, other) • Spatial coverage[1], Months of occurrence, Frequency of occurrence[2]	• Concentrations[3,4] • Limiting factors • Contributing factors[5]
	TURBIDITY	• Secchi disk depths: High (<1m), Medium (1≥m, ≤3m), Low (>3m), Blackwater area • Spatial coverage[1], Months of occurrence, Frequency of occurrence[2]	• Concentrations[3,4] • Contributing factors[5]
	SUSPENDED SOLIDS	• Concentrations: Problem (significant impact upon biological resources) No Problem (no significant impact) • Months of occurrence, Frequency of occurrence[2]	(no trends information collected)
	NUISANCE ALGAE **TOXIC ALGAE**	• Occurrence Problem (significant impact upon biological resources) No Problem (no significant impact) • Dominant species • Event duration (Hours, Days, Weeks, Seasonal, Other) • Months of occurrence, Frequency of occurrence[2]	• Event duration[3,4] • Frequency of occurrence[3,4] • Contributing factors[5]
	MACROALGAE **EPIPHYTES**	• Abundance Problem (significant impact upon biological resources) No Problem (no significant impact) • Months of occurrence, Frequency of occurrence[2]	• Abundance[3,4] • Contributing factors[5]
NUTRIENTS	**NITROGEN**	• Maximum dissolved surface concentration: High (≥1 mg/l), Medium (≥0.1, <1 mg/l), Low (≥0, < 0.1 mg/l) • Spatial coverage[1], Months of occurrence	• Concentrations[3,4] • Contributing factors[5]
	PHOSPHORUS	• Maximum dissolved surface concentration: High (≥0.1 mg/l), Medium (≥0.01, <0.1 mg/l), Low (≥0, < 0.01 mg/l) • Spatial coverage[1], Months of occurrence	• Concentrations[3,4] • Contributing factors[5]
DISSOLVED OXYGEN	**ANOXIA (0 mg/l)** **HYPOXIA (>0mg/l ≤ 2mg/l)** **BIOL. STRESS (>2mg/l ≤ 5mg/l)**	• Dissolved oxygen condition Observed No Occurrence • Stratification (degree of influence): (High, Medium, Low, Not a factor) • Water column depth: (Surface, Bottom, Throughout water column) • Spatial coverage[1], Months of occurrence, Frequency of occurrence[2]	• Min. avg. monthly bottom dissolved oxygen conc.[3,4] • Frequency of occurrence[3,4] • Event duration[3,4] • Spatial coverage[3,4] • Contributing factors[5]
ECOSYSTEM / COMMUNITY RESPONSE	**PRIMARY PRODUCTIVITY**	• Dominant primary producer: Pelagic, Benthic, Other	• Temporal shift • Contributing factors[5]
	PLANKTONIC COMMUNITY	• Dominant taxonomic group (number of cells): Diatoms, Flagellates, Blue-green algae, Diverse mixture, Other	• Temporal shift • Contributing factors[5]
	BENTHIC COMMUNITY	• Dominant taxonomic group (number of organisms): Crustaceans, Molluscs, Annelids, Diverse mixture, Other	• Temporal shift • Contributing factors[5]
	SUBMERGED AQUATIC VEG. **INTERTIDAL WETLANDS**	• Spatial coverage[1]	• Spatial coverage[3,4] • Contributing factors[5]

NOTES

(1) SPATIAL COVERAGE (% of salinity zone): High (>50, ≤100%), Medium (>25, ≤50%), Low (>10, ≤25%), Very Low (>0, ≤10%), No SAV / Wetlands in system

(2) FREQUENCY OF OCCURRENCE: Episodic (conditions occur randomly), Periodic (conditions occur annually or predictably), Persistent (conditions occur continually throughout the year)

(3) DIRECTION OF CHANGE: Increase, Decrease, No trend

(4) MAGNITUDE OF CHANGE: High (>50%, ≤100%), Medium (>25%, ≤50%), Low (>0%, ≤25%)

(5) POINT SOURCE(S), NONPOINT SOURCE(S), OTHER

Table 1: *Project parameters and characteristics.*

Trends information is requested for characterization of the direction, magnitude, and time period of change for the past 20 to 25 years. In cases where a trend has been observed, ancillary information is requested about the factors influencing the trend.

Spatial Framework

A consistently applied spatial framework was also required. ORCA's National Estuarine Inventory (NEI) was used (see inside front cover). For the survey, each parameter is characterized for three salinity zones as defined in the NEI (tidal fresh 0-0.5 ppt, mixing 0.5-25 ppt, seawater >25 ppt). Not all zones are present in all NEI estuaries; thus, the NEI model provides a consistent basis for comparisons among these highly variable estuarine systems.

Reliability of Responses

Finally, respondents were asked to rank the reliability of their responses for each parameter as either highly certain or speculative inference, reflecting the robustness of the data upon which the response is based. This is especially important given that responses are based upon a range of information sources, from statistically tested monitoring data to general observations. The objective is to exploit all available information that can provide insight into the existing and historic conditions in each estuary, and to understand its limitations.

The survey questions were reviewed by selected experts and then tested and revised prior to initiating the national survey. Salinity maps, based upon the NEI salinity zones, were distributed with the survey questions for orientation. Updates and/or revisions to these maps were made as appropriate.

Collecting the Data

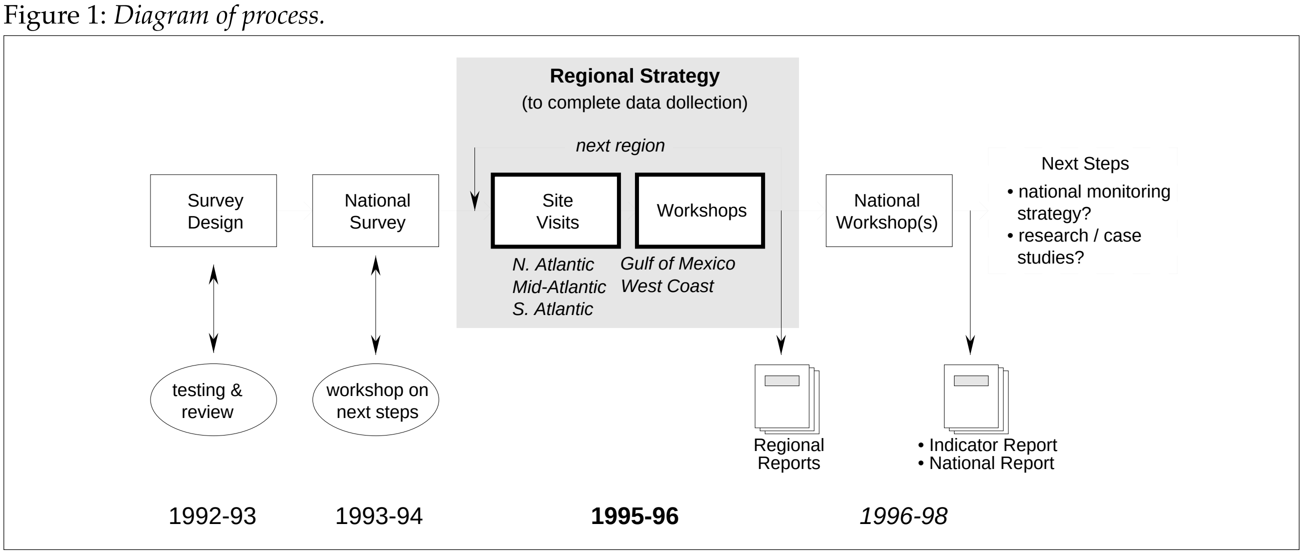
Over 400 experts and managers agreed to participate in the initial survey. Survey forms were mailed to the experts, who then mailed in their responses. The response rate was approximately 25 percent with at least one response for 112 of the 129 estuaries being surveyed.

The initial survey methods and results were evaluated in May 1994 by a panel of NOAA, state, and academic eutrophication experts. The panel recommended that ORCA continue the project and adopt a regional approach for data collection involving site visits to selected experts to fill data gaps and revise salinity maps, regional workshops to finalize and reach consensus on the responses to each question (including salinity maps), and regional reports on the results. The revised strategy was implemented in the summer of 1994 starting with the 22 estuaries of the Mid-Atlantic region (Figure 1).

Estuaries are targeted for site visits based upon the completeness of the data received from the original mailed survey forms. The new information is incorporated into the project data base and summary materials are then prepared for a regional workshop.

Workshop participants are local and regional experts (at least one per estuary representing the group of people with the most extensive knowledge and insight about an estuary). In general, these individuals have either filled out a survey form and/or participated in a site visit. Preparations include sending all regional data to participants prior to the workshop. Participants are also encouraged to bring to the workshop relevant data and reports. At the workshop, at least two work

Figure 1: *Diagram of process.*



groups are established based upon geography. The survey data and salinity maps for each estuary are then carefully reviewed. ORCA staff facilitate the discussions and record the results. At the close of the workshop, participants are asked to identify "critical" references such as reports and other publications that describe nutrient enrichment in one or more of the region's estuaries.

Workshop results are summarized for each estuary and mailed to workshop participants for review. The data are then compiled for presentation in a regional report that is also reviewed by participants prior to publication. The regional process, from site visits to publication of a regional report, takes approximately six months to complete. Some tasks are conducted concurrently.

Next Steps

The regional report is in progress for the Pacific Coast (Figure 1). A national assessment report of the status and health of the nation's estuaries will be developed from the survey results. The regional results and final national data base will be available over the Internet through the ORCA SEA Division's World Wide Web site (see inside front cover). Formulating a national response to estuarine nutrient enrichment, and developing a national "indicator" on coastal ecosystem health, will require one or more workshops to discuss and reach consensus on the methods and products resulting from these analyses. This work is currently scheduled for early 1998. ORCA is funding a series of small contracts with regional experts to provide additional technical support for these tasks.

Regional Overview

This section presents an overview of the survey results. It begins with a brief introduction to the regional geography and a summary of how the results were compiled. Narrative summaries are then presented for each parameter in four subsections: Algal Conditions, Nutrients, Dissolved Oxygen, and Ecosystem/ Community Response. Figures include a regional map showing the location of 37 Gulf of Mexico estuaries and the Mississippi/Atchafalya River Plume, a summary of probable-months-of-occurrence by parameter, four maps illustrating existing conditions for selected parameters, and a summary of recent trends by estuary for selected parameters.

The Setting: Regional Geography

The Gulf of Mexico Region includes 37 estuarine systems plus the Mississippi/Atchafalaya River Plume, encompassing a total water surface area of more than 23, 938 mi^2. The entire region is part of the Gulf Coastal Plain, which consists of the Eastern and Western Gulf Plain and the Mississippi Alluvial Plain (Hunt, 1967). The Gulf Coast is characteristic of a gently sloping, lowland environment. Historical periods of coastal flooding and intense sediment deposition have sculpted the Gulf of Mexico shoreline. Today, much of the region is comprised of extensive wetland areas, sandy beaches and barrier islands. For this report, the Gulf of Mexico Region is divided into four distinct subregions: The Western Florida Coast, the Big Bend/ Panhandle Coast, the Mississippi Delta/Louisiana Coast and the Texas Coast. The Western Florida Coast extends from Florida Bay to near Tarpon Springs, Florida. The Big Bend/Panhandle Coast includes all

Highlights of Regional Results

Note: Tidal fresh = 6%, Mixing = 57%, Seawater = 37% of regional estuarine surface area (11,682 mi^2)
Mississippi/Atchafalya River Plume = 12,256 mi^2

Chlorophyll *a*

Hypereutrophic concentrations (>60 µg/l) are observed episodically in four of 37 estuaries and persistently in three estuaries, affecting less than 1% of the regional estuarine area. High concentrations (>20 µg/l) are observed in 18 estuaries, with highest concentrations occurring in spring and winter in 1/3 of the estuaries, in summer in 1/3, and persistently in the remaining 1/3. Concentrations increased in 13 estuaries, decreased in 6, were unchanged in 13, and were unknown in 5 estuaries. Concentrations are high in the mixing zone of Mississippi/Atchafalaya Plume between February and May, with increasing trends.

Toxic Algal Blooms

Toxic algal blooms, primarily *Gymnodinium* spp., are reported to occur in 25 estuaries, mostly on an episodic basis lasting from days to weeks. These blooms typically occur June - October or January - March. There was no trend in the frequency of occurrence of toxic blooms for all or part of 21 estuaries, and trends were unknown for all or parts of 14 estuaries. Frequency of occurrence of these blooms increased in one estuary and decreased in one. Toxic blooms occur in the Mississippi/Atchafalaya Plume, but it is unknown if they pose a problem to biological resources.

Nitrogen

High nitrogen concentrations (>1.0 mg/l) were reported in 18 of 37 estuaries throughout the year, though in some estuaries they are highest during winter months. Concentrations are reported to have increased in 14 estuaries, decreased in 9 estuaries, showed no trend in 7 estuaries, and trends were unknown for 7 estuaries. High concentrations are observed in the mixing zone of the Mississippi/ Atchafalaya Plume, with increasing trends.

Phosphorus

High phosphorus concentrations (>0.1 mg/l) were observed in 22 estuaries, affecting up to 33% of the regional estuarine area. Concentrations for about half of the estuaries were high all year, and were highest in winter and spring for the rest. Concentrations have increased in 12 estuaries, decreased in 11 estuaries, remained unchanged in 8 estuaries and were unknown in 6 estuaries. Highest concentrations in the mixing zone of the Mississippi/Atchafalaya Plume are medium, with increasing trends.

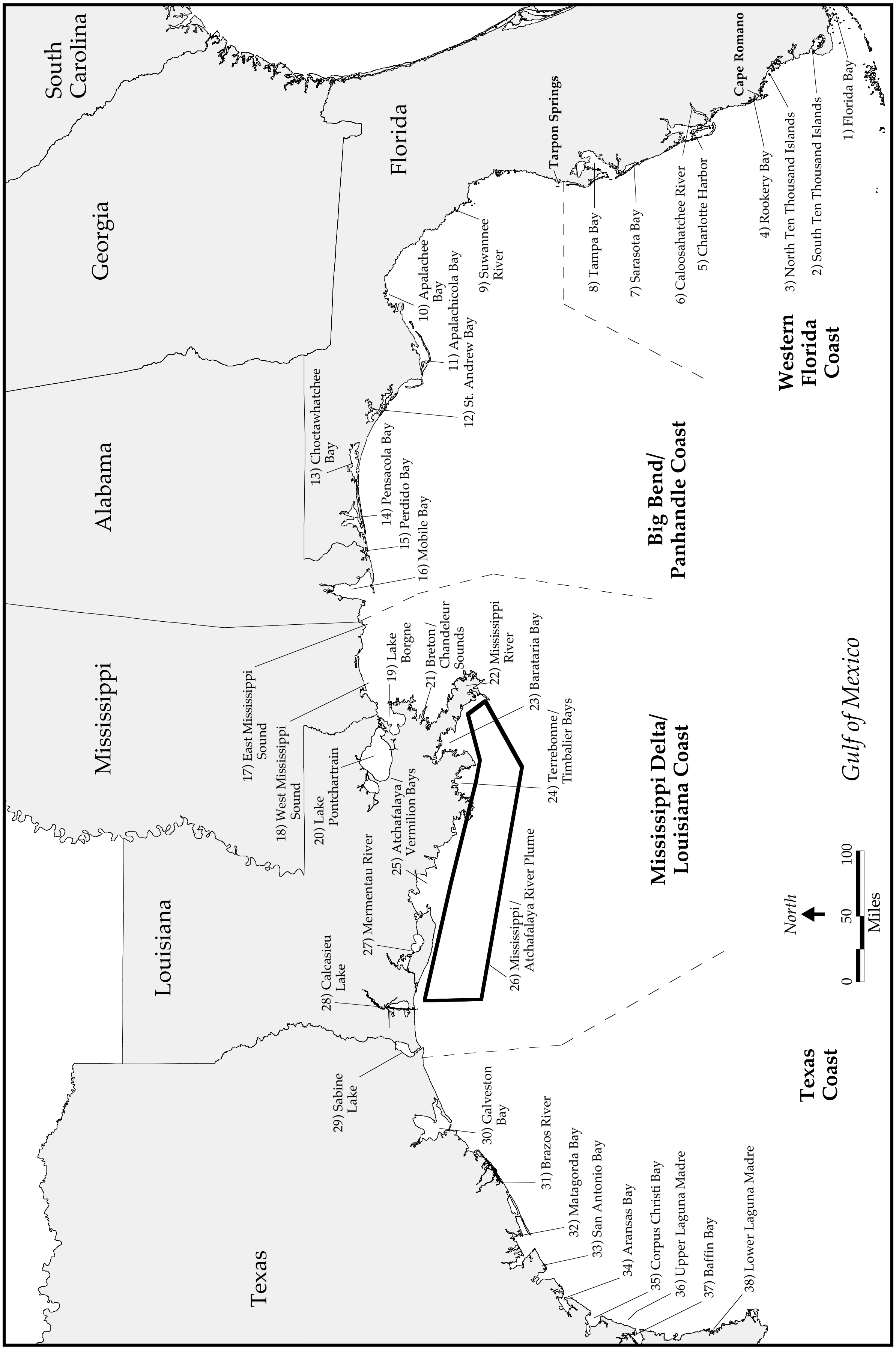
Hypoxia

Hypoxia is observed periodically June - October in 30 of 37 estuaries and is persistent in Lower Laguna Madre, affecting up to 25% of the regional estuarine area. It is observed in bottom waters in about half the estuaries, and throughout the water column in the other half. Water column stratification was reported to be a major influence on hypoxia. Spatial coverage of hypoxic occurrences have decreased in five estuaries, increased in four, remained the same in 14 estuaries, and was unknown in 13 estuaries. Hypoxia is observed in bottom waters of the Mississippi/Atchafalaya Plume, and the spatial extent has increased.

Anoxia

Anoxia is observed periodically in bottom waters of 16 estuaries and throughout the water column in five estuaries, over a maximum of 6% of the regional estuarine area. These events occur during June - October and water column stratification is a significant influence. The spatial coverage of anoxic events has decreased in 4 estuaries, increased in 3 estuaries, remained the same for 13 estuaries and are unknown in 18 estuaries. Anoxia is observed in bottom waters of the Mississippi/ Atchafalaya Plume mixing zone in July and August. Trends in the Plume were unknown.

Figure 2: *Regional map of the Gulf of Mexico's 37 estuaries and the Mississippi/Atchafalaya River Plume.*



of the Big Bend area of Florida, the Florida Panhandle and Mobile Bay in Alabama. The Mississippi Delta/ Louisiana Coast spans the coastline from the Mississippi-Alabama border west to the chenier plain systems of western Louisiana. The Texas Coast subregion stretches from Galveston Bay to Lower Laguna Madre near the U.S.-Mexican border.

Western Florida Coast

The Western Florida Coast contains eight estuarine systems characterized in this report, encompassing approximately 1,737 mi^2 of water surface area (883 mi^2 within Florida Bay). The systems located in the southernmost reaches of Florida are dominated by mangrove islands, tidal channels and extensive wetlands found along the coastal fringe of the Everglades (Mitsch and Gosselink, 1986). The coastal lowland area of southern Florida is extremely complex and highly affected by tidal action, weather-related events and canal structures. From Cape Romano northward, the shoreline consists of sandy beaches, some rocky areas, swamplands and tidal marshes. In this area, the nearly level coastal plain is covered with sand of varying thickness over a limestone or Karst topography (Beccasio, 1982). Freshwater inflow in the Western Florida Coast is dominated by the Hillsborough, Alafia, Peace and Caloosahatchee river systems. Tidal range is approximately 2 to 3 ft. throughout the subregion.

Big Bend/Panhandle Coast

The Big Bend/Panhandle Coast consists of eight estuarine systems encompassing approximately 1,588 mi^2 of water surface area. The Big Bend area of Florida is composed of a drowned Karst topography and dominated by rugged shoreline, wide, shallow pools and expansive areas of freshwater and tidal marshes. Tidal range in the Big Bend area is approximately 3.5 ft. Freshwater inflow is dominated by the Suwannee River, which is responsible for 15% of the total flow to the west coast of Florida (Beccasio, 1982). Estuaries of the Panhandle Coast consist mainly of smooth, sandy beaches and well developed dune systems. The coastline is partially enclosed and protected by barrier islands. The protected bays typically have mud bottoms and high discharge rates from freshwater sources. Tidal range in the Panhandle Coast is 1.5 to 2.0 ft.

The Mississippi Delta/Louisiana Coast

The Mississippi Delta/Louisiana Coast consists of 12 estuarine systems encompassing approximately 5,791 mi^2 of water surface area, and the Mississippi/ Atchafalaya River Plume (12,256 mi^2). The Mississippi Delta area contains seven estuarine systems and subsystems extending from eastern Mississippi Sound through Atchafalaya Bay. The entire Mississippi Delta area is greatly affected by the Mississippi River and indirectly by the Atchafalaya River (Beccasio, 1982). Nearshore environments in this subregion are typically characterized by shallow, turbid embayments and extensive marsh systems located throughout most estuaries. The drainage patterns of this subregion have been highly altered by man-made channels. Tidal range within the Mississippi Delta subregion is 1.2 ft. The three remaining chenier plains estuaries to the west (Mermentau, Calcasieu Lake and Sabine Lake) make up the Louisiana Coast portion of this subregion. The coastline is exposed to ocean waters without the protection of barrier islands. The semi-permanent currents, prevailing southeasterly winds and wave-driven currents control circulation patterns in the immediate nearshore areas of these estuaries (Gosselink et al., 1979). Significant inflow from the Mississippi and Atchafalaya rivers and from small coastal rivers reduce nearshore salinities and bring about density gradients near the estuary mouths (see p. 10). Many of the lowlying inland areas surrounding these estuaries contain extensive brackish and freshwater marshes. The marshes are often partitioned by stranded beach ridges, cheniers or by spoil banks produced from dredged materials (Beccasio, 1982).

Texas Coast

The Texas Coast contains nine estuarine systems encompassing 2,565 mi^2 of water surface area. The subregion is composed of a shoreline dominated by large bays, lagoons and barrier islands. The estuaries are typically bordered by tidal marshes and mud-sand flats (Orlando et al., 1993). As in the Florida Panhandle estuaries, the shallow, lagoonal estuaries of Texas are semi-enclosed by barrier islands. Freshwater discharge is mainly from river systems such as the Trinity, Brazos and Guadelupe. The presence of barrier islands, coupled with low runoff and high evaporation rates along the southern Texas coast, produces hypersaline conditions in these estuaries, especially in the summer months. The lack of a dominant freshwater source can also influence water levels within southern Texas estuaries during dry periods (Orlando et al., 1993). Direct precipitation contributes significantly to the total freshwater discharge into the estuaries of southern Texas. Tidal range in this subregion is from 0.5 ft. to 1.5 ft.

About the Results

The survey results are organized into four sections: Algal Conditions, Nutrients, Dissolved Oxygen, and Ecosystem Response. Each section contains a general overview followed by more detailed summaries for each parameter. This material is based on the individual estuary summaries presented later in this report. Regional patterns and anomalies are highlighted and existing conditions and trends are reviewed. Probable months of occurrence by parameter and by salinity zone are presented in Figure 3. Regional maps summarizing existing conditions for selected parameters are presented in Figure 4 (p. 11). A summary of recent trends for all parameters is presented in Figure 5 (pp. 14-15).

Data Reliability

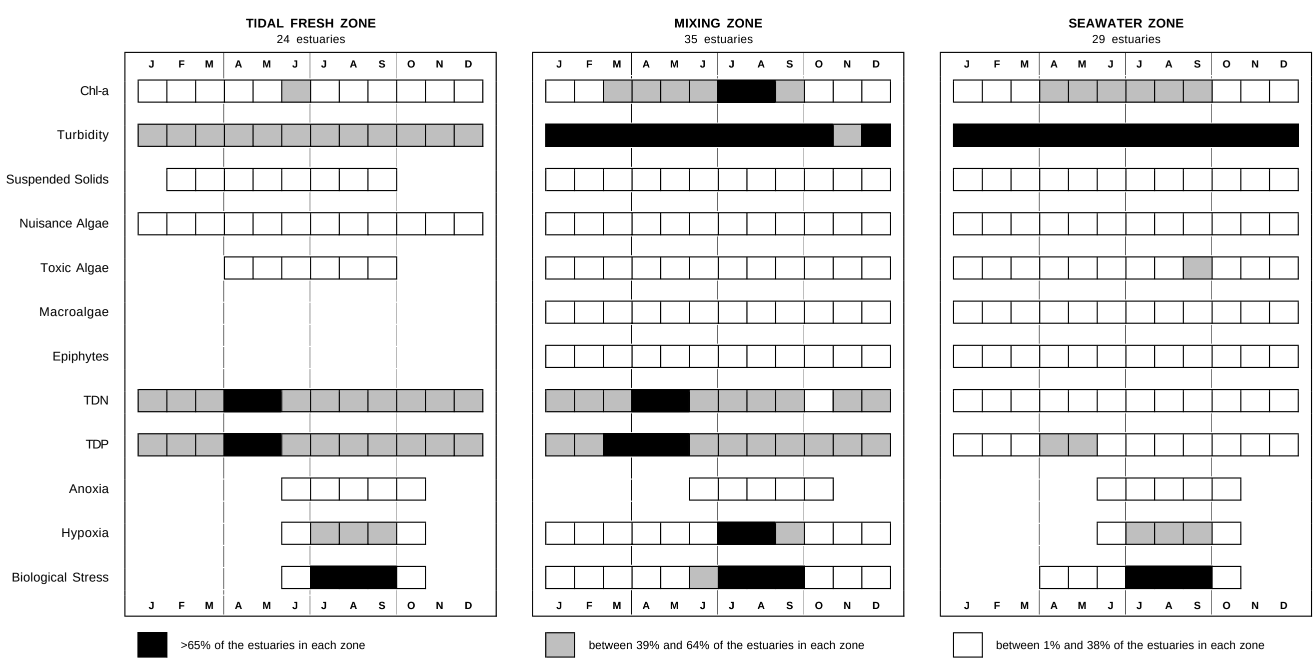
As described in the introduction, participants were asked to rank the reliability of their responses as either highly certain or speculative inference. Over 90 percent of the responses are highly certain. Where relevant, speculative inferences are noted in the narrative below and on the estuary summaries that follow. A highly certain response is based upon temporally and spatially representative data from long-term monitoring, special studies or literature. A speculative inference is based upon either very limited data or general observations. When respondents could not offer even a speculative inference, the value was recorded as "unknown."

Algal Conditions

Algal conditions were examined in the Gulf of Mexico region by characterizing existing conditions and trends for chlorophyll *a*, turbidity, suspended solids, nuisance and toxic algae, macroalgal abundance and epiphyte abundance (Table 1). High concentrations and problem conditions are fairly evenly distributed throughout the region for most of the parameters. Extreme conditions generally occur between April and October, although in some estuaries extreme conditions occur throughout the year. High or greater chlorophyll *a* concentrations (>20 µg/l) occur in 18 estuaries. High

Figure 3: *Probable months of occurrence by parameter and by salinity zone (average).*

This figure illustrates the probable months, over a typical annual cycle, for which parameters are reported to occur at their maximum value. The black tone represents months where maximum values occur in at least 65 percent of the 37 Gulf of Mexico estuaries for a particular salinity zone. For example, tidal fresh zones occur in 24 estuaries; therefore, a black tone indicates a maximum value was recorded in 16 or more estuaries. Similarly, for the mixing zone, black represents 23 or more estuaries, and for the seawater zone it represents 19 or more estuaries. Gray represents months where maximum values occur in 39 to 64 percent of the estuaries in that salinity zone, and unshaded boxes (white) represent months where maximum values occur between 1 and 38 percent of the estuaries in that zone. "Months-of-occurrence" data were not collected for Ecosystem/Community Response parameters (i.e., primary productivity, planktonic community, benthic community, SAV, and intertidal wetlands).



turbidity (secchi disk depths <1 m) occurs in 33 estuaries and suspended solids are problematic in 12 estuaries. Nuisance algae causes biological resource impacts in 22 estuaries, and toxic algae causes biological resource impacts in 25 estuaries. Macroalgal and epiphyte abundance each cause resource impacts in 10 estuaries.

Chlorophyll a

Medium or greater concentrations (>5 µg/l) were reported in 34 estuaries, occurring across a maximum of 65 percent of the regional estuarine surface area. However, as chlorophyll *a* concentrations increase across a gradient of medium to hypereutrophic, the number of affected estuaries and the amount of regional surface area decreases. That is, high or greater concentrations (>20 µg/l) occur in 18 estuaries across a maximum of 22 percent of the regional estuarine surface area, and hypereutrophic concentrations occur in seven estuaries over only four percent of the regional surface area. Except for a very small area in Pensacola Bay, the Big Bend/Panhandle Coast is the only subregion in which high or greater concentrations do not typically occur. High or greater concentrations were reported to occur over a larger area (64 percent) of the regional tidal fresh zone surface area than concentrations in the mixing and seawater zones (20 and 19 percent, respectively). High or greater concentrations generally occur periodically for one or more months between March and October. In Barataria Bay, San Antonio Bay, Aransas Bay and the Laguna Madre system, the concentrations occur throughout the year. Concentrations reported for four estuaries are based in part on speculative inference.

During the period ca. 1970-1995, chlorophyll *a* concentrations decreased in six estuaries and increased in 13 estuaries. Concentrations remained unchanged in 13 estuaries and were unknown in five. Concentrations increased and decreased simultaneously in different parts of the seawater zone of Florida Bay from 1990 to

Mississippi and Atchafalaya River Plume

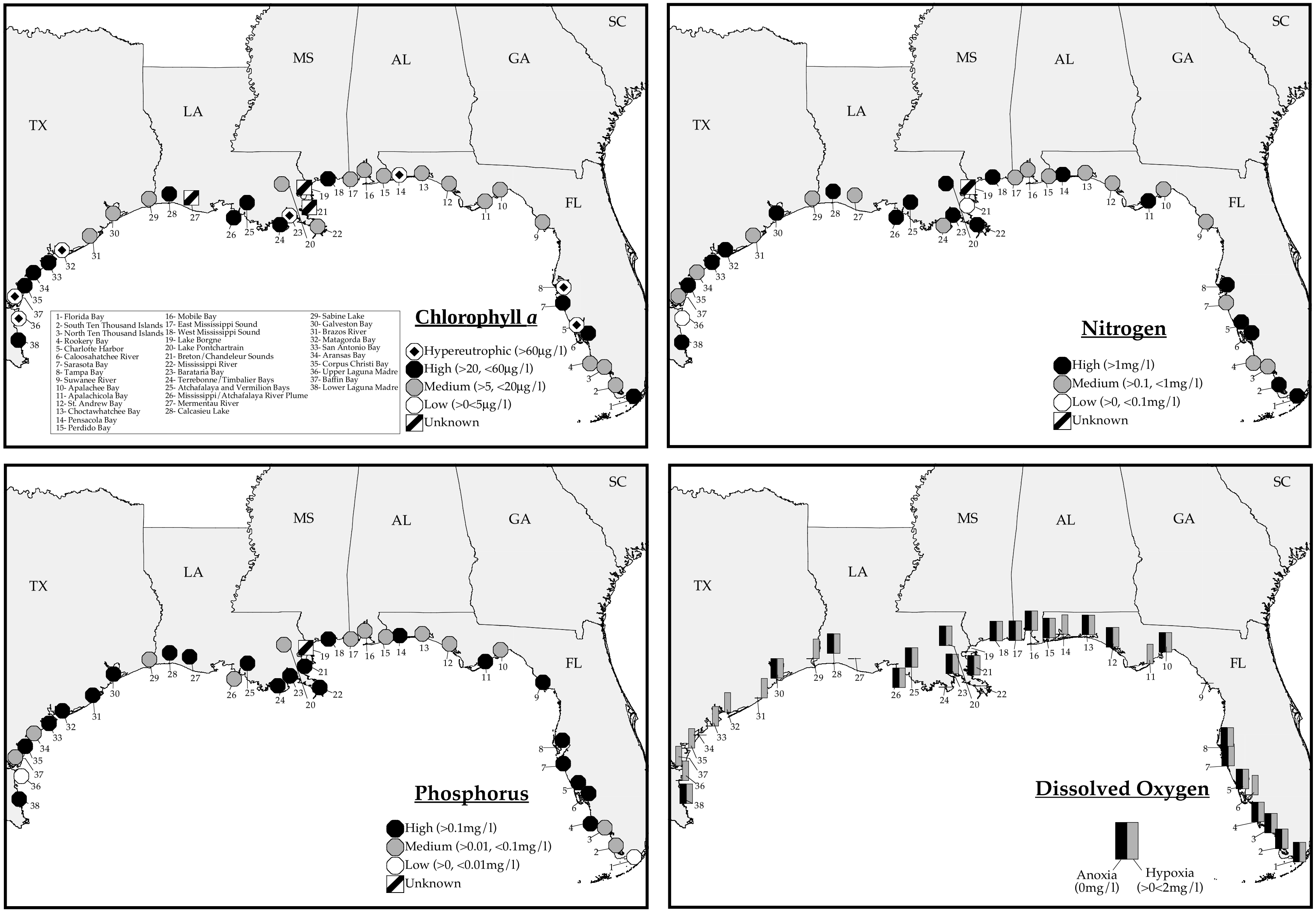
The Mississippi and Atchafalaya River Plume is a 12,256 mi^2 zone located west of the confluence of the Mississippi and Atchafalaya Rivers and the Gulf of Mexico (Rabalais et al., 1992). The plume is included in this report because it has many estuarine characteristics; is a major influence on the water quality of productive estuaries lying to the west (e.g., Barataria, Terrebonne, Timbalier, Atchafalaya, Vermilion Bays); and 28% of the total U.S. annual commercial fishery yield is harvested there.

The watershed for the Mississippi and Atchafalaya Rivers encompasses over one million mi^2 (approximately 40% of the area of the contiguous 48 states), and has an average annual inflow of approximately 700,000 cfs, making it the largest single source of freshwater to the Louisiana continental shelf. This inflow is a major feature of the continental shelf and can be traced as far west as Port Aransas on the South Texas coast (Rabalais et al., 1996). This is also the single largest source of nutrients to the shelf, thus, nutrient-associated water quality degradation in the plume is a major concern.

Nutrient-enhanced productivity on the continental shelf has caused a spatially extensive and seasonally prevalent zone of hypoxia, and to a lesser degree, anoxia, that is observed every summer in bottom waters off the coast of Louisiana and Texas (Rabalais et al., 1992). The loadings from the Mississippi and Atchafalaya Rivers are the source of this widespread hypoxia (Turner and Rabalais, 1994). Evidence from sediment cores and recent sampling surveys shows that the frequency, duration and spatial coverage of these annual hypoxic events have increased during the past century (Eadie et al., 1992; Rabalais et al., 1996). The increase is attributed to land use changes in the watershed since 1900 that have resulted in significant increases in nitrogen and phosphorus inputs and declines in silica (Turner and Rabalais, 1994). These changes in nutrient ratios have resulted in changes in the composition of phytoplanton species; for example, toxic and noxious forms are now present that were previously either absent or less dominant (Rabalais et al., 1996). The increase ofthese toxic forms has obvious implications for human health and fisheries. In addition, as the less preferentially grazed phytoplankton become more dominant, the food chain stucture may be altered (Turner and Rabalais, 1991).

Please note: Conditions in the Plume are not discussed in the general text. For more information on algal conditions, nutrients, dissolved oxygen and ecosystem/community responses, see the Mississippi/Atchafalaya River Plume estuary summary on p. 49.

Figure 4: *Existing conditions for chlorophyll a, nitrogen, phosphorus, and dissolved oxygen. Symbols indicate that an existing condition(s) (e.g., hypereutrophic for chlorophyll a, anoxia and/or hypoxia for dissolved oxygen) was reported in at least a portion of one salinity zone of an estuary at some time during a typical annual cycle. <u>Symbols do not necessarily represent existing conditions across an entire estuary</u>. For a more complete review of individual estuaries, turn to the estuary summaries beginning on page 22.*



1996. The trends reported are based in part on speculative inference for 10 estuaries.

Turbidity

High turbidity concentrations (secchi disk depths <1 m) were reported to occur in 32 estuaries covering 68 percent of the regional estuarine surface area. Although high concentrations occur in all subregions, the Big Bend/Panhandle Coast area is characterized more by moderate turbidity conditions and naturally occurring blackwater areas. High concentrations occur in up to 96 percent of the surface area of the tidal fresh zone, 79 percent of the mixing zone, and 46 percent of the seawater zone. Medium or greater concentrations (secchi disk depths <3 m) were reported to occur in 36 estuaries with a spatial extent of up to 96 percent of the tidal fresh zone, 88 percent of the mixing zone, and 84 percent of the seawater zone. Medium and high concentrations occur persistently throughout the year in 29 estuaries, during the summer in four estuaries and during the winter in three.

During the period 1970-1995, turbidity concentrations were reported to have decreased in nine estuaries, increased in eight estuaries, and remained unchanged in 17 estuaries. Trends were unknown for three estuaries and were based in part on speculative inference in five estuaries (Figure 5).

Total Suspended Solids

Suspended solids were reported as impacting biological resources (e.g., submerged aquatic vegetation, filter feeders, etc.) in 12 estuaries. The impacts are reported to occur all year in four estuaries, periodically from May through September in five estuaries and during the winter months in three estuaries. Information reported was based in part on speculative inference for four estuaries. Trends information was not collected for suspended solids.

Nuisance Algae

Biological resource impacts due to nuisance algae were reported to occur in 22 estuaries throughout the Gulf of Mexico region. In the Western Florida Coast sub region, impacts from *Synechococcus* spp., *Anabaena* spp., *Chlorococcus minutus, Microcystis aeruginosa* and other unidentified blue-green algae and dinoflagellate species occur fromApril to November. Events are weeks to seasonal in duration. In the Panhandle Coast, nuisance algal events are mostly episodic, have a duration of days, and occur between July and September. In Choctawhatchee Bay, however, the events occur periodically and are seasonal in duration. Species identified as impacting resources in the Panhandle Coast are *Anacystis* spp., *Anabaena* spp., *Cladophora* spp., *Enteromorpha* spp., *Chlamydomonas* spp. *and Aphanocapsa* spp. In the Mississippi Delta/Louisiana Coast subregion, events are mostly episodic and last from days in some estuaries to seasons in others. Impacts generally occur between May and September; in Mississippi Sound however, nuisance algae impacts may also occur from January to February, and in Barataria Bay, blue-green algal blooms occur persistently throughout the year. Species identified as impacting resources in the Mississippi Delta/Louisiana Coast subregion are *Exuviella* spp., *Prorocentrum minimum, Alexandrium* spp., *Anabaena circinalis, Katodinium rotundum, Microcystis aeruginosa, Anacystis* spp., *Gymnodinium sanguinium* and other unidentified dinoflagellates. Nuisance algae impacts along the Texas coast occur mostly episodically between May and September. Event durations vary from days to weeks to months. In Upper Laguna Madre, Baffin Bay and part of Lower Laguna Madre, *Aureoumbra lagunensis* impacts occur throughout the year. Other species identified as impacting resources are *Noctiluca* spp. and unidentified blue-green algae and flagellates. The reported information on nuisance algae was based on speculative inference for five estuaries.

During the period 1970-1995, the frequency and/or duration of event occurrences increased, mostly at a high magnitude of change in eight estuaries. Decreases of low to high magnitude occurred in Tampa Bay and Galveston Bay. Conditions remained unchanged in 18 estuaries, and were unknown in 10 estuaries. Trends information was based on speculative inference for seven estuaries (Figure 5).

Toxic Algae

Biological resource impacts due to toxic species were reported to occur in 25 estuaries throughout the Gulf of Mexico region. The impacts occur episodically in 18 of the estuaries and periodically in parts of Florida Bay, Choctawhatchee Bay and Perdido Bay. In Lake Borgne, Brazos River, Matagorda Bay and San Antonio Bay, the toxic algae impacts were reported to have occurred one time only. Toxic algal events in the Gulf of Mexico estuaries are variable in duration, lasting days to weeks in some estuaries and months to seasonally in others. Impacts generally occur between June and October, except in Florida Bay and Apalachee Bay, where impacts occur between January and March. Additionally, in five estuaries, toxic algal events are unpredictable and may occur during any month of the year. The toxic species *Gymnodinium breve* was associated with biological resource impacts in 16 of the 21 impacted estuaries. Other toxic species reported as causing resource impacts are *Alexandrium monilata*, *Anabaena circinalis*, *Anacystis* spp. and *Prorocentrum* *minimum*. Toxic algae also occur in some Gulf estuaries, such as Atchafalaya/Vermilion Bays, but the impacts to biological resources are unknown. Toxic algae information was based on speculative inference for six estuaries.

During the period 1970-1995, increases in the duration and frequency of toxic algal events were reported to occur in Apalachicola Bay. In Tampa Bay, the duration and frequency of toxic algal events decreased during the years 1980 to 1995. Conditions were reported as unchanged in 21 estuaries and were unknown in 14 estuaries. Trends information was based on speculative inference for six estuaries (Figure 5).

Macroalgal Abundance

Biological resource impacts due to macroalgae were reported to occur periodically between April and October in nine estuaries. In Sarasota Bay and San Antonio Bay, impacts occur in February, and in parts of Florida Bay, impacts occur persistently throughout the year. Also, impacts were speculated to occur episodically during May in the Suwannee River mixing zone. Macroalgal conditions were unknown in two estuaries. Reported macroalgal abundance information was based in part on speculative inference for two estuaries.

During the period 1970-1995, macroalgal abundance impacts increased in Florida Bay, Lake Pontchartrain, San Antonio Bay, Aransas Bay and Corpus Christi Bay. Declines of a high magnitude occurred in Tampa Bay and were speculated to have occurred in Sarasota Bay. Conditions remained unchanged in 19 estuaries and were unknown in 12 estuaries. Reported macroalgal abundance trends were based in part on speculative inference for four estuaries (Figure 5).

Epiphyte Abundance

Biological resource impacts due to epiphytes were reported to occur in 10 estuaries. Conditions occur throughout the year in four estuaries and periodically between April and October in six estuaries. Epiphyte abundance conditions are unknown in four estuaries. Reported epiphyte abundance information was based in part on speculative inference for four estuaries.

Epiphyte abundance impacts increased (ca. 1970-1995) in Florida Bay, Lake Pontchartrain, San Antonio Bay, Aransas Bay and Corpus Christi Bay. No decreases in epiphyte abundance were reported, and conditions remained unchanged in 20 estuaries. Epiphyte abundance was unknown for 13 estuaries and based in part on speculative inference for three estuaries (Figure 5).

Nutrients

Nutrient concentrations were characterized by collecting information on existing conditions (maximum values observed over a typical annual cycle) and trends. The intent was to collect information for total dissolved nitrogen and phosphorus, since it is the dissolved forms that are most available for uptake by phytoplankton. Unless specifically noted, information for nutrients presented in this report refers to total dissolved nitrogen (TDN) and phosphorus (TDP), including the inorganic and organic forms. The individual estuary pages should be consulted for more in-depth summaries of reported nutrient concentrations.

Results indicate that medium and high concentrations of both nitrogen and phosphorus are pervasive in the Gulf of Mexico region. High concentrations of phosphorus (≥ 0.1 mg/l) were reported in 22 estuaries. For 10 estuaries, concentrations were high all year. High concentrations of nitrogen (≥ 1.0 mg/l) occurred in 18 estuaries; in eight estuaries, concentrations were high all year. Medium concentrations of nitrogen ($\geq 0.1, < 1.0$ mg/l) occurred in 29 estuaries; persistently in 12. Medium phosphorus concentrations ($\geq 0.01, < 0.1$ mg/l) were observed in 36 estuaries, occurring throughout the year in 11 estuaries.

Nitrogen

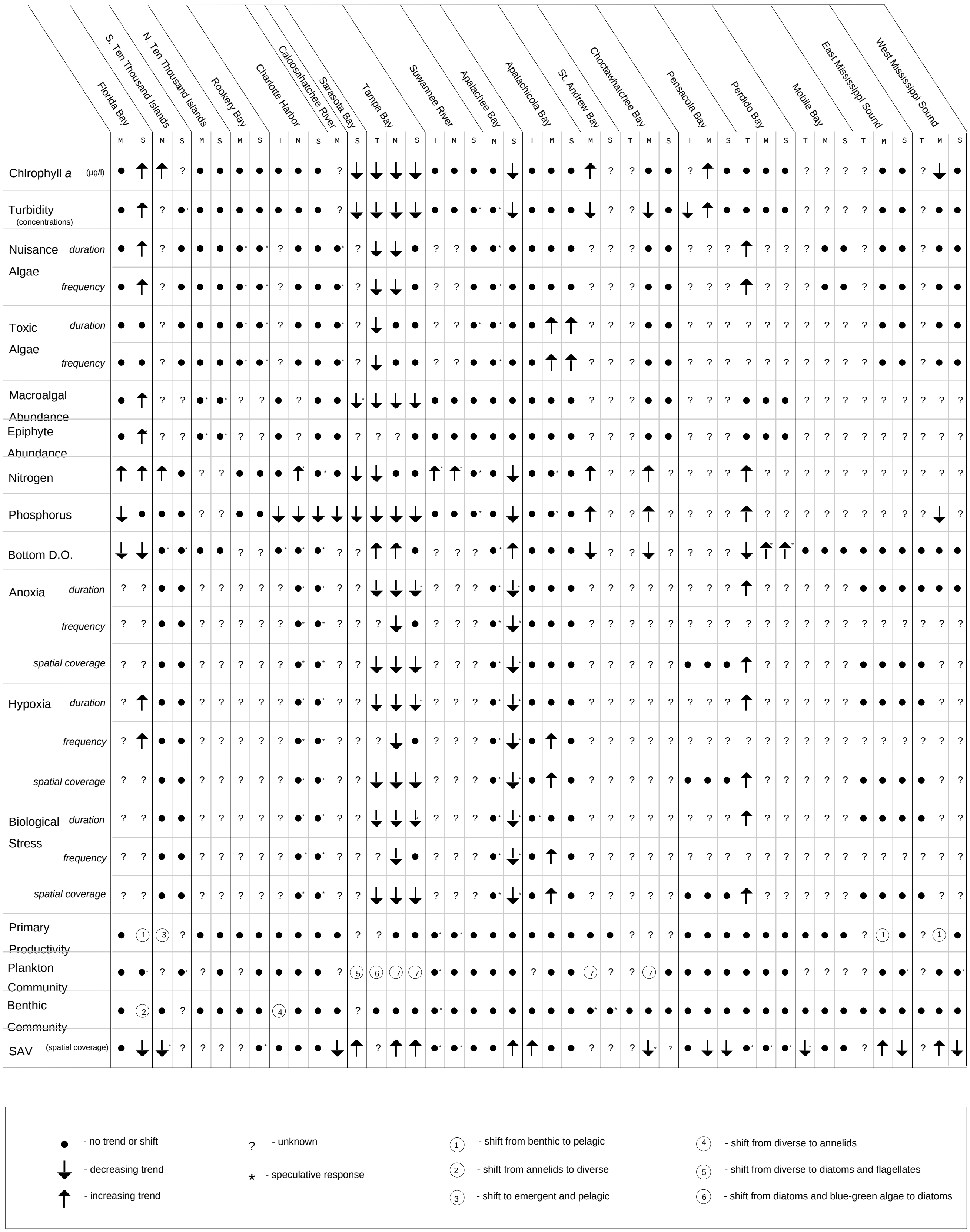
High nitrogen concentrations have been observed in 18 of the 37 estuaries in up to 78 percent of the regional tidal fresh zones, 22 percent of the mixing zone, and up to 5 percent of the seawater zone. High nitrogen concentrations are observed in up to 19 percent of the regional estuarine area mostly during the summer and fall, but for eight estuaries concentrations are persistently high. Medium concentrations of nitrogen were reported in 29 estuaries in up to seven percent of the region tidal fresh zone, up to 50 percent of the mixing zone and up to 21 percent of the seawater zone.

Between 1970 and 1995, nitrogen concentrations have increased in 13 estuaries and decreased in nine estuaries. For eight estuaries concentrations did not change, and for seven estuaries trends were unknown. Responses were based on speculative inference for six estuaries.

Phosphorus

High phosphorus concentrations were reported in 22 of the 37 estuaries in up to 78 percent of the regional tidal fresh zone, up to 44 percent of the regional mixing zone and up to 11 percent of the regional seawater zone. High concentrations were observed in up to 33

Figure 5: *Recent trends (1970 - present) for selected parameters by estuary by salinity zone (T, tidal fresh; M, mixing; S, seawater). All salinity zones are not present in all estuaries. Most of the 2,016 possible values are no trend (940). There are 154 decreasing trends, 155 increasing trends, and 737 unknowns. The remaining 30 responses display shifts in the primary*



productivity, planktonic community or benthic community. 151 values are based on speculative inferences. For a more complete listing of the trends parameters, see Table 1 on page 3

Lake Borgne	Lake Pontchartrain		Breton / Chandeleur Sounds		Mississippi River		Barataria Bay			Terrebonne / Timbalier Bays		Atchafalaya / Vermilion Bays		Miss. / Atchafalaya R. Plume	Mermentau River		Calcasieu Lake		Sabine Lake			Galveston Bay			Brazos River			Matagorda Bay			San Antonio Bay		Aransas Bay			Corpus Christi Bay	Upper Laguna Madre	Baffin Bay	Lower Laguna Madre	
M	T	M	M	S	T	M	T	M	S	T	M	M	S	M	T	M	T	M	T	M	S	T	M	S	T	M	S	T	M	S	M	S	T	M	S	S	S	M	S	
?	↑	●	?	?	●	●	↑	↑	↑	↑*	↑*	↑	●	?	?	↑	●	●	?	↓	↓	↓*	●	?	●	●	●	●	●	●	●	●	●	↑	↑	↑	↑	↑	↑	(µg/l) Chlorophyll *a*
?	↑*	↓*	?	?	●	●	●	?	?	↓	↓	↓	●	●	●	●	●	●	↓	↓	↓	●	●	?	●	↑	↑	↑	↑	●	●	●	●	●	●	↑	↑	●	↑	Turbidity (concentrations)
?	?	●	?	?	?	?	↑	?	?	?	?	?	?	?	?	●	●	↑*	?	↓	●	●	●	?	●*	●	●	●	●	●	●	●	●	?	●	↑	↑	●	↑	Nuisance Algae — *duration*
?	?	●	?	?	?	?	↑	?	?	?	?	?	?	?	?	●	●	↑*	?	↓	●	●	●	?	●*	●*	●*	●	●	●	●	●	●	↑*	●	↑	↑	●	↑	*frequency*
?	?	●	?	?	?	?	?	?	?	?	?	?	?	?	?	●	●	?	?	●	●	●	●	?	●*	●	●	●	●	●	●	●	●	●	●	?	?	●	●	Toxic Algae — *duration*
?	?	●	?	?	?	?	?	?	?	?	?	?	?	?	?	●	●	?	?	●	●	●	●	?	●*	●	●	●	●	●	●	●	●	●	●	?	?	●	●	*frequency*
?	●	●	?	?	?	?	●	●	●	●	●	●	●	●	●	●	●	●	?	?	●	?	?	?	●	●	●	●*	↑	●*	●	↑	●	?	↑	●	●	●	●	Macroalgal Abundance
?	●	●	?	?	?	?	●	?	●	●	●	●	●	●	●	●	●	●	?	?	●	?	?	?	●	●	●	●*	↑	●*	●	↑	●	?	↑	●	●	●	●	Epiphyte Abundance
?	↑	●	?	?	●	●	↑*	↑	↑	↑	↑	↑	●	●	↓*	↓*	●	↓*	↓	↓	↓	●	●	?	?	↓	●	↑	●	●	↓	↓	?	●	●	●	↓	↑	●	Nitrogen
?	↑	↑*	?	?	●	●	↑*	●	●	●	●	↑	●	↓	●	●	↓*	↓*	↓	↓	↓	●	●	?	?	●	↑	↑	↑	↑*	●	↑	?	↑	●	↑	↓	↑	↑	Phosphorus
?	?	●	●*	?	●	●	?	?	?	↓	●	↓	?	●	●	↑	↑	↑	↑	●	●	●	●	?	●	●	↑	●	●	●	↑	●	?	●	↑	●	●	●	●*	Bottom D.O.
?	?	●	?	●*	●	●	?	?	?	↑	●	?	?	●	↑	●	↓	●	↓	↓*	●	●	●	?	●	●	●	?	?	?	●	●	?	●	●	●	●	●	●	Anoxia — *duration*
?	?	●	?	●*	●	●	?	?	?	↑	?	?	?	●	?	●	↓	●	↓	↓*	●	●	●	?	●	●	●	?	?	?	●	●	?	●	●	●	●	●	●	*frequency*
?	?	●	?	●*	●	●	?	?	?	↑	●	?	?	●	↑	●	↓	●	↓	↓	●	●	●	?	●	●	●	?	?	?	●	●	?	●	●	●	●	●	●	*spatial coverage*
?	?	●	?	●*	●	●	?	?	?	↑	●	↑	?	●	↑	↓*	↓	●	↓	↓*	●	●	●	?	●	●	●	?	?	?	↓	●	?	●	●	●	●	●	↑	Hypoxia — *duration*
?	?	●	?	●*	●	●	?	?	?	↑	?	↑	?	●	?	↓*	↓	●	↓	↓*	●	●	●	?	●	●	●	?	?	?	↓	●	?	●	●	●	●	●	↑	*frequency*
?	?	●	?	●*	●	●	?	?	?	↑	●	↑	?	●	↑	↓	↓	●	↓	↓	●	●	●	?	●	●	●	?	?	?	↓	●	?	●	●	●	●	●	↑*	*spatial coverage*
?	?	●	?	●*	●	●	?	?	?	↑	●	↑	?	●	↑	●	↓	●	↓	↓*	●	●	●	?	●	●	●	?	?	?	↓	●	?	●	●	●	●	●	↑	Biological Stress — *duration*
?	?	●	?	●*	●	●	?	?	?	↑	?	↑	?	●	?	●	↓	●	↓	↓*	●	●	●	?	●	●	●	?	?	?	↓	●	?	●	●	●	●	●	↑	*frequency*
?	?	●	?	●*	●	●	?	?	?	↑	●	↑	?	●	↑	●	↓	●	↓	↓	●	●	●	?	●	●	●	?	?	●	↓	●	?	●	●	●	●	●	↑*	*spatial coverage*
?	●	(8)	●	?	●	●	?	(10)	(10)	(12)	?	●	●	●	●	(10)	●	●	●	●	●	●	●	?	●	●	●	●	●	●	●	●	●	●	●	(13)	●	●	(13)	Primary Productivity
?	?	(9)	?	?	●	●	?	?	●	●	●	●	●	?	●	●	●*	●*	?	?	?	?	?	?	●	●	●	●	●	●	●	●	●	●	●	(14)	(14)	●	(14)	Plankton Community
?	●	●	●*	●*	●	●	●	(11)	(11)	●	●	(4)	●	?	●	●	●	●	●	●	●	●	●	?	●	●	●	●	●	●	●	●	?	●	●	(4)	(4)	(15)	(4)	Benthic Community
?	●	↓	●	↓	●	●	↑	↑	↑	↑	?	●	●	?	●	↓	●	●	●	↓	↓	●	●	?	●	↑	●	●	↓	●	●	↓	●	●	●	↓	↑	?	↑	(spatial coverage) SAV

(7) - shift from blue-green algae to diatoms

(8) - shift from wetlands to pelagic and wetlands

(9) - shift from blue-green algae to diverse

(10) - shift from emergent to pelagic and benthic

(11) - shift from pelagic to benthic/pelagic

(12) - shift from anthropods to diverse

(13) - shift from benthic to pelagic/SAV

(14) - shift from diverse to Aureoumbra

(15) - no benthic life

percent of the regional estuarine area during the summer and fall for most estuaries, but persistently in 10 estuaries. Medium phosphorus concentrations were reported for 22 estuaries in up to six percent of the tidal fresh area, up to 41 percent of the regional mixing zone and up to 22 percent of the regional seawater zone.

Between 1970 and 1995, phosphorus concentrations decreased in 11 estuaries and increased in 11 estuaries. Phosphorus concentrations remained the same in nine estuaries; trends were unknown in six estuaries. For six estuaries, responses were based on speculative inference (Figure 5).

Dissolved Oxygen

Dissolved oxygen conditions were characterized by collecting information about existing conditions and trends for anoxia (0 mg/l), hypoxia (>0 mg/l, ≤2 mg/l), and biologically stressful concentrations (>2 mg/l, ≤5 mg/l). The occurrence, timing (both time of year and duration), frequency of occurrence (periodic or episodic), location in the water column (surface, bottom, or throughout) and spatial extent (high, medium, or low) of each observed condition is recorded. The influence of water column stratification (high, medium, low, not a factor) on development of low dissolved oxygen was also noted.

Anoxic conditions were reported to occur in 21 estuaries, and hypoxia in 31 estuaries. In general, both conditions are observed annually during the summer and early fall (June to October) and water column stratification is reported to influence their development. Typically, these conditions are observed in bottom waters; however, anoxia and hypoxia occur throughout the water column in some estuaries. In general, anoxia is observed in all subregions except Texas, while hypoxia is observed in estuaries throughout the region. Biologically stressful concentrations were reported to occur annually in the summer and early fall in all 37 estuaries. For the majority of estuaries, biologically stressful concentrations occur throughout the water column; stratification was reported as a factor in the development of this condition.

Minimum bottom water dissolved oxygen concentrations were reported as unchanged in 16 estuaries from 1970 to 1995. Concentrations increased in nine estuaries, decreased in four estuaries and trends were unknown for seven estuaries. In Perdido Bay, concentrations were reported to have increased in the mixing and seawater zones and to have decreased in the tidal fresh zone. For six estuaries, responses were based on speculative inference.

Anoxia

Anoxic conditions were reported to occur mostly in bottom waters of 21 estuaries, accounting for two to six percent of the regional estuarine area and occurring throughout all subregions except for Texas. This condition occurs on a periodic basis from June through October. The influence of water column stratification on the development of anoxia ranged from low to high except for North Ten Thousand Islands, Sarasota Bay, Barataria Bay and Calcasieu Lake, for which it was not a factor. The spatial extent of anoxia is low in the tidal fresh zone (up to 16 percent of area), and very low in the mixing (up to five percent) and seawater zone (up to seven percent) zones. For part or all of three estuaries it is unknown whether anoxia occurs, and for part or all of five estuaries, responses were based on speculative inference.

Declines in duration, frequency of occurrence, and spatial coverage of anoxic events were reported for Tampa Bay, Apalachee Bay, Sabine Lake and Galveston Bay. Increases in duration and spatial coverage were reported for Perdido Bay, Atchafalaya/Vermilion Bays, and Calcasieu Lake, and increases in frequency of occurrence were also noted for Atchalafaya/Vermilion Bays. For 17 estuaries anoxia trends were reported as unchanged, and for 14 estuaries trends were reported as unknown. Trend assessments were based on speculative inference for four estuaries (Figure 5).

Hypoxia

Hypoxic conditions (>0 mg/l, ≤2 mg/l) were reported to occur in bottom waters in 26 estuaries and throughout the water column in five estuaries. For the majority of estuaries, this condition is observed periodically from June through October, with the exception of Lower Laguna Madre where it is observed year-round. The spatial extent of observed hypoxia is up to a maximum of 25 percent of the regional estuarine area, up to 39 percent of the tidal fresh zone, up to 18 percent of the mixing zone and up to 35 percent of the seawater zone. This assessment was based on speculative inference for two estuaries.

Decreases in the duration, frequency of occurrence and spatial coverage of hypoxic events were reported for Tampa Bay, Apalachee Bay, Sabine Lake, Galveston Bay and Aransas Bay. Increases in one or all characteristics of hypoxia were reported for Atchafalaya/Vermilion Bays, Lower Laguna Madre, Florida Bay, Perdido Bay and Apalachicola Bay. Trends for the remaining Gulf estuaries were almost equally split between no change (14 estuaries) in hypoxia and unknown (12 estuaries). Duration and spatial coverage increased in the tidal fresh zone of Calcasieu Lake, but in the mixing zone all three characteristics decreased. For five estuaries, trends assessments were based on speculative inference (Figure 5).

Biological Stress

Biologically stressful levels of dissolved oxygen (>2 mg/l, ≤5 mg/l) were reported to occur in all Gulf of Mexico estuaries, except Lake Borgne and Mermentau River. This condition occurs on a periodic basis in bottom waters of 19 estuaries and throughout the water column in part or all of 23 estuaries. In the majority of estuaries it occurs from June through October, though in some Texas estuaries it begins in April, and in Lower Laguna Madre the condition is persistent. Stratification is a factor in most estuaries, but for all or part of 15 estuaries it is not a factor. The cumulative area over which it is reported accounts for a maximum of 48 percent of the total regional estuarine area, up to 67 percent of the tidal fresh zone, up to 41 percent of the mixing zone and up to 57 percent of the seawater zone. For two estuaries, responses were based on speculative inference.

Decreases in duration, frequency of occurrence, and spatial extent were reported for Tampa Bay, Apalachee Bay, Sabine Lake, Galveston Bay and Aransas Bay. Increases in one or all characteristics of biologically stressful concentrations were noted for Apalachicola Bay, Perdido Bay, Atchafalaya/Vermilion Bays, Calcasieu Lake and Lower Laguna Madre. For 15 estuaries, biologically stressful trends were unchanged; trends were reported to be unknown for 12 estuaries. For seven estuaries, responses were based on speculative inference (Figure 5).

Ecosystem/Community Response

The responses of estuarine ecosystems to nutrient inputs were characterized by collecting information on the status and trends of four parameters: primary productivity, pelagic and benthic communities, and submerged aquatic vegetation (SAV). Results indicated that primary productivity in the Gulf of Mexico region is dominated by the pelagic community or a mixture of pelagic and other communities (i.e., benthic, submergent and/or emergent). Diatoms, or a diverse mixture that includes diatoms, dominate the plankton community, while annelids, or a diverse mixture that includes annelids, dominate the benthic community. SAV was reported in all but three of the region's estuaries, mostly in the mixing and seawater zones at a low or very low spatial coverage.

Information regarding historical shifts in the estuarine ecosystem indicated that changes took place in 27 Gulf of Mexico estuaries during the period 1970-95, primarily in the mixing and seawater zones. Changes in all four ecosystem parameters occurred in three estuaries at opposite ends of the Gulf of Mexico region – Florida Bay and Upper and Lower Laguna Madre. Changes in three parameters (mostly primary productivity, the benthic community and SAV spatial coverage) were reported in Lake Pontchartrain, Barataria Bay, Terrebonne/Timbalier Bays and Baffin Bay. In general, where changes in primary productivity occurred, dominance shifted from a benthic to a pelagic community or from an emergent to a submergent community. Within the pelagic community, dominance shifted from blue-green algae to diatoms in a number of Florida estuaries and from diatoms or a diverse mixture of plankton groups to the brown tide algae, *Aureoumbra lagunensis,* in estuaries of southern Texas. A shift from a diversely mixed benthic community to one dominated increasingly by annelids was reported in six estuaries, mostly in the Texas Coast subregion. The spatial coverage of SAV was reported to have declined in parts of 17 estuaries and to have increased in parts of 12 estuaries. The factors most attributed to shifts/trends in the ecosystem parameters were changes in point and nonpoint sources, changes in hydrology and the physical alteration of the watershed.

Primary Productivity

Pelagic (plankton) communities were identified as the dominant primary producer in one or more salinity zones in 27 Gulf of Mexico estuaries, representing 47 percent of the region's estuarine surface area. In most of the region's remaining area, the dominant producer reported was a diverse mixture of pelagic communities and one of three other producers: emergent (wetland) communities in parts of 12 estuaries, benthic communities in parts of nine estuaries, and SAV in parts of three estuaries. Across the region, pelagic organisms were the most reported primary producer in each salinity zone. A diverse mixture of pelagic and benthic communities was dominant in 50 percent of the region's tidal fresh zone, although this area was comprised of only two estuaries: Barataria Bay and the Atchafalaya/Vermilion Bays. Pelagic communities were the most reported primary producer in all Gulf subregions except the Mississippi Delta/Louisiana Coast, where a mixture of pelagic and benthic organisms were dominant. Wetlands, or a mixture of wetlands and pelagic communities, were reported mostly in the mixing zone within the Mississippi Delta/Louisiana Coast and Panhandle Coast subregions. SAV, or a diverse mixture of SAV and pelagic communities, was the dominant primary producer in the seawater zone of Florida Bay and estuaries of the Texas Coast.

Historical shifts in dominance (ca. 1970-95) from one primary producer to another, were reported in parts of 13 estuaries, mostly in the mixing and seawater zones. In six estuaries, dominance shifted from benthic to pelagic organisms, primarily due to changes in non point sources and/or the physical alteration of the watershed. In five other estuaries, primary production shifted from an emergent to a submergent system (either pelagic, benthic and/or SAV) as a result of disturbances to the estuarine basin. A shift from pelagic to benthic organisms in the Apalachee Bay seawater zone was attributed to changes in point sources; a similar shift in the Atchafalaya/Vermilion Bays tidal fresh zone was attributed to physical alteration of the watershed. Shifts were reported as unchanged in all or parts of 27 estuaries (51 percent of the region's estuarine surface area). No information was available for the remaining 17 percent of the region.

Pelagic Community

Diatoms were reported as the dominant plankton group, in terms of abundance, in the Gulf of Mexico region, occurring in at least one salinity zone in 20 estuaries, particularly in the mixing and seawater zones and in the Western Florida Coast and Big Bend/Panhandle Coast subregions. In parts of 17 estuaries, no single plankton group was identified as dominant, but rather a mixture of groups, including diatoms, flagellates, and/or blue-green algae. Communities dominated by blue-green algae, or a diverse mixture that included blue-green algae, were reported in parts of eight estuaries, including 65 percent of the region's tidal fresh zone. Flagellates, or a diverse mixture that included flagellates, were reported in parts of eight estuaries. No information was available for parts of 16 estuaries.

During the period 1970-1995, shifts in plankton dominance from one taxonomic group to another were reported in eight estuaries, primarily in the mixing and seawater zones. In three estuaries within the Western Florida Coast and Panhandle Coast subregions, dominance shifted from blue-green algae to diatoms, due to changes in point and nonpoint sources. A shift from diatoms, or a diverse mixture of plankton groups to the brown tide alga, *Aureoumbra lagunensis*, was reported in the seawater zone of Baffin Bay and the Upper and Lower Laguna Madre, and was attributed to transport from offshore waters and changes in nonpoint sources. Dominance shifted to blue-green algae from diatoms in the seawater zone of Florida Bay as a result of changes in point and nonpoint sources, and from green algae in the mixing zone of Lake Pontchartrain due to unknown factors. Shifts were reported as unchanged in all or parts of 26 estuaries (59 percent of the region's estuarine surface area). No information was available for parts of 18 estuaries.

Benthic Community

In parts of 28 estuaries, no single group was identified as the dominant (most abundant) benthic community, but rather a diverse mixture of groups, including annelids, crustaceans, mollusks, and/or insects. Annelids were reported as the dominant community in all or parts of 24 estuaries, and a diverse mixture that included annelids was reported in parts of nine estuaries. Communities dominated by insects, or a diverse mixture that included insects, were reported in the tidal fresh zone of seven estuaries within the Panhandle Coast and Mississippi Delta/Louisiana Coast subregions. Mollusks, or a diverse mixture that included mollusks, were reported in parts of five estuaries, including 54 percent of the region's tidal fresh zone. The tidal fresh and mixing zones of Atchafalaya/Vermilion Bays were reported to be a diverse mixture with mollusks and crustaceans dominating.

Shifts in benthic dominance from one taxonomic group to another were reported to have occurred in eight Gulf of Mexico estuaries during the period 1970-1995. In five estuaries within the Texas Coast and one within the Louisiana Coast, a shift from a diversely mixed community to one dominated increasingly by annelids was reported, mostly in the mixing and seawater zones. The contributing factors attributed to this shift were changes in point sources and the occurrence of brown tides. Crustaceans declined in dominance in the mixing zone of Barataria Bay and the Terrebonne/Timbalier Bays due to physical alteration of the watershed. A shift from annelids to mollusks was reported in the mixing zone of Florida Bay; however, the factors contributing to the shift were unknown. The benthic community shifted from a diverse mixture to one increasingly dominated by an unnamed exotic species in the tidal fresh zone of Charlotte Harbor. Shifts were reported as unchanged in parts of all but five Gulf of Mexico estuaries; in two of those estuaries (Sarasota Bay and Lake Borgne), no information was available.

Submerged Aquatic Vegetation (SAV)

The presence of SAV was reported in parts of every Gulf of Mexico estuary except three in the Mississippi Delta/Louisiana Coast subregion (Mississippi River, Atchafalaya/Vermilion Bays, Mermentau River). No SAV was reported in parts of 17 estuaries. The spatial coverage of SAV (to depths of one meter below mean low water) was reported to be low (>10≤25 percent surface area) or very low (≤10 percent surface area) in 32 estuaries, particularly in the mixing zone. A medium spatial coverage (>25≤50 percent surface area) was reported in nine estuaries, primarily in the seawater zone and in the Western Florida Coast subregion. The spatial coverage was high (>50 percent surface area) in the seawater zone of Apalachee Bay and the Upper and Lower Laguna Madre. For all estuaries in which SAV was reported, the combined spatial coverage was equivalent to between 12 and 24% of the region's estuarine surface area.

The spatial coverage of SAV was reported to have declined in 15 estuaries, primarily in the mixing and seawater zones. Declining trends generally occurred at a low or medium magnitude (0-50 percent change), with the exception of the mixing zone of Lake Pontchartrain and Galveston Bay, where the magnitude was high (>50 percent change). Several factors were attributed to the declines, including physical alteration of the watershed in seven estuaries, changes in nonpoint sources in five estuaries and changes in hydrology in three estuaries. Epiphytes and macroalgae were reported to contribute to the declining coverage in the mixing zone of Lake Pontchartrain and the seawater zone of the Lower Laguna Madre. A decrease in coverage in the mixing zone of Choctawhatchee Bay was associated with an increase in suspended solids. Other factors attributed to declining coverages included an increase in suspended solids in the mixing zone of Choctawhatchee Bay, competition with an exotic species (*Hydrilla*) in the Atchafalaya River, changes in point sources in the mixing zone of San Antonio Bay, and brown tide occurrence in Lower Laguna Madre.

No change in spatial coverage was reported in six estuaries. An increase in coverage was reported in 11 estuaries, particularly in the Mississippi Delta/Louisiana Coast and Texas Coast subregions. Increasing trends occurred mostly at a low magnitude (0-25 percent change), with the exception of the seawater zone of the Upper Laguna Madre and Baffin Bay, where the magnitude was medium (>25≤50 percent change), and the tidal fresh zone of Apalachicola, where the magnitude was high (>50 percent change). Factors attributed to the increases included changes in nonpoint sources in seven estuaries, changes in point sources in three estuaries, and physical alteration of the watershed in six estuaries. Climate fluctuations were reported to contribute to increased coverage in the mixing zone of Matagorda Bay and the seawater zone of the Upper Laguna Madre. An increase in mixing zone of the Western Mississippi Sound was associated with changes in hydrology. No information was available for parts of 16 estuaries.

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Estuary Summaries

This section presents one-page summaries on the status and trends of eutrophication conditions for the 37 Gulf of Mexico estuaries and the Mississippi/Atchafalaya River Plume. The summary information is organized into four sections: algal conditions, nutrients, dissolved oxygen, and ecosystem/community responses. Each page also includes a salinity map depicting the spatial framework for which survey information was collected, selected physical and hydrologic characteristics, and a narrative overview of the survey information.

Salinity Maps. Salinity maps depict the estuary extent, salinity zones, and subareas within salinity zones. Salinity zones are divided into tidal fresh (0.0-0.5 ppt), mixing (0.5-25.0 ppt) and seawater (>25.0 ppt) based on average annual salinity found throughout the water column. Subareas were identified by survey participants as regions that were either better understood than the rest of a salinity zone, or that behaved differently, or both. Each map also has an inset showing the location of the estuary and its estuarine drainage area (EDA) (see below).

Physical and Hydrologic Data. Physical and hydrologic characteristics data are included so that readers can better understand the survey results and make meaningful comparisons among the estuaries. The EDA is the land and water component of a watershed that drains into and most directly affects estuarine waters. The average daily inflow is the estimated discharge of freshwater into the estuary. Surface area includes the area from the head of tide to the boundary with other water bodies. Average depth is the mean depth from mid-tide level. Volume is the product of the surface area and the average depth.

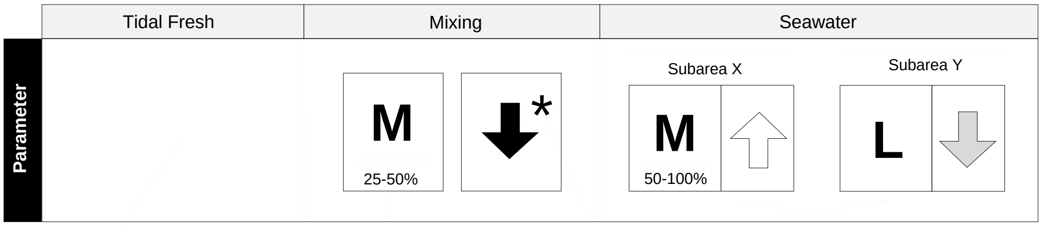
Survey Results. Selected data are presented in a unique format that is intended to highlight survey results for each estuary. The existing conditions symbols represent either the maximum conditions predominating for one or more months in a typical year, or indicate resource impacts due to bloom events. The trends (circa 1970-1995 unless otherwise stated) symbols indicate either the direction and magnitude of change in concentrations, or in the frequency of occurrence.

The four sections on each page include a text block to highlight additional information such as probable months of occurrence and periodicity for each parameter, limiting factors to algal biomass, nuisance and toxic algal species, nutrient forms and degree of water column stratification.

Some parameters are not characterized by symbols on the estuary pages. These include macroalgal and epiphyte abundance, biological stress, minimum average monthly bottom dissolved oxygen trends, temporal shifts in primary productivity, benthic community shifts, intertidal wetlands and planktonic community shifts. These parameters are described in the Regional Overview section (starting on page 6) and, where relevant, are highlighted in the text blocks under each parameter section on the estuary pages.

See the next page for a key that explains the symbols used on the summary pages. See Table 1 on page 3 for complete details about the characteristics of each parameter.

Key to Symbols Used on Estuary Summaries

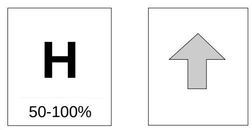


Salinity Zone Absent: if the salinity zone is not present in the estuary the entire box is left blank

Spatial Coverage: surface area over which condition occurs (not listed for nuisance/toxic algae or low/not observed conditions)

Reliability: indicates assessment made from speculative inferences

Salinity Zone Divided: salinity zones are often divided into subareas to account for unique characteristics



Existing Conditions

Concentrations

(Chl a, Turbidity, Nutrients, SAV)

E hypereutrophic
- chl-*a*: >60 µg/l

H high
- chl-*a*: >20, $\leq$60 µg/l
- turbidity: secchi <1m
- TDN: $\geq$1 mg/l
- TDP: $\geq$0.1 mg/l
- SAV >50, $\leq$100 % coverage

M medium
- chl-*a*: >5, $\leq$20 µg/l
- turbidity: secchi $\geq$1m, $\leq$3m
- TDN: $\geq$0.1, <1 mg/l
- TDP: $\geq$0.01, <0.1 mg/l
- SAV >25, $\leq$ 50 % coverage

L low
- chl-*a*: >0, $\leq$5 µg/l
- turbidity: secchi >3m
- TDN: >0, <0.1 mg/l
- TDP: >0, <0.01 mg/l
- SAV >10, $\leq$ 25 % coverage

VL very low
- SAV >0, $\leq$10 % coverage

NS no SAV in zone

B blackwater area

? unknown

Event Occurrences

(Nuisance/Toxic Algae, d.o.)

Y impacts on resources
- nuisance algae: impacts occur
- toxic algae: impacts occur

or

low d.o. is observed
- anoxia: 0 mg/l
- hypoxia: >0, $\leq$2 mg/l

N no resource impacts
- no nuisance algae impacts
- no toxic algae impacts

or

low d.o. not observed
- no anoxic events
- no hypoxic events

? unknown

Trends (circa 1970-1995)

(Concentrations or Frequency of Event Occurrences)

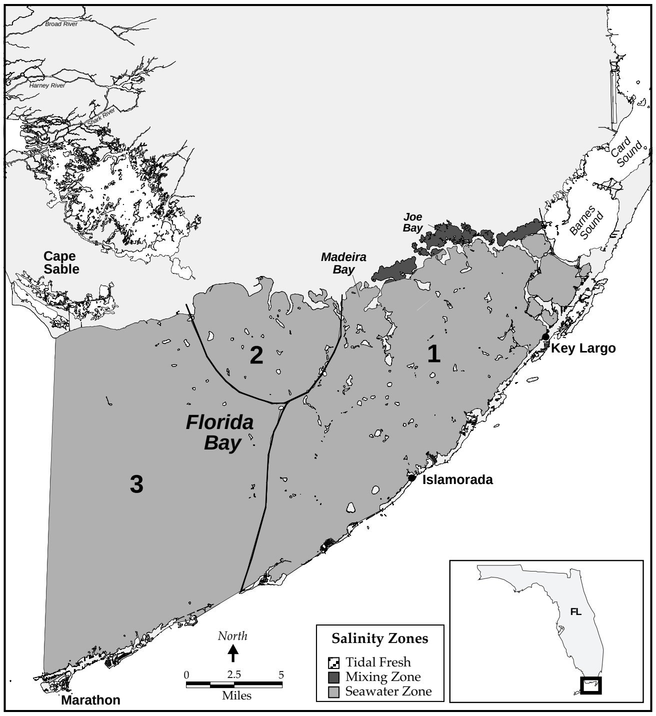
Direction of Change

- ⬆ increase
- ⬇ decrease
- – – – no trend
- ? unknown

Magnitude of Change

- high >50%, $\leq$100%
- medium >25%, $\leq$50%
- low >0%, $\leq$25%
- magnitude unknown

Florida Bay



In Florida Bay, chlorophyll *a* concentrations range from low to high and turbidity and nitrogen concentrations range from medium to high. Phosphorus concentrations are low. Nuisance and toxic blooms occur only in the seawater zone. Anoxia and hypoxia are also observed. SAV spatial coverage is medium.

Trends for chlorophyll *a*, turbidity, nuisance algae, and nitrogen increased, while SAV spatial coverage and phosphorus concentrations decreased. Most trends for anoxia and hypoxia are unknown, except an increase in hypoxia in Zone 2. Toxic algal blooms have remained unchanged.

Physical and Hydrologic Characteristics

Estuarine Drainage Area *(mi2)* **991** Avg. Daily Inflow *(cfs)* **n/a**

	Estuary	TF	Mixing	Seawater Zone 1	Seawater Zone 2	Seawater Zone 3
Surface Area *(mi2)*	883.1		14.5	352.1	89.0	427.5
Average Depth *(ft)*	7.3		1.0	n/a	n/a	n/a
Volume *(billion cu ft)*	179		0.4	n/a	n/a	n/a

A shallow, lagoonal estuary. Salinity patterns largely affected by periodic discharges from water control structures. Salinity variability dominated by prevailing wind-driven circulation and weather events. A vertically mixed water column persists and salinities are high to hypersaline. Tidal range is approximately 2 ft near Cape Sable.

Algal Conditions

	TF	Mixing	Seawater Zone1	Seawater Zone 2	Seawater Zone 3
Chlorophyll a		L ---	M* 10-25% ↓*	H 50-100% ↑	M 25-50% ↑
Turbidity		M 50-100% ---	H 50-100% ↑	H 50-100% ↑	H 25-50% ↑
Nuisance Algae		N ---	N ---	Y ↑	Y ↑
Toxic Algae		N ---	N ---	N ---	Y ---

Maximum Chl-a concentrations occur periodically in January in Zone 1 with phosphorus limiting, June to January in Zone 2 with phosphorus and silica limiting, and September to January in Zone 3 with nitrogen and silica limiting. 1990-96 Chl-a decrease in Zone 1 attributed to hydrologic changes, and increases in Zones 2 and 3 attributed to external salinities. Increase in turbidity speculated to be attributed to resuspension in Zone 1, internal sources in Zone 2, and external sources and SAV in Zone 3. Nuisance blue-green Synechococcus spp. occurs periodically June to January in Zone 2 and October to February in Zone 3, and toxic Gymnodinium breve occurs periodically February to March. Increase in nuisance blooms reported for 1976-86.

Ecosystem/Community Responses

	TF	Mixing	Seawater Zone 1	Seawater Zone 2	Seawater Zone 3
SAV		M ---	M ↓	M ↓	M ↓

Primary productivity dominated by emergent and pelagic communities in mixing zone, benthic in Zone 1, pelagic in Zone 2, and pelagic/benthic in Zone 3; Zones 2 and 3 were historically benthic. Planktonic community is diverse in mixing zone and Zone 1, dominated by blue-green algae and diatoms in Zone 2, and diatoms in Zone 3; benthic community dominated by annelids in mixing zone and Zone 3, diverse in Zones 1 and 2. External conditions contributed to loss of annelid dominance in Zone 2.

Nutrients

	TF	Mixing	Seawater Zone 1	Seawater Zone 2	Seawater Zone 3
Nitrogen		M 50-100% ↑	M 50-100% ↑	H 50-100% ---	M 50-100% ---
Phosphorus		L ↓	L ↓	L ---	L ---

Figure shows dissolved organic nitrogen. Dissolved inorganic is low except in Zone 2 where it is medium. Maximum concentrations occur May/June through September, except in Zone 3 where medium concentrations are observed throughout the year.

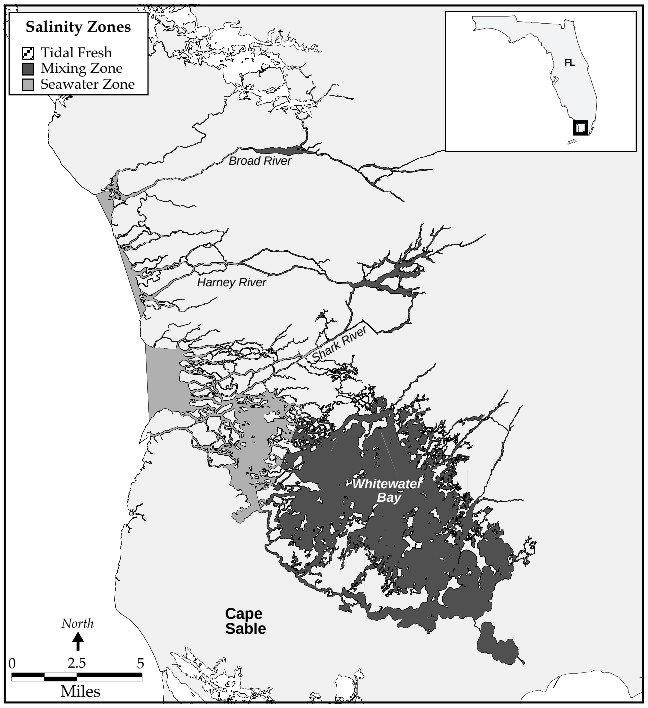
Dissolved Oxygen

	TF	Mixing	Seawater Zone 1	Seawater Zone 2	Seawater Zone 3
Anoxia		N ?	N ?	Y 50-100% ?	Y* 0-10% ?
Hypoxia		Y 50-100% ?	Y 50-100% ?	Y 50-100% ↑	Y 50-100% ?

Low dissolved oxygen conditons occur throughout the water column periodically between June and October.

Key on page 23

South Ten Thousand Islands



In South Ten Thousand Islands, chlorophyll *a* concentrations are medium, turbidity is high, and no toxic or nuisance blooms are observed. Nitrogen concentrations range from medium to high and phosphorus concentrations are medium. Anoxia and hypoxia are observed in both the mixing and seawater zones. Spatial coverage of SAV is low.

Chlorophyll *a* and nitrogen concentrations have increased and SAV spatial coverage has decreased. Nuisance and toxic blooms, nitrogen, phosphorus, anoxia and hypoxia were unchanged.

Physical and Hydrologic Characteristics

Estuarine Drainage Area (*mi2*) **1,244** Avg. Daily Inflow (*cfs*) **n/a**

	Estuary	Tidal Fresh	Mixing	Seawater
Surface Area (*mi2*)	78.2		57.4	20.8
Average Depth (*ft*)	6.5		6.0	6.9
Volume (*billion cu ft*)	14		9.6	4.0

A shallow, lagoonal estuary consisting of Whitewater Bay, small tidal rivers, small mangrove islands, and tidal marshes. Receives majority of freshwater as overland sheet flow from Shark River Slough and regulated canals from Lake Okeechobee. Circulation is wind driven and a vertically mixed water column exists. Tidal range is 3.6 ft near mouth of Whitewater Bay.

Algal Conditions

	Tidal Fresh	Mixing		Seawater	
Chlorophyll *a*		M 25-50%	↑	M 50-100%	?
Turbidity		H 50-100%	?	H 50-100%	--- *
Nuisance Algae		?	?	N *	---
Toxic Algae		N	?	N *	---

Maximum Chl-*a* concentrations occur throughout the year with co-limiting factors of phosphorus and nitrogen. Increase in Chl-*a attributed to hydrologic changes. High turbidity occurs throughout the year.*

Ecosystem/Community Responses

	Tidal Fresh	Mixing		Seawater	
SAV		L	↓ ? *	L	?

Primary productivity is a mix of salt marsh and pelagic in mixing zone and emergent, pelagic and benthic in seawater zone. Mixing zone productivity historically dominated by salt marsh, but speculated to have changed due to alterations of hydrology. Planktonic community dominated by diatoms; benthic community is a diverse mixture.

Nutrients

	Tidal Fresh	Mixing		Seawater	
Nitrogen		H 50-100%	↑ ?	M 50-100%	---
Phosphorus		M 50-100%	---	M 50-100%	---

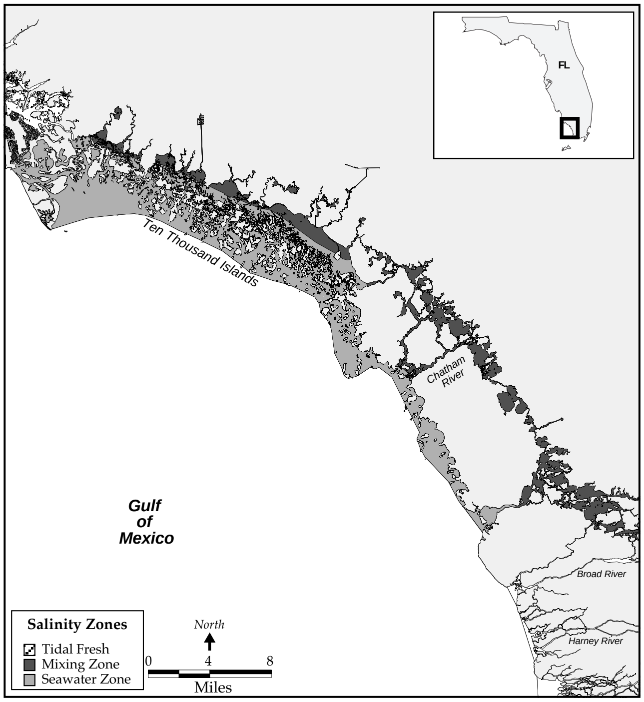
In mixing zone, nitrogen concentrations are for dissolved organic nitrogen. Conditions occur December - May.

Dissolved Oxygen

	Tidal Fresh	Mixing		Seawater	
Anoxia		Y 50-100%*	---	Y * 50-100%*	---
Hypoxia		Y 50-100%*	---	Y * 50-100%*	---

Conditions occur throughout the water column July and September; episodically for anoxia, and periodically for hypoxia.

North Ten Thousand Islands



In North Ten Thousand Islands, chlorophyll *a* and phosphorus concentrations are medium. Nitrogen concentrations range from low to medium and turbidity is high. Nuisance and toxic blooms are not observed, but anoxia and hypoxia are. SAV spatial coverage ranges from very low to medium.

Chlorophyll *a*, turbidity, nuisance and toxic blooms remained unchanged. Nutrients, dissolved oxygen and SAV trends were unknown.

Physical and Hydrologic Characteristics

Estuarine Drainage Area *(mi2)* **902** Avg. Daily Inflow *(cfs)* **n/a**

	Estuary	Tidal Fresh	Mixing	Seawater
Surface Area *(mi2)*	130.8		42.1	88.7
Average Depth *(ft)*	5.7		5.3	5.8
Volume *(billion cu ft)*	21		6.2	14

A shallow estuary consisting of small mangrove islands, small tidal channels and tidal marshes. Receives majority of freshwater from overland sheet flow and regulated canal structures connected to Lake Okeechobee. Circulation is wind driven and a vertically mixed water column is typical. Tidal range is 3.5 ft near Chatham River mouth.

Algal Conditions

	Tidal Fresh	Mixing		Seawater	
Chlorophyll *a*		M 50-100%	- - -	M 25-50%	- - -
Turbidity		H 50-100%	- - -	H 25-50%	- - -
Nuisance Algae		N	- - -	N	- - -
Toxic Algae		N	- - -	N	- - -

Maximum Chl-*a* concentrations occur periodically in the summer with co-limiting factors of phosphorus and nitrogen. High turbidity occurs periodically in summer.

Nutrients

	Tidal Fresh	Mixing		Seawater	
Nitrogen		M 50-100%	?	L	?
Phosphorus		M 50-100%	?	M 50-100%	?

In the mixing zone nitrogen concentrations reported are dissolved organic nitrogen. Medium concentrations occur December through May.

Ecosystem/Community Responses

	Tidal Fresh	Mixing		Seawater	
SAV		VL	?	M	?

Primary productivity is emergent and pelagic in mixing zone, and pelagic in seawater zone. Planktonic community dominated by diatoms in seawater zone; benthic community is a diverse mixture.

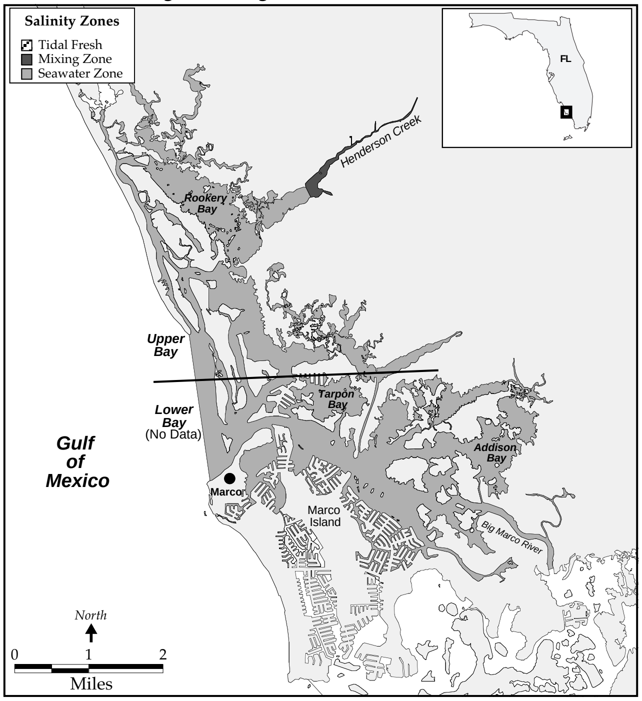
Dissolved Oxygen

	Tidal Fresh	Mixing		Seawater	
Anoxia		Y 10-25%	?	Y* 0-10%	?
Hypoxia		Y 25-50%	?	Y 10-25%	?

Biological stress is observed in 50 - 100 percent of the mixing zone and 25 - 50 percent of the seawater zones. D.O. conditions occur throughout water column between July and September. Anoxia occurrences are episodic, hypoxia and biological stress occurrences are periodic.

Key on page 23

Rookery Bay



In Rookery Bay, chlorophyll *a* concentrations are medium, turbidity is high, nitrogen concentrations are medium and phosphorus concentrations range from medium to high. There are no observed nuisance and toxic blooms. Anoxia and hypoxia are reported to occur in the mixing zone. SAV spatial coverage ranges from low to very low. Parameters for lower bay are unknown.

Trends were stable with the exception of unknown trends for anoxia, hypoxia, and SAV coverage in the mixing zone.

Physical and Hydrologic Characteristics

Estuarine Drainage Area *(mi2)* **141** Avg. Daily Inflow *(cfs)* **n/a**

	Estuary	Tidal Fresh	Mixing	Seawater Upper Bay	Seawater Lower Bay
Surface Area *(mi2)*	**15.2**		**0.2**	**6.3**	**8.7**
Average Depth *(ft)*	**5.0**		**3.7**	**n/a**	**n/a**
Volume *(billion cu ft)*	**2.1**		**0.09**	**n/a**	**n/a**

A shallow estuary consisting of Rookery Bay, and small embayments with small mangrove islands and tidal channels. Receives majority of freshwater from Henderson Creek and overland sheet flow. Circulation is wind driven and a vertically mixed water column is typical. Tidal range is 1.7 ft near the mouth of the Addison Bay.

Algal Conditions

	Tidal Fresh	Mixing	Seawater (Upper Bay)
Chlorophyll *a*		M (25-50%) / ---	M (25-50%) / ---
Turbidity		H (50-100%) / ---	H (50-100%) / ---
Nuisance Algae		N / --- *	N / --- *
Toxic Algae		N / --- *	N / --- *

Maximum Chl-*a* concentrations occur episodically with a limiting factor of nitrogen, speculated to be co-limiting with phosphorus in seawater zone. High turbidity occurs all year in mixing zone and episodically in seawater zone.

Ecosystem/Community Responses

	Tidal Fresh	Mixing	Seawater (Upper Bay)
SAV		VL / ?	L / --- *

Primary productivity is dominated by emergent and pelagic communities. Planktonic community dominated by diatoms; benthic community dominated by annelids.

Nutrients

	Tidal Fresh	Mixing	Seawater (Upper Bay)
Nitrogen		M (50-100%) / ---	M (25-50%) / ---
Phosphorus		M (50-100%) / ---	H (25-50%) / ---

Nitrogen concentrations reported are dissolved inorganic nitrogen. Conditions occur July to October.

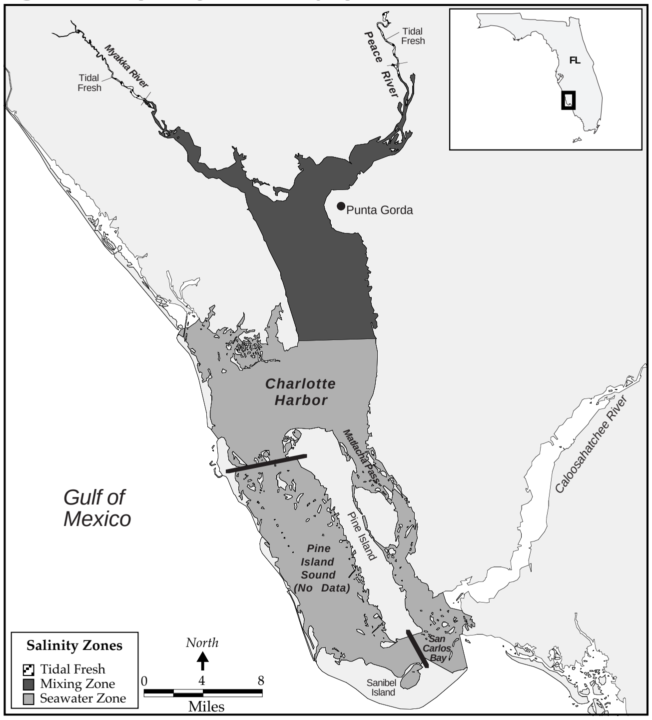
Dissolved Oxygen

	Tidal Fresh	Mixing	Seawater (Upper Bay)
Anoxia		Y * ? / ?	N / ?
Hypoxia		Y * ? / ?	N / ?

Biological stress is observed in mixing and seawater zones. Months of occurrence, frequency, and water column stratification effects are unknown.

Key on page 23

Charlotte Harbor



In Charlotte Harbor, chlorophyll *a* concentrations range from medium to hypereutrophic and turbidity is characteristic of a blackwater system. Nuisance and toxic algal blooms occur and anoxia and hypoxia are also observed. Nitrogen concentrations range from low to high, and phosphorus concentrations are high. SAV spatial coverage is low in the mixing zone and medium in the seawater zone. Parameters for Pine Island Sound are unknown.

Conditions remained mostly unchanged. The exceptions are a decrease in phosphorus concentrations and a speculated increase in nitrogen.

Physical and Hydrologic Characteristics

Estuarine Drainage Area *(mi2)* **4,877** Avg. Daily Inflow *(cfs)* **3,958**

	Estuary	Tidal Fresh	Mixing	Seawater
Surface Area *(mi2)*	**209.0**	**2.0**	**86.8**	**120.2**
Average Depth *(ft)*	**8.7**	**6.2**	**9.3**	**8.4**
Volume *(billion cu ft)*	**50.7**	**0.3**	**2.4**	**28.1**

Consists of Charlotte Harbor proper, Matlacha Pass, San Carlos Bay, and tidal areas of the Peace, Myakka and Caloosahatchee Rivers (Pine Island Sound is not characterized). Receives majority of freshwater inflow from Peace and Caloosahatchee Rivers. Canal construction affects surficial inputs of freshwater. Salinity structure is vertically and laterally stratified during summer rainy season. Tidal range is 1.3 ft near mouth of Myakka River.

Algal Conditions

	Tidal Fresh		Mixing		Seawater	
Chlorophyll *a*	E 50-100%	--- *	E 25-50%	---	M 25-50%	---
Turbidity	B	---	B	---	B	---
Nuisance Algae	Y	?	Y	---	N	---
Toxic Algae	Y*	?	N	---	Y	---

Maximum Chl-*a* concentrations occur periodically in spring in tidal fresh zone with a limiting factor of light, periodically in summer in mixing zone with limiting factors of light and nitrogen, and episodically in fall in seawater zone with a limiting factor of nitrogen. Nuisance *Anabaena* spp.,*Chlorococcus minutus*, and *Microcystis aeruginosa* occur episodically April to June. Toxic *Gymnodinium breve* occurs episodically.

Ecosystem/Community Responses

	Tidal Fresh		Mixing		Seawater	
SAV	NS	---	L	---	M	---

Primary productivity dominated by pelagic community. Plelagic community dominated by blue-green algae in tidal fresh zone, flagellates and diatoms in mixing zone, and diatoms in seawater zone; benthic community dominated by annelids in tidal fresh and mixing zones and is diverse in seawater zone. Introduction of exotic species speculated to contribute to loss of benthic diversity in tidal fresh zone. SAV trend is from 1982-1994.

Nutrients

	Tidal Fresh		Mixing		Seawater	
Nitrogen	M 50-100%	---	H 50-100%	↑ *	L	--- *
Phosphorus	H 50-100%	↓	H 50-100%	↓	H 50-100%	↓

Nitrogen reported as dissolved inorganic nitrogen. Elevated DIN and TDP occur all year. Elevated TKN occurs July through October.

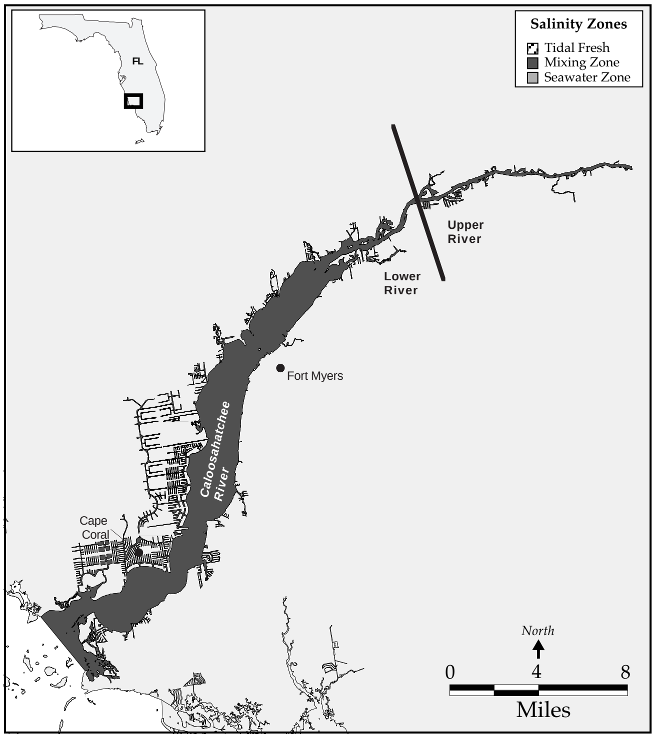
Dissolved Oxygen

	Tidal Fresh		Mixing		Seawater	
Anoxia	?	?	Y* ?	--- *	N	--- *
Hypoxia	Y 50-100%	?	Y 50-100%	--- *	Y 0-10%*	--- *

Low dissolved oxygen occurs on bottom, and water column stratification is significant factor in mixing and seawater zones. Biological stress occurs over medium to high spatial extent of all zones. Conditions occur July through October, episodically in tidal fresh and seawater zones, and periodically in mixing zone.

Key on page 23

Caloosahatchee River



In Caloosahatchee River, chlorophyll *a*, turbidity, nitrogen and phosphorus concentrations are high. Nuisance and toxic blooms and anoxia are not observed. Hypoxia occurs in the upper river. SAV spatial coverage is very low.

Trends are mostly unknown with some exceptions. Nuisance and toxic blooms have remained stable, and declines were observed in SAV spatial coverage and phosphorus concentrations in the lower river.

Physical and Hydrologic Characteristics

Estuarine Drainage Area *(mi2)* **1,373** Avg. Daily Inflow *(cfs)* **1,900**

	Estuary	Tidal Fresh	Mixing: Upper River	Mixing: Lower River	Seawater
Surface Area *(mi2)*	31.6		1.5	30.1	
Average Depth *(ft)*	8.7		4.2	4.6	
Volume *(billion cu ft)*	7.7		0.2	3.9	

An elongated subsystem to Charlotte Harbor that is used regularly as a navigation channel. Water flow and flood stage heights are maintained by structures for flood control, irrigation and municipal water supply. Seasonal variability can influence salinity structure within the Upper River. Tidal range is approximately 1 ft near the estuary mouth.

Algal Conditions

	Tidal Fresh	Mixing: Upper River	Mixing: Lower River	Seawater
Chlorophyll *a*		H (50-100%) ?	H (25-50%) ?	
Turbidity		H (50-100%) ?	H (50-100%) ?	
Nuisance Algae		N --- *	N --- *	
Toxic Algae		N --- *	N --- *	

High Chl-*a* occurs periodically early summer with co-limiting factors of nitrogen and phosphorus in Lower River, and nitrogen, phosphorus and light in Upper River. High turbidity occurs periodically May to October.

Ecosystem/Community Responses

	Tidal Fresh	Mixing: Upper River	Mixing: Lower River	Seawater
SAV		L ↓	VL ↓	

Primary productivity is dominated by pelagic community. Pelagic community dominance is unknown; benthic community is diverse. SAV decrease attributed to changes in light, salinity, and freshwater inflow.

Nutrients

	Tidal Fresh	Mixing: Upper River	Mixing: Lower River	Seawater
Nitrogen		H (50-100%) ?	H (50-100%) ---	
Phosphorus		H (50-100%) ?	H (50-100%) ↓	

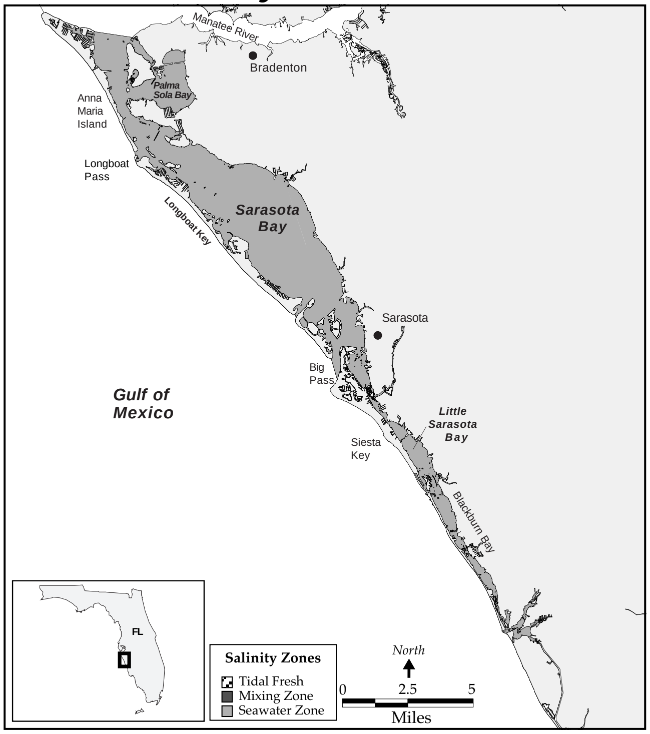
Elevated concentrations occur persistently throughout the year.

Dissolved Oxygen

	Tidal Fresh	Mixing: Upper River	Mixing: Lower River	Seawater
Anoxia		N ?	N ?	
Hypoxia		Y (10-25%) ?	N ?	

Hypoxia occurs periodically on bottom May through August. Biological stress occurs throughout the water column periodically over a high spatial extent of the Upper River and over a very low extent of the Lower River from May through September.

Sarasota Bay



In Sarasota Bay, chlorophyll *a* and phosphorus concentrations are high, and turbidity and nitrogen concentrations are medium. Nuisance and toxic blooms, as well as anoxia and hypoxia, are observed. SAV spatial coverage is medium.

Chlorophyll *a*, turbidity, nitrogen and phosphorus concentrations declined, while SAV spatial coverage increased. Trends for nuisance and toxic blooms, and for anoxia and hypoxia, are unknown.

Physical and Hydrologic Characteristics

Estuarine Drainage Area (*mi2*) **282** Avg. Daily Inflow (*cfs*) **380**

	Estuary	Tidal Fresh	Mixing	Seawater
Surface Area (*mi2*)	**51.0**			**51.0**
Average Depth (*ft*)	**6.4**			**6.4**
Volume (*billion cu ft*)	**9.1**			**9.1**

An elongated bar-built coastal lagoon. Wind and tidal flows at Longboat and Big Pass influence circulation patterns. Receives majority of freshwater inflow from several small tributaries and storm-water drains. Salinity structure is determined by seasonal patterns of precipitation and evaporation. Tidal range is 1.3 ft in the bay.

Algal Conditions

	Tidal Fresh	Mixing	Seawater
Chlorophyll *a*			H (10-25%) ↓
Turbidity			M (50-100%) ↓
Nuisance Algae			Y ?
Toxic Algae			Y ?

Chl-*a* concentrations occur periodically in summer with a limiting factor of nitrogen. Medium turbidity occurs throughout the year. Decrease in Chl-*a* and turbidity associated with point and non-point sources. Toxic *Gymnodinium breve* occurs in seawater zone episodically.

Ecosystem/Community Responses

	Tidal Fresh	Mixing	Seawater
SAV			M ↑

Primary productivity is dominated by pelagic community. Pelagic community was diverse, now dominated by diatoms and flagellates; benthic community is dominated by annelids. Increase in SAV is attributed to changes in non-point sources and upgrades of STP (40% reduction, 1988-95).

Nutrients

	Tidal Fresh	Mixing	Seawater
Nitrogen			M (50-100%) ↓
Phosphorus			H (50-100%) ↓

Concentrations are reported as total nitrogen and total phosphorus. Elevated concentrations occur throughout the year.

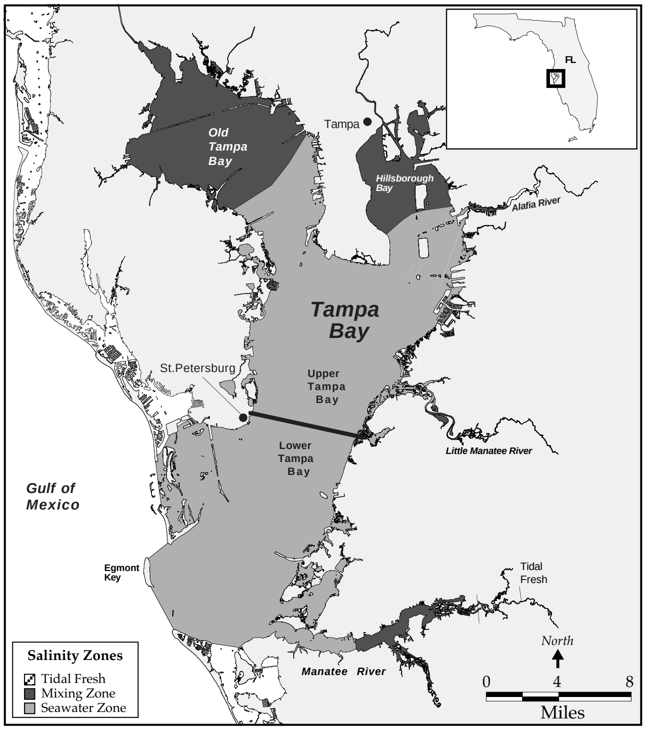
Dissolved Oxygen

	Tidal Fresh	Mixing	Seawater
Anoxia			Y (10-25%) ?
Hypoxia			Y (10-25%) ?

Anoxia and hypoxia occur on bottom periodically between June and September. Biological stress occurs over a medium spatial extent and throughout the water column June to September.

Key on page 23

Tampa Bay



In Tampa Bay, chlorophyll *a* concentrations range from medium to hypereutrophic and turbidity from medium to high. Nuisance and toxic blooms are observed, as well as anoxia and hypoxia. Nitrogen concentrations range from medium to high and phosphorus concentrations are high. SAV spatial coverage ranges from low to medium.

Algal conditions, nutrients, anoxia and hypoxia all decreased, while SAV spatial coverage increased.

Physical and Hydrologic Characteristics

Estuarine Drainage Area *(mi2)* **2,538** Avg. Daily Inflow *(cfs)* **2,400**

	Estuary	Tidal Fresh	Mixing	Seawater	
				Upper Bay	Lower Bay
Surface Area *(mi2)*	346.1	1.0	84.2	107.3	153.6
Average Depth *(ft)*	12.8	3.0	9.0	n/a	n/a
Volume *(billion cu ft)*	123.5	0.1	21.1	n/a	n/a

A shallow, Y-shaped estuary composed of the main bay, Hillsborough and Old Tampa Bays. Circulation has been altered by dredged channels, disposal sites, major causeways and shoreline landfills. Approximately 85% of the freshwater inflow is from four main tributaries. Salinity structure is primarily determined by seasonal freshwater discharge. Tidal range is 2.2 ft at Egmont Key.

Algal Conditions

	Tidal Fresh		Mixing		Seawater Upper Bay		Seawater Lower Bay	
Chlorophyll *a*	M* ?	↓ (grey)	E 25-50%	↓ (black)	H 50-100%	↓ (grey)	M 50-100%	---
Turbidity	M ?	↓ (grey)	H 50-100%	↓ (grey)	H 10-25%	↓ (black)	M 50-100%	---
Nuisance Algae	Y	↓ (black)	Y	↓ (grey)	N	---	N	---
Toxic Algae	N	↓ ? (white)	N	---	N	---	Y	---

Maximum Chl-*a* concentrations occur periodically June to October with limiting factors of nitrogen and light. Highest turbidity occurs periodically July to October. Nuisance blue-greens and dinoflagellates occur periodically in summer and toxic *Gymnodinium breve* occurs in seawater zone episodically. Trends in algal conditions 1980-1995 attributed to changes in point and non-point sources.

Ecosystem/Community Responses

	Tidal Fresh		Mixing		Seawater Upper Bay		Seawater Lower Bay	
SAV	L	?	L	↑ (white)	M	↑ (white)	M	↑ ? (white)

Primary productivity is dominated by the pelagic community. Pelagic community dominated by diatoms; benthic community dominated by annelids in tidal fresh and mixing zones and is diverse in seawater zone. Increase in SAV due to changes in point and non-point sources, due to 10-year nitrogen limitations.

Nutrients

	Tidal Fresh		Mixing		Seawater Upper Bay		Seawater Lower Bay	
Nitrogen	H ?	↓ (white)	M 50-100%	---	M 50-100%	---	M 50-100%	---
Phosphorus	H ?	↓ (black)	H 50-100%	↓ (black)	H 50-100%	↓ (grey)	H 50-100%	↓ (grey)

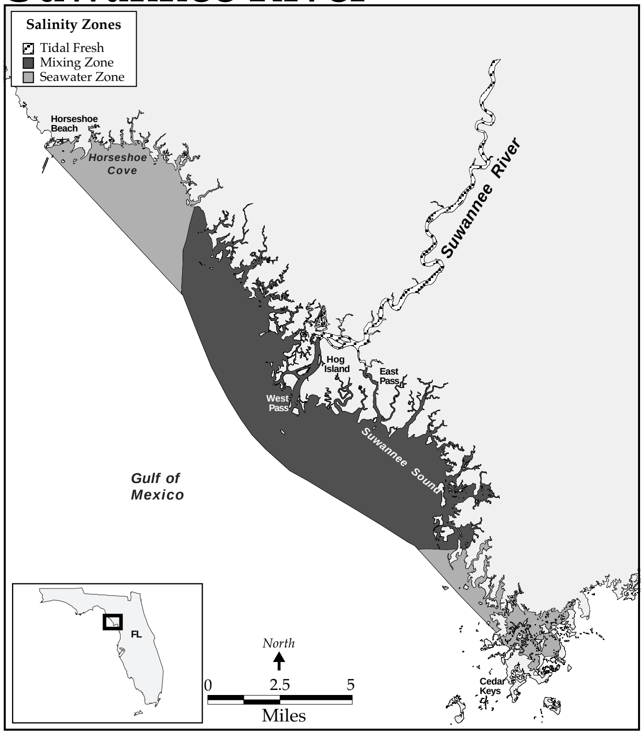
Nitrogen concentrations are for dissolved inorganic nitrogen. Total nitrogen is high in mixing and upper seawater zones. Elevated concentrations in tidal fresh zone occur July to September/October and December to January. Trends reported for 1980- 95.

Dissolved Oxygen

	Tidal Fresh		Mixing		Seawater Upper Bay		Seawater Lower Bay	
Anoxia	Y 10-25%	?	Y 0-10%	↓ ? (white)	Y 10-25%	?	N	---
Hypoxia	Y 10-25%	?	Y 10-25%	↓ ? (white)	Y 10-25%	?	N	---

Low dissolved oxygen conditions occur periodically July to October in bottom waters. Biological stress occurs on bottom in 25 to 50 percent of lower seawater July to October. Water column stratification contributes moderately to low dissolved oxygen conditions in tidal fresh zone. Trends reported for 1980-95. Minimum average monthly bottom dissolved oxygen increased to a low extent in tidal fresh and mixing zones.

Suwannee River



In Suwannee River, chlorophyll *a* concentrations range from low to medium. The tidal fresh and mixing zones are blackwater; turbidity in the seawater zone is moderate. There are no observed nuisance blooms but toxic blooms occur episodically. Concentrations of nitrogen are medium and phosphorus concentrations range from medium to high. Anoxia and hypoxia are not observed. SAV spatial coverage ranges from very low to medium.

Algal conditions, phosphorous concentrations and SAV remained unchanged, while nitrogen concentrations increased. Dissolved oxygen trends are unknown.

Physical and Hydrologic Characteristics

Estuarine Drainage Area *(mi2)* **1,845** Avg. Daily Inflow *(cfs)* **11,200**

	Estuary	Tidal Fresh	Mixing	Seawater
Surface Area *(mi2)*	49.9	3.0	28.8	18.1
Average Depth *(ft)*	4.9	3.5	4.6	5.5
Volume *(billion cu ft)*	6.8	0.3	3.7	2.8

Consists of Suwannee Sound, the Suwannee River delta, and extensive wetland areas. Freshwater discharge dominated by Suwannee River (2nd largest freshwater source in Florida) and from groundwater sources. Salinity structure is governed by seasonal discharge. Salinity variability most apparent in Suwannee Sound where tides are a dominant influence and range is approximately 3 ft.

Algal Conditions

	Tidal Fresh		Mixing		Seawater	
Chlorophyll *a*	L	--- *	M 50-100%*	--- *	?	?
Turbidity	B	---	B	---	M 50-100%	--- *
Nuisance Algae	N	?	N	?	N	---
Toxic Algae	N	?	N	?	Y	---

Maximum Chl-*a* concentrations occur periodically May to September with a limiting factor of nitrogen. Toxic blooms occur episodically.

Nutrients

	Tidal Fresh		Mixing		Seawater	
Nitrogen	M 50-100%	↑ *	M 50-100%	↑ *	M 50-100%	--- *
Phosphorus	H 50-100%	---	H 50-100%	---	M 50-100%	--- *

Maximum total dissolved nitrogen concentrations occur June to September. Maximum total dissolved phosporus concentrations occur January to April.

Ecosystem/Community Responses

	Tidal Fresh		Mixing		Seawater	
SAV	L	--- *	VL	--- *	M	---

Primary productivity is dominated by marshes in tidal fresh zone, by the pelagic and marsh communities in mixing zone, and by the pelagic and benthic communities in seawater zone. Planktonic community dominated by diatoms; benthic community dominated by aquatic insects in tidal fresh zone and is diverse in mixing and seawater zones.

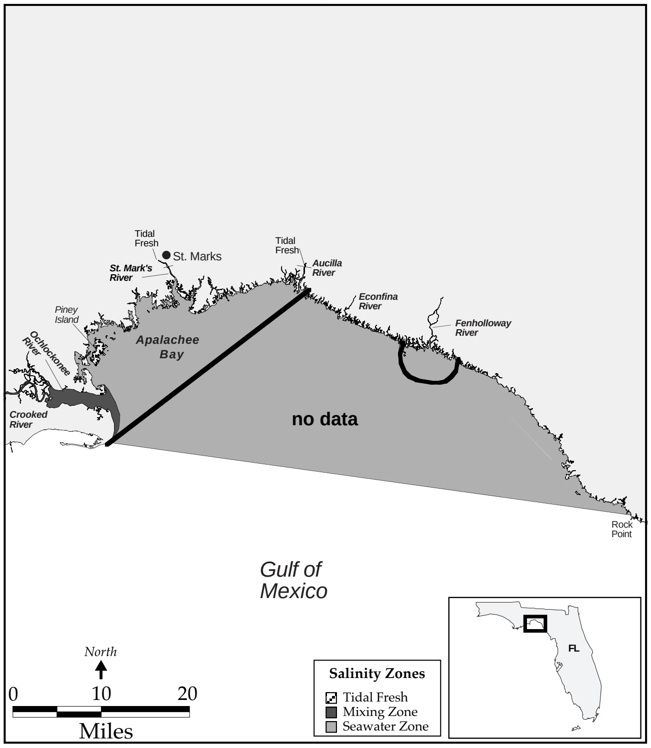
Dissolved Oxygen

	Tidal Fresh		Mixing		Seawater	
Anoxia	N	?	N	?	N	?
Hypoxia	N	?	N	?	N	?

Biological stress is speculated to occur over a low spatial extent of tidal fresh zone in bottom waters periodically from June to September.

Key on page 23

Apalachee Bay



In Apalachee Bay, chlorophyll *a*, nitrogen and phosphorus concentrations range from low to medium. Turbidity is blackwater in the tidal fresh zone and medium to high in the mixing and seawater zones. Nuisance blooms are not observed, but toxic blooms are observed in the seawater zone. Anoxia and hypoxia are observed. SAV spatial coverage ranges from very low to high.

In the Fenholloway River, SAV spatial coverage increased, while declines were reported for chlorophyll *a*, turbidity, nitrogen, phosphorus, anoxia and hypoxia.

Physical and Hydrologic Characteristics

Estuarine Drainage Area (*mi2*) **3,836** Avg. Daily Inflow (*cfs*) **5,300**

	Estuary	TF	Mixing	Seawater: Apalachee Bay	Seawater: Fenholloway R.
Surface Area (*mi²*)	710.6	0.1	16.5	153.0	16.7
Average Depth (*ft*)	10.2	7.3	5.8	n/a	n/a
Volume (*billion cu ft*)	202.1	0.02	2.7	n/a	n/a

An open-water estuarine system whose boundaries are not consistently defined. Periphery is lined by many small estuaries, streams, springs, lakes, and freshwater marshes. Salinity structure determined by seasonal freshwater discharge from the Econfina, Fenholloway and Ochlockonee Rivers. Tides typically range 2.1 ft near the entrances to major rivers.

Algal Conditions

	Tidal Fresh	Mixing		Seawater: Apalachee Bay		Seawater: Fenholloway River	
Chlorophyll a		L	---*	M 25-50%	---	M 50-100%	↓
Turbidity		B	---*	M 25-50%	---	H 50-100%	↓
Nuisance Algae		N	---*	N	---	N	---
Toxic Algae		N	---*	Y	---	N	---

Maximum Chl-*a* concentrations occur periodically March to May in mixing zone and are persistent in seawater zone, with a speculated limiting factor of nitrogen for both zones. Turbidity concentrations occur all year. Decrease in Chl-*a* and turbidity reported for 1975-95 and due to changes in point sources.

Ecosystem/Community Responses

	Tidal Fresh	Mixing		Seawater: Apalachee Bay		Seawater: Fenholloway River	
SAV		VL	---	H	---*	L	↑

Primary productivity is dominated by the pelagic community in mixing zone and Fenholloway River, and is benthic and pelagic in seawater zone. Planktonic community dominated by diatoms; benthic community dominated by annelids in mixing zone and Fenholloway River and is diverse in seawater zone. Increase in SAV attributed to change in point sources.

Nutrients

	Tidal Fresh	Mixing		Seawater: Apalachee Bay		Seawater: Fenholloway River	
Nitrogen		M* 50-100%*	---	L	---	M 50-100%	↓
Phosphorus		M* 50-100%*	---	L	---	M 50-100%	↓

Elevated concentrations occur November to April in mixing zone and all year in Fenholloway River. Decreases attributed to changes in point sources.

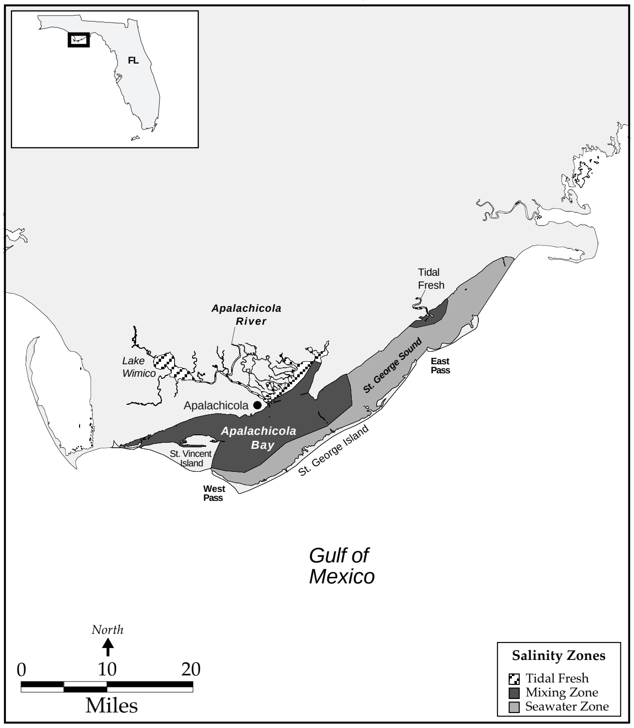
Dissolved Oxygen

	Tidal Fresh	Mixing		Seawater: Apalachee Bay		Seawater: Fenholloway River	
Anoxia		N	---	N	---	Y 10-25%	↓*
Hypoxia		N	---	Y 0-10%	---	Y 25-50%	↓*

Conditions occur on bottom periodically June to September. Biological stress observed over 50 to 100 percent of Fenholloway River. Water column stratification contributes moderately to dissolved oxygen conditions. Decreases in frequency, duration, and spatial coverage of low dissolved oxygen attributed to changes in point sources.

Key on page 23

Apalachicola Bay



In Apalachicola Bay, chlorophyll *a* concentrations range from low to medium. The tidal fresh zone is blackwater, but in the mixing and seawater zones, turbidity is medium to high. Nuisance blooms are not observed, but toxic blooms occur. Nitrogen and phosphorus concentrations range from low to high. Hypoxia is observed, but anoxia does not occur. SAV spatial coverage ranges from very low to low.

Trends for most parameters were unchanged. SAV spatial coverage and observations of toxic algal blooms and hypoxia have increased.

Physical and Hydrologic Characteristics

Estuarine Drainage Area *(mi²)* **1,921** Avg. Daily Inflow *(cfs)* **29,100**

	Estuary	Tidal Fresh	Mixing	Seawater
Surface Area *(mi²)*	**229.2**	**16.2**	**133.3**	**79.7**
Average Depth *(ft)*	**9.0**	**9.0**	**7.9**	**12.9**
Volume *(billion cu ft)*	**57.5**	**4.1**	**29.4**	**28.7**

A broad, shallow lagoonal system separated from the Gulf of Mexico by three barrier islands. Consists of Apalachicola Bay and several smaller embayments. Apalachicola River is primary source of freshwater (largest freshwater source in Florida). Salinity structure is determined by its discharge and by tidal influence near the passes. Tidal range is 1.6 ft near the passes.

Algal Conditions

	Tidal Fresh		Mixing		Seawater	
Chlorophyll a	L	---	M 50-100%	---	L	---
Turbidity	B	---	H 50-100%	---	M 50-100%	---
Nuisance Algae	N	---	N	---	N	---
Toxic Algae	N	---	Y	↑	Y	↑

Maximum Chl-*a* concentrations occur periodically December to April with a limiting factor of nitrogen in mixing zone and light in tidal fresh zone. Turbidity occurs throughout year. Toxic *Gymnodinium breve* occurs in seawater zone episodically June to October.

Ecosystem/Community Responses

	Tidal Fresh		Mixing		Seawater	
SAV	L	↑	VL	---	L	---

Primary productivity is a mix of emergent, benthic and pelagic in tidal fresh zone, and dominated by the pelagic community in mixing and seawater zones. Planktonic community dominated by diatoms in mixing and seawater zones; benthic community dominated by annelids and aquatic insects in tidal fresh zone, is diverse in mixing zone, and dominated by annelids in seawater zone.

Nutrients

	Tidal Fresh		Mixing		Seawater	
Nitrogen	H 50-100%	---	M 50-100%	--- *	L	---
Phosphorus	H 50-100%	---	M 50-100%	--- *	L	---

Elevated concentrations occur December through April.

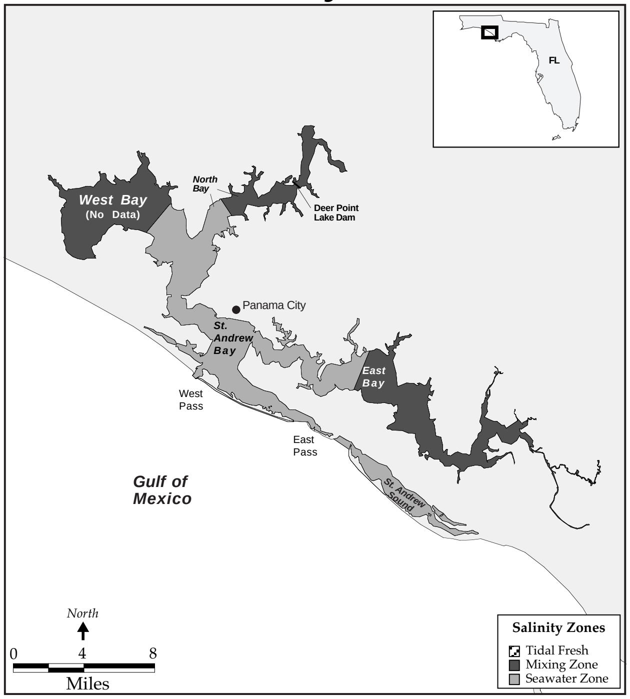
Dissolved Oxygen

	Tidal Fresh		Mixing		Seawater	
Anoxia	N	---	N	---	N	---
Hypoxia	N	---	Y 10-25%	⇧	N	---

Biological stress observed in up to 10 percent of tidal fresh and 50 to 100 percent of mixing zone. Low dissolved oxygen conditions occur in bottom waters periodically June to October. Water column stratification is a highly significant factor. Increase in frequency and spatial coverage attributed to non-point sources.

Key on page 23

St. Andrew Bay



In St. Andrew Bay, chlorophyll *a* concentrations are medium in the mixing zone and unknown in the seawater zone. Turbidity, nitrogen and phosphorus concentrations are medium. Nuisance and toxic blooms, and anoxia and hypoxia, are observed. SAV spatial coverage is low.

In the North Bay and East Bay mixing zones, chlorophyll *a* and nutrient concentrations increased, while turbidity decreased. All other conditions are unknown.

Physical and Hydrologic Characteristics

Estuarine Drainage Area *(mi2)* **1,160** Avg. Daily Inflow *(cfs)* **4,500**

	Estuary	Tidal Fresh	Mixing	Seawater
Surface Area *(mi2)*	98.3		52.0	45.3
Average Depth *(ft)*	11.9		8.6	17.0
Volume *(billion cu ft)*	32.6		12.5	21.5

A relatively deep, Y-shaped embayment which includes St. Andrew, West, North, and East Bays. Minimal freshwater is supplied by Econfina Creek and Bear Creek (not pictured) across the Deer Point Lake Dam. Salinity structure determined by seasonal freshwater discharge from Econfina Creek and precipitation. Tide range is 1.3 ft near West Pass.

Algal Conditions

	Tidal Fresh		Mixing		Seawater	
Chlorophyll a			M 50-100%	↑	?	?
Turbidity			M 50-100%	↓	M 50-100%	?
Nuisance Algae			Y	?	Y	?
Toxic Algae			Y	?	Y	?

Maximum Chl-*a* concentrations occur periodically in summer with a limiting factor of phosphorus; increase associated with point and non-point sources. Highest turbidity occurs periodically February to October. Nuisance *Anacystis spp.*, *Anabaena spp.* and toxic *Gymnodinium breve* occur episodically for days in summer.

Ecosystem/Community Responses

	Tidal Fresh		Mixing		Seawater	
SAV			L*	?	L	?

Primary productivity dominated by the pelagic community. Planktonic community dominated by diatoms; benthic community dominated by annelids in mixing zone and is a diverse mixture with annelids dominating in seawater zone.

Nutrients

	Tidal Fresh		Mixing		Seawater	
Nitrogen			M 50-100%	↑	M 50-100%	?
Phosphorus			M 50-100%	↑	M 50-100%	?

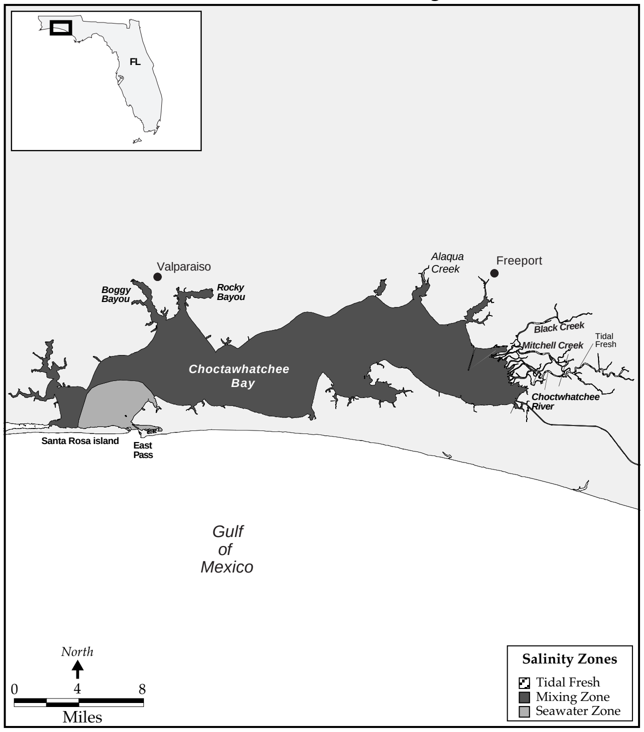
Elevated nitrogen occurs April to September. Elevated phosphorus occurs February/March to September.

Dissolved Oxygen

	Tidal Fresh		Mixing		Seawater	
Anoxia			Y 10-25%	?	N	?
Hypoxia			Y 10-25%	?	N	?

Biological stress observed over a high spatial extent of mixing zone and low extent of seawater zone. Low dissolved oxygen conditions occur in bottom waters periodically July to September. Water column stratification contributes to a low extent to dissolved oxygen conditions. Minimum average monthly bottom dissolved oxygen concentrations decreased in mixing zone from 1970-95.

Choctawhatchee Bay



In Choctawhatchee Bay, chlorophyll *a* concentrations are medium, turbidity ranges from medium to high, and both nuisance and toxic blooms are observed. Nitrogen and phosphorus concentrations range from low to medium. Anoxia and hypoxia are observed. SAV spatial coverage ranges from none to very low.

In the mixing zone, turbidity concentrations and SAV spatial coverage decreased, while nitrogen and phosphorus concentrations increased. Trends in the tidal fresh zone were unknown, as were all trends for dissolved oxygen.

Physical and Hydrologic Characteristics

Estuarine Drainage Area (*mi2*) **2,226** Avg. Daily Inflow (*cfs*) **8,500**

	Estuary	Tidal Fresh	Mixing	Seawater
Surface Area (*mi2*)	130.2	1.0	119.1	10.1
Average Depth (*ft*)	14.2	13.0	13.8	18.6
Volume (*billion cu ft*)	51.5	0.4	45.8	5.2

A relatively deep, and narrow lagoon consisting of Choctawhatchee Bay, Choctawhatchee River delta, and several smaller embayments. Separated from the Gulf of Mexico by a barrier spit along the southern shore. Vertical salinity stratification determined by seasonal freshwater discharge from Choctawhatchee River. Tidal range is 0.6 ft near East Pass.

Algal Conditions

	Tidal Fresh		Mixing		Seawater	
Chlorophyll *a*	?	?	M 50-100%	---	M 50-100%	---
Turbidity	H 50-100%	?	M 50-100%	↓ ?	M 50-100%	---
Nuisance Algae	?	?	Y	---	Y	---
Toxic Algae	?	?	Y	---	Y	---

Maximum Chl-*a* concentrations occur periodically in summer with a limiting factor of phosphorus. High turbidity occurs persistently in tidal fresh zone, and periodically March to September in mixing and seawater zones. Nuisance *Anacystis, Anabaena* and*Biddelphia spp*. and toxic *Anacystis* and *Anabaena spp*. occur periodically in summer in mixing zone and nuisance *Cladophora* and *Enteromorpha spp*. and toxic *Gymnodinium breve* and *Gonyaulax monilata* occur periodically in summer in seawater zone.

Ecosystem/Community Responses

	Tidal Fresh		Mixing		Seawater	
SAV	NS	?	VL	↓ *	VL	?

Primary productivity dominated by the pelagic community. Planktonic community dominated by diatoms in mixing and seawater zones, although blue-green algae previously dominated in mixing zone; benthic community is diverse tidal fresh zone, dominated by annelids in mixing zone, and speculated to be diverse in seawater zone. Decrease in SAV speculated to be due to increased suspended solids and coastal erosion.

Nutrients

	Tidal Fresh		Mixing		Seawater	
Nitrogen	M 50-100%	?	M 50-100%	↑	L	?
Phosphorus	M 50-100%	?	M 50-100%	↑	L	?

Elevated nutrient concentrations occur all year in tidal fresh zone and May to September in the mixing zone. Increase attributed to non-point sources.

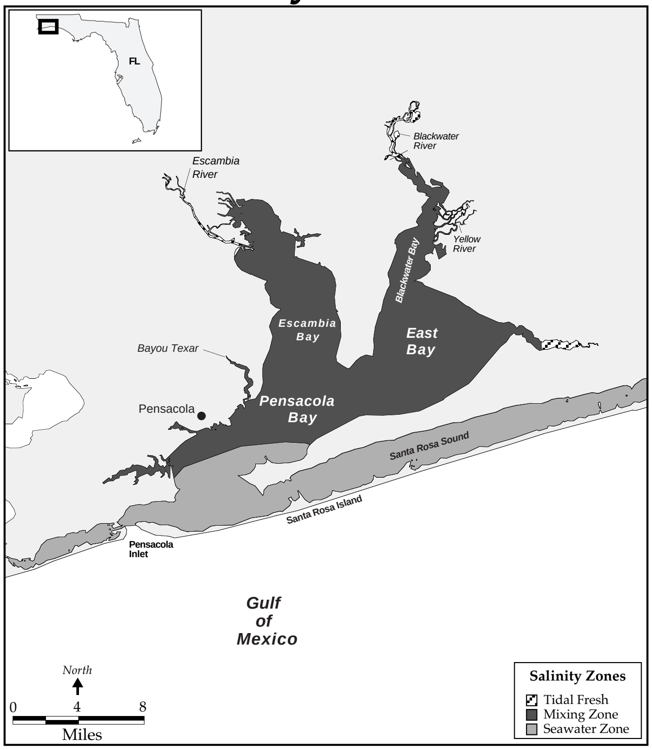
Dissolved Oxygen

	Tidal Fresh		Mixing		Seawater	
Anoxia	N	?	Y 10-25%	?	N	?
Hypoxia	Y 25-50%	?	Y 25-50%	?	Y ?	?

Biological stress observed over 50 to 100 percent of tidal fresh and mixing zones and 25 to 50 percent of seawater zone. Conditions occur mostly in bottom waters June to October. Water column stratification is a moderate to highly significant factor in mixing zone.

Key on page 23

Pensacola Bay



In Pensacola Bay, chlorophyll *a* concentrations range from low to hypereutorphic. The tidal fresh zone is mostly blackwater; turbidity is moderate in the rest of the estuary. Nuisance and toxic blooms are not observed. Nitrogen and phosphorus concentrations range from low to high. Anoxia is not observed, but hypoxia is observed in the Escambia River and in the mixing zone. SAV spatial coverage is very low.

Chlorophyll *a* concentrations increased to a high extent in the mixing zone. Turbidity decreased in the Escambia River but increased in Bayou Texar. SAV spatial coverage decreased to a high extent in Bayou Texar and in the seawater zone. Trends for nuisance and toxic algae, nutrients and dissolved oxygen are unknown.

Algal Conditions

	Tidal Fresh: In General	Tidal Fresh: Escambia River	Mixing: In General	Mixing: Bayou Texar	Seawater
Chlorophyll a	M 10-25% ?	L ---	M 50-100% ↑	E 0-10% ⇧ *	L – – –
Turbidity	B ---	M 50-100% ⇩	M 50-100% ---	M 50-100% ⇧ *	M 50-100% – – –
Nuisance Algae	N ?	N ?	N ?	N ?	N ?
Toxic Algae	N ?	N ?	N ?	N ?	N ?

In mixing zone, maximum Chl-*a* concentrations occur periodically March to August with a limiting factor of phosphorus. Nitrogen is limiting in Bayou Texar. Increase in Chl-*a* reported for 1977-91 associated with point and non-point sources. Turbidity occurs throughout the year; decrease due to changes in point and non-point sources and increase attributed to point sources.

Ecosystem/Community Responses

	Tidal Fresh: In General	Tidal Fresh: Escambia River	Mixing: In General	Mixing: Bayou Texar	Seawater
SAV	NS ---	VL ---	VL ---	L * ↓	VL ↓

Primary productivity dominated by the pelagic community in Escambia River, Bayou Texar, and seawater zone, and by pelagic and benthic communities in mixing zone. Planktonic community is diverse; benthic community dominated by aquatic insects in tidal fresh zone, annelids in mixing zone, and is diverse in seawater zone. Decrease in SAV attributed to point and non-point sources.

Physical and Hydrologic Characteristics

Estuarine Drainage Area *(mi²)* **3,449** Avg. Daily Inflow *(cfs)* **11,600**

	Estuary	Tidal Fresh: In General	Tidal Fresh: Escambia R.	Mixing: In General	Mixing: Bayou Texar	Seawater
Surface Area *(mi²)*	190.1	0.9	0.6	117.4	0.5	70.7
Average Depth *(ft)*	12.7	n/a	n/a	n/a	n/a	20.4
Volume *(billion cu ft)*	67.3	n/a	n/a	n/a	n/a	40.2

A drowned river estuary and lagoon consisting of Santa Rosa Sound and Pensacola, Escambia, East, and Blackwater Bays. Separated from the Gulf of Mexico by Santa Rosa Island. Navigation channels are important conduits for salinity intrusion. Salinity structure is determined by seasonal freshwater discharge primarily from the Escambia River. Tidal range is 3.2 ft near the mouth of the bay.

Nutrients

	Tidal Fresh: In General	Tidal Fresh: Escambia River	Mixing: In General	Mixing: Bayou Texar	Seawater
Nitrogen	M 50-100% ?	H 50-100% ?	M 50-100% ?	H 50-100% ?	L ?
Phosphorus	M 50-100% ?	H 50-100% ?	M 50-100% ?	M 50-100% ?	L ?

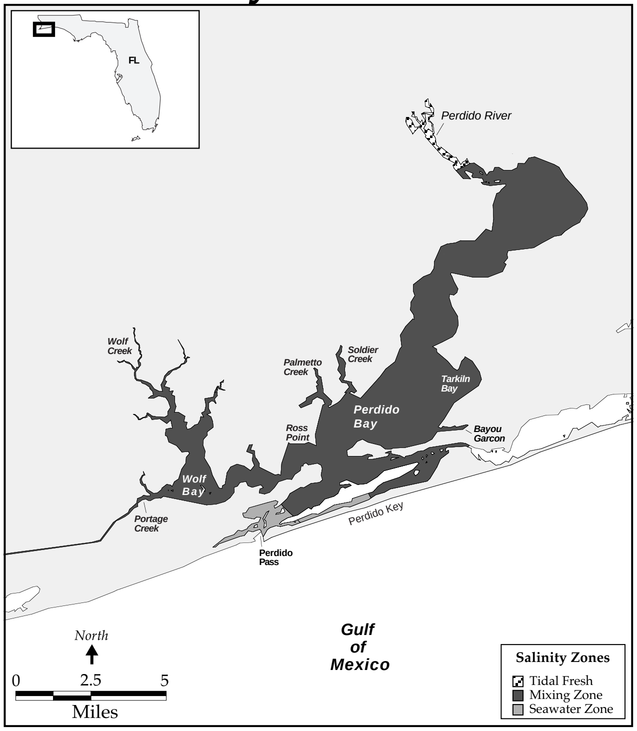
Elevated concentrations occur March to August except in Bayou Texar where they occur all year.

Dissolved Oxygen

	Tidal Fresh: In General	Tidal Fresh: Escambia River	Mixing: In General	Mixing: Bayou Texar	Seawater
Anoxia	N ?	N ?	N ?	N ?	N ?
Hypoxia	N ?	Y 10-25% ?	Y 10-25% ?	N ?	N ?

Biological stress observed in 25 to 50 percent of tidal fresh zone, 50 to 100 percent of general mixing zone, and 10 to 25 percent of seawater zone. Conditions occur periodically June to September in bottom waters. Water column stratification is moderate factor in general mixing zone. Spatial coverage of conditions has not changed during 1970-95.

Perdido Bay



In Perdidio Bay, chlorophyll *a*, nitrogen and phosphorus concentrations range from low to medium. The tidal fresh zone is blackwater and turbidity in the mixing and seawater is medium or high. Nuisance and toxic blooms and anoxia and hypoxia are observed. SAV spatial coverage ranges from none to low.

Nuisance blooms and nutrient concentrations increased in the tidal fresh zone. Chlorophyll *a*, turbidity and SAV remained unchanged. All other trends were unknown.

Physical and Hydrologic Characteristics

Estuarine Drainage Area *(mi2)* **1,185** Avg. Daily Inflow *(cfs)* **2,200**

	Estuary	Tidal Fresh	Mixing	Seawater
Surface Area *(mi2)*	50.0	0.4	48.3	1.3
Average Depth *(ft)*	6.9	6.0	7.1	3.7
Volume *(billion cu ft)*	9.6	0.1	9.6	0.1

A small system consisting of Perdido Bay and several small creeks, separated from the Gulf of Mexico by Perdido Key. Direct exchange is restricted to Perdido Pass. Deep areas influence stratification by trapping saline bottom waters and maintaining moderate to highly stratified conditions. Salinity structure also determined by seasonal discharge from Perdido River. Tidal range within bay is 1.6 ft.

Algal Conditions

	Tidal Fresh		Mixing		Seawater	
Chlorophyll *a*	M 25-50%	- - - *	M 50-100%	- - - *	L	- - - *
Turbidity	B	- - -	H 50-100%	- - -	M 50-100%	- - -
Nuisance Algae	N	↑	Y	?	N	?
Toxic Algae	Y	?	?	?	N	?

Maximum Chl-*a* concentrations occur periodically in summer with a limiting factor of light in tidal fresh zone, nitrogen and phosphorus in mixing zone, and phosphorus in seawater zone. Turbidity occurs persistently all year. Nuisance *Chlamydomonas* and *Aphanocapsa spp.* and toxic *Anacystis* and *Anabaena spp.* occur in summer.

Ecosystem/Community Responses

	Tidal Fresh		Mixing		Seawater	
SAV	NS	- - - *	VL	- - - *	L	- - - *

Primary productivity is dominated by the pelagic community. Planktonic community is a diverse mixture; benthic community dominated by aquatic insects in tidal fresh zone, annelids in mixing zone and is diverse in seawater zone.

Nutrients

	Tidal Fresh		Mixing		Seawater	
Nitrogen	M 50-100%	↑	M 50-100%	?	L	?
Phosphorus	M 50-100%	↑	M 50-100%	?	L	?

Elevated concentrations occur April to October.

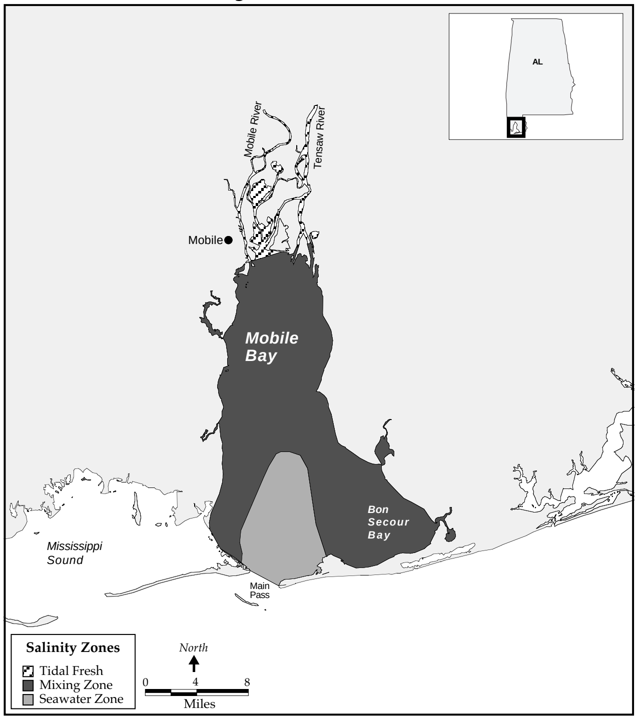
Dissolved Oxygen

	Tidal Fresh		Mixing		Seawater	
Anoxia	Y 50-100%	?	N	?	N	?
Hypoxia	Y 10-25%	?	Y 25-50%	?	N	?

Anoxia and hypoxia occur periodically June to October in bottom waters. Biological stress occurs periodically June to September throughout water column in 10 to 25 percent of tidal fresh, 50 to 100 percent of mixing zone, and 25 to 50 percent of bottom seawater. Water column stratification is a highly significant factor in dissolved oxygen conditions. Minimum average monthly bottom dissolved oxygen decreased in tidal fresh and increased in mixing and seawater zones. Duration and spatial coverage of low dissolved oxygen increased to a low extent in tidal fresh zone.

Key on page 23

Mobile Bay



In Mobile Bay, chlorophyll *a* concentrations are medium. Turbidity ranges from medium to high. Nitrogen concentrations range from low to medium and phosphorus concentrations are medium. Nuisance blooms do not occur, but toxic blooms are reported. Both anoxia and hypoxia occur. SAV spatial coverage is very low in the mixing zone and medium in the seawater zone.

SAV spatial coverage decreased in the tidal fresh zone. Trends are mostly unknown for the remaining conditions.

Physical and Hydrologic Characteristics

Estuarine Drainage Area (*mi2*) **4,841** Avg. Daily Inflow (*cfs*) **79,300**

	Estuary	Tidal Fresh	Mixing	Seawater
Surface Area (*mi2*)	417.5	22.8	320.9	73.8
Average Depth (*ft*)	9.9	17.9	8.9	11.8
Volume (*billion cu ft*)	115.2	11.4	79.6	24.3

A drowned river valley estuary consisting of the main bay, Mobile River, Tensaw River, and small embayments. Navigation channels are an important mechanism for salinity intrusion. Salinity structure is determined by Mobile River and the bay is moderately stratified throughout the year. Tidal range is 1.3 ft near Main Pass.

Algal Conditions

	Tidal Fresh		Mixing		Seawater	
Chlorophyll *a*	?	?	M 50-100%	?	M 10-25%	?
Turbidity	H 50-100%	?	H 25-50%	?	M 50-100%	?
Nuisance Algae	?	?	?	?	N	- - -
Toxic Algae	?	?	Y	?	Y	?

Maximum Chl-*a* concentrations occur periodically April to September in mixing zone and December to May in seawater zone, with co-limiting factors of nitrogen and phosphorus. Turbidity occurs throughout the year. *Gymnodinium breve* reported October to December 1996.

Ecosystem/Community Responses

	Tidal Fresh		Mixing		Seawater	
SAV	M	↓ *	VL	- - -	NS	- - -

Primary productivity is a mixture of pelagic, wetlands and SAV in the tidal fresh zone, and dominated by the pelagic community in the mixing and seawater zones. Planktonic community dominance is unknown; benthic community dominated by annelids.

Nutrients

	Tidal Fresh		Mixing		Seawater	
Nitrogen	M 50-100%	?	M 50-100%	?	L	?
Phosphorus	M 50-100%	?	M 25-50%	?	M 25-50%	?

Elevated concentrations occur all year in tidal fresh zone and January to May in seawater zone.

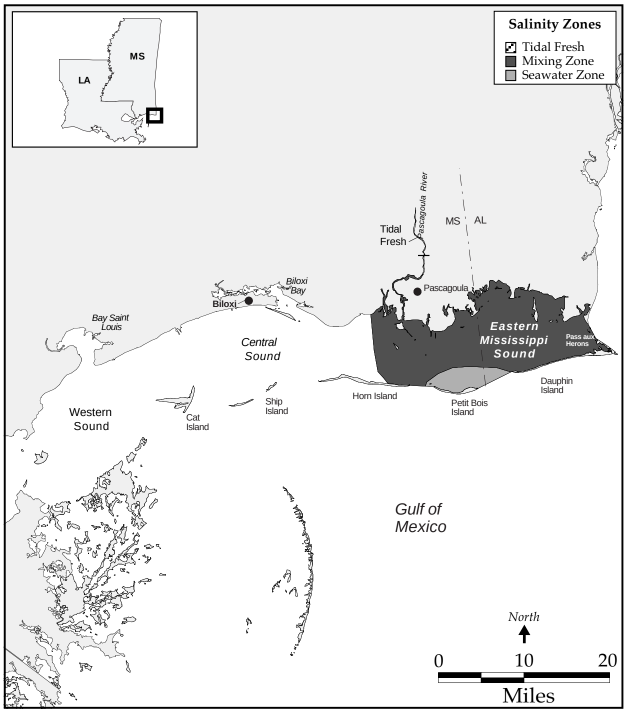
Dissolved Oxygen

	Tidal Fresh		Mixing		Seawater	
Anoxia	N	?	Y 0-10%	?	N	?
Hypoxia	Y 25-50%	?	Y 25-50%	?	Y 10-25%	?

Conditions occur periodically July to October in bottom waters. In mixing zone, anoxia occurs only in ship channel, but biological stress occurs throughout the water column. Minimum average monthly bottom dissolved oxygen concentrations did not change during 1970 to 1995.

Key on page 23

East Mississippi Sound



In East Mississippi Sound, chlorophyll *a* concentrations are medium, turbidity is high, and nitrogen and phosphorus concentrations range from low to medium. Nuisance blooms and toxic blooms occur. Anoxia occurs only in the tidal fresh area, while hypoxia is observed to a low extent throughout the system. SAV spatial coverage is very low.

Algal conditions remained unchanged. Nutrient and dissolved oxygen trends were unknown. SAV increased in the mixing zone but decreased in the seawater zone.

Physical and Hydrologic Characteristics

Estuarine Drainage Area (*mi2*) **n/a** Avg. Daily Inflow (*cfs*) **n/a**

	Estuary	Tidal Fresh	Mixing	Seawater
Surface Area (*mi2*)	**278.8**	**0.3**	**254.2**	**24.3**
Average Depth (*ft*)	**n/a**	**n/a**	**n/a**	**n/a**
Volume (*billion cu ft*)	**n/a**	**n/a**	**n/a**	**n/a**

Easternmost portion of Mississippi Sound, includes Pascagula River delta complex. Tidal exchange occurs with Gulf of Mexico through Petit Bois Pass and with Mobile Bay through Pass aux Herons. Salinity structure is determined primarily by seasonal freshwater discharge from Pacagoula and Mobile Rivers. Interestuary exchanges contribute significantly to salinity variability and stratification occurs in navigation channels. Tidal range is 1.7 ft near the main passes.

Algal Conditions

	Tidal Fresh		Mixing		Seawater	
Chlorophyll a	?	?	M 50-100%	- - - *	M 50-100%	- - -
Turbidity	?	?	H 50-100%	- - -	H 50-100%	- - -
Nuisance Algae	?	?	Y	- - -	?	- - -
Toxic Algae	?	?	Y	- - -	Y	- - -

Maximum Chl-*a* concentrations occur periodically March to September with a limiting factor of light in mixing zone and nitrogen and phosphorus in seawater zone. Turbidity occurs throughout year. Nuisance *Exuviella* and *Prorocentrum minimum* occurs episodically January to February and nuisance dinoflagellates and *Gonyaulax monilata* occur July to September. Toxic *Gymnodinium breve* reported October to December of 1996.

Ecosystem/Community Responses

	Tidal Fresh		Mixing		Seawater	
SAV	L	?	VL	↑	L	↓

Primary productivity dominated by wetland and pelagic communities in tidal fresh, speculated to be pelagic in mixing with loss of benthic due to watershed alterations and non-point sources, and is benthic and pelagic in seawater zone. Planktonic community speculated to be diverse in mixing and diatoms in seawater zone; benthic community dominated by aquatic insects in tidal fresh, annelids in mixing, and is diverse in seawater zone. Increase in SAV reported for 1990-1995; decrease due to alterations to watershed, freshwater inflow and non-point sources.

Nutrients

	Tidal Fresh		Mixing		Seawater	
Nitrogen	?	?	M 50-100%	?	L	?
Phosphorus	?	?	M 50-100%	?	L	?

Medium concentrations occur January to May.

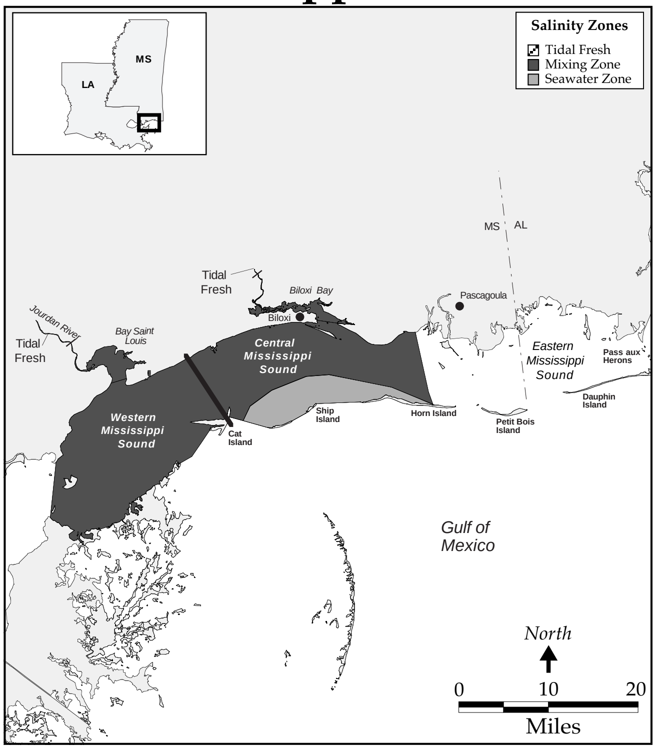
Dissolved Oxygen

	Tidal Fresh		Mixing		Seawater	
Anoxia	Y 25-50%	?	N	?	N	?
Hypoxia	Y 50-100%	?	Y 10-25%	?	Y 10-25%	?

Biological stress observed over medium to high spatial extent of all zones. In tidal fresh, conditions observed July to September throughout water column; in mixing zone, conditions observed June to September in bottom for hypoxia and throughout water column for biological stress; in seawater zone, conditions observed July to September in bottom waters. Water column stratification is highly significant factor in all zones. Minimum average monthly bottom dissolved oxygen, duration, and spatial coverage did not change from 1970-95.

Key on page 23

West Mississippi Sound



In West Mississippi Sound, chlorophyll *a* and turbidity concentrations range from medium to high. Nuisance and toxic blooms, and anoxia and hypoxia, are observed. Nitrogen and phosphorus concentrations range from low to high. SAV spatial coverage is low to very low.

Chlorophyll *a* and phosphorus concentrations decreased. Turbidity concentrations, and nuisance and toxic bloom occurrence, remained unchanged. SAV coverage decreased in Bay Saint Louis and the seawater zone, and increased in all other areas of the mixing zone.

Physical and Hydrologic Characteristics

Estuarine Drainage Area (mi^2) **n/a** Avg. Daily Inflow (cfs) **n/a**

	Estuary	Tidal Fresh	Mixing: Western Sd.	Mixing: Bay St. Louis	Mixing: Central Sd.	Mixing: Biloxi Bay	Seawater
Surface Area (mi^2)	635.4	0.3	300.9	16.0	214.9	11.8	91.5
Average Depth (ft)	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Volume (billion cu ft)	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Western portion of Mississippi Sound, includes Bay St. Louis delta complex, Biloxi River and Bay. In Western Sound, salinity structure is determined primarily by seasonal freshwater discharge from Pearl River and from Mississippi River through Lake Borgne and Pontchartrain. Vertically homogeneous salinity structure in Central Sound determined primarily by winds and tides. Salinity is lower in Western Sound than in Central or Eastern Sound, and it is highly variable. Tidal range is 1.7 ft near the main passes.

Algal Conditions

	Tidal Fresh	Mixing: Western Sd.	Mixing: Bay Saint Louis	Mixing: Central Sd.	Mixing: Biloxi Bay	Seawater
Chlorophyll a	? ?	M (50-100%) ?	M (50-100%) ?	M (50-100%) ↓	H (10-25%) ↓	M (50-100%) --
Turbidity	? ?	M (50-100%) --	H (50-100%) --	H (50-100%) --	H (50-100%) --	M (50-100%) --
Nuisance Algae	? ?	N ?	N ?	Y --	N --	N --
Toxic Algae	? ?	Y ?	Y* ?	Y --	Y --	Y --

In Western Sound and Bay St. Louis, maximum Chl-*a* concentrations occur periodically March to September with a limiting factor of light. Maximum Chl-*a* concentrations occur June to August in Biloxi Bay with nitrogen limiting, March to September in Central Sound with light limiting, and April to September in seawater zone with limiting factors of nitrogen and phosphorus. 1980-95 Chl-*a* decrease associated with sewage treatment plant. Turbidity occurs all year. Nuisance *Exuviella spp.* and *Prorocentrum minimum* occur in winter and nuisance *Gonyaulax monilata* and dinoflagellates occur July to September. Toxic *Gymnodinium breve* reported October to December of 1996 and March of 1997.

Ecosystem/Community Responses

	Tidal Fresh	Mixing: Western Sd.	Mixing: Bay Saint Louis	Mixing: Central Sd.	Mixing: Biloxi Bay	Seawater
SAV	L ?	VL ↑	VL ↓	VL ↑	VL ↑	L ↓

Primary productivity dominated by wetland and pelagic communities in tidal fresh, and speculated to be pelagic in mixing zone, and benthic/pelagic in seawater zone. Planktonic community speculated to be diverse in mixing and diatom dominated in seawater zone. Benthic community dominated by aquatic insects in tidal fresh and annelids in mixing zone. SAV increase reported for 1990-95; decrease in Bay Saint Louis and seawater zone due to alteration of watershed, freshwater inflow and non-point sources.

Nutrients

	Tidal Fresh	Mixing: Western Sd.	Mixing: Bay Saint Louis	Mixing: Central Sd.	Mixing: Biloxi Bay	Seawater
Nitrogen	? ?	M (50-100%) ?	M (50-100%) ?	M (50-100%) ?	H (25-50%) ?	L ?
Phosphorus	? ?	L ?	L ?	M (50-100%) ↓?	H (25-50%) ↓?	L ?

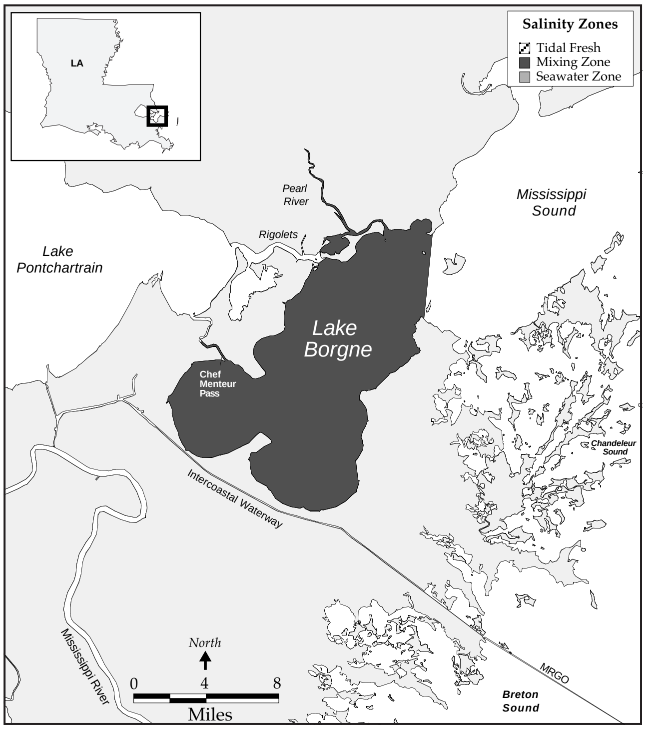
Elevated concentrations occur June to August in Biloxi Bay and April to September in rest of mixing zone. Decreases from 1985-95 attributed to changes in point sources.

Dissolved Oxygen

	Tidal Fresh	Mixing: Western Sd.	Mixing: Bay Saint Louis	Mixing: Central Sd.	Mixing: Biloxi Bay	Seawater
Anoxia	Y (25-50%) ?	N ?	N ?	N ?	N ?	N ?
Hypoxia	Y (50-100%) ?	N ?	N ?	Y (10-25%) ?	Y (10-25%) ?	Y (25-50%) ?

Biological stress observed in 10 to 25 percent of Western Sound and Bay St. Louis, 25 to 50 percent of Central Sound and seawater zone, and 50 to 100 percent of tidal fresh zone. Conditions occur periodically July to September, throughout water column in tidal fresh zone, and in bottom waters in mixing and seawater zones. Water column stratification is a highly significant factor.

Lake Borgne



For Lake Borgne, very little information was reported for existing conditions. Turbidity is high, SAV spatial coverage is very low, and no anoxia or hypoxia is observed.

Trends for this system are unknown.

Physical and Hydrologic Characteristics

Estuarine Drainage Area (*mi2*) **7,790** Avg. Daily Inflow (*cfs*) **25,100**

	Estuary	Tidal Fresh	Mixing	Seawater
Surface Area (*mi2*)	272.1		272.1	
Average Depth (*ft*)	9.5		9.5	
Volume (*billion cu ft*)	72.1		72.1	

Located in the Mississippi River deltiac plain, with the Pearl River as major source of freshwater inflow. Salinities have been altered since construction of Mississippi River Gulf Outlet (MRGO) and other channels connecting the lake with Breton and Mississippi Sounds. Density currents within MRGO setup vertical stratification. Tidal range is 0.9 ft near mouth of the Pearl River.

Algal Conditions

	Tidal Fresh	Mixing	Seawater
Chlorophyll a		? ?	
Turbidity		H (50-100%) ?	
Nuisance Algae		? ?	
Toxic Algae		Y ?	

High turbidity occurs throughout the year. Toxic *Anabaena* spp. occurred in 1997.

Ecosystem/Community Responses

	Tidal Fresh	Mixing	Seawater
SAV		VL ?	

Primary productivity dominated by pelagic community. Planktonic community is speculated to be diverse; benthic community dominated by annelids.

Nutrients

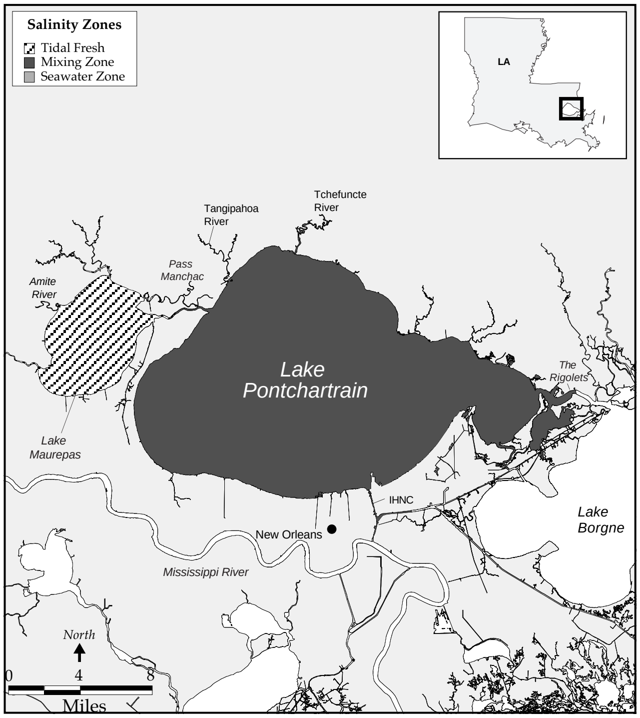
	Tidal Fresh	Mixing	Seawater
Nitrogen		? ?	
Phosphorus		? ?	

Dissolved Oxygen

	Tidal Fresh	Mixing	Seawater
Anoxia		N ?	
Hypoxia		N ?	

Key on page 23

Lake Pontchartrain



In Lake Pontchartrain, chlorophyll *a* concentrations range from low to medium and turbidity is high. Nuisance and toxic blooms, and anoxia and hypoxia, occur. Nitrogen concentrations range from medium to high and phosphorus from low to medium. SAV spatial coverage is very low.

Chlorophyll *a*, nitrogen and phosphorus concentrations increased. Turbidity increased in the tidal fresh zone and decreased in the mixing zone. SAV spatial coverage decreased. Nuisance and toxic algae and dissolved oxygen conditions have remained unchanged in the mixing zone.

Physical and Hydrologic Characteristics

Estuarine Drainage Area *(mi2)* **5,399** Avg. Daily Inflow *(cfs)* **10,700**

	Estuary	Tidal Fresh			Mixing	Seawater
		Lake Maurepas	Amite R.	Other Tribs.		
Surface Area *(mi2)*	748.2	96.0	1.0	1.0	650.2	
Average Depth *(ft)*	11.1	n/a	n/a	n/a	10.8	
Volume *(billion cu ft)*	231.5	n/a	n/a	n/a	195.8	

Located in the Mississippi River deltiac plain, consists of Lake Pontchartrain, Lake Maurepas, and Pass Manchac. The Amite-Comite and Tangipahoa Rivers are major sources of freshwater inflow. Eastern portion salinities have been altered since the construction of the Inner Harbor Navigation Channel. The Rigolets account for 60% of the tidal exchange. Winds and density currents are a dominant forcing mechanism on salinity structure. Tidal range is 0.9 ft near mouth of Pearl River.

Algal Conditions

	Tidal Fresh: Lake Maurepas		Tidal Fresh: Amite River		Tidal Fresh: Other Tributaries		Mixing		SW
Chlorophyll *a*	L	↑? *	?	↑? *	?	↑? *	M 50-100%	---	
Turbidity	H 50-100%	↑ *	H 50-100%	↑ *	H 50-100%	↑ *	H 50-100%	↓ *	
Nuisance Algae	N *	?	N *	?	N *	?	Y	---	
Toxic Algae	N *	?	N *	?	N *	?	Y	---	

Maximum Chl-*a* concentrations in mixing zone occur periodically May to July with co-limiting factors of nitrogen and light. Increase in Chl-*a* speculated to be due to population increase and diversion. Turbidity occurs all year with decrease attributed to cessation of shell dredging, and increase due to watershed alterations. Nuisance *Anabaena circinalis, Katodinium rotundum* and *Microcystis aeruginosa*. Toxic *Anabaena circinalis* occurs periodically May to July speculated to be result of spillwater from Bonnet Carre diversion in March 1997.

Ecosystem/Community Responses

	Tidal Fresh: Lake Maurepas		Tidal Fresh: Amite River		Tidal Fresh: Other Tributaries		Mixing		SW
SAV	NS	---	?	?	?	?	VL	↓	

Primary productivity in Lake Maurepas and mixing zone is dominated by pelagic and wetland communities. Planktonic community is diverse in mixing zone with blue-green algae dominating; benthic community dominated by mollusks and aquatic insects in Lake Maurepas and mollusks in mixing zone. SAV decrease due to shoreline alteration, epiphytes, and non-point sources.

Nutrients

	Tidal Fresh: Lake Maurepas		Tidal Fresh: Amite River		Tidal Fresh: Other Tributaries		Mixing		SW
Nitrogen	?	?	H 50-100%	↑ *	M 50-100%	↑ *	M 50-100%	---	
Phosphorus	?	?	M 50-100%	↑ *	L	↑ *	M 50-100%	↑ *	

Elevated concentrations observed all year in Amite River and February to March in mixing zone.

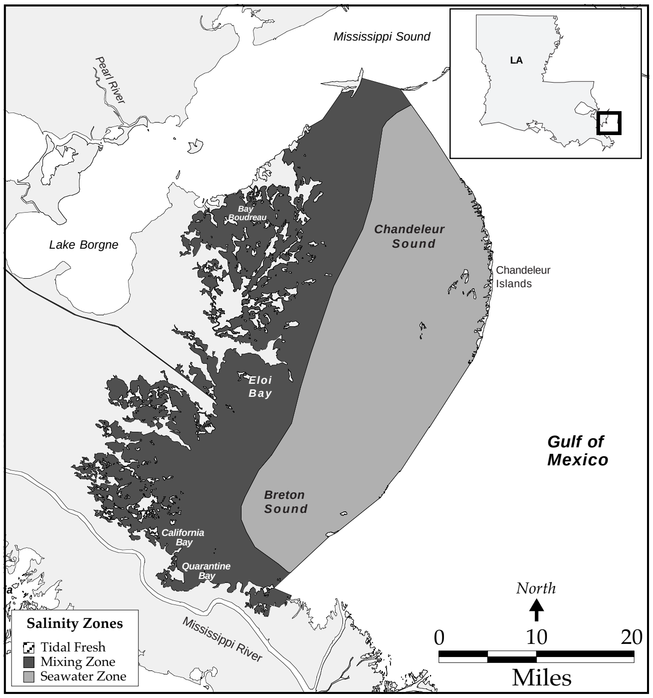
Dissolved Oxygen

	Tidal Fresh: Lake Maurepas		Tidal Fresh: Amite River		Tidal Fresh: Other Tributaries		Mixing		SW
Anoxia	N	?	Y 50-100%*	?	?	?	Y 0-10%	---	
Hypoxia	Y 10-25%	?	Y 50-100%*	?	?	?	Y 10-25%	---	

In Lake Maurepas, low dissolved oxygen conditons occur periodically July to September in bottom waters. In Amite River, low dissolved oxygen conditons occur periodically July to September in bottom waters for anoxia and throughout water column for hypoxia. In mixing zone, conditions occur June to October; anoxia occurs episodically at bottom, hypoxia periodically at bottom, and biological stress periodically throughout water column.

Key on page 23

Breton/Chandeleur Sounds



In Breton/Chandeleur Sounds, turbidity concentrations range from medium to high. Nitrogen is low and phosphorus is high in the mixing zone. Nuisance algal blooms are not observed in the seawater zone. Anoxia and hypoxia are observed. SAV spatial coverage is very low. All other conditions are unknown.

SAV spatial coverage declined and anoxia and hypoxia were unchanged in the mixing zone. All other trends are unknown.

Physical and Hydrologic Characteristics

Estuarine Drainage Area (*mi²*) **2,491** Avg. Daily Inflow (*cfs*) **10,300**

	Estuary	Tidal Fresh	Mixing	Seawater
Surface Area (*mi²*)	1,662.4		781.6	880.8
Average Depth (*ft*)	8.9		5.6	12.2
Volume (*billion cu ft*)	412.5		122.0	299.6

Located in the Mississippi River deltaic plain. Consists of Breton and Chandeleur Sounds with many small embayments and tidal marshes throughout. Pearl River is major source of freshwater inflow. Winds, density currents, and tidal influences are dominant forcing mechanisms on salinity structure. Tidal range is 0.9 ft near mouth of Pearl River.

Algal Conditions

	Tidal Fresh	Mixing		Seawater	
Chlorophyll a		?	?	?	?
Turbidity		H 25-50%	?	M 50-100%	?
Nuisance Algae		?	?	N	?
Toxic Algae		?	?	?	?

Turbidity concentrations occur throughout the year.

Ecosystem/Community Responses

	Tidal Fresh	Mixing		Seawater	
SAV		NS	- - -	VL	⇩ *

Primary productivity is dominated by pelagic and wetland communities in mixing zone, and by pelagic community in seawater zone. Planktonic community dominance is unknown; benthic community dominated by annelids in mixing zone and is diverse in seawater zone. Decrease in SAV attributed to hurricanes, tropical storms, and cold fronts.

Nutrients

	Tidal Fresh	Mixing		Seawater	
Nitrogen		L	?	?	?
Phosphorus		H ?	?	?	?

Nitrogen concentrations are nitrite and nitrate. Phosphorus is reported as total phosphorus. High phosphorus observed all year.

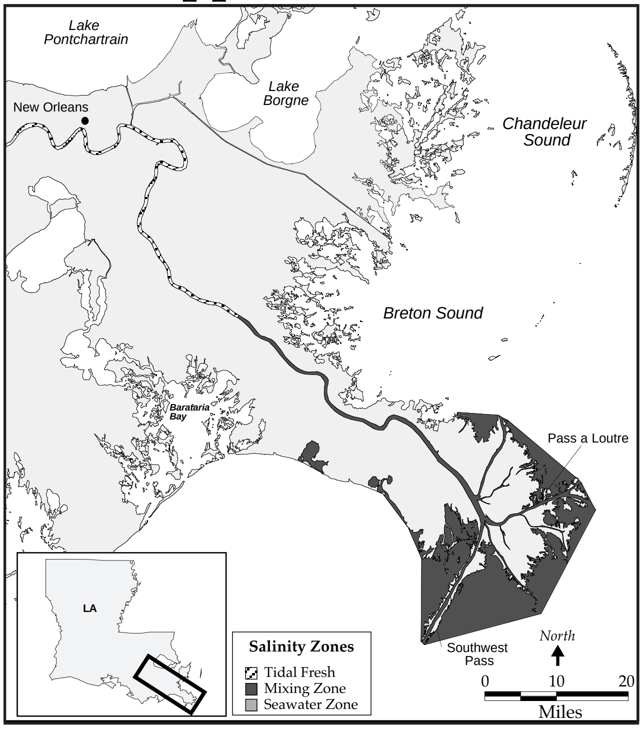
Dissolved Oxygen

	Tidal Fresh	Mixing		Seawater	
Anoxia		N	- - - *	Y 0-10%	?
Hypoxia		N	- - - *	Y 10-25%	?

Biological stress observed over 10 to 25 percent of mixing zone and 25 to 50 percent of seawater zone. Anoxic and hypoxic onditions occur periodically July to September, at bottom, except for biological stress, which occurs throughout water column in seawater zone.

Key on page 23

Mississippi River



In the Mississippi River, chlorophyll *a* concentrations range from low to medium and turbidity is high. Nuisance and toxic blooms are not observed. Nitrogen and phosphorus concentrations are high. Anoxia and hypoxia do not occur and there is no SAV in the system.

Trends were stable for all parameters except nuisance and toxic blooms, for which trends are unknown.

Physical and Hydrologic Characteristics

Estuarine Drainage Area *(mi2)* **1,846** Avg. Daily Inflow *(cfs)* **464,400**

	Estuary	Tidal Fresh	Mixing	Seawater
Surface Area *(mi2)*	378.3	54.9	323.4	
Average Depth *(ft)*	23.1	60.4	17.6	
Volume *(billion cu ft)*	243.0	92.0	159.0	

A river dominated estuarine system consisting of the Mississippi River and delta area with many small embayments and tidal marshes. As the largest single freshwater source in the U.S., the Mississippi River influences salinity distributions throughout the entire Louisiana and Texas Coast. Tidal range is 1.2 ft near the Southwest Pass.

Algal Conditions

	Tidal Fresh		Mixing		Seawater
Chlorophyll a	L	- - -	M 50-100%	- - -	
Turbidity	H 50-100%	- - -	H 50-100%	- - -	
Nuisance Algae	N	?	N	?	
Toxic Algae	N	?	N	?	

In mixing zone, maximum Chl-*a* concentrations occur periodically in summer with limiting factor of light. Turbidity occurs all year.

Ecosystem/Community Responses

	Tidal Fresh		Mixing		Seawater
SAV	NS	- - -	NS	- - -	

Primary productivity is dominated by the pelagic community. Planktonic community is a diverse mixture; benthic community dominated by annelids and crustaceans in tidal fresh zone and annelids in mixing zone.

Nutrients

	Tidal Fresh		Mixing		Seawater
Nitrogen	H 50-100%	- - -	H 50-100%	- - -	
Phosphorus	H 50-100%	- - -	H 50-100%	- - -	

High concentrations occur all year. A high magnitude increase in nutrients due to non-point sources occurred from 1940-70 then leveled off.

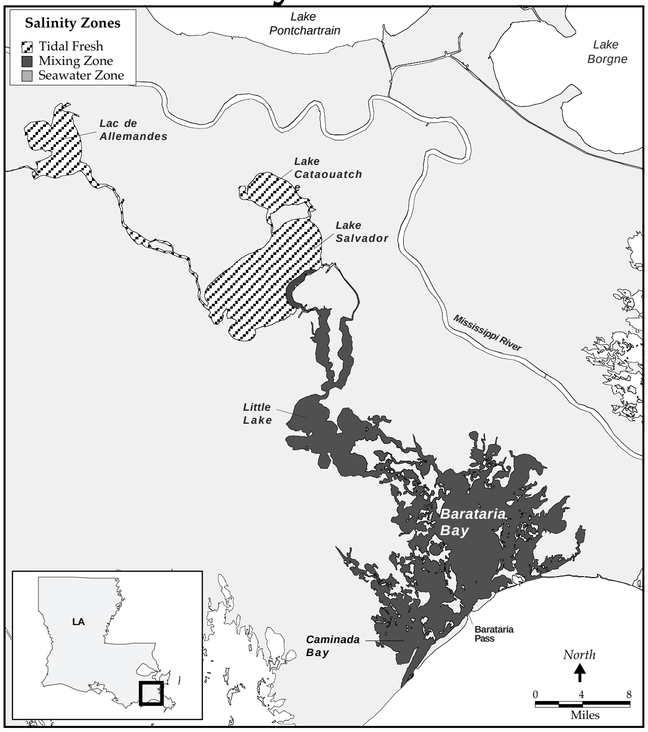
Dissolved Oxygen

	Tidal Fresh		Mixing		Seawater
Anoxia	N	- - -	N	- - -	
Hypoxia	N	- - -	N	- - -	

Biological stress periodically observed in up to 10 percent of mixing zone on bottom from July to September. Water column stratification is a highly significant factor.

Key on page 23

Barataria Bay



In Barataria Bay, chlorophyll *a* concentrations range from high to hypereutrophic and turbidity is high. Nuisance blooms occur in the tidal fresh zone. Nutrient concentrations are high, and anoxia and hypoxia are observed. Toxic algal conditions are unknown. SAV spatial coverage is low to medium.

Chlorophyll *a* , SAV, nitrogen, phosphorus and nuisance blooms all increased. Turbidity remained unchanged in the tidal fresh area. All other trends were unknown.

Physical and Hydrologic Characteristics

Estuarine Drainage Area *(mi2)* **2,193** Avg. Daily Inflow *(cfs)* **5,500**

	Estuary	Tidal Fresh	Mixing	Seawater
Surface Area *(mi2)*	359.2	109.6	249.6	
Average Depth *(ft)*	4.5	6.5	3.7	
Volume *(billion cu ft)*	45.1	19.9	25.7	

An estuarine-wetland system of Mississippi River deltaic plain. Lower portion consists of Caminada and Barataria Bays with shallow, wide area of open water interspersed with numerous marsh islands. Upper portion is composed of tidal marshes separated by tidal creeks, bayous and shallow lakes. An extensive network of small navigation channels and drainage canals has significantly altered hydrology. Salinity structure is largely determined by the advection of seasonal freshwater from the Mississippi River and by rainfall. Tide range is 1.2 ft near Barataria Pass.

Algal Conditions

	Tidal Fresh		Mixing		Seawater	
Chlorophyll a	E 50-100%	↑	H 50-100%	↑		
Turbidity	H 50-100%	- - -	H 50-100%	?		
Nuisance Algae	Y	↑	?	?		
Toxic Algae	?	?	?	?		

Maximum Chl-*a* concentrations occur throughout the year with limiting factors of nitrogen, phosphorus and silica in tidal fresh zone, and nitrogen and phosphorus in mixing zone. Turbidity is high throughout the year. Nuisance blue-green algae occurs persistently. Increase in Chl-*a* and nuisance blooms due to point and non-point sources.

Ecosystem/Community Responses

	Tidal Fresh		Mixing		Seawater	
SAV	M	↑ (open)	L	↑ (open)		

Primary productivity dominated by pelagic and benthic communities. Salt marshes were dominant but declined due to watershed alterations. Planktonic community is diverse with blue-green algae dominating; benthic community is diverse with annelids dominant in mixing zone. SAV increase due to changes in point and non-point sources in tidal fresh zone, and watershed alteration and emergent marsh loss in mixing zone.

Nutrients

	Tidal Fresh		Mixing		Seawater	
Nitrogen	H 50-100%	↑ (open) ? *	H 50-100%	↑ (open) ? *		
Phosphorus	H 50-100%	↑ (open) ? *	H 25-50%	- - -		

Elevated nitrogen concentrations occur October to May in tidal fresh zone and December to April in mixing zone. High phosphorus concentrations occur all year.

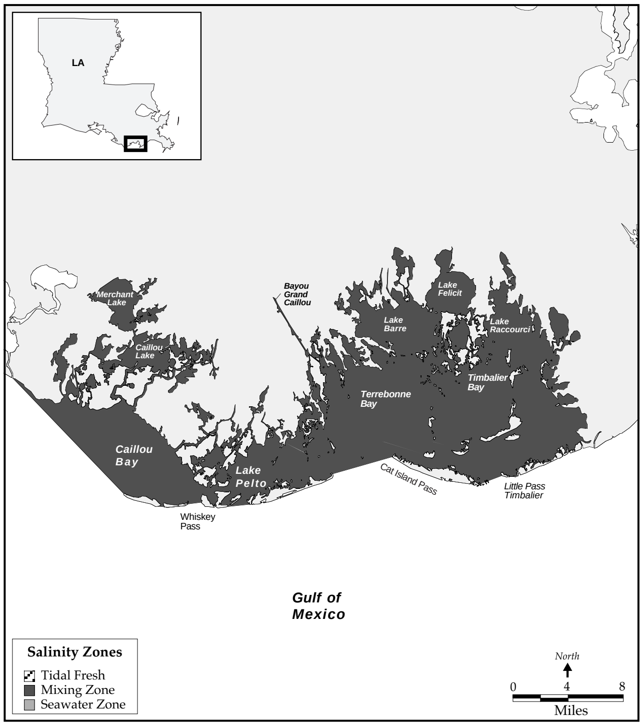
Dissolved Oxygen

	Tidal Fresh		Mixing		Seawater	
Anoxia	Y 10-25%	?	Y 0-10%	?		
Hypoxia	Y 25-50%	?	Y 0-10%	?		

In tidal fresh zone, conditions occur in bottom waters periodically June to September. In mixing zone, conditions occur throughout water column episodically June to September.

Key on page 23

Terrebonne/Timbalier Bays



In Terrebonne/Timbalier Bays, chlorophyll *a* concentrations and turbidity are high. Nuisance and toxic blooms occur episodically. Nitrogen concentrations are medium and phosphorus is high. Anoxia and hypoxia are not observed. SAV spatial coverage is low.

Chlorophyll *a*, nitrogen concentrations and SAV spatial coverage have increased; phosphorus concentrations remained unchanged. Other trends are unknown.

Physical and Hydrologic Characteristics

Estuarine Drainage Area (mi^2) **1,492** Avg. Daily Inflow (*cfs*) **4,600**

	Estuary	Tidal Fresh	Mixing	Seawater
Surface Area (mi^2)	515.2		515.2	
Average Depth (*ft*)	4.7		4.7	
Volume (*billion cu ft*)	67.5		67.5	

A major interdistributary basin within the Mississippi River Deltaic plain. Upper portion is composed of tidal marshes separated by tidal creeks, bayous and shallow lakes. Construction of the Bayou Lafourche dam and Mississippi River (not pictured) levees in the early 1900's has restricted inflow. Salinity structure is largely determined by advection of seasonal freshwater from Mississippi River and by rainfall. Tidal range is 1.2 ft near Cat Island Pass.

Algal Conditions

	Tidal Fresh	Mixing	Seawater
Chlorophyll a		H (50-100%) ↑	
Turbidity		H (50-100%) ?	
Nuisance Algae		Y* ?	
Toxic Algae		Y* ?	

Maximum Chl-*a* concentrations occur periodically January to September with limiting factors of nitrogen, phosphorus, and silica, and increase associated with non-point sources. Turbidity is high throughout the year. Nuisance *Noctiluca* spp. occur episodically March to May and toxic *Gymnodinium sangineum* and *Pseudo-nitzschia* spp. occur episodically throughout the year.

Ecosystem/Community Responses

	Tidal Fresh	Mixing	Seawater
SAV		L ↑?	

Primary productivity is dominated by pelagic and benthic communities. Historically, salt marshes were dominant producer but declined due to watershed alterations. Planktonic and benthic communities are a diverse mixture. Increase in SAV also due to physical alteration of watershed.

Nutrients

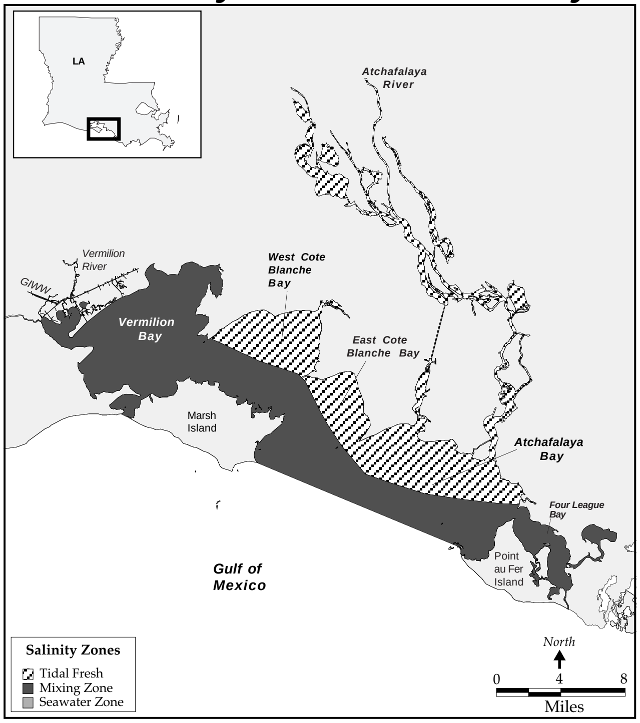
	Tidal Fresh	Mixing	Seawater
Nitrogen		M (?) ↑	
Phosphorus		H (?) - - -	

Dissolved Oxygen

	Tidal Fresh	Mixing	Seawater
Anoxia		N ?	
Hypoxia		N ?	

Biological stress observed periodically in bottom waters July to September over 25 to 50 percent of mixing area.

Atchafalaya/Vermilion Bays



In Atchafalaya/Vermilion Bays, chlorophyll *a* and turbidity are high. Nuisance and toxic blooms occur, but it is unknown whether they pose a problem. Nitrogen concentrations are high and phosphorus concentrations range from medium to high. Anoxia and hypoxia are both observed in the tidal fresh zone. SAV spatial coverage is high in the general tidal fresh zone.

Increasing trends were reported for chlorophyll *a* , nitrogen, anoxia and hypoxia. Turbidity and SAV spatial coverage decrease,d and phosphorus concentrations remained unchanged. Trends for nuisance and toxic algal blooms are unknown.

Physical and Hydrologic Characteristics

Estuarine Drainage Area (*mi2*) **7,261** Avg. Daily Inflow (*cfs*) **223,800**

	Estuary	Tidal Fresh		Mixing	Seawater
		In General	Atchafalaya R.		
Surface Area (*mi2*)	832.6	239.1	86.7	506.8	
Average Depth (*ft*)	6.5	n/a	n/a	5.4	
Volume (*billion cu ft*)	150.8	n/a	n/a	76.3	

Includes four major waterbodies, numerous bayous, locks, and canals. Receives majority of freshwater from Atchafalaya and Vermilion Rivers. Active and nonliving oyster reefs create numerous shallow areas which affect circulation and salinity. Salinity structure is determined primarily by discharge from the Atchafalaya River. Tidal range is 1.9 ft near mouth of Atchafalaya Bay.

Algal Conditions

	Tidal Fresh: In General		Tidal Fresh: Atchafalaya River		Mixing		Seawater
Chlorophyll a	H 50-100%	↑ *	H 50-100%	↑ *	H 25-50%	↑ *	
Turbidity	H 50-100%	↓	H 50-100%	↓	H 50-100%	↓	
Nuisance Algae	?	?	?	?	N	?	
Toxic Algae	?	?	?	?	N	?	

Maximum Chl-a concentrations occur periodically April to September with limiting factor of light in Atchafalya River, light and nitrogen in tidal fresh zone, and light, nitrogen and phosphorus in mixing zone. High turbidity is persistent. Chl-a and turbidity trends attributed to non-point sources. Nuisance and toxic species present in mixing zone, but unknown if a problem.

Ecosystem/Community Responses

	Tidal Fresh: In General		Tidal Fresh: Atchafalaya River		Mixing		Seawater
SAV	H	↓ ?	NS	?	NS	?	

Primary productivity is pelagic and benthic in Atchafalaya R., pelagic, benthic and emergent in tidal fresh zone, and pelagic and emergent in mixing zone. Pelagic productivity declined in Atchafalaya R. due to watershed alterations. Planktonic community dominated by blue-green algae; benthic community dominated by arthropods in Atchafalaya R., mollusks and arthropods in tidal fresh zone and mollusks and annelids in mixing zone. Decrease in SAV due to introduction of Hydrilla triggering a decrease in indigenous species.

Nutrients

	Tidal Fresh: In General		Tidal Fresh: Atchafalaya River		Mixing		Seawater
Nitrogen	H 50-100%	↑	H 50-100%	↑	H 50-100%	↑	
Phosphorus	H 50-100%	---	H 50-100%	---	M 50-100%	– – –	

Elevated concentrations occur all year in tidal fresh zone and November to April in mixing zone.

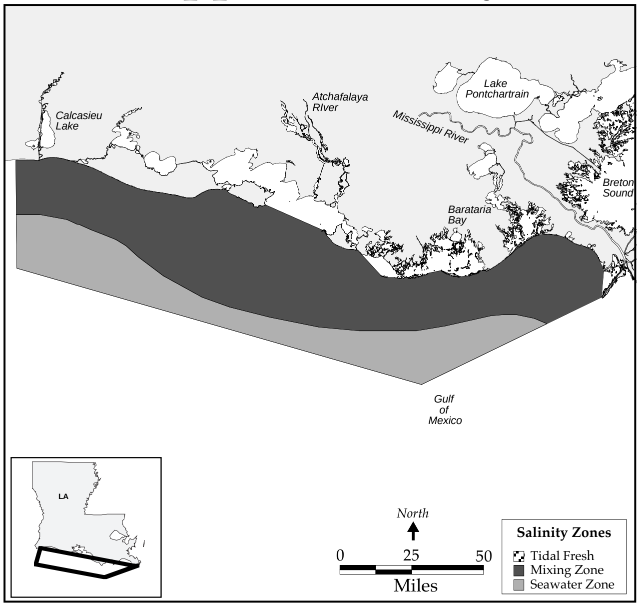
Dissolved Oxygen

	Tidal Fresh: In General		Tidal Fresh: Atchafalaya River		Mixing		Seawater
Anoxia	N	---	Y 10-25%	↑	N	?	
Hypoxia	N	---	Y 25-50%	↑	N	?	

Biological stress observed in 50 to 100 percent of both zones. Conditions occur periodically June to October in bottom waters. Water column stratification is a highly significant factor. Increases in frequency, duration, and spatial coverage attributed to changes in non-point sources.

Key on page 23

Mississippi/Atchafalaya River Plume



In the Mississippi/Atchafalaya River Plume, chlorophyll *a* concentrations range from low to high. Turbidity ranges from low to medium. Nitrogen concentrations range from low to high and phosphorus from low to medium. Nuisance and toxic blooms occur. Hypoxia and anoxia are observed over this area. There is no SAV in this system.

Chlorophyll *a*, nitrogen, phosphorus and hypoxia have increased and turbidity has decreased. Trends for nuisance and toxic blooms and, anoxia are unknown.

Physical and Hydrologic Characteristics

Estuarine Drainage Area (*mi²*) **n/a** Avg. Daily Inflow (*cfs*) **n/a**

	Estuary	Tidal Fresh	Mixing	Seawater
Surface Area (*mi²*)	**12,256.0**		**8,672.0**	**3,584.0**
Average Depth (*ft*)	**n/a**		**n/a**	**n/a**
Volume (*billion cu ft*)	**n/a**		**n/a**	**n/a**

A product of freshwater discharged from the Mississippi and Atchafalaya Rivers. During high inflow periods, a substantial volume of freshwater is carried in a westerly direction via a semipermanent offshore current, causing nearshore waters to become diluted along the Louisiana coast. The diluted oceanic water is periodically advected into estuaries along the Mississippi Deltaic Plain affecting salinity distributions and circulation within these estuaries.

Algal Conditions

	Tidal Fresh	Mixing		Seawater	
Chlorophyll *a*		H 50-100%	↑	L	- - -
Turbidity		M 50-100%	↓	L	- - -
Nuisance Algae		Y	?	N	?
Toxic Algae		Y*	?	N	?

Chl-*a* concentrations occur periodically February to May with limiting factors of nitrogen, light and silica and increase due to non-point sources. Medium turbidity occurs throughout the year with the decrease reported from 1982-97 due to increased productivity. Nuisance *Skeletonema* spp., and some toxic species occur in bloom proportion, but speculative if a problem to biological resources.

Ecosystem/Community Responses

	Tidal Fresh	Mixing		Seawater	
SAV		NS	- - -	NS	- - -

Primary productivity has increased and is dominated by the pelagic community. Planktonic community dominated by diatoms in spring and blue-green algae in summer; benthic community dominated by annelids in mixing zone and is diverse with annelids dominant in seawater zone. Non-point sources contributed to loss of benthic diversity in mixing zone.

Nutrients

	Tidal Fresh	Mixing		Seawater	
Nitrogen		H 25-50%	↑	L	- - -
Phosphorus		M 25-50%	↑	L	- - -

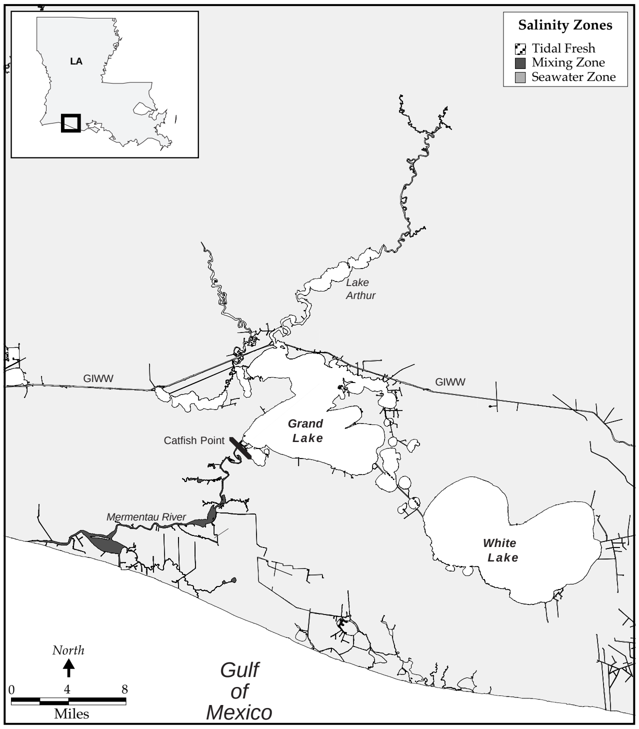
Elevated nitrogen occurs February to April, phosphorus months unknown. Trends attributed to non-point sources.

Dissolved Oxygen

	Tidal Fresh	Mixing		Seawater	
Anoxia		Y 10-25%	?	N	?
Hypoxia		Y 50-100%	↑	Y 50-100%	?

Biological stress observed in 50 to 100 percent of mixing and seawater zones. In mixing zone anoxia observed July to August, hypoxia and biological stress April to September. Anoxia occurs at bottom, hypoxia in lower half of column, and biological stress throughout water column. In seawater zone, hypoxia occurs at bottom May to August and biological stress throughout water column April to September. Water column stratification is moderate to highly significant factor in both zones.

Mermentau River



In Mermentau River, chlorophyll *a* concentrations are unknown. Turbidity and phosphorus are high and nitrogen concentrations are medium. Nuisance, toxic blooms, anoxia and hypoxia are not observed. There is no SAV in this system.

Trends for turbidity, anoxia, hypoxia, nitrogen and SAV were unchanged; phosphorus concentrations decreased. Nuisance and toxic bloom trends are unknown.

Physical and Hydrologic Characteristics

Estuarine Drainage Area *(mi2)* **1,391** Avg. Daily Inflow *(cfs)* **4,393**

	Estuary	Tidal Fresh	Mixing	Seawater
Surface Area *(mi2)*	**7.0**		**7.0**	
Average Depth *(ft)*	**3.9**		**0.0**	
Volume *(billion cu ft)*	**0.8**		**0.8**	

Extends from the head of tide at the Catfish Point Control Structure near Grand Lake to its terminus at the mouth. Impoundments built in early 1950's near Grand and White Lakes control salinity intrusion into those water bodies. Seasonal responses to freshwater discharge occur in the unregulated lower Mermentau River. This estuary is most influenced by periodic control structure releases and frontal passages.

Algal Conditions

	Tidal Fresh	Mixing	Seawater
Chlorophyll *a*		? ?	
Turbidity		H 50-100% ---	
Nuisance Algae		N ?	
Toxic Algae		N ?	

High turbidity occurs periodically and episodically December to January and April. Nuisance species are present, but not considered a problem.

Ecosystem/Community Responses

	Tidal Fresh	Mixing	Seawater
SAV		NS ---	

Primary productivity is dominated by emergent wetlands. Planktonic and benthic community dominance are unknown.

Nutrients

	Tidal Fresh	Mixing	Seawater
Nitrogen		M* ? ---	
Phosphorus		H* ? ↓	

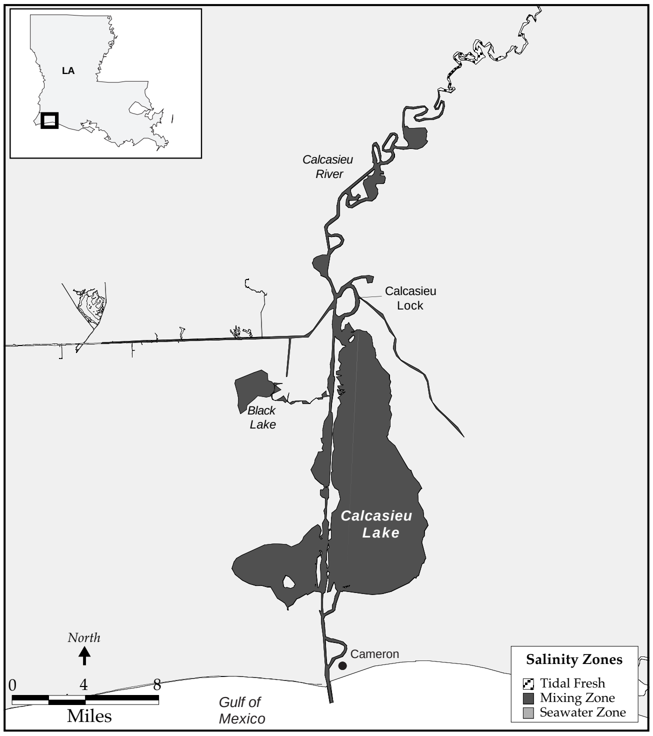
Concentrations reported are for nitrite and nitrate and total phosphorus. Medium nitrogen concentrations occur all year, high phosphorus occurs December and March through April. Decrease attributed to changes in non-point sources.

Dissolved Oxygen

	Tidal Fresh	Mixing	Seawater
Anoxia		N ---	
Hypoxia		N ---	

Key on page 23

Calcasieu Lake



In Calcasieu Lake, chlorophyll *a* and turbidity concentrations are high. Nuisance and toxic blooms, and anoxia and hypoxia, are observed. Nitrogen and phosphorus concentrations range from medium to high. SAV spatial coverage is low.

Chlorophyll *a* concentrations have increased. Turbidity, nuisance and toxic blooms, phosphorus and anoxia have remained unchanged. SAV spatial coverage, nitrogen concentrations and hypoxia decreased.

Physical and Hydrologic Characteristics

Estuarine Drainage Area *(mi^2)* **1,045** Avg. Daily Inflow *(cfs)* **6,300**

	Estuary	Tidal Fresh	Mixing	Seawater
Surface Area *(mi^2)*	**99.7**	**0.6**	**99.1**	
Average Depth *(ft)*	**9.4**	**26.3**	**9.2**	
Volume *(billion cu ft)*	**26.1**	**0.4**	**25.4**	

Consists of Calcasieu Lake and several secondary embayments. Receives majority of freshwater from Calcasieu River. Freshwater also flows between Mermentau and Calcasieu rivers by way of Calcasieu Lock. Several small navigation canals exist throughout the Calcasieu River basin. Seasonal flows influence the upper lake and Calcasieu River more than the lower estuary.

Algal Conditions

	Tidal Fresh		Mixing		Seawater
Chlorophyll *a*	H* 50-100%	?	H* 50-100%	↑	
Turbidity	H ?	---	H ?	---	
Nuisance Algae	N	?	Y	---	
Toxic Algae	N	?	Y	---	

Maximum Chl-*a* concentrations occur February to April with nitrogen as the limiting factor. High turbidity occurs in summer. Nuisance *Anacystis montana* occurs periodically in summer and toxic *Alexandrium monilata* and *Prorocentrum minimum* occurs episodically August to October.

Ecosystem/Community Responses

	Tidal Fresh		Mixing		Seawater
SAV	NS	---	L	↓	

Primary productivity is dominated by pelagic community in tidal fresh zone, and is emergent, pelagic and benthic in mixing zone. Planktonic community dominated by diatoms in tidal fresh zone and is diverse in mixing zone; benthic community dominated by annelids in tidal fresh zone and is diverse in mixing zone. Decrease in SAV attributed to alterations to watershed and point sources.

Nutrients

	Tidal Fresh		Mixing		Seawater
Nitrogen	M 50-100%	↓*	H 10-25%	↓*	
Phosphorus	M 50-100%	---	H 10-25%	---	

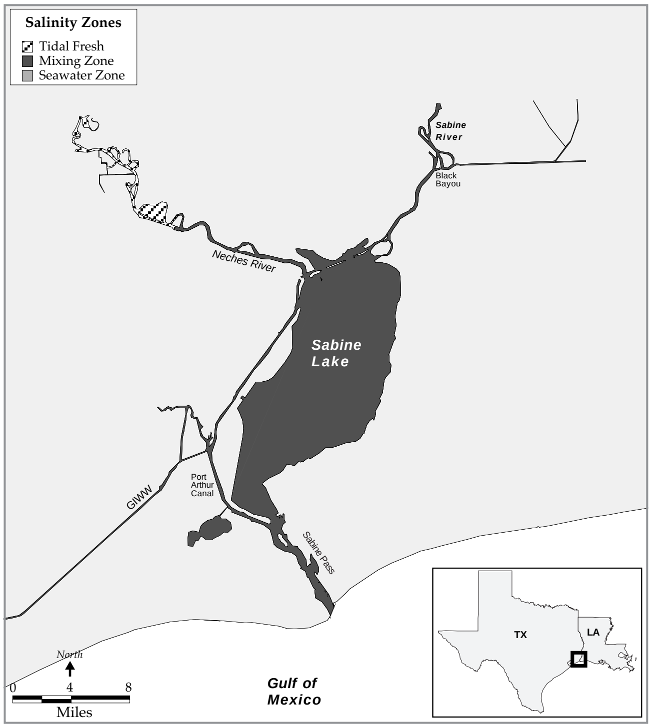
Elevated nutrient concentrations occur March to May. Decreases are attributed to changes in point sources.

Dissolved Oxygen

	Tidal Fresh		Mixing		Seawater
Anoxia	Y 0-10%	?	Y 0-10%	---	
Hypoxia	Y 10-25%	?	Y 25-50%	↓*	

Biological stress observed in 50 to 100 percent of tidal fresh and mixing zones. Conditions occur July to September throughout water column (anoxia on bottom in mixing zone). Minimum average monthly bottom dissolved oxygen increased to a low extent in seawater zone from 1985-95. Decreases in frequency, duration, and spatial coverage of hypoxia attributed to point source changes.

Sabine Lake



In Sabine Lake, concentrations of chlorophyll *a*, nitrogen and phosphorus are medium and turbidity is high. Nuisance blooms occur but toxic blooms do not. Hypoxia is observed over a very low area. SAV spatial coverage is very low.

Nitrogen and phosphorus concentrations decreased and nuisance blooms increased. For all other parameters, trends have remained unchanged.

Physical and Hydrologic Characteristics

Estuarine Drainage Area (*mi2*) **4,786** Avg. Daily Inflow (*cfs*) **17,200**

	Estuary	Tidal Fresh	Mixing	Seawater
Surface Area (*mi2*)	102.2	3.2	99.0	
Average Depth (*ft*)	8.2	15.0	8.1	
Volume (*billion cu ft*)	23.3	1.3	22.3	

Consists of a relatively broad and shallow open bay, and a narrow, deep channel on the western side. Receives majority of freshwater from Sabine and Neches Rivers. The main navigation channel (36 ft in depth) significantly influences circulation and salinity patterns. Since 1948, timing and fluctuations of river flow has been affected by approximately 20 reservoirs that have been constructed within the watershed. Tidal range is 0.5 to 1.0 ft at Sabine Pass.

Algal Conditions

	Tidal Fresh		Mixing		Seawater
Chlorophyll *a*	M 25-50%	- - -	M 25-50%	- - -	
Turbidity	H 50-100%	- - -	H 50-100%	- - -	
Nuisance Algae	N	- - -	Y	↑ *	
Toxic Algae	N	- - -	N	?	

Maximum Chl-*a* concentrations occur periodically April to September with light as the limiting factor. Turbidity occurs persistently throughout the year. Nuisance *Gymnodinium sanguinium* occurs episodically May to July with increase speculated to be attributed to non-point sources.

Ecosystem/Community Responses

	Tidal Fresh		Mixing		Seawater
SAV	NS	- - -	VL	- - -	

Primary productivity is dominated by the pelagic community in tidal fresh zone and pelagic and wetland communities in mixing zone. Planktonic community dominated by blue-green algae in tidal fresh zone and diatoms in mixing zone; benthic community dominated by mollusks in tidal fresh zone and is diverse in mixing zone.

Nutrients

	Tidal Fresh		Mixing		Seawater
Nitrogen	M 50-100%	- - -	M 50-100%	↓ *	
Phosphorus	M 50-100%	↓ *	M 50-100%	↓ *	

Medium concentrations occur all year. Decreases attributed to changes in point sources.

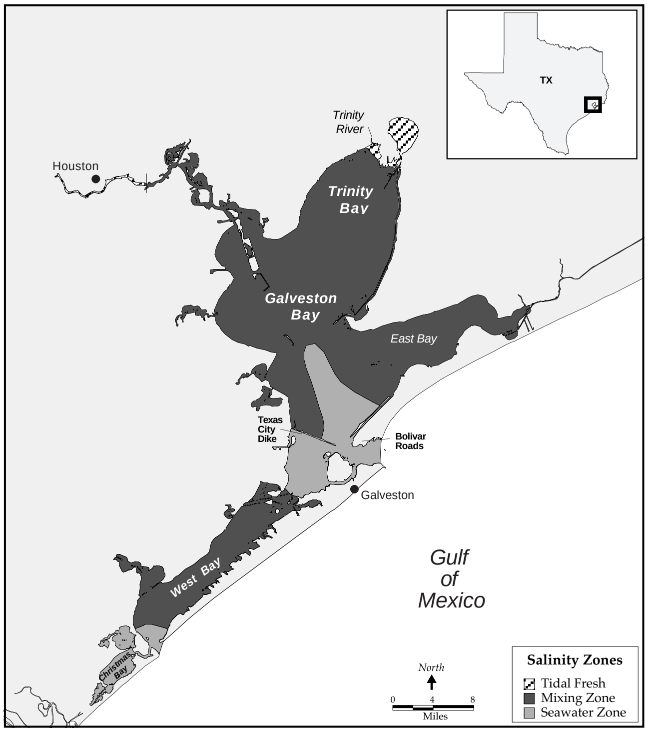
Dissolved Oxygen

	Tidal Fresh		Mixing		Seawater
Anoxia	N	↓	N	- - -	
Hypoxia	N	↓	Y 0-10%	- - -	

Hypoxia observed periodically July to August in bottom waters. Biological stress observed in mixing zone periodically July to September throughout water column. Water column stratification is moderate factor contributing to hypoxic conditions. Decreases in frequency, duration, and spatial coverage attributed to changes in point sources.

 Key on page 23

Galveston Bay



In Galveston Bay, chlorophyll *a* concentrations range from low to medium. Turbidity ranges from medium to high, and nitrogen and phosphorus concentrations range from low to high. Nuisance and toxic blooms, and hypoxia and anoxia, are observed. SAV spatial coverage is very low.

Trends for all parameters have decreased with the exception of toxic blooms, which have remained stable.

Physical and Hydrologic Characteristics

Estuarine Drainage Area (*mi2*) **4,441** Avg. Daily Inflow (*cfs*) **15,414**

	Estuary	Tidal Fresh: In General	Tidal Fresh: Trinity River	Mixing	Seawater: Lower Galveston	Seawater: Christmas Bay
Surface Area (*mi2*)	553.0	1.6	9.6	462.1	70.1	9.6
Average Depth (*ft*)	6.2	n/a	n/a	6.4	n/a	n/a
Volume (*billion cu ft*)	95.6	n/a	n/a	82.4	n/a	n/a

Consists of several major embayments including Trinity, Galveston, East, West, and Christmas Bays. Receives majority of freshwater inflow from Trinity River. During high flow, Texas City Dike inhibits low salinity water from entering West Bay. Seasonal freshwater discharge from Trinity River determines salinity structure. Winds from frontal passages promote water column mixing. Tidal range is 1.4 ft near Bolivar Roads.

Algal Conditions

	Tidal Fresh: In General	Tidal Fresh: Trinity River	Mixing	Seawater: Lower Galveston	Seawater: Christmas Bay
Chlorophyll *a*	M 50-100% ?	M 50-100% ?	M 50-100% ↓	M 10-25% ↓	L* ---
Turbidity	H 50-100% ↓	H 50-100% ↓	H 50-100% ↓	H 50-100% ↓	M 50-100% ---
Nuisance Algae	N ?	N ?	N ↓?	Y* ---	N ?
Toxic Algae	N ?	N ?	Y* --	Y* ---	N ?

Maximum Chl-*a* concentrations occur episodically spring and summer with limiting factors of nitrogen in all zones co-limiting with light in tidal fresh zone and phosphorus and light in mixing zone. Chl-*a* trends reported for 1989-95 in mixing and 1970-95 in seawater zone. Turbidity occurs all year except in tidal fresh where it occurs episodically and periodically February to June. Decreases in Chl-*a* and turbidity associated with changes in point and non-point sources. Toxic *Gonyaulax* spp. occur episodically in summer.

Ecosystem/Community Responses

	Tidal Fresh: In General	Tidal Fresh: Trinity River	Mixing	Seawater: Lower Galveston	Seawater: Christmas Bay
SAV	NS ---	VL ?	VL ↓	NS ---	L ↓

Primary productivity dominated by pelagic community except Trinity River (salt marsh) and Christmas Bay (pelagic/benthic). Planktonic community dominance unknown; benthic community dominated by annelids in tidal fresh and mixing zones, and mollusks in Trinity River and Christmas Bay. Decrease in SAV in mixing zone due to watershed alterations and physical disturbances, and in Christmas Bay from changes in point and non-point sources.

Nutrients

	Tidal Fresh: In General	Tidal Fresh: Trinity River	Mixing	Seawater: Lower Galveston	Seawater: Christmas Bay
Nitrogen	H 50-100% ↓	M 50-100% ---	M 25-50% ↓	M 50-100% ↓	L ---
Phosphorus	H 50-100% ↓	M 50-100% ---	H 50-100% ↓	M 50-100% ↓	L ---

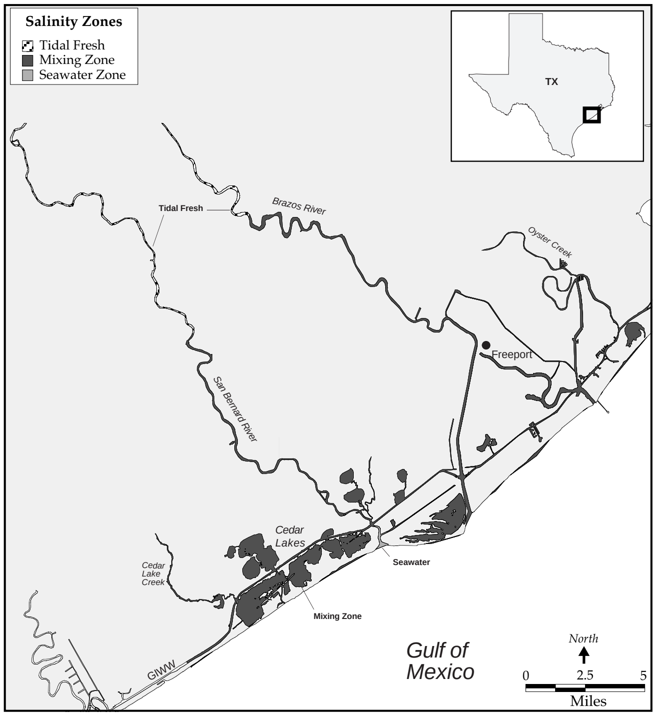
Elevated concentrations in tidal fresh zone occur April to October and in mixing zone May to December. In Lower Galveston Bay, medium nitrogen occurs April to June, and medium phosphorus occurs all year.

Dissolved Oxygen

	Tidal Fresh: In General	Tidal Fresh: Trinity River	Mixing	Seawater: Lower Galveston	Seawater: Christmas Bay
Anoxia	Y 10-25% ↓	N ---	N ↓*	N ---	N ---
Hypoxia	Y 50-100% ↓	N ---	Y 10-25% ↓*	N ---	N ---

In tidal fresh zone, low dissolved oxygen occurs periodically June to September in bottom. In mixing zone, conditions occur July to September in bottom, episodically for hypoxia and periodically for biological stress. Water column stratification has moderate influence on dissolved oxygen conditions.

Brazos River



In Brazos River, chlorophyll *a* concentrations are medium and turbidity is high. Nuisance blooms do not occur and toxic blooms occur only in the seawater zone. Nitrogen concentrations are medium and phosphorus ranges from medium to high. Anoxia is not observed but hypoxia occurs. SAV spatial coverage is very low.

Trends for all parameters were stable with the exception of chlorophyll *a* concentrations, which have decreased in the tidal fresh zone.

Physical and Hydrologic Characteristics

Estuarine Drainage Area (*mi2*) **2,792** Avg. Daily Inflow (*cfs*) **7,400**

	Estuary	Tidal Fresh	Mixing	Seawater
Surface Area (*mi2*)	18.1	1.1	16.9	0.1
Average Depth (*ft*)	3.8	8.0	3.4	12.0
Volume (*billion cu ft*)	1.9	0.2	1.6	0.03

Includes Brazos and San Bernard Rivers, Cedar Lakes and the GIWW (Gulf Intercoastal Waterway). Floodgates block flow between Brazos River and the GIWW. Flows from San Bernard River are not as confined to river channel as Brazos River and may influence salinities over a larger portion of the estuary. Tide range is 0.6 ft near mouth of Brazos River.

Algal Conditions

	Tidal Fresh		Mixing		Seawater	
Chlorophyll *a*	M 50-100%	↓ *	M 25-50%	- - -	?	?
Turbidity	H 50-100%	- - -	H 50-100%	- - -	H ?	?
Nuisance Algae	N	- - -	N	- - -	N	?
Toxic Algae	N	- - -	N	- - -	Y	?

Maximum Chl-*a* concentrations occur periodically in summer in tidal fresh zone, and episodically all year in mixing zone with light as limiting factor in both zones. Decrease in Chl-*a* reported for 1990-94. Turbidity occurs throughout the year. One occurrence of toxic *Gymnodinium breve* was reported in the seawater zone (year unidentified).

Ecosystem/Community Responses

	Tidal Fresh		Mixing		Seawater	
SAV	NS	- - -	VL	- - -	NS	?

Primary productivity dominated by pelagic community in tidal fresh and mixing zones. Planktonic community dominance is unknown; benthic community speculated to be diverse in tidal fresh zone and dominated by annelids in mixing and seawater zones.

Nutrients

	Tidal Fresh		Mixing		Seawater	
Nitrogen	M 50-100%	- - -	M 50-100%	- - -	?	?
Phosphorus	H 50-100%	- - -	M 50-100%	- - -	?	?

Elevated nitrogen concentrations occur all year in tidal fresh and December to July in mixing zone. Elevated phosphorus occurs April to June in tidal fresh and all year in mixing zone.

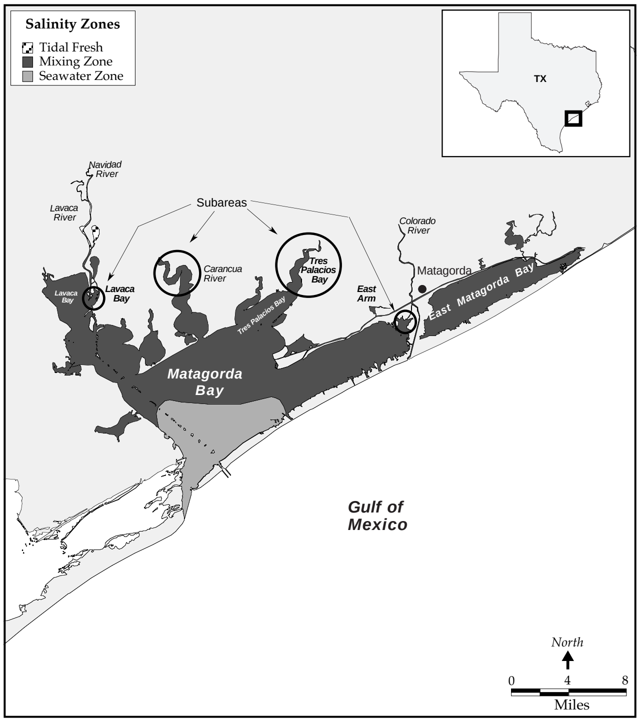
Dissolved Oxygen

	Tidal Fresh		Mixing		Seawater	
Anoxia	N	- - -	N	- - -	?	?
Hypoxia	N	- - -	Y 25-50%	- - -	?	?

Biological stress is observed in 10 to 25 percent of tidal fresh and 25 to 50 percent of mixing zone. Conditions occur periodically in bottom waters from June to September. Water column stratification is a highly significant factor in mixing zone.

Key on page 23

Matagorda Bay



In Matagorda Bay, chlorophyll *a* concentrations range from low to hypereutrophic and turbidity is high. Nuisance and toxic blooms are observed. Nitrogen concentrations are medium to high and phosphorus is high. Hypoxia does not occur but anoxia does. SAV spatial coverage ranges from none to low.

Turbidity and SAV spatial coverage have increased. Nutrient concentrations have increased in the East Arm of the mixing zone, and phosphorus has increased in the seawater zone. Both nitrogen and phosphorus concentrations have decreased in Lavaca Bay. All other trends are stable.

Physical and Hydrologic Characteristics

Estuarine Drainage Area (mi^2) **5,901** Avg. Daily Inflow (*cfs*) **6,236**

	Estuary	TF	Mixing: In General	Mixing: Lavaca Bay	Mixing: East Arm	Seawater
Surface Area (mi^2)	439.6	2.3	344.0	4.8	2.0	75.3
Average Depth (*ft*)	7.0	2.6	n/a	n/a	n/a	9.5
Volume (*billion cu ft*)	85.8	0.2	n/a	n/a	n/a	19.9

A broad, shallow lagoonal system separated from the Gulf of Mexico by Matagorda Peninsula. Includes Colorado River, and Matagorda, East Matagorda, Lavaca, Carancahua, and Tres Palacios Bays. Receives majority of freshwater inflow from Colorado, Lavaca/Navidad and Tres Palacios basins. Vertically homogeneous conditions commonly exist in the open bay.

Algal Conditions

	Tidal Fresh		Mixing: In General		Mixing: All subareas		Seawater	
Chlorophyll *a*	H 50-100%	---	M 50-100%	---	E 50-100%	---	L	---
Turbidity	H 50-100%	---	H 50-100%	↑			H 25-50%	↑
Nuisance Algae	N	---*	Y	---*			N	---*
Toxic Algae	N	---*	N	---			Y	---

Maximum Chl-*a* concentrations occur periodically March to August with light and nitrogen as co-limiting factors. Turbidity occurs all year with increases due to point sources reported for 1968-89. Nuisance *Aureoumbra lagunensis* occurred episodically in summer of 1992 and toxic *Gymnodinium breve* occurred episodically in fall of 1986 and September to October 1996.

Ecosystem/Community Responses

	Tidal Fresh		Mixing		Seawater	
SAV	NS	---	L	↑	L	---

Primary productivity dominated by pelagic community. Planktonic community dominated by flagellates and diatoms in tidal fresh zone, is diverse in mixing zone, and dominated by diatoms in seawater zone; benthic community is diverse with annelids dominating. Increase in SAV attributed to climatic cycles.

Nutrients

	Tidal Fresh		Mixing: In General		Mixing: Subareas	Lavaca Bay	East Arm	Seawater	
Nitrogen	H 50-100%	?	H 10-25%	---	H 10-25%	↓	↑	M 50-100%	---
Phosphorus	H 50-100%	?	H 50-100%	---	H 50-100%	↓	↑	H 50-100%	↑

Concentrations are for total nitrogen and total phosphorus. Elevated nitrogen concentrations occur April to July plus October to November in seawater. Elevated phosphorus occurs March to August in tidal fresh, April to July and October to November in mixing and seawater zones. Increases in East Arm attributed to diversion channel plus changes in point and non-point sources. Decreases attributed to point source changes.

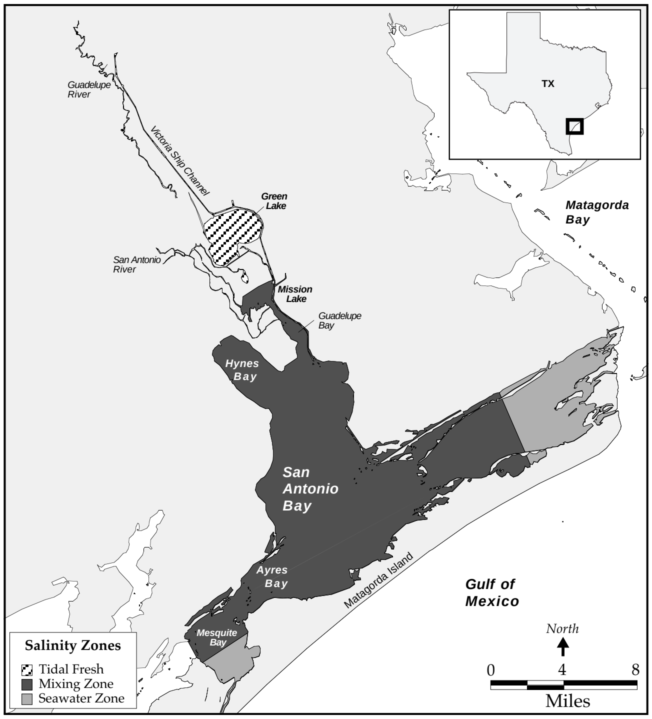
Dissolved Oxygen

	Tidal Fresh		Mixing		Seawater	
Anoxia	N	---	N	---	N	---
Hypoxia	Y 50-100%	---	Y 10-25%	---	Y 10-25%	---

Low dissolved oxygen conditions occur episodically August to October in bottom waters (throughout water column in mixing zone for biological stress). Water column stratification is moderate to highly significant factor.

Key on page 23

San Antonio Bay



In San Antonio Bay, chlorophyll *a* concentrations range from low to high and turbidity is high. Nuisance and toxic blooms have occurred infrequently. Nitrogen and phosphorus concentrations range from low to high. Anoxia does not occur, but hypoxia is observed episodically. SAV spatial coverage is low or very low.

Chlorophyll *a* concentrations and nuisance and toxic bloom events have remained stable. Turbidity, nitrogen and phosphorus concentrations have increased; SAV spatial coverage has decreased. Trends for anoxia and hypoxia are unknown.

Physical and Hydrologic Characteristics

Estuarine Drainage Area *(mi2)* **1,556** Avg. Daily Inflow *(cfs)* **4,100**

	Estuary	Tidal Fresh	Mixing	Seawater
Surface Area *(mi2)*	**215.0**	**11.2**	**168.7**	**35.1**
Average Depth *(ft)*	**4.3**	**4.0**	**4.3**	**4.3**
Volume *(billion cu ft)*	**25.7**	**1.2**	**20.4**	**4.2**

Consists of San Antonio, Espiritu Santo and Mesquite Bays, and several secondary bays. Receives majority of freshwater inflow from Guadalupe and San Antonio Rivers. Construction of navigation channels has modified circulation patterns. Freshwater inflow is retained in system for extended periods thereby lowering salinities. Meteorologic forcing can alter salinities by increasing saltwater intrusion from adjacent estuaries. North winds associated with cold fronts tend to increase water column mixing .

Algal Conditions

	Tidal Fresh		Mixing		Seawater	
Chlorophyll *a*	L	- - -	H 10-25%	- - -	M 50-100%	- - -
Turbidity	H 50-100%	↑	H 50-100%	↑	H 50-100%	- - -
Nuisance Algae	N	- - -	Y*	- - -	Y*	- - -
Toxic Algae	N	- - -	Y	- - -	Y	- - -

Maximum Chl-*a* concentrations occur episodically all year with limiting factor of phosphorus speculated to be co-limiting with nitrogen. Turbidity occurs persistently all year with increases speculated to be due with point and non-point sources. Nuisance blue-greens occurred episodically for days in September of 1990 and toxic *Gymnodinium breve* occurred episodically in fall of 1986.

Ecosystem/Community Responses

	Tidal Fresh		Mixing		Seawater	
SAV	NS	- - -	VL	↓	L	- - -

Primary productivity dominated by pelagic community. Planktonic and benthic communities are diverse. Decrease in SAV associated with point and non-point sources.

Nutrients

	Tidal Fresh		Mixing		Seawater	
Nitrogen	H 50-100%	↑	H 25-50%	- - -	L	- - -
Phosphorus	H 50-100%	↑	H 25-50%	↑	L	↑*

High nutrient concentrations occur all year in tidal fresh zone and November to March in mixing zone.

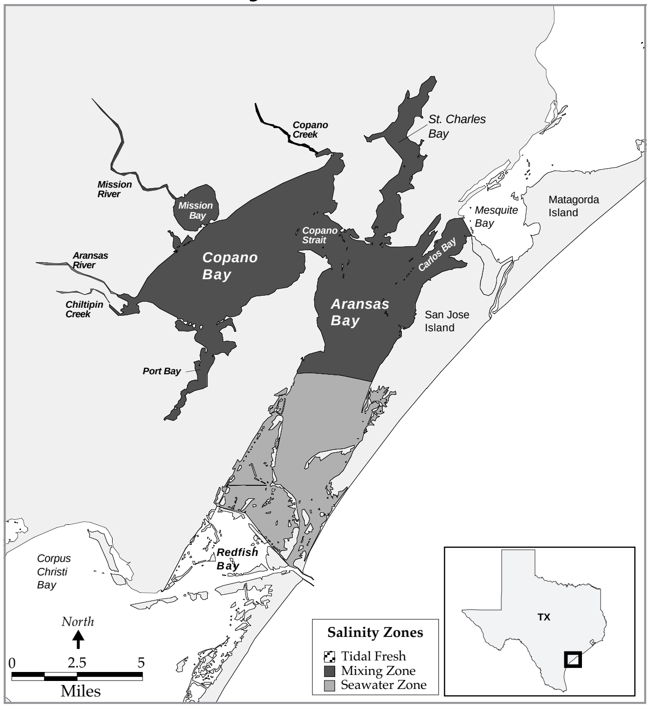
Dissolved Oxygen

	Tidal Fresh		Mixing		Seawater	
Anoxia	N	?	N	?	N	?
Hypoxia	N	?	Y 10-25%	?	N	?

Biological stress observed in 10 to 25 percent of mixing and seawater zones. Conditions occur April to October. Hypoxia occurs episodically on bottom, biological stress periodically throughout the water column. Water column stratification is a highly significant factor.

 Key on page 23

Aransas Bay



In Aransas Bay, chlorophyll *a* concentrations range from medium to high and turbidity is high. Nuisance and toxic blooms are observed but anoxia and hypoxia are not. Nitrogen and phosphorus concentrations range from low to medium. SAV spatial coverage ranges from very low in the mixing zone to medium in the seawater zone.

SAV spatial coverage, nitrogen concentrations and hypoxia occurrences have decreased; phosphorus concentrations have increased. All other parameters remained unchanged.

Physical and Hydrologic Characteristics

Estuarine Drainage Area (*mi2*) **2,671** Avg. Daily Inflow (*cfs*) **1,000**

	Estuary	Tidal Fresh	Mixing: In General	Mixing: Creeks	Seawater
Surface Area (*mi2*)	203.0		142.3	2.0	58.7
Average Depth (*ft*)	5.3		n/a	n/a	7.3
Volume (billion cu ft)	29.9		n/a	n/a	11.9

A lagoonal estuary separated from the Gulf of Mexico by San Jose Island. Consists of Copano, Aransas, and Mission Bays, plus other secondary embayments. Freshwater inflow tends to be from isolated pulses during high inflow months which depress salinities within Copano Bay. Existence of oyster reefs across Copano Bay impedes water circulation and affects salinity patterns in upper estuary.

Algal Conditions

	Tidal Fresh	Mixing: In General		Mixing: Creeks		Seawater	
Chlorophyll *a*		M 50-100%	---	H 50-100%	---	M 10-25%	---
Turbidity		H 50-100%	---	H 50-100%	---	H 10-25%	---
Nuisance Algae		Y	---	Y	---	N	---
Toxic Algae		Y	---	N	---	Y	---

Maximum Chl-*a* concentrations occur episodically all year in Creeks, and April to August in mixing and seawater zones with limiting factor of nitrogen in all zones. Turbidity occurs persistently. Nuisance *Aureoumbra lagunensis* occurs episodically all year in Creeks and in summer in mixing zone. Toxic *Gymnodinium breve* occurred in July of 1986 and 1991 in mixing zone, and occurs episodically in fall in seawater zone.

Ecosystem/Community Responses

	Tidal Fresh	Mixing: In General		Mixing: Creeks		Seawater	
SAV		VL	?	NS	---	M	⇩

Primary productivity is dominated by pelagic community in Creeks, is a mix of pelagic, wetland and SAV in mixing zone, and wetlands and SAV in seawater zone. Planktonic community dominated by *Aureoumbra lagunensis* in Creeks and by diatoms in mixing and seawater zones; benthic community dominated by annelids. Decrease in SAV due to non-point sources, macroalgae, epiphytes, and physical disturbance.

Nutrients

	Tidal Fresh	Mixing: In General		Mixing: Creeks		Seawater	
Nitrogen		M 25-50%	⇩	L	---	M 25-50%	⇩
Phosphorus		M 25-50%	---	L	---	M 25-50%	⇧

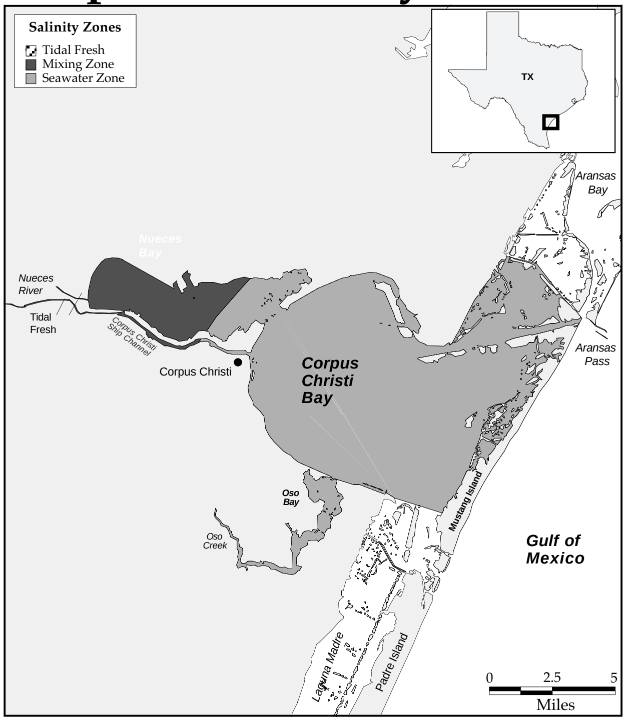
Concentrations reflect total nitrogen in mixing zone and trends reflect dissolved inorganic nitrogen. Elevated nitrogen occurs November to May. Elevated phosphorus occurs all year in mixing and April to October in seawater zone. Trends attributed to changes in non-point sources.

Dissolved Oxygen

	Tidal Fresh	Mixing: In General		Mixing: Creeks		Seawater	
Anoxia		N	---	N	---	N	---
Hypoxia		N	---	N	⇩	N	---

Biological stress observed over 50 to 100 percent of seawater zone, occuring throughout water column periodically July to September. Moderate increase in minimum average bottom dissolved oxygen concentrations and decrease in frequency, duration, and spatial extent of hypoxia and biological stress attributed to changes in point sources.

Corpus Christi Bay



In Corpus Christi Bay, chlorophyll *a* concentrations are medium to high. Turbidity is high and both nitrogen and phosphorus concentrations range from low to high. Nuisance and toxic blooms are observed. Anoxia does not occur, but hypoxia occurs in the seawater zone. SAV spatial coverage ranges from none to low.

Trends in turbidity, toxic blooms, nitrogen concentrations, anoxia, hypoxia and SAV spatial coverage have remained stable. Chlorophyll *a*, nuisance blooms and phosphorus concentrations increased.

Physical and Hydrologic Characteristics

Estuarine Drainage Area (*mi2*) **1,955** Avg. Daily Inflow (*cfs*) **1,200**

	Estuary	Tidal Fresh	Mixing	Seawater
Surface Area (*mi2*)	207.8	n/a	18.1	189.7
Average Depth (*ft*)	7.8	n/a	7.9	7.4
Volume (*billion cu ft*)	45.2	n/a	3.9	39.1

A bar-built system separated from the Gulf of Mexico by Mustang Island. Consists of Corpus Christi and Nueces Bays and two secondary bays, Oso and Redfish Bays. Receives majority of freshwater inflow from isolated pulses during high inflow months from Nueces River and Oso Creek. Salinities can reach hypersaline levels especially near Laguna Madre. Evaporation is dominant influence on salinity structure.

Algal Conditions

	Tidal Fresh		Mixing		Seawater	
Chlorophyll a	M 10-25%	---	H 25-50%	↑	M 50-100%	↑
Turbidity	H 50-100%	---	H 50-100%	---	H 50-100%	---
Nuisance Algae	N	---	Y	↑ *	Y	---
Toxic Algae	N	---	Y	---	Y	---

Maximum Chl-a concentrations occur all year in tidal fresh zone with limiting factors of nitrogen and light, and periodically February to October in mixing and seawater zones with limiting factor of nitrogen. Increase in Chl-a due to point and non-point sources. Turbidity occurs all year. Nuisance Aureoumbra lagunensis and blue-greens occurred in 1991 in mixing zone and Aureoumbra lagunensis and Noctaluca occurs periodically February to March in seawater zone. Toxic Gymnodinium breve occurs fall and toxic Alexandrium monilata occurred in August of 1992.

Ecosystem/Community Responses

	Tidal Fresh		Mixing		Seawater	
SAV	NS	---	VL	---	L	---

Primary productivity dominated by pelagic community in tidal fresh zone, pelagic and wetland in mixing zone, and pelagic and SAV in seawater zone. Planktonic community dominated by blue-green algae and diatoms in tidal fresh zone, is a diverse mixture with blue-green algae dominant in mixing zone, and a diverse mixture with diatoms dominant in seawater zone. Benthic community dominated by aquatic insects in tidal fresh zone, and is diverse with annelids dominant in mixing and seawater zones.

Nutrients

	Tidal Fresh		Mixing		Seawater	
Nitrogen	H 50-100%	?	M 50-100%	---	L	---
Phosphorus	H 50-100%	?	M 50-100%	---	L	---

Elevated nutrient concentrations occur all year in tidal fresh zone, November to January and April to July in mixing zone. Phosphorus increased from 1968 to 1989 to a low extent in the mixing and seawater zones and then leveled off.

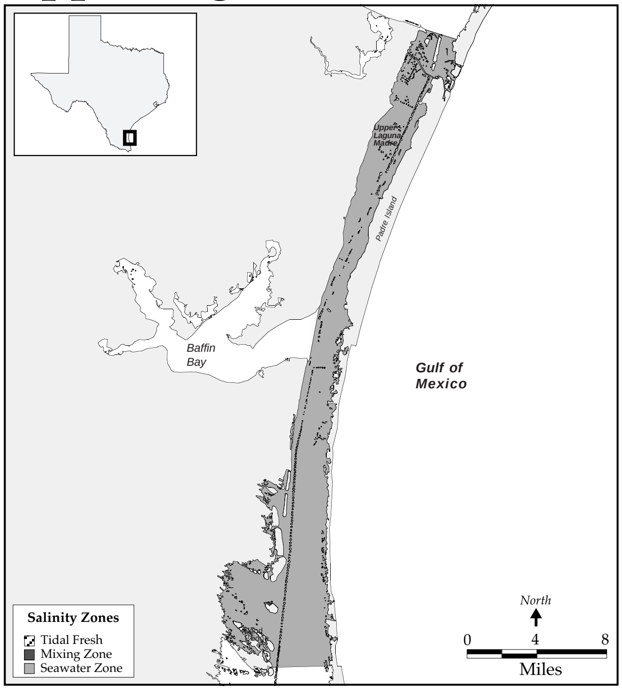
Dissolved Oxygen

	Tidal Fresh		Mixing		Seawater	
Anoxia	N *	?	N	---	N	---
Hypoxia	N *	?	N	---	Y 10-25%	---

Hypoxia occurs periodically June to August in bottom waters. Stratification is moderate factor in hypoxic conditions. Biological stress observed periodically in 50 to 100 percent of mixing zone and 25 to 50 percent of seawater zone, throughout water column.

Key on page 23

Upper Laguna Madre



In Upper Laguna Madre, chlorophyll *a* concentrations are hypereutrophic, turbidity is high and nuisance blooms are observed, though toxic blooms are not. Nitrogen and phosphorus concentrations are low. Anoxia is not observed, but hypoxia occurs periodically. SAV spatial coverage is high.

Chlorophyll *a* concentrations, turbidity, nuisance blooms and phosphorus concentrations increased. Nitrogen concentrations, anoxia and hypoxia remained stable. Trends for toxic blooms are unknown. SAV increased in shallow bays but decreased in channels.

Algal Conditions

	Tidal Fresh	Mixing	Seawater
Chlorophyll a			E 50-100% ↑
Turbidity			H 50-100% ↑
Nuisance Algae			Y ↑
Toxic Algae			N ?

Maximum Chl-*a* concentrations occur periodically all year with limiting factor of nitrogen and an increase reported for 1990-96. Turbidity occurs persistently all year with increases attributed to brown tides. Nuisance *Aureoumbra lagunensis* occurs persistently throughout the year. Chl-*a* and nuisance bloom increases associated with non-point sources.

Ecosystem/Community Responses

	Tidal Fresh	Mixing	Seawater
SAV			H; Shallow Bays ↑; Deep Channels ↓

Primary productivity is dominated by pelagic and SAV communities. Planktonic community dominated by *Aureoumbra lagunensis*, but previously was diverse; benthic community is diverse with annelids dominating due to onset of the brown tide. Decrease in SAV in deep channels due to *Aureoumbra lagunensis* (light limitation) and increase in shallow bays due to changes in climate and watershed.

Physical and Hydrologic Characteristics

Estuarine Drainage Area (*mi2*) **5,396** Avg. Daily Inflow (*cfs*) **627**

	Estuary	Tidal Fresh	Mixing	Seawater
Surface Area (*mi2*)	**226.5**			**226.5**
Average Depth (*ft*)	**2.5**			**2.5**
Volume (*billion cu ft*)	**15.8**			**15.8**

A bar-built coastal lagoon separated from the Gulf of Mexico by Padre Island. Major bays are Upper Laguna Madre and South Bay. Consists mostly of mud-sand flats inundated by wind driven flows. A land bridge of mud-sand separates the Upper and Lower Laguna Madre. Direct precipitation contributes approximately 65% of total freshwater discharged. Salinity structure is determined by isolated pulses and intense evaporation rather than by seasonal freshwater discharges.

Nutrients

	Tidal Fresh	Mixing	Seawater
Nitrogen			L - - -
Phosphorus			L ↑

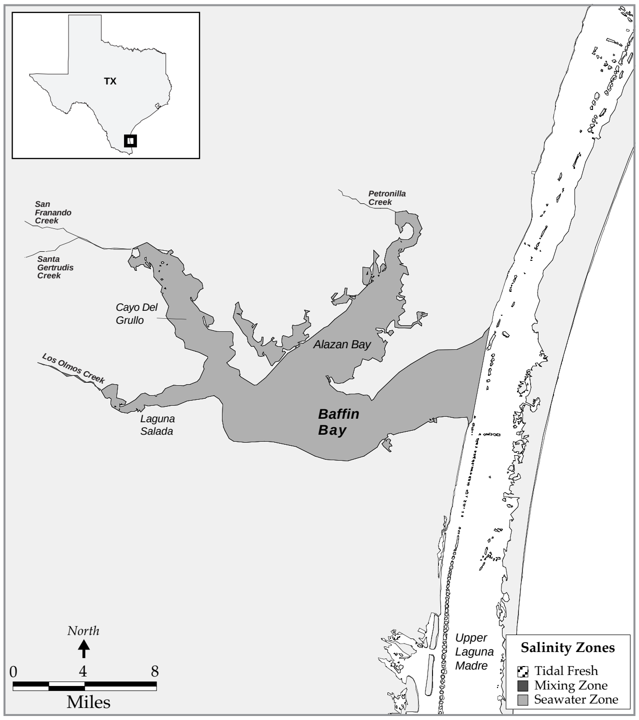
Dissolved Oxygen

	Tidal Fresh	Mixing	Seawater
Anoxia			N - - -
Hypoxia			Y 25-50% - - -

Hypoxia observed periodically June to August at bottom. Biological stress observed periodically throughout water column over 50 to 100 percent of seawater zone April to October.

Key on page 23

Baffin Bay



In Baffin Bay, chlorophyll *a* concentrations are hypereutrophic, turbidity is high and nuisance "brown tide" blooms occur, but toxic blooms do not. Nitrogen and phosphorus concentrations are medium. Anoxia does not occur, but hypoxia is observed infrequently. SAV spatial coverage is very low.

Chlorophyll *a* and turbidity concentrations, nuisance blooms and SAV spatial coverage increased. Nitrogen and phosphorus concentrations decreased due to brown tides. Occurrences of anoxia and hypoxia are unchanged, and trends for toxic blooms are unknown.

Physical and Hydrologic Characteristics

Estuarine Drainage Area (*mi2*) **3,407** Avg. Daily Inflow (*cfs*) **400**

	Estuary	Tidal Fresh	Mixing	Seawater
Surface Area (*mi2*)	94.1			94.1
Average Depth (*ft*)	4.2			4.2
Volume (*billion cu ft*)	11.0			11.0

Subsystem to Upper Laguna Madre, consists of mud-sand flats inundated by wind driven flows. Direct precipitation contributes approximately 65% of the total freshwater discharged to the system. Salinity structure is determined by isolated pulses and intense evaporation rather than by seasonal freshwater discharges.

Algal Conditions

	Tidal Fresh	Mixing	Seawater
Chlorophyll *a*			E 50-100% ↑
Turbidity			H 50-100% ↑
Nuisance Algae			Y ↑
Toxic Algae			N ?

Maximum Chl-*a* concentrations occur periodically all year with limiting factor of nitrogen. Turbidity occurs persistently. Increases in Chl-*a* and turbidity reported for 1989-95 and are associated with non-point sources. Nuisance *Aureoumbra lagunensis* occurs throughout the year, with increases attributed to non-point sources.

Ecosystem/Community Responses

	Tidal Fresh	Mixing	Seawater
SAV			VL ↑

Primary productivity dominated by pelagic community. Planktonic community dominated by *Aureoumbra lagunensis* , but previously was diverse; benthic community is diverse with annelids dominating due to brown tides. Increase in SAV associated with lower salinities.

Nutrients

	Tidal Fresh	Mixing	Seawater
Nitrogen			M 50-100% ↓
Phosphorus			M 50-100% ↓

Nutrient concentrations occur all year. Trends for 1989 to 1995. Decrease attributed to persistent brown tide.

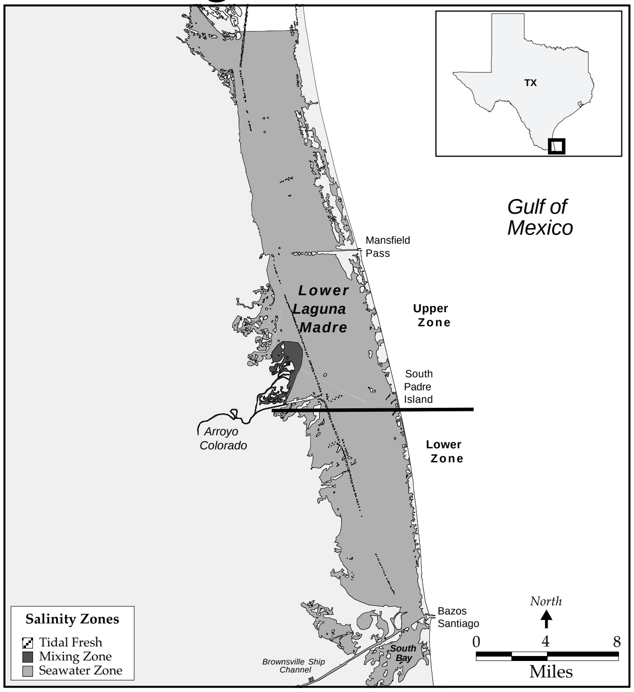
Dissolved Oxygen

	Tidal Fresh	Mixing	Seawater
Anoxia			N ---
Hypoxia			Y 10-25% ---

Hypoxia observed one time at bottom in August 1988. Biological stress observed episodically at bottom July to September over 50 to 100 percent of zone.

Key on page 23

Lower Laguna Madre



In Lower Laguna Madre, chlorophyll *a* concentrations are medium to high and turbidity is high. Nuisance blooms occur persistently and toxic blooms are observed episodically. Anoxia and hypoxia are observed in the mixing zone. Nitrogen concentrations range from low to high, and phosphorus from medium to high. SAV spatial coverage is high.

Chlorophyll *a* turbidity and nutrient concentrations, as well as nuisance bloom and hypoxia events, increased. SAV spatial coverage decreased; anoxia and toxic bloom events have remained unchanged.

Physical and Hydrologic Characteristics

Estuarine Drainage Area *(mi2)* **5,396** Avg. Daily Inflow *(cfs)* **627**

	Estuary	Tidal Fresh	Mixing	Seawater Upper Zone	Seawater Lower Zone
Surface Area *(mi2)*	506.1		10.7	309.4	186.0
Average Depth *(ft)*	2.5		2.3	n/a	n/a
Volume *(billion cu ft)*	35.2		0.7	n/a	n/a

A bar-built coastal lagoon separated from the Gulf of Mexico by Padre Island. Consists mostly of mud-sand flats inundated by wind driven flows. A land bridge of mud-sand separates Upper and Lower Laguna Madre. Direct precipitation contributes approximately 65% of total freshwater discharged. Salinity structure is determined by isolated pulses and intense evaporation rather than by seasonal freshwater discharges.

Algal Conditions

	Tidal Fresh	Mixing		Seawater Upper Zone		Seawater Lower Zone	
Chlorophyll *a*		H 50-100%	⇧	H 50-100%	↑	M 50-100%	↑
Turbidity		H 50-100%	---	H 50-100%	↑	H 50-100%	↑
Nuisance Algae		Y	---	Y	↑	Y	↑
Toxic Algae		N	---	Y	---	Y	---

Chl-*a* concentrations occur periodically with limiting factor of nitrogen in mixing zone, periodically December to March in Lower zone, and March to June in Upper zone. Turbidity occurs persistently except in Lower Zone where it is periodic December to March. Nuisance blue-greens and flagellates occur persistently in mixing zone, *Aureoumbra* lagunensis occurs episodically December to March in Lower Zone and all year in Upper Zone. Toxic *Gymnodinium breve* and *Gonyaulax monilata* occur episodically in summer. Increases in algal conditions due to point and non-point sources.

Ecosystem/Community Responses

	Tidal Fresh	Mixing		Seawater Upper Zone		Seawater Lower Zone	
SAV		VL	?	H	⇩	H	⇩

Primary productivity dominated by pelagic community in mixing zone, by SAV in Lower Zone, and by pelagic and SAV communities in Upper Zone. Planktonic community dominated by blue-green algae and flagellates in mixing zone, by diatoms in Lower Zone and by *Aureoumbra lagunensis* in Upper Zone; benthic community dominated by annelids in mixing and Upper Zone and is diverse in Lower Zone. Decrease in SAV in Lower Zone is due to dredging activities and in Upper Zone is due to *Aureoumbra lagunensis* bloom.

Nutrients

	Tidal Fresh	Mixing		Seawater Upper Zone		Seawater Lower Zone	
Nitrogen		H 50-100%	⇧	M 50-100%	---	L	---
Phosphorus		H 50-100%	⇧	M 50-100%	⇧	M 50-100%	⇧

Elevated concentrations occur all year.

Dissolved Oxygen

	Tidal Fresh	Mixing		Seawater Upper Zone		Seawater Lower Zone	
Anoxia		Y 25-50%	---	N	?	N	?
Hypoxia		Y 50-100%	⇧	N	?	N	?

Anoxia observed at bottom periodically June to September. Hypoxia and biological stress occur throughout water column all year in mixing and periodically May to September in seawater zone. Hypoxia and biological stress frequency, duration, and spatial coverage increased 1990 to 1996; attributed to sewage treatment and shrimp farming.

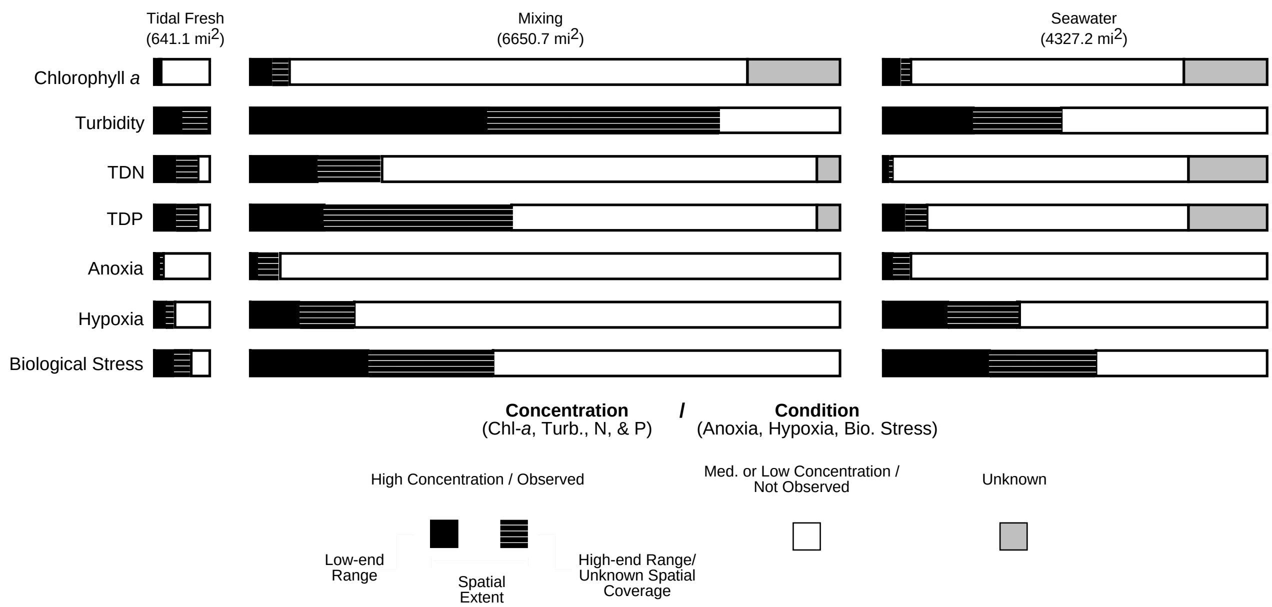
Key on page 23

Regional Summary

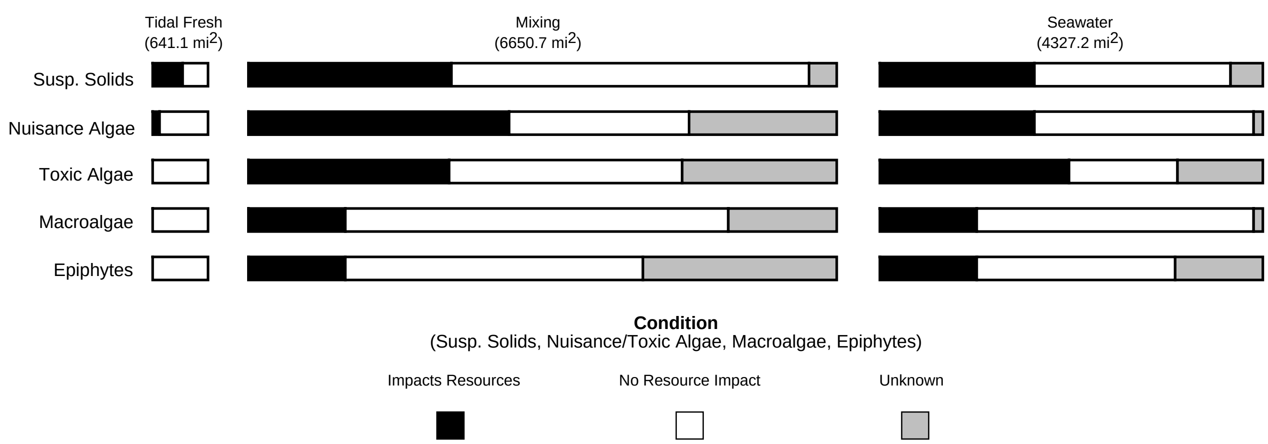
The following summarizes the status of existing conditions for 12 parameters as a cumulative percentage of total estuarine surface area for three salinity zones.

The spatial extent of existing conditions was recorded for each salinity zone in each estuary when indicators were recorded at their maximum thresholds, i.e., when chl-*a* was recorded as hypereutrophic, when turbidity, nitrogen or phosphorus were recorded as high, and when anoxia, hypoxia or biologically stressed oxygen conditions were observed. Four broad ranges of spatial extent were used: high (51%-100% of the surface area in a particular zone of an estuary), medium (26%-50%), low (10%-25%), and very low (1%-10%). For some estuaries, existing conditions were reported but spatial coverage was unknown.

The figure represents a method for quantifying results. A black bar shows conservative estimates of cumulative spatial extent (e.g., high spatial extent equals 51% of an estuary's surface area). A black bar with white lines shows liberal estimates (e.g., high equals 100% and unknown spatial coverage also equals 100%). White bars show the cumulative total surface area reported to have low concentrations or no observed conditions.



The presence of suspended solids, nuisance algae, toxic algae, macroalgae and epiphytes in each salinity zone was reported as either impacting biological resources, not impacting resources, or unknown. The spatial extent of these conditions was not recorded.



Appendix 1: Participants

The persons below supplied the information included in this report. Survey participants provided the initial data to ORCA via survey forms sent through the mail. Site visit participants provided additional data through on-site interviews with project staff. These persons also reviewed initial survey data where available. Workshop participants reviewed and revised, in a workshop setting, preliminary aggregate results and, where possible, provided additional data that was still missing. All participants also had the opportunity to provide comments and suggestions on the estuary salinity maps.

Gulf of Mexico Regional Workshop (July 8-12, 1996 New Orleans, LA)

Eastern Gulf *(Florida Bay to Mississippi River)*

Joe Boyer	Florida International University
Fred Bryan	Louisiana State University
Dennis Demcheck	USGS Water Resources Division
Juli Dixson	University of Southern Mississippi
Peter Doering	South Florida Water Management District
H. Lee Edminston	Apalachicola Bay NERR
Randy Edwards	Mote Marine Laboratory
Dave Flemer	U.S. Environmental Protection Agency
Michael Hein	Water and Air Research, Inc.
Richard Iverson	Florida State Universtiy
Brian Lapointe	Harbor Branch Oceanographic Institute
Rodney Mach	U.S. Army Corps of Engineers
Robert Mattson	Suwannee River Water Management District
Cynthia Moncrieff	Gulf Coast Research Laboratory
Gerold Morrison	SW Florida Water Management District
Michael Poirrier	University of New Orleans
Chet Rakocinski	Gulf Coast Research Laboratory
Kevin Summers	U.S. Environmental Protection Agency
Carmelo Tomas	Florida Marine Research Institute
David Tomasko	S.W. Florida Water Management District
Gabriel Vargo	University of South Florida
Jeff Waters	Lake Pontchartrain Basin Foundation
Terry Whitledge	University of Texas, Marine Science Institute

Western Gulf *(Barataria Bay to Lower Laguna Madre)*

Tom Bianchi	Tulane University
David Brock	Texas Water Development Board
Fred Bryan	Louisiana State University
Dave Buzon	Texas Parks and Wildlife Department
Quay Dortch	Louisiana Universities Marine Consortium
Ken Dunton	University of Texas, Marine Science Institute
Dave Flemer	U.S. Environmental Protection Agency
Cynthia Gorham	U.S. Environmental Protection Agency
Warren Pulich	Texas Parks and Wildlife Department
Bill Rizzo	National Biological Survey
Dugan Sabins	LA Department of Environmental Quality
Kerry St. Pe	LA Department of Environmental Quality
Dean Stockwell	University of Texas, Marine Science Institute
Kevin Summers	U.S. Environmental Protection Agency
Steven Twidwell	Texas Natural Resources Conservation Commission
Robert Twilley	University of Southwestern Louisiana
Terry Whitledge	University of Texas, Marine Science Institute

Participated in absentia

Gary Gaston	University of Mississippi
Paul Montagna	University of Texas, Marine Science Institute
Jonathon Pennock	Univeristy of Alabama
Nancy Rabalais	Louisiana Univerisities Marine Consortium
William Schroeder	University of Alabama
R. Eugene Turner	Louisiana State University
George Ward	University of Texas

Survey/Site Visits

* participated in site visit
• participated in survey and site visit

Florida Bay
James Forqurean	Florida International Univ.
Greg Graves	FL Dept. of Env. Regulation
Jay Zieman	Univ. of Virginia

South Ten Thousand Islands
Thomas Smith III	Rookery Bay NERR

North Ten Thousand Islands
Thomas Smith III	Rookery Bay NERR

Rookery Bay
Thomas Smith III	Rookery Bay NERR
Gabriel Vargo	Univ. of South Florida

Charlotte Harbor
Ben McPherson	U.S. Geological Survey
Ralph Montgomery	Envrionmental Quality Lab
Albert Walton, Jr.	FL Dept. of Env. Regulation

Caloosahatchee River
Peter Doering*	South FL Water Mgmt. District
Dan Haurnet*	South FL Water Mgmt. District
Albert Walton, Jr.	FL Dept. of Env. Regulation

Sarasota Bay
Kelly Dixson	Mote Marine Laboratory
David Tomasko	SW FL Water Mgmt. District

Tampa Bay
Tom Cardinale	Hillsborough Env. Pro. Comm.
Jo Roger Johansson	City of Tampa Study Group
Gerold Morrison	SW FL Water Mgmt. District
Michael Perry	SW FL Water Mgmt. District
Gabriel Vargo	University of South Florida

Suwannee River
Janice Fellers	Suwannee R. Wat. Mgmt. Dist.
Robert Mattson	Suwannee R. Wat. Mgmt. Dist.

Apalachee Bay
Don Axelrad*	FL Dept. of Env. Protection
Joe Hand*	FL Dept. of Env. Protection
Graham Lewis*	NW FL Water Mgmt. District.
Robert Mattson	Suwannee R. Wat. Mgmt. Dist.
Donald Ray	FL Dept. of Env. Regulation

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Donald Ray	FL Dept. of Env. Regulation

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Graham Lewis*	NW FL Water Mgmt. District.
Donald Ray	FL Dept. of Env. Regulation

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Joe Hand*	FL Dept. of Env. Protection
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Skip Livingston*	Florida State University
Donald Ray	FL Dept. of Env. Regulation

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Graham Lewis*	NW FL Water Mgmt. District.
Donald Ray*	FL Dept. of Env. Regulation

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Joe Hand*	FL Dept. of Env. Protection
Graham Lewis*	NW FL Water Mgmt. District.
Skip Livingston*	Florida State University
Donald Ray	FL Dept. of Env. Regulation

Mobile Bay
Gary Gaston	University of Mississippi
Cynthia Moncrieff•	Gulf Coast Research Lab
Jonathon Pennock•	University of Alabama
William Schroeder*	University of Alabama

Mississippi Sound
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Robert Dickey*	Gulf Coast Seafood Lab
Juli Dixson*	Univ. of Southern Mississippi
Gary Gaston	University of Mississippi
Jerry McLelland*	Gulf Coast Research Lab
Cynthia Moncreiff•	Gulf Coast Research Lab
Jonathon Pennock•	University of Alabama
Harriet Perry*	Gulf Coast Research Lab
Chet Rakocinski*	USM IMS Gulf Research Lab
Don Redalje*	Univ. of Southern Mississippi
William Schroeder*	University of Alabama
R. Eugene Turner *	Louisiana State University

Lake Borgne
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Ronnie Best*	National Biological Survey
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Dennis Demcheck*	USGS
Quay Dortch	LA Universities Marine Consor.
Tom Doyle*	National Biological Survey
Lori Johnson*	National Biological Survey
Clifford Kenwood*	Lake Pontchartrain Foundation
Rodney Mach*	U.S. Army Corps of Engineers
William Rizzo*	National Biological Survey
Jeff Waters*	Lake Pontchartrain Foundation

Lake Pontchartrain

Marina Argyrou	Tulane University
Neil Armingeon*	Lake Pontchartrain Foundation
Bruce Baird*	USACE
Ronnie Best*	National Biological Survey
Tom Bianchi*	Tulane University
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Charly Demas*	USGS
Dennis Demcheck*	USGS
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Lori Johnson*	National Biological Survey
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Breton/Chandeleur Sounds

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Dennis Demcheck*	U.S. Geological Survey
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Albert Hindrichs*	LA Dept. of Environ. Quality
Rodney Mach*	U.S. Army Corps of Engineers
Hilary Neckles	National Biological Survey
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Mississippi River

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Steven Lohrenz	Univ. of Southern Mississippi
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Barataria Bay

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Mike Porrier	University of New Orleans
William Rizzo*	National Biological Survey
Dugan Sabins	LA Dept. of Environ. Quality
Kerry St. Pe'*	LA Dept. of Environ. Quality
Robert Twilley*	Univ. of Southwestern LA

Mississippi River/Atchafalaya River Plume

Nancy Rabalais	LA Universities Marine Consor.

Terrebonne/Timbalier Bays

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Kerry St. Pe'*	LA Dept. of Environ. Quality
Robert Twilley*	Univ. of Southwestern LA

Atchafalaya/Vermilion Bays

Michael Dagg	LA Universities Marine Consor.
Dugan Sabins	LA Dept. of Environ. Quality
Robert Twilley*	Univ. of Southwestern LA

Mermentau River

Jan Boydstun	LA Dept. of Environ. Quality
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Robert Twilley*	Univ. of Southwestern LA

Calcasieu Lake

Gary Gaston	University of Mississippi
Dugan Sabins	LA Dept. of Environ. Quality

Sabine Lake

Tom Bianchi•	Tulane University
Gary Powell	TX Water Development Board

Galveston Bay

Ed Buskey*	University of Texas
Larry Land	U.S. Geological Survey
Gary Powell	TX Water Development Board
William Rizzo*	National Biological Survey
Patrick Roques*	TX Natural Res. Cons. Comm.
Frank Shipley	Galveston Bay NEP
Dean Stockwell*	University of Texas
William Wardle	Texas A&M, Galveston
James Webb	Texas A&M, Galveston
Terry Whitledge•	University of Texas

Brazos River

George Guillen	Texas Water Commission
David Brock*	TX Water Development Board
Ed Buskey*	University of Texas
Cynthia Gorham*	U.S. Env. Protection Agency
Gary Powell	TX Water Development Board
Warren Pulich*	TX Parks and Wildlife Dept.
Patrick Roques*	TX Natural Res. Cons. Comm.
Dean Stockwell*	University of Texas
George Ward	University of Texas
Terry Whitledge•	University of Texas

Matagorda Bay

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Cynthia Gorham*	U.S. Env. Protection Agency
Cynthia Moncrieff•	Gulf Coast Research Lab
Warren Pulich*	TX Parks and Wildlife Dept.

San Antonio Bay

Ed Buskey*	University of Texas
Gary Powell	TX Water Development Board
Patrick Roques*	TX Natural Res. Cons. Comm.
Louis Sage	Bigelow Lab of Marine Science
Dean Stockwell*	University of Texas
Terry Whitledge•	University of Texas

Aransas Bay

Jim Bowman*	TX Natural Res. Cons. Comm.
David Brock*	TX Water Development Board
Ed Buskey*	University of Texas
Hudson Deyoe*	Texas A&M University
Nichole Fisher*	Texas A&M University
Russell J. Miget*	Texas A&M University
Gary Powell	TX Water Development Board
Patrick Roques*	TX Natural Res. Cons. Comm.
Dean Stockwell*	University of Texas

Richard Volk*	Corpus Christi NEP
George Ward	University of Texas
Terry Whitledge•	University of Texas

Corpus Christi Bay

Ed Buskey*	University of Texas
Hudson Deyoe*	Texas A&M University
Russell J. Miget*	Texas A&M University
Gary Powell	TX Water Development Board
Patrick Roques*	TX Natural Res. Cons. Comm.
Louis Sage	Bigelow Lab of Marine Science
Dean Stockwell*	University of Texas
Richard Volk*	Corpus Christi NEP
Terry Whitledge•	University of Texas

Upper Laguna Madre

Ed Buskey*	University of Texas
Gary Powell	TX Water Development Board
Patrick Roques*	TX Natural Res. Cons. Comm.
Dean Stockwell*	University of Texas
Terry Whitledge•	University of Texas

Baffin Bay

Jim Bowman*	TX Natural Res. Cons. Comm.
David Brock*	TX Water Development Board
Ed Buskey*	University of Texas
Hudson Deyoe*	Texas A&M University
Nichole Fisher*	Texas A&M University
Paul Montagna*	University of Texas
Russell J. Miget*	Texas A&M University
Gary Powell	TX Water Development Board
Patrick Roques*	TX Natural Res. Cons. Comm.
Dean Stockwell*	University of Texas
George Ward	University of Texas
Terry Whitledge•	University of Texas

Lower Laguna Madre

David Brock	TX Water Development Board
Ed Buskey*	University of Texas
Paul Montagna*	University of Texas
Gary Powell	TX Water Development Board
Patrick Roques*	TX Natural Res. Cons. Comm.
Dean Stockwell*	University of Texas
Kevin Summers	U.S. Env. Protection Agency
Terry Whitledge•	University of Texas

Appendix 2: Estuary References

The following references were recommended by one or more Eutrophication Survey participants as critical background material for understanding the nutrient enrichment characteristics of individual Gulf of Mexico estuaries. In some cases, the survey results are based directly upon these publications. This list is not comprehensive; some estuaries are not included because no suggestions were received.

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Appendix 3: NEI Estuaries

*One hundred twenty-nine estuaries are included in the National Estuarine Inventory (NEI). Some estuaries are actually subsystems of larger estuaries, although each is being evaluated indepedently for the Eutrophication Survey project (e.g., Potomac River is a sub-system of Chesapeake Bay). **There are additional estuaries characterized for the Eutrophication Survey project that are not NEI estuaries**. However, those estuaries may be added to the NEI in the future. For more information on the National Estuarine Inventory, see the inside front cover of this report.*

North Atlantic (16)

Passamaquoddy Bay
Englishman Bay
Narraguagus Bay
Blue Hill Bay
Penobscot Bay
Muscongus Bay
Damariscotta River
Sheepscot Bay
Kennebec/Androscoggin Rivers
Casco Bay
Saco Bay
Great Bay
Merrimack River
Massachusetts Bay
Boston Bay
Cape Cod Bay

Mid Atlantic (22)

Buzzards Bay
Narragansett Bay
Gardiners Bay
Long Island Sound
Connecticut River
Great South Bay
Hudson River/Raritan Bay
Barnegat Bay
New Jersey Inland Bays
Delaware Bay
Delaware Inland Bays
Maryland Inland Bays
Chincoteague Bay
Chesapeake Bay
Patuxent River
Potomac River
Rappahannock River
York River
James River
Chester River
Choptank River
Tangier/Pocomoke Sounds

South Atlantic (21)

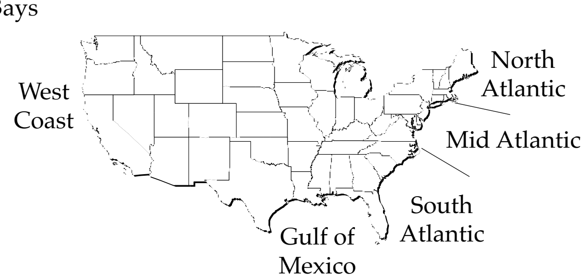
Albemarle/Pamlico Sounds
Pamlico/Pungo Rivers
Neuse River
Bogue Sound
New River
Cape Fear River
Winyah Bay
North/South Santee Rivers
Charleston Harbor
Stono/North Edisto Rivers
St. Helena Sounds
Broad River
Savannah River
Ossabaw Sound
St. Catherines/Sapelo Sounds
Altamaha River
St. Andrew/St. Simons Sounds
St. Marys R./Cumberland Snd
St. Johns River
Indian River
Biscayne Bay

Gulf of Mexico (36)

Florida Bay
South Ten Thousand Islands
North Ten Thousand Islands
Rookery Bay
Charlotte Harbor
Caloosahatchee River
Sarasota Bay
Tampa Bay
Suwannee River
Apalachee Bay
Apalachicola Bay
St. Andrew Bay
Choctawhatchee Bay
Pensacola Bay
Perdido Bay
Mobile Bay
Mississippi Sound
Lake Borgne
Lake Pontchartrain
Breton/Chandeleur Snds
Mississippi River
Barataria Bay
Terrebonne/Timbalier Bays
Atchafalaya/Vermilion Bays
Mermentau River
Calcasieu Lake
Sabine Lake
Galveston Bay
Brazos River
Matagorda Bay
San Antonio Bay
Aransas Bay
Corpus Christi Bay
Upper Laguna Madre
Baffin Bay
Lower Laguna Madre

West Coast (34)

Tijuana Estuary
San Diego Bay
Mission Bay
Newport Bay
San Pedro Bay
Alamitos Bay
Anaheim Bay
Santa Monica Bay
Morro Bay
Monterey Bay
Elkhorn Slough
San Francisco Bay
Cent. San Francisco Bay/
San Pablo/Suisun Bays
Drakes Estero
Tomales Bay
Eel River
Humboldt Bay
Klamath River
Rogue River
Coos Bay
Umpqua River
Siuslaw River
Alsea River
Yaquina Bay
Siletz Bay
Netarts Bay
Tillamook Bay
Nehalem River
Columbia River
Willapa Bay
Grays Harbor
Puget Sound
Hood Canal
Skagit Bay



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