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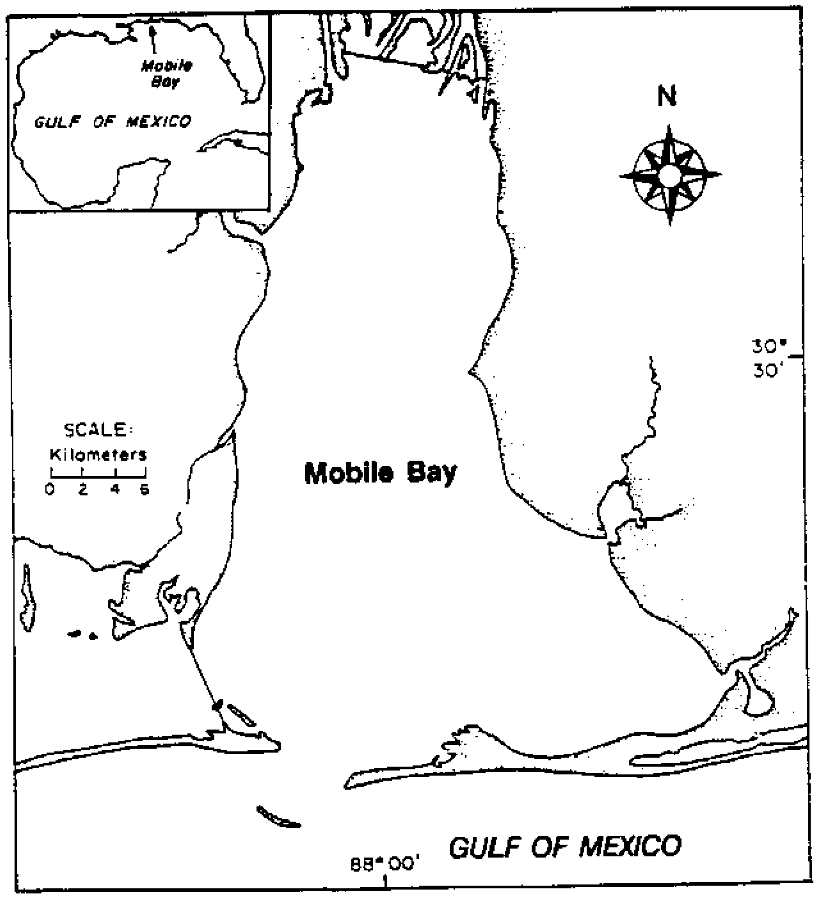
NOAA Estuary-of-the-Month
Seminar Series Number 15

Mobile Bay: Issues, Resources, Status, and Management

January 1990



U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NOAA ESTUARINE PROGRAMS OFFICE

NOAA Estuary-of-the-Month
Seminar Series Number 15

Mobile Bay: Issues, Resources, Status, and Management

Proceedings of a Seminar

Held November 17, 1988
Washington, D. C.

U.S. DEPARTMENT OF COMMERCE
Robert A. Mosbacher, Sr., Secretary

National Oceanic and Atmospheric Administration
John A. Knauss, Under Secretary

NOAA Estuarine Programs Office
Samuel E. McCoy, Director (Acting)

The National Oceanic and Atmospheric Administration,

U.S. Fish and Wildlife Service,

and

U.S. Environmental Protection Agency

present

An Estuary-of-the-Month Seminar

Mobile Bay:
Issues, Resources, Status, and Management

November 17, 1988

U.S. Department of Commerce
14th and Constitution Avenue, N.W.
Room 4830
Washington, D.C.

FOREWORD

The following are the proceedings of a seminar on Mobile Bay, held on November 17, 1988 at the Herbert C. Hoover Building of the U.S. Department of Commerce in Washington, D.C. It was one of a continuing series of "Estuary-of-the-Month" seminars sponsored by the NOAA Estuarine Programs Office (EPO), held with the objective of bringing to public attention the important research and management issues of our Nation's estuaries. To this end, the participants presented historical and scientific overviews of the Bay area, including an examination of management issues and research needs in Mobile Bay.

ACKNOWLEDGEMENTS

We gratefully acknowledge the assistance of Drs. James I. Jones, Mississippi-Alabama Sea Grant Program; Judy Stout and George Crozier, Marine Environmental Sciences Consortium; and William Hosking, Alabama Cooperative Extension Service, who had principal responsibility for assembling the speakers and whose familiarity with the Bay area and its people were invaluable. The seminar was coordinated in Washington, D.C., by Catherine L. Mills, NOAA Estuarine Programs Office (EPO) Gulf of Mexico Regional Coordinator, with the help of other members of the EPO staff. We would also like to express our appreciation to Dr. Judy Stout and Mrs. Lynn Bryant of the Alabama Marine Environmental Sciences Consortium who were responsible for editorial and technical preparation of this document.

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Questions concerning these proceedings may be directed to the NOAA Estuarine Programs Office, Universal Building, Room 625, 1825 Connecticut Avenue, N.W., Washington, D.C. 20235, telephone (202) 673-5243.

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INTRODUCTION

by

James I. Jones, Director
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Ocean Springs, MS

These Proceedings of the Estuary-of-the-Month Seminar on Mobile Bay are based on a seminar held November 17, 1988, in Washington, D.C. Although not verbatim, the articles in this volume closely correspond to the presentations which were given at that seminar. We welcome this opportunity to share our knowledge, enthusiasm and concern regarding the Mobile Bay estuary. The following discussion will identify and elucidate the reasons for our intense personal and professional interest in this estuarine system.

We hope that the reader will share our enthusiasm and that our expositions will provide increased knowledge of this estuary's history, natural and cultural resources, and environmental, biological, sociological and economic characteristics. Such knowledge will provide an enhanced understanding and appreciation of the Mobile Bay estuarine system's unique opportunities, problems and challenges.

We have prepared what we believe to be an informative and comprehensive proceedings volume. This publication and the seminar represent the efforts of a number of organizations and individuals. These organizations are represented by the seminar speakers:

- Ms. Phyllis Hallmon, Office of Senator Richard Shelby
- Dr. George Crozier, Alabama Marine Environmental Sciences Consortium, Dauphin Island Sea Lab
- Dr. George Flowers, Tulane University
- Dr. Will Schroeder, University of Alabama/Dauphin Island Sea Lab
- Mr. Charles Horn, Alabama Department of Environmental Management
- Dr. Judy Stout, University of South Alabama/Dauphin Island Sea Lab
- Dr. Robert Shipp, Coastal Research and Development Institute, University of South Alabama
- Mr. Arthur Dyas, Southeastern Natural Resource and Appraisal Company
- Mr. Steve Johnson, Mobile Area Chamber of Commerce
- Mr. Tim Savage, Baldwin County Commission
- Dr. James Jones, Mississippi-Alabama Sea Grant Consortium

The Alabama Sea Grant Extension Service, Alabama Cooperative Extension Service and the Auburn University Department of Fisheries have also contributed to this endeavor.

As the principal organizer it was my pleasure to develop and conduct this effort. I wish to thank the NOAA Estuarine Programs Office both on behalf of the Mississippi-Alabama Sea Grant Consortium, which I represent, and the other institutions and organizations which participated in and contributed to this activity. I also wish to thank the Environmental Protection Agency and the U.S. Fish and Wildlife Service for their role in this seminar series. We are grateful for this forum which allowed us to discuss the characteristics of Mobile Bay and to expound on our perception of how those characteristics and the pressures and patterns of past and present will interact to shape the future of this major American estuary.

OVERVIEW

by

George F. Crozier and John J. Dindo
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GEOGRAPHY

Mobile Bay is a submerged river valley about 31 miles (50 km) long from its mouth to the causeway at the northern end. It is about 23 miles (37 km) across at its widest in Bon Secour Bay and averages 10.8 miles (17 km) in width (Chermock 1974). Its southern terminus is integrated with the eastern portion of Mississippi Sound and is the initiation of the barrier island chain that constitutes the southern margin of both Mississippi and Chandeleur Sound. The offshore system is bounded to the east by the DeSoto Canyon and the Mississippi River delta to the west and is commonly referred to as the Mississippi- Alabama Shelf. This area has been traversed by 23 tropical storms in this century, ten of which impacted the Alabama coast (ADECA 1987a).

HISTORY

Archaeological evidence from shell mounds and middens reflects details of habitation back to 1500 B.C. and expands with the appearance of the Mississippian culture around 1000 A.D. The Mobile Indians were occupying the area when the first Europeans appeared in the 16th and 17th centuries.

The first ship's log which identifies Mobile Bay is dated 1517 by Captain D'Esperago. In 1519 the Spanish governor of Jamaica sent Captain Pineda to find an easy route to the west. Captain Pineda sailed into Mobile Bay and named it Rio de la Palma, Bay of the Holy Spirit. Forty different Indian hamlets were discovered around the bay at that time (Summersell 1957).

In 1699 Generals Iberville and Bienville sailed into Mobile Bay while leading an exploration of the Louisiana territories. Finding deep water close to the shore of Dauphin Island, they claimed the area for France. By 1709 a major French fort, Fort Louis, was established on the Mobile River and this area became the first capitol of the great Louisiana territory.

The present site of the city of Mobile was established in 1711. In 1763 the British acquired the region at the end of the French and Indian War and held it only until 1780 when the Spanish made it part of Florida. During the War of 1812 the United States took the city and added it to the Mississippi Territory. In 1819 Alabama was admitted to the Union and Mobile granted a city charter.

The city became a major port specializing in timber when the first ship channel was dredged in 1830. The state seceded in 1861 and the port was blockaded for four years. The Battle of Mobile Bay in 1864 was the beginning of the end for the Confederacy. The port of Mobile was the last defended port for import of guns, ammunition and clothing. The famous battle of Mobile Bay ended the blockade and the city surrendered in April 1865 after 17 days of bombardment. The area's importance as a port and transshipment point extended through World War II, declined with the closing of Brookley Air Force Base, but has perhaps been revitalized by recent waterways expansion.

HYDROGRAPHY/ENVIRONMENT

The Mobile Bay estuarine system is located virtually in the center of the northern edge of the Gulf of Mexico (Fig. 1). The estuary drains the 6th largest watershed in the country and the relatively wet climate of the region raises the discharge volume to fourth place, exceeded only by the Mississippi, Yukon and Columbia Rivers. The discharge contains large amounts of suspended sediment, exceeding an estimated 4 million tons/year. The water area of the bay itself is approximately 1,068 km^2 (264,000 acres) and the Mobile-Tensaw River system delta represents another 81 km^2 (20,000 acres) (Crance 1971). For comparison Chesapeake Bay is about 10 times the area, 3 times the average depth but has only 1.5 times the drainage area. The Mobile-Tensaw River Delta, with 681 km^2 (168,250 acres) of wetlands and bottomland hardwood forest, is designated as a National Natural Landmark and the fact that it is contiguous with the urban development of metropolitan Mobile is one of the striking anachronisms of this estuary. The state also has Weeks Bay, one of the nation's 21 National Estuarine Research Reserves, on the northern edge of Bon Secour Bay and an Audubon Sanctuary on Dauphin Island.

The roughly 50 miles of beach at the other end of the system constitute almost 41 km^2 (10,000 acres) of duneland and barrier island features. In contrast, wetland habitats occupy over 494 km^2 (122,000 acres) (ACAB 1980). This combination of habitats produce over 38 million pounds of finfish and shellfish recently valued at about $64 million annually.

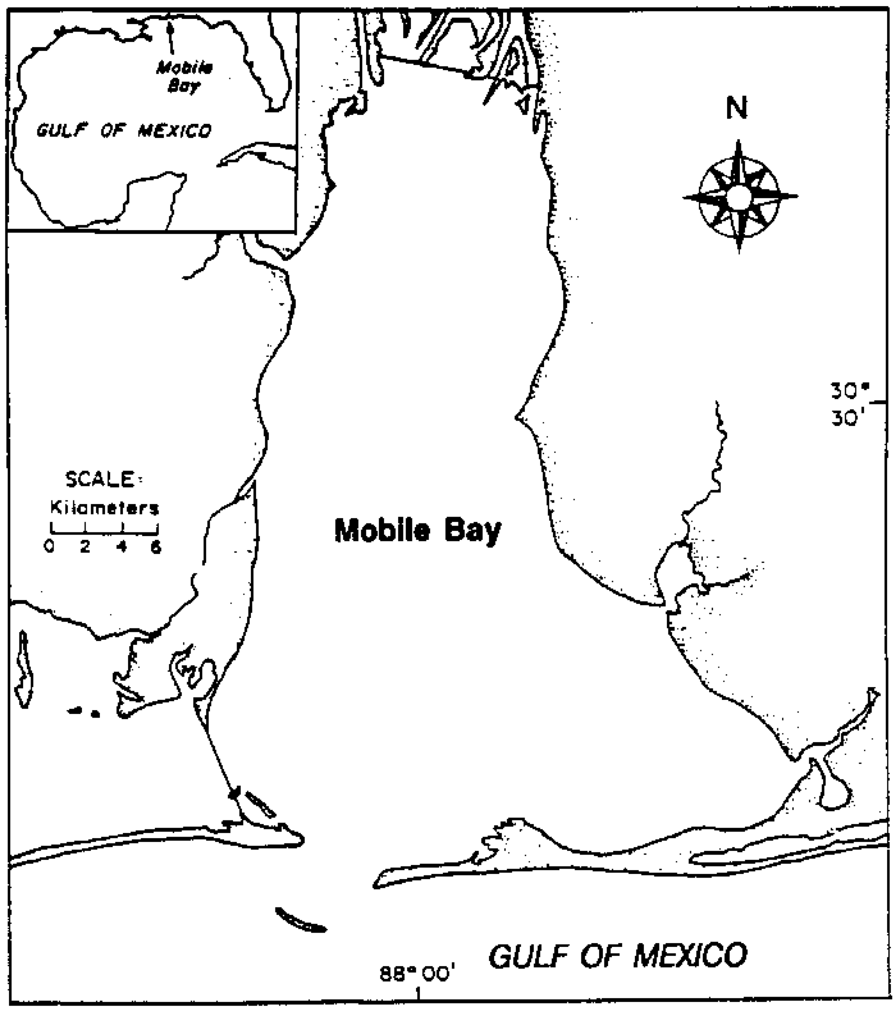
LAND USE

The estuary and surrounding lands constitute the southwest portion of the state and are contained within two coastal counties, Mobile County on the west and Baldwin County to the east. These are the third and first largest counties in the state with 3274 km^2 (809,100 acres) and 4178 km^2 (1,032,320 acres) respectively (ADECA 1987b).

The two counties share the confluence of the Alabama and Tombigbee Rivers as well as Mobile Bay itself. Both counties are extensively committed to silviculture (approximately 60 percent of the land) but the production facilities of the timber industry are located in Mobile County.

The two counties are remarkably dissimilar in most resource characteristics once you leave the forest. Baldwin County's land is 18 percent agricultural, 20.9 percent in water and wetlands and only 3 percent urbanized. The 1985 population was about 90,000 individuals or a density of 56/mi^2. Mobile County is 13.5 percent agricultural, only 12.7 percent is wetlands, and is 11 percent urbanized. It

Figure 1. Map of Mobile Bay with inset showing its location in the Gulf of Mexico.



includes the second largest city in the state, Mobile. The 1985 county density was 307/mi^2 with half of the population of 380,000 living in metropolitan Mobile.

ECONOMY

The vast majority of these nearly half-a-million people living in the Mobile Bay area depend upon the estuary for their livelihood, sustenance and/or recreation. The growth of the city of Mobile has historically been tied to the transportation industry and the site is a point of exchange between river, ocean, land, rail and air transport. The recent opening of the Tennessee-Tombigbee waterway will further consolidate that position because the waterway linked the Port of Mobile with the 16,000-mile inland waterway system and brought it 800 miles closer to major inland ports.

Commercial development is located largely in Mobile County while Baldwin County has become both a suburb to the city of Mobile and a desirable retirement area because of the climate and relatively low cost of living. The principal industries of the area are paper, chemicals, petroleum, cement, seafood processing, shipbuilding and transportation. Over 70 manufacturing industry centers can be identified, with the majority in Mobile County. Baldwin County has shown a much larger rate of population growth than Mobile County, in fact, the largest of the state in recent years. A site at Theodore, AL on the western shore is among the newest of the Navy Homeports.

As the community has become more aware of the fragility of the coastal ecosystems there has been emerging an appreciation and enthusiasm for the recreation and tourism "industry." Travel income from 68 million tourists netted the state $138 million and it is safe to assume that the coast generated a large percentage of that figure.

Hydrocarbon production, at least in the form of natural gas, is on the verge of skyrocketing in the state. Natural gas, in significant amounts, was discovered in the mouth of Mobile Bay in 1980. Mobil Oil began production this year and Exxon is in the process of permitting their production phase. The various finds of natural gas indicate a positive economic impact for the region and the state well into the 21st century.

IMPACTS

All of this resource identification, use and manipulation is not without negative impact. While we have 106 industrial, 15 sewage and 29 semi-private/small service discharges, the bay is shallow and therefore has a low receiving volume. It has restricted openings to the gulf, contributing to poor flushing under low flow conditions, while occasionally demonstrating massive discharge under a large hydraulic head. At that time it receives enormous volumes of fine riverborne sediments which interact with all manner of introduced substances. The Mobile Bay system has finite limits on its ability to provide living resources, mineral resources, transportation, recreational benefits and waste assimilation. The following presenters will deal with these various areas in more detail, but it is fair to make the general observation that Mobile Bay may be experiencing one of the broadest resource demand challenges in the country today.

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Marine Environmental Sciences Consortium Contribution Number 162

GEOLOGICAL AND GEOCHEMICAL CHARACTERIZATION

by

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INTRODUCTION

Mobile Bay is the primary depositional basin for the sixth largest river system in the United States. The rivers discharging into the bay drain a watershed of more than 110,000 km^2 (43,000 mi^2), which includes more than two-thirds of the State of Alabama and portions of neighboring Mississippi, Tennessee, and Georgia as well. The mean discharge of some 1,750 m^3/sec (62,000 ft^3/sec) ranks the contributory river system as the fourth largest in the United States, in terms of discharge, exceeded only by the Mississippi, Columbia, and Yukon (Ryan 1969). The rivers that ultimately discharge into the bay include the Warrior, Tombigbee, Tallapoosa, Coosa, Alabama, and Mobile (Fig. 1). Even with the major restrictions that have recently been imposed by various State an Federal regulatory agencies, the bay must still accept large quantities of effluent. As an example, an estimated 162 million gallons of municipal and industrial waste enters the bay each day solely from sources in the Mobile, Alabama area (Loyacano and Busch 1979). Hence, there is little surprise that analyses of bottom sediments and fauna collected in the bay yield levels of inorganic contaminants well above those from other bays in the northern Gulf of Mexico.

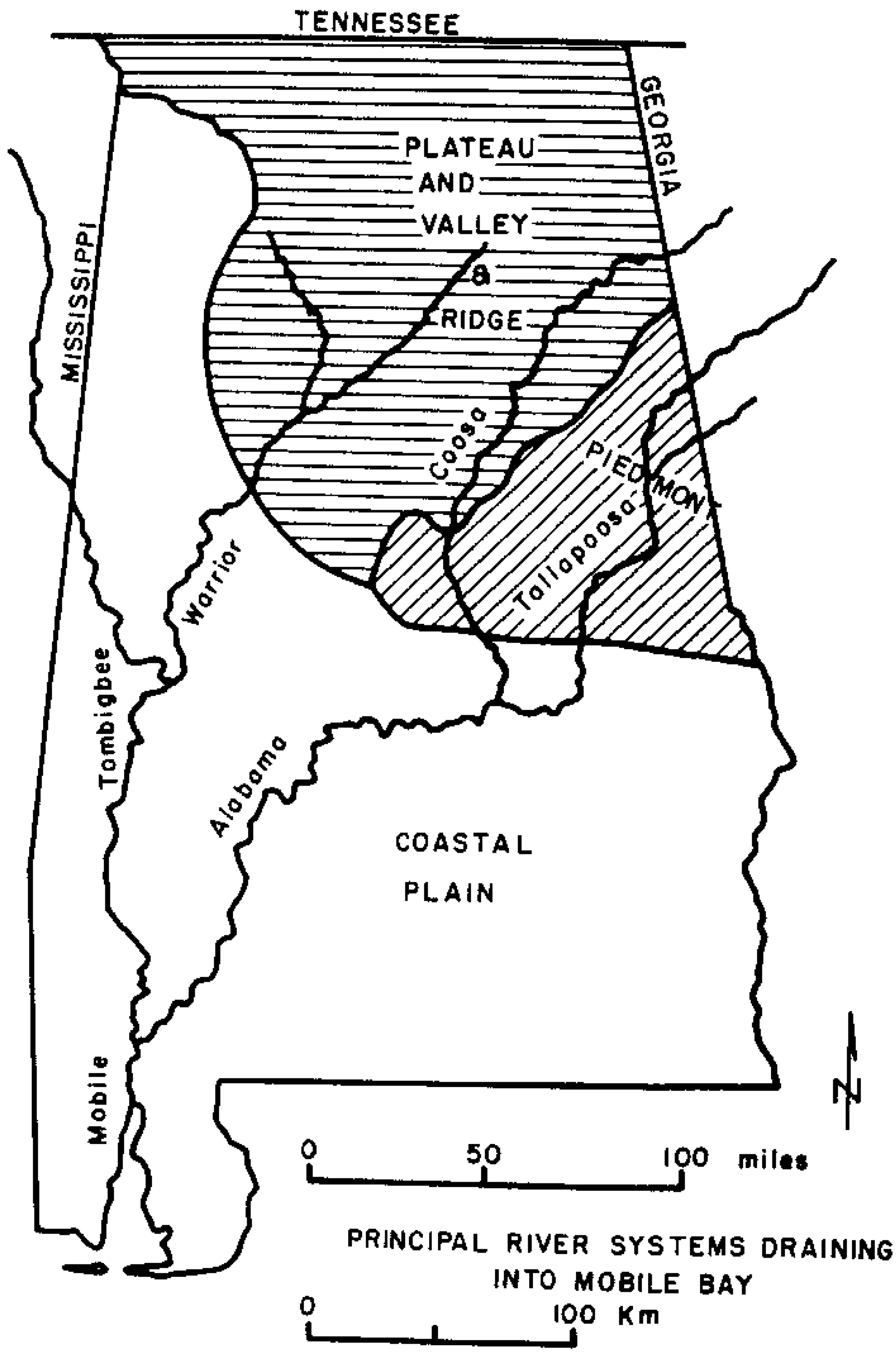
DESCRIPTION

Size

Mobile Bay is separated from the Gulf of Mexico by the Dauphin Island barrier island complex and by the westward prograding spit that forms the Fort Morgan Peninsula. In terms of size, the bay is approximately 50 km (31 miles) long and varies in width from 16 km (10 mi) just east of the city of Mobile to over 38 km (24 mi) near its southern limit where Bon Secour Bay adds substantially to its size. The total surface area of the estuary is approximately 1,070 km^2 (413 mi^2) and depths in the bay generally range from less than 1 m (3 ft) to over 9 m (30 ft).

Average depths are more on the order of 3 m (10 ft) (Crance 1971). A 12.2 m (40 ft) deep ship channel has been dredged nearer to the western side of the bay in order to allow commercial vessels access to the Port of Mobile and to permit

Figure 1. Physiographic map of Alabama (modified after Lamb, 1979).



passage of ships utilizing the Tennessee-Tombigbee Waterway System. This channel is 122 m (400 ft) wide and is currently being deepened to a depth of 14.5 m (48 ft) to accommodate deeper draft vessels.

Development

The estuary that now includes Mobile Bay lies adjacent to the Gulf of Mexico near the southern terminus of the Gulf Coastal Plain physiographic province (Fig. 1). Mobile Bay was formed by the flooding of a Pleistocene-age river valley as a result of the melting of the last (i.e., Wisconsin) ice sheet. The original river that occupied the site discharged well offshore of the present coastline and, in fact, can still be identified by the presence of a large, submerged, arcuate delta complex whose base is about 16 km (10 mi) wide and extends nearly 6.5 km (4 mi) offshore into the Gulf of Mexico. Because the top of this submerged delta is presently some 3 m (10 ft) below sea level, it is apparent that the most recent event in the Pleistocene history of coastal Alabama involved a rise in sea level of about 3 m (10 ft). This was sufficient not only to cause drowning of the ancestral Mobile River channel itself but also a large area of the adjacent flood plain. Collectively, these both are now incorporated as Mobile Bay (see Carlston 1950; Lamb 1979). The in-filling of the northern part of the bay that formed the present-day delta at the head of the bay accompanied this rise in sea level and represents deposition that took place in a bay that was much larger that the present bay system, possibly extending as far north as Mt. Vernon, Alabama (Lamb 1979). The present bay, therefore, is a geologically young estuary and dates from the last major eustatic rise in sea level. Its present shape also largely dates from this event, making the age of the bay only a few thousand years at best.

Man's recorded impact on the bay is, therefore, even more recent and, excepting its use by prehistoric tribes, dates less than 1,000 years. While the first known historical visit to the bay is still the subject of some controversy, a bronze plaque located in front of the Old Inn, on Fort Morgan peninsula, bears the inscription: "In memory of Prince Madoc, a Welsh explorer who landed on the shores of Mobile Bay in 1170 and left behind with the Indians the Welsh language." Whether fact or fiction, the alleged visit by this unchronicled Welshman has received serious attention by a number of scholars because of identical Welsh and Indian words used by tribes as far north as Tennessee and as far south as Mexico.

Historical knowledge of visits to Mobile Bay can be traced to 1519 when Alonzo Pineda, while on an exploration expedition, first entered the "Bay of Ochus" (various spellings), as it was then known by the local Indian tribes. Pineda renamed the bay Espirtu Santo and, during his 40 day stay, explored the surrounding area and mapped the bay. Panfilo de Narvaez, in 1528, is also thought to have visited the bay, largely as a consequence of a need for fresh water. Somewhat later, in 1540, Francisco Maldonado is reported to have anchored in the bay with four ships in order to resupply DeSoto's ill-fated expedition. Since that time, Mobile Bay was visited at least six different times before the Spanish began several ill-fated attempts to colonize the area, commencing in 1558. Actual settlement of the Mobile Bay area, however, was forced to await its "rediscovery" by the LeMoyne brothers, Iberville and Bienville, who entered the bay in 1699 and found it an ideal site for a settlement. Iberville, in 1702, moved the Capital of French Louisiana, then at Maurepas (near present Ocean Springs, Mississippi), to the Mobile Bay area. The region has been continuously occupied since that time.

Sedimentological History

As with all estuaries, Mobile Bay has been characterized by gradual infilling. The general pattern has been to fill most rapidly near the head (i.e., the present delta region) and then to fill in progressively the more distant areas. Natural events, such as major storms, may slow or temporarily reverse this trend (see Isphording and Imsand 1987), as may also the activities of man, but the ultimate fate of all estuaries is to gradually become filled in. Consequently, it is likely that within the next thousand years or so Mobile Bay will probably become an alluvial-deltaic plain similar to the present delta at the head of the bay (Hardin et al. 1976). This trend is well illustrated by examination of historical maps of the bay and comparing them with present bathymetric charts. A British Admiralty Chart dated 1771, for example, showed that the water depth at the head of the bay, directly east of the City of Mobile, averaged approximately 7 feet; similar measurements taken by the "U.S. Engineering Corps," in 1864, for the same area showed average depths of about 6 feet indicating a shoaling rate near the head of the bay of approximately 1 foot per 100 years. While this rate might at first seem excessive [in view of the fact that measurements on the Gulf of Mexico continental shelf are more on the order of 0.4 mm/yr (0.13 ft/100 years)], measurements made in other Gulf Coast estuaries are well in excess of this value [see Isphording, Imsand, and Flowers (1987)]. In Apalachicola Bay, Florida, for example, the average sedimentation rate has been calculated at 6.74 mm/year (2.21 ft/100 years). Further, sedimentation values calculated by Hardin, et al. (1976) also fall within this same magnitude range indicating that Mobile Bay is similar in terms of its overall sedimentation rate (see Table 1) to other bays in the northern Gulf that are the termination sites of large rivers.

The effects of man's activities on sedimentation rates within the bay are striking and have caused infilling at rates orders of magnitude greater than those attributable to natural processes. Ryan (1969), for example, has estimated that rates in excess of 3 ft/100 years may well exist in the area immediately south of the delta. Isphording, et al. (1984) have shown that the bulk of the acceleration of sedimentation rates in Mobile Bay can be traced to the early 1800's when extensive development of cotton and tobacco farming was initiated within the State, utilizing slave labor. The clearing of land for agriculture invariably was accompanied by markedly increased erosion rates into nearby streams (Fig. 2) and this sediment load ultimately found its way into Mobile Bay. Hence, examination of maps of the bay drafted prior to 1830 show striking differences when compared with those drawn in the interval from 1840 to 1870. Numerous additional distributary channels are apparent in the delta complex at the head of the bay and the increased amount of sediment being carried into the bay caused the near isolation of a number of other areas that were previously open to the bay. An excellent example of this can be seen in the development of D'Olive Bay, located in the extreme northeastern portion of Mobile Bay (Fig. 3). Maps constructed of the bay prior to 1862 make no mention of D'Olive Bay, nor is it even shown as existing. The formation of the spit that separates it from Mobile Bay probably

Figure 2. Sedimentation discharge for various watersheds (from Isphording et al. 1984).

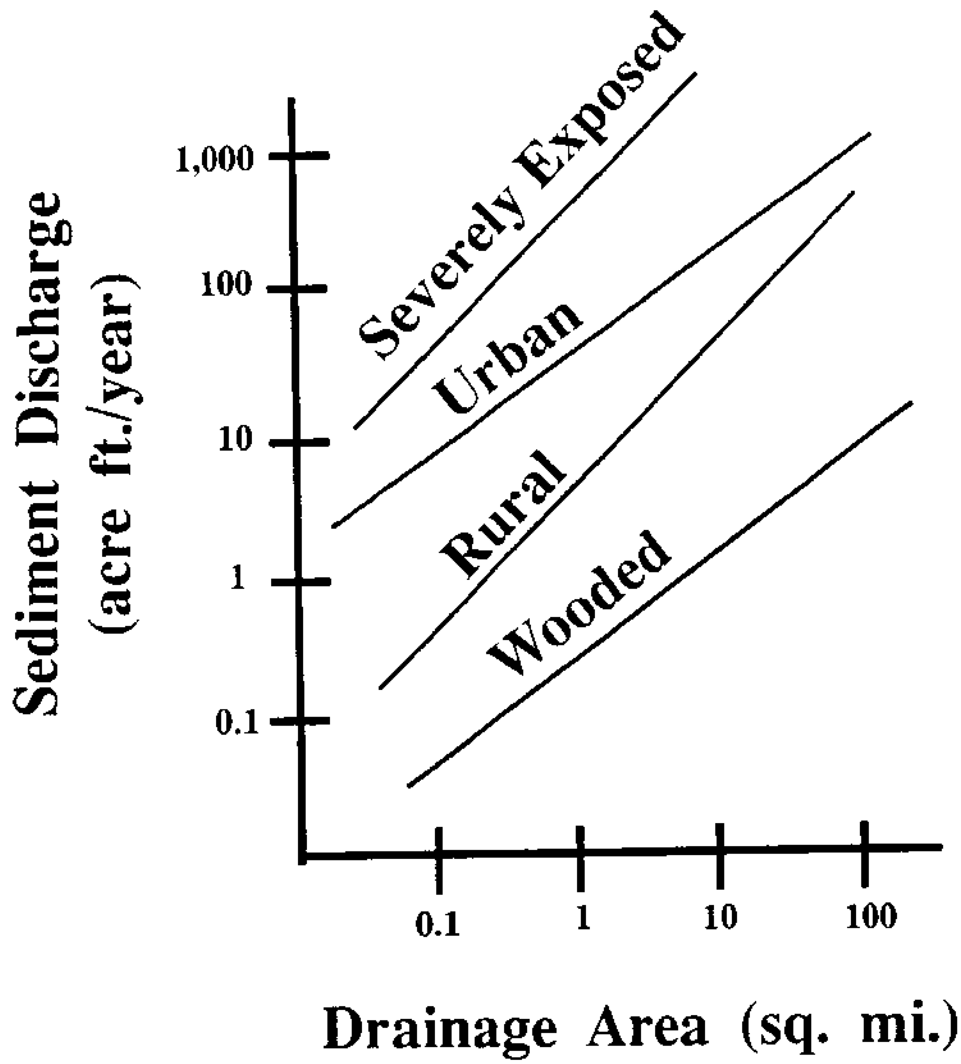


Figure 3. Map showing the location of D'Olive Bay (from Isphording et al. 1984).

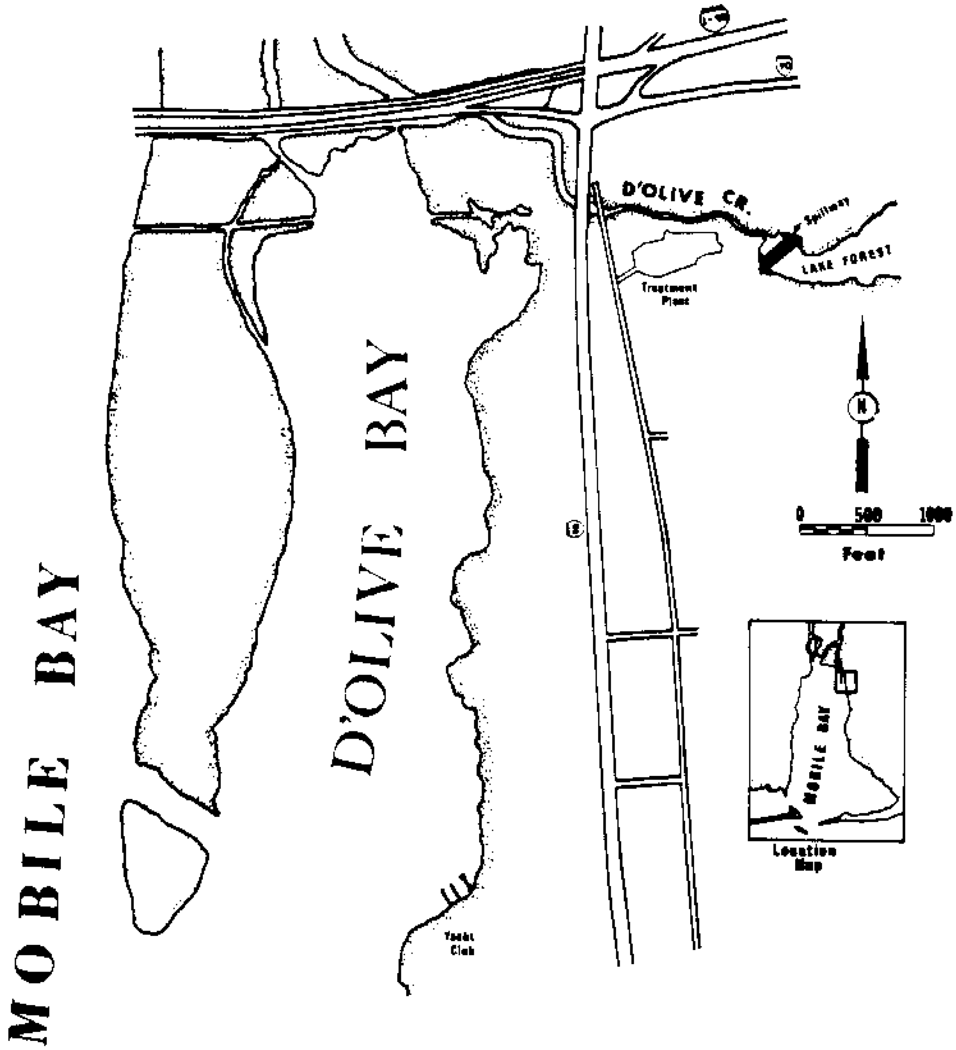


Table 1. Average annual depositional rates for upper Mobile Bay, lower Mobile Bay, and overall average rate (Modified from Hardin et al. 1976).

	Annual Average			120 Yr. Average
	1852	1920	1973	1853-1973
ENTIRE BAY				
Mean Depth (in feet)	10.71	9.60	8.71	
Infilling Rate	|—1.63—|	|—1.68—|		1.65
UPPER BAY				
Mean Depth (in feet)	8.90	7.60	7.07	
Infilling Rate	|—1.91—|	|—1.00—|		1.51
LOWER BAY				
Mean Depth (in feet)	12.52	11.59	10.35	
Infilling Rate (per 100 years)	|—1.36—|	|—2.34—|		1.79

began after 1820 as a result of increased sediment loading of the river system, coincident with agricultural development in the State (see Isphording, et al. 1984).

SEDIMENT CHARACTERISTICS

Sources

Five major river systems are responsible for collection and transport of sediments into Mobile Bay (see Fig. 1). These rivers originate far to the north of the bay in rocks of markedly different age and character and in rocks that have been subjected to significant differences in exposure and weathering. These differences have exerted controls not only on the amount of sediment contributed from a given area, but also on the mineralogy and chemistry of the detritus as well.

Areas drained by the Tallapoosa River, for example, include a large portion of east-central Alabama and extreme west-central Georgia, all of which are underlain by deeply weathered crystalline rocks of the southeastern Piedmont Province. The Coosa River, in contrast, originates within a folded sequence of limestones, shales, sandstones, etc. that belong to the Ridge and Valley Province. This region largely consists of more recently exposed Paleozoic-age rocks that include both the Blue Ridge Mountains and the Appalachian Range. To the west, the Warrior River drains rocks of similar age, however unlike those in the Ridge and Valley Province, those in the Cumberland Plateau region are essentially flat-lying. The remaining rivers, the Tombigbee, Alabama, and Mobile, all drain areas of geologically younger sediments that have been assigned to the Coastal Plain Province. Because these sediments are largely made up of uncemented sands, silts, and clays, they are more easily eroded and thereby contribute the greatest percentage of sediments of Mobile Bay.

Mineralogy

The mineral composition of Mobile Bay bottom sediments consists largely of the clay minerals montmorillonite (70 percent), kaolinite (20 percent), and illite (10 percent). Most of the montmorillonite can be traced to erosion of older Coastal Plain rocks, particularly those exposed in an arcuate zone lying nearer to the northern boundary of this province in an area known as the "Black Belt." This region gets its name from exposures of a dark brown to black, organic-rich, montmorillonite clay that belongs to the geological unit known as the Ripley Formation. Montmorillonite clays, unlike their kaolinite and illite counterparts, are extremely fertile and form excellent agricultural soils. On the negative side, however, their high cation exchange capacity coupled with their small particle size and extensive presence of lattice defects, result in these clays having an enhanced ability to absorb both organic and inorganic contaminants. Thus, as will be discussed below, the high percentage of these clays in Mobile Bay bottom sediments has worked to the bay's detriment.

The kaolinitic clays found in Mobile Bay, in contrast, are mainly derived from the ancient, deeply weathered rocks of the southeastern Piedmont (via the Tallapoosa River system). To a lesser extent, the mineral is also derived from younger sediments exposed in the southern part of the Coastal Plain province. Even though abundant in Mobile Bay bottom sediments, these clays create far less problems because of their minimal ability of absorbing, and retaining, organic and inorganic contaminants.

Illite, the remaining major clay mineral in the bay's sediments, is intermediate between montmorillonite and kaolinite in its ability to absorb pollutants. When considered on a world-wide basis, this mineral is the most common of all clays yet it makes up only 10 percent of Mobile Bay sediments. Its origin in these can be traced largely to the same montmorillonite-rich units that form the older Coastal Plain rocks and, to a lesser extent, the rock formations of the Ridge and Valley and Cumberland Plateau provinces.

Sediment Size

The bottom sediments of Mobile Bay are unique in the northern Gulf of Mexico in consisting, dominantly, of particles falling into Shepard's (1954) size range of "clay," "silty clay," and "sandy clay" (see Fig. 4). Put more simply, Mobile Bay has a larger proportion of very fine-grained sediments than any other northern Gulf estuary. This fact results chiefly from the extensive delta and distributary system that has built up at the head of the bay which has acted to trap coarser (larger) grained detrital material. As a consequence, only the finest particles are generally carried into the bay from the contributory river systems and any larger (sand) sized detritus is chiefly derived from erosion from immediately adjacent sedimentary units exposed around the bay's perimeter.

The dominance of the finer grain sizes in the bay is significant from an environmental standpoint because the finer the particle size, the larger the surface area and, consequently, its ability to absorb organic and inorganic contaminants. Thus, not only does the bay's mineralogy favor absorption of heavy metal and organic contaminants but the same phenomenon is also enhanced by the plethora of fine-grained particles that dominate its sediments.

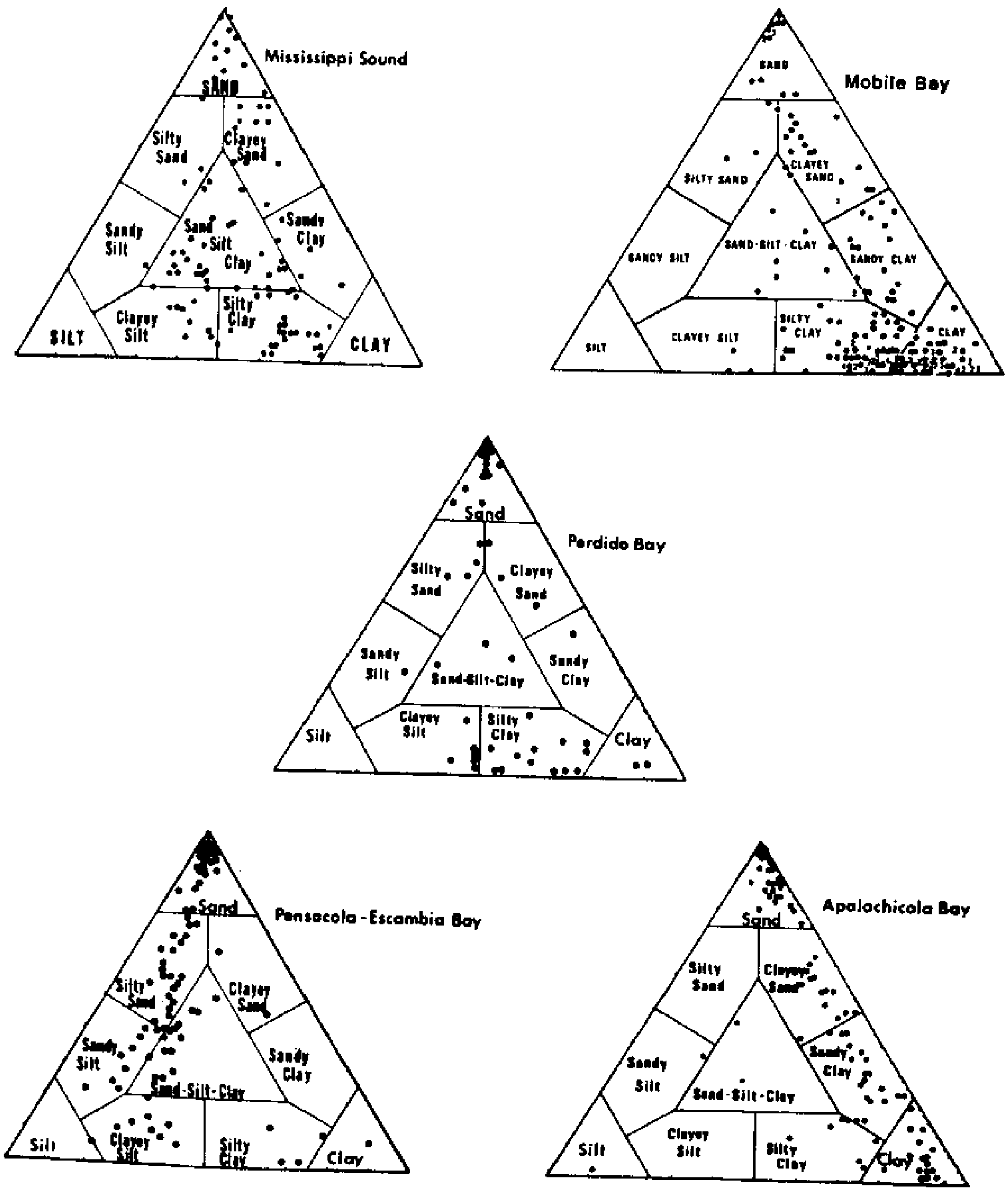
Organic Carbon Content

A third "strike" against Mobile Bay, from the standpoint of potential for environmental contamination, is found in the organic content of the bottom sediments. In an earlier publication (see Isphording, Stringfellow, and Flowers 1985) it was noted that Mobile Bay has the highest average content of organic carbon for any bay or estuary in the northern Gulf of Mexico (see Table 2.) The consequences of this lie in the fact that organic particles also have an enhanced ability of absorbing municipal and industrial pollutants and metal ions that are contributed to the bay by both natural and man-related processes. Hence, the combination of high montmorillonite content, high organic content, predominance of very fine-grained sediments, and a heavily industrialized contributory watershed has made it difficult for the bay to avoid the stigma of becoming "environmentally impacted."

Table 2. Organic carbon content of northern Gulf of Mexico bays and estuaries (modified from Isphording, Stringfellow, and Flowers 1985).

Location	Percent Organic Carbon
Mobile Bay	3.24
Mississippi Sound	0.82
Perdido Bay	1.33
Pensacola Bay	2.90
Apalachicola Bay	0.75

Figure 4. Ternary diagrams showing size analyses for samples from bay, estuaries, and coastal lagoons in the northern Gulf of Mexico (from Isphording, Stringfellow, and Flowers 1985).



SEDIMENT CHEMISTRY

General Discussion

Anthropogenic point sources of metals and organic compounds rank as the most important factor controlling pollutants entering Mobile Bay (Isphording and Flowers 1987). Brady (1979) reported that nearly 189 million gallons of industrial and municipal effluent is discharged into the bay each day just from sources located in the Mobile, Alabama area. When other contributions from cities and manufacturing firms located elsewhere in the water-shed are considered, it is obvious that literally thousands of point sources are contributing to the bay's contaminant load. Further, because of the restricted circulation patterns within the bay, it shallow depth, and the aforementioned high montmorillonite, organic carbon, and abundance of fine- grained sediments, it is no wonder that the bay contains higher metal values than any other bay in the northern Gulf. This can be seen in Table 3 which compares average values of metals in the bottom sediments of the bay with those from other bays in the region. Using the classification scheme developed by Prater and Hoke (1980) for assessing heavy metal contamination in harbors, it is evident from Table 4 that Mobile Bay is a moderately to heavily impacted harbor in terms of the concentrations of the metals considered.

Effect on Indigenous Fauna

To date, the etiological effects of heavy metals in marine organisms are only imperfectly known. Whereas some metals (e.g., iron and zinc) can apparently be tolerated at fairly high levels, others (cadmium, mercury, lead, etc.) can be hazardous to the organism even when ingested at extremely low levels. Knowledge of this fact is by no means new and can be traced to scholars living more than one thousand years ago. Hippocrates (370 B.C.), Pliny (A.D. 50), and Dioscorides (A.D. 100) noted the toxicity of high levels of lead whereas Aristotle (A.D. 300) described the properties of cadmium compounds and commented upon their health hazard. Similarly, Ramazzini described mercury poisoning that he traced to mercurial unctions being used by surgeons in the early 1700's and selenium poisoning was identified in Columbia, South America as early as 1560. More recently, investigators have become suspicious that a number of metals may be suspect in cardiovascular disease (vanadium, barium, copper, lithium, strontium) and others have been implicated in certain forms of cancer (arsenic, beryllium, cadmium, lead, nickel) (see Schroeder 1960; Voors 1971; Berg and Burbank 1972). High levels of mercury in fish contamination by industrial discharge were directly linked to mercury poisoning and related teratogenic effects in persons living adjacent to Minimata Bay, Japan, and the contamination of drinking waters by cadmium in mine wastes was identified as the causative factor in Itai Itai Byo disease, also in Japan (see Kurland et al. 1960).

Thus, even though many metals can be shown to be necessary for life functions, essentially all metals can be shown to produce harmful effects if certain threshold levels are exceeded. Hence, while the human body does attempt to regulate and prevent "spillover" by tying up the metals in the form of metalloenzymes (metallothioneins), excessive accumulation can take place with

Table 3. Bottom sediment heavy metal contents (in parts per million) for bays, estuaries, and coastal lagoons in the northern Gulf of Mexico.

Metal	Mobile Bay	Perdido Bay	Pensacola Bay	Escambia Bay	Blackwater Bay	Apalachicola Bay	Mississippi Sound
Cadmium	1.1	1.0	1.0	1.0	1.0	1.2	1.0
Lead	51.0	--	40.0	19.0	13.0	61.0	15.0
Iron	35,648.0	32,740.0	24,074.0	29,298.0	11,520.0	26,776.0	23,107.0
Nickel	57.0	36.0	16.0	9.0	3.0	28.0	24.0
Cobalt	15.0	27.0	10.0	12.0	5.0	18.0	13.0
Chromium	63.0	15.0	56.0	40.0	13.0	34.0	57.0
Copper	32.0	31.0	19.0	9.0	3.0	37.0	20.0
Zinc	120.0	72.0	140.0	43.0	20.0	57.0	74.0

Table 4. Classification of Mobile Bay sediments as being non- polluted (NP), moderately polluted (MP), or heavily polluted (HP) based on averages for harbors presented by Prater and Hoke (1980).

Metal	Classification
Cadmium	LLNE*
Lead	MP
Iron	HP
Nickel	HP
Chromium	MP
Copper	MP
Zinc	MP

*LLNE indicates that the lower limit for the classifications NP and MP have not been established for the metal in question.

deleterious effect upon the individual. Estuaries having high sediment metal pollution must therefore be viewed with concern, not only because of the effects on the indigenous fauna, but also because of the etiological consequences that may result by consumption of such fauna by other forms higher up in the trophic pyramid.

Metal Levels in Mobile Bay Fauna

Because of the high levels of heavy metals in the bottom sediments it might be suspected that fauna from Mobile Bay (especially filter feeders) would reflect this phenomenon by the presence of elevated quantities of certain metals in their tissue. To test this, specimens were collected from reefs throughout the bay of the common oyster *Crassostrea virginica* and metal levels were then determined. Oysters serve as an especially useful barometer for heavy metal contamination because a number of studies have documented the toxicity levels for different metals for this species and have also established the mechanism of metal uptake and tissue accumulation (see Zamuda and Sunda 1982; Zaroogian et al. 1979; Cunningham and Tripp 1973). Further, at least with respect to this species, once the metal has accumulated in the tissue, it apparently remains for a considerable time and is not easily eliminated. This was demonstrated by a study carried out by Mowdy (1981) who placed oysters from Mobile Bay in tanks for a period of six months and found that depuration levels amounted to only 25 percent for his time period. Similarly, Greig and Wenzlof (1978) showed that no significant elimination of cadmium had occurred in oysters after 40 weeks in a low cadmium environment.

That a definite relationship exists between heavy metals in bottom sediments and levels in the tissue of indigenous oyster species can be seen by examination of levels of zinc found in Gulf Coast oysters, shown in Table 5. Mobile Bay oysters contained significantly higher amounts of zinc than those from any other bay for which data were available. It should also be emphasized that the figures shown in Table 5 represent **average** values only; some specimens from Mobile Bay actually levels of zinc in excess of 4,000 parts per million! Table 6 shows a comparison of heavy metals in tissue for Mobile Bay oysters versus those from nearby St. Louis Bay (which was also characterized by high zinc levels). It is obvious that, with the exception of titanium, Mobile Bay specimens has considerably higher quantities of all other metal species.

SUMMARY

Few estuaries in the northern Gulf of Mexico have been the subject of more controversy than Mobile Bay during the past 10 years. Not only is the bay the location of the largest seaport in the northern Gulf, it also serves as the southern terminus of the Tennessee-Tombigbee Waterway and was recently designated as a homeport for a portion of the recently created Caribbean flotilla. Its development, however, has been a constant battle between those interested in further expanding the bay's resources versus those concerned that this will further impact the delicate environmental balance that now exists. Hence strong opposition was mounted against oil drilling in the bay, the basing of a hazardous waste incinerator ship near Mobile, deepening of the existing ship channel, and establishment of new sewage outfall lines, just to name a few examples. While some of the concerns of environmentalists have been shown to be unfounded (e.g. oil drilling, creation of dredge disposal islands in the bay, widespread organic contamination), other concerns must certainly be carefully considered. By virtue of the fact that the bay's bottom sediments are: (1) rich in smectite clays, (2) high in organic content, and (3) made up predominantly of very fine-grained sediments, any discharge of excessive levels of organic and/or inorganic contaminants into to bay will be assured of extended residence times. Because of this, there is also the likelihood some of these contaminants will become ingested by bottom feeders and filter feeding organisms. Ultimately, these contaminants may well be passed onto forms higher up the food chain and eventually reach man. Further, in view of the fact that the bay's bottom already are heavily loaded with some heavy metals, there is some doubt as to whether discharge levels presently approved by Federal and State agencies are, in fact, proper. While such quantities may well be safe for discharge into a bay containing bottom sediments made up of clean sands that have little ability to absorb contaminants, this same discharge into a bay containing sediments such as those in Mobile Bay that are already impacted may well create problems in the future. For this reason, all bays, estuaries, lagoons, etc. that are the sites of municipal and industrial effluent discharge should be carefully examined with respect to their sediment composition and properties in order that realistic restrictions may be imposed that will safeguard the site for the foreseeable future.

Table 5. **Zinc levels (in ppm) in *Crassostrea virginica* for sites in southeastern United States (modified after Lytle and Lytle 1982; Isphording, Stringfellow, and Helton 1983).**

Locations	Zinc (in ppm)
Mobile Bay, Alabama	1,887
San Antonio Bay, Texas	322
Flower Garden, Texas	268
Graveline Bayou, Mississippi	618
St. Louis Bay, Mississippi	821
Apalachicola Bay, Florida	158
U.S. Southeast Coast (average)	103

Table 6. **Average heavy metal content (in ppm) in specimens of *Crassostrea virginica* from St. Louis Bay, Mississippi and Mobile Bay, Alabama. relative difference between samples from the two sites is shown as "concentration factor." St. Louis Bay is considered to be relatively free of heavy metal contamination. (Modified after Isphording and Flowers 1987).**

Metal	St. Louis Bay Mississippi	Mobile Bay Alabama	Concentration Factor
Cobalt	0.04	11.0	275.0
Chromium	0.10	0.1	1.0
Copper	32.00	106.0	3.3
Iron	57.00	694.0	12.2
Nickel	0.20	18.0	90.0
Titanium	2.00	1.0	0.5
Vanadium	2.00	63.0	31.5
Zinc	821.00	1,887.0	2.3

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CLIMATE AND OCEANOGRAPHY

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GENERAL CHARACTERIZATION

Mobile Bay (30.5°N, 88°W) is located on the northern coast of the Gulf of Mexico east of the Mississippi River Delta (Fig. 1). It is connected to both the Gulf of Mexico and east Mississippi Sound. The bay (Fig. 2) is triangular in shape with the apex inland to the north and the long axis (50 km; 31 miles) oriented perpendicular to the coastline. It has an average width of 17 km (10.5 miles) and a maximum width of 38 km (23.5 miles). Its average depth at mean high water is approximately 3 m (10 ft) and its maximum depth, located at East Main Pass, is 14 m (46 ft). The surface area and volume of the bay, at mean high water, is calculated to be 1,058 km^2 (264,470 acres) and 3.2×10^9 m^3 (1.1×10^{11} ft^3) (Crance 1971).

Climate

The Mobile Bay estuary lies in a humid subtropical climate region (Trewartha and Horn 1980), a climate that dominates the Gulf coast states and the Florida peninsula. Summers are characteristically warm while winters are relatively mild with occasional cold waves. In the contiguous United States this region is second only to the Pacific Northwest in total annual rainfall (Baldwin 1973) receiving precipitation from a combination of winter storms, thunderstorms and tropical systems.

<u>Summer Climate</u>. High pressure over the Atlantic is a dominant factor in the summer weather pattern. This semi-permanent weather system, called the subtropical anticyclone, provides a persistent southerly flow of humid air from the

Figure 1. Location map showing selected estuaries along the northern Gulf of Mexico. (From Schroeder and Wiseman 1986.)

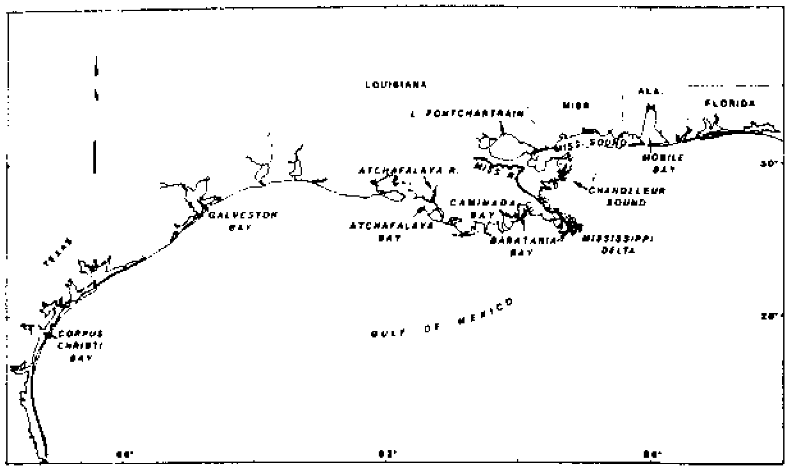
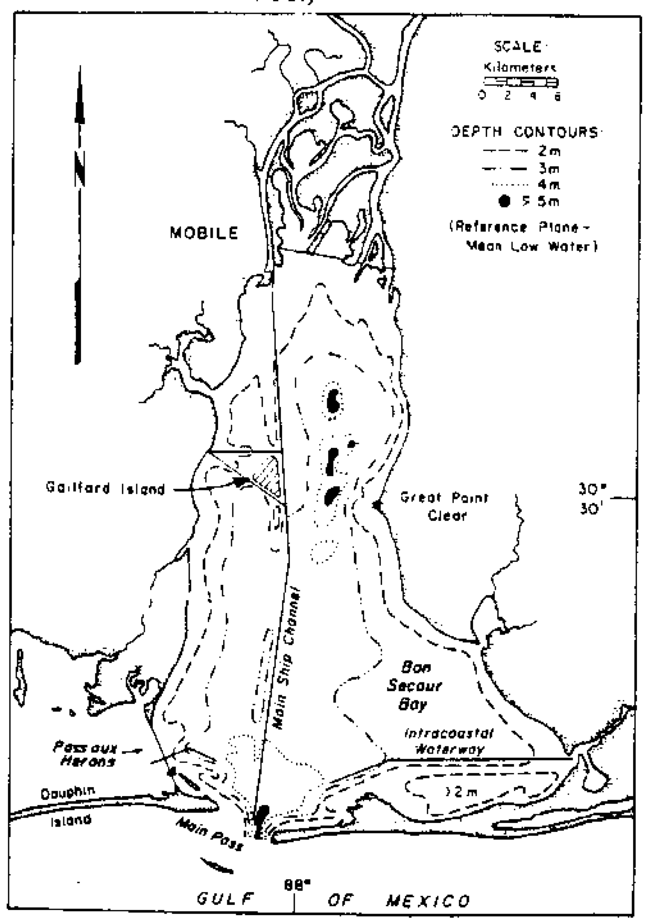


Figure 2. Bathymetric map of the Mobile Bay estuary. (Modified from Schroeder and Wiseman 1988.)



Gulf of Mexico. This air is normally unstable and thus is easily lifted and condensed through convective heating or sea breeze convergence. As a result, thunderstorms are frequent and account for the major portion of summer rainfall. In fact, the frequency of thunderstorms over coastal Alabama is surpassed only by the Florida peninsula.

A sea breeze from the Gulf and the bay produces a prominent area of convergence to the east and west of the bay. Largely because of this convergence, these two areas have the highest annual rainfall totals along the Gulf coast averaging nearly 165 cm (65 in). On the other hand, summer rainfall is considerably less over the bay and along the immediate shoreline due to subsidence within the sea breeze flow. Tropical disturbances also produce high rainfall amounts. However, these systems are normally extensive and thus amounts usually vary on large spatial scales.

The influx of moisture from the Gulf of Mexico, in combination with numerous thunderstorms, produces a small diurnal temperature range during the summer. Average maximum air temperatures during the summer months vary from the low 30°C (90°F) range to the mid to upper 20°C (80°F) range around and over the bay. Although temperatures may rise rapidly during the morning hours, the high frequency of thunderstorms usually limits the daily temperature peak at around 32 to 33°C (90 to 92°F) (Williams 1973). Because of the high absolute humidity during this period, temperatures of 38°C (100°F) or higher are occasionally observed around the bay.

<u>Winter Climate.</u> During the winter months, the Atlantic subtropical anticyclone retreats southward allowing the polar front to make numerous incursions into the Gulf states region from September to May. On the average, cold waves of polar continental or arctic air last for about three days with the coldest temperatures occurring on the second or third mornings when the winds are weak.

The arrival of polar air is frequently marked by heavy rain and a strong wind shift from southerly to northwesterly. Freezes are not uncommon around the bay. Temperatures of -7°C (20°F) or colder occur every other year with readings of -12°C (10°F) or colder reoccurring approximately every five years. When extremely low temperatures occur for at least two successive nights, freezing of the bay may take place near shore.

The Mobile Bay estuary creates a well defined "temperature shadow" along the eastern shore where temperatures are modified by the warmer bay waters. When northwest winds prevail, nighttime temperatures may be 5 to 8°C (10 to 15°F) warmer than those experienced on the western shore. A strong temperature contrast between the bay and shore or between the bay and an incoming air mass is frequently the source of dense fog, a common occurrence in the spring.

<u>Winter Storms.</u> Although summer thunderstorms are numerous and greatly contribute to high annual rainfall totals, winter storms also produce heavy downpours. Those winter storms with the greatest impact originate in west Texas or along the Texas coast and are usually formed by upper atmosphere troughs that track across the southwestern U.S. Surface cyclones that develop beneath these

troughs either move eastward from Texas across the Gulf states or along the coast. Storms of this type gain enormous energy from the contrast between warm Gulf waters and cold polar air positioned over the Gulf states.

Each storm that approaches coastal Alabama is preceded by south and southeast winds. Depending on the central barometric pressure and track of the storm, tides rapidly build ahead of the storm. Winds of 10 to 15 m s^{-1} (20 to 30 k) are not uncommon with higher gusts occurring in squall lines. The most intense winter storms are those that track across Louisiana, southern Mississippi and southwest Alabama. This track places the bay in the warm sector of the storm very close to the storm's center. Such a position usually results in a strong southerly flow with torrential rain, coastal flooding and a likelihood of severe thunderstorms. When this situation occurs, a squall line forms just ahead of the cold front with individual thunderstorms moving north and northeastward. The high frequency of winter storms originating in Texas and crossing the Gulf states accounts for a secondary rainfall maximum in March for many Gulf coast regions. For areas around Mobile Bay, July slightly exceeds March as the wettest month with an average of more than 17.8 cm (7 in) of rain.

Tropical Storms. The central Gulf coast has one of the highest frequencies of hurricane landfall in the United States. From 1871 through 1980 an average of 2.2 tropical storms made landfall along every 18.5 km (10 nautical miles) stretch of the coast (Neumann et al. 1981). However, by an oddity of nature the Mobile Bay region escaped a direct hit from a major hurricane for more than 50 years ending with Hurricane Frederic in 1979. When a hurricane strikes the Alabama coast, the point of landfall with respect to the entrance to the bay is extremely important. Landfall to the west of the bay results in the full impact of the right-front quadrant on Mobile Bay. The storm surge is forced into the bay and is funneled northward as occurred in the hurricanes of 1906, 1916 and 1979 (Fig. 3).

Tropical storms are capable of producing enormous rainfalls over the bay. Rainfall of 13 to 25 cm (5 to 10 in) are not unusual. However, hurricane rainfall totals vary considerably from storm to storm. When totals are high, the combination of flood runoff, erosion and the destruction of trees and buildings in shoreline gullies, by wind channeling (Williams 1980), results in the transport of large amounts of sediment and debris into the bay which can have a profound post-storm impact on the ecosystem. On the other hand, when rainfall is low, airborne sea salt does extensive damage to vegetation throughout the surrounding wetlands.

Freshwater Input

The principal source of run-off into the bay is the Mobile River system (carrying the combined flows of the Alabama and Tombigbee Rivers), which accounts for approximately 95 percent of the freshwater input and enters through five distributaries of the Mobile River Delta at the northern end of the bay (Schroeder 1979a). The average discharge of the system for the period 1929 to 1983 is 1,848 $m^3 s^{-1}$ (65,253 $ft^3 s^{-1}$), but the annual discharge varies considerably from year to year (see Schroeder and Wiseman 1986; Fig. 4). The lowest 7-day average flow on record is 223 $m^3 s^{-1}$ (7,874 $ft^3 s^{-1}$), which occurred in 1954

Figure 3. The tracks of the strongest hurricanes to landfall at or near Mobile Bay.

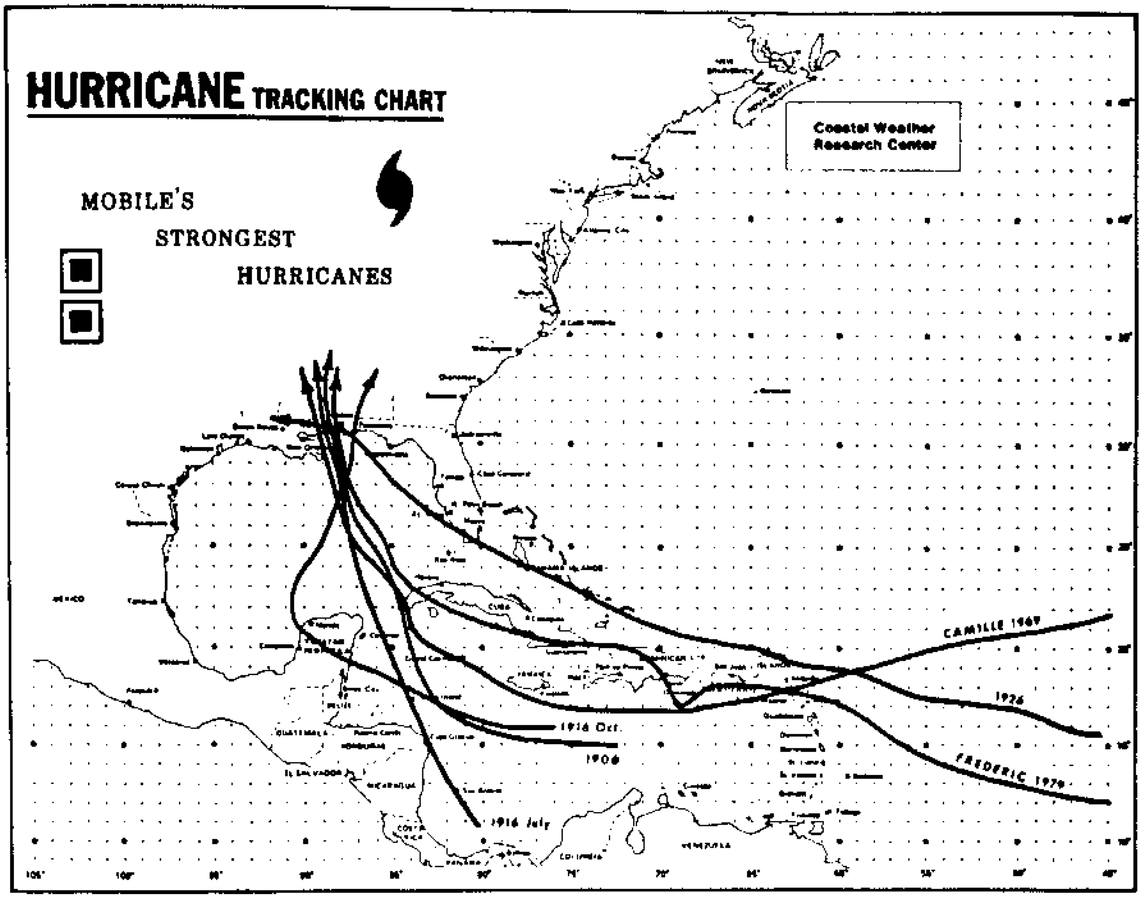
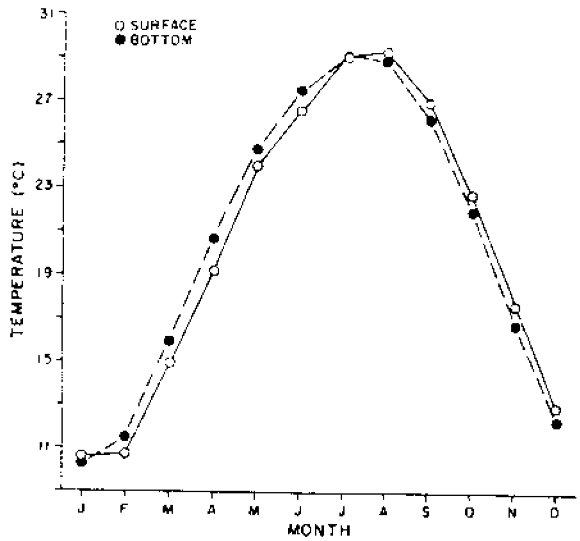
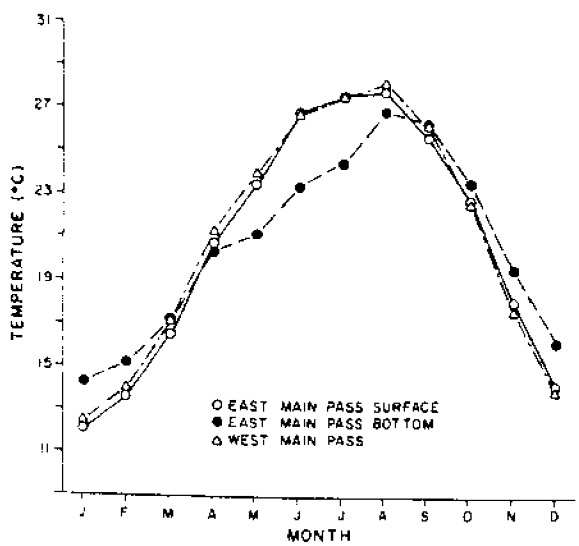


Figure 4. Thermal regime of upper (A) and Main Pass (B), Mobile Bay. Values are three-month running averages. (From Schroeder and Lysinger 1979.)

A.



B.



(Peirce 1966). The highest 7-day average flow on record is 13,977 $m^3 s^{-1}$ (493,528 $ft^3 s^{-1}$), which occurred in 1979 (Schroeder 1980).

Tides and Sea Level

Mobile Bay is primarily under the influence of a daily astronomical tide with a mean range of 0.4 m (1.3 ft), a maximum tropic tide range of 0.8 m (2.6 ft), and a minimum equatorial tide range of less than 0.1 m (less than 0.2 ft). Additional information on tides can be found in Marmer (1954). Schroeder and Wiseman (1985), utilizing 11 years of NOAA/NOS tide data from the east end of Dauphin Island, document both seasonal variability in mean sea level and aperiodic, non-tidal perturbations in sea level along the Alabama coast. The seasonal cycle of mean sea level is: low in winter and early summer; and high in spring and late summer through the fall. These fluctuations result from a combination of local-regional winds, river run-off, and thermal expansion-contraction of the water column. The short-term non-tidal response along the coast to winter "cold front" storms is a rapid sea level set up - set down sequence, while strong easterly winds and flooding events result in periods of sea level set up. The impact of tropical cyclones is dependent on the path, speed of propagation, size, and intensity of the individual storms.

In the northeastern Gulf of Mexico, long term (1000-10,000 y) fluctuations in mean sea level have been occurring very slowly. For example, Shepard (1960) calculated that between 17,000 to 8,000 yBP sea level rose at a rate of 0.85 m (2.8 ft) per century. From 8,000 to around 3,600 yBP, when sea level reached its present-day level, Coleman and Smith (1964) calculate even a slower rise of 0.3 m (1.0 ft) per century. The most recent estimate for sea level change along the Gulf coast is +1.8 mm y^{-1} or +0.18 m per century (+0.07 in y^{-1} or +0.59 ft y^{-1}) by Aubrey and Emery (1983).

Hydrography

Temperature. Water temperatures range from highs of 30 to 33° C (86 to 91°F) to a low of 0° C (ice). Figure 4 depicts the thermal regimes of both upper Mobile Bay and Main Pass, Mobile Bay. Seasonal periods are well defined in these figures except for the bottom waters of Main Pass. Winter occurs from December through February, spring from March through May, summer from June through August and fall from September through November. For the bottom waters of Main Pass the winter season is the same but there is a four-month spring warming season from March through June, a summer that lags one month behind the remainder of the bay and occurs from July through September and only a two month fall cooling season during October and November. For more detailed information see Schroeder and Lysinger (1979).

Strong thermal stratification has not been observed in Mobile Bay on a regular basis. Schroeder and Lysinger (1979) report that the monthly averaged thermal vertical structure in the upper bay undergoes an annual reversal, with stable gradients generally occurring from August through January, unstable gradients from February through June, and homogeneous conditions in July. During the periods of stratification the average differences between surface and bottom temperatures were equal to or less than 1.0°C (approximately 2.0°F) except during April, when the surface waters were 1.5°C (approximately 3°F) cooler than the bottom waters.

Salinity. The salinity regime of Mobile Bay encompasses direct, bay-wide influence of high salinity Gulf of Mexico waters during extended periods of low river discharge at one extreme (Schroeder 1979a; Schroeder and Lysinger 1979) to near dominance by freshwater under flooding conditions at the other extreme (Schroeder 1977a). Specifically, salinity values ranging from 0 to 35.0 ppt have been observed in the lower bay while in the upper bay the range is 0 to 24.0 ppt.

Because the bay-wide salinity regime varies principally as a function of the discharge rate of the Mobile River system, which has been shown to be highly variable (see Schroeder 1978 or Schroeder and Lysinger 1979), no set seasonal salinity patterns exist. However, in general, the lowest salinities are normally present sometime between February and May when high river discharge and flooding ordinarily occur and the highest salinities are present sometime between August and November when low river discharges ordinarily occur.

Within the bay, salinities have been observed to change on a number of different time scales. At tidal periodicities, salinities in both the upper and lower layers can exhibit large variations. In addition, when stratification is strong, the motion in the two layers may contain significant independent components. Thus, both the absolute values and the surface-to-bottom differences change during a tidal cycle (Fig. 5; station locations are in Fig. 6). Schroeder and Wiseman (1986) report that strong vertical stratification occurs under the following conditions:

1. Moderate to high river discharge and weak winds; and

2. Persistent southward-directed wind stress and low river discharge.

Vertical salinity differences as high as 10 to 15 ppt and 20 to 30 ppt have been observed in the northern and southern ends of the bay, respectively.

Lysinger (1982) carried out an extensive study of the hydrography of Main Pass. He concluded that waters in the deeper eastern side of the pass always show salinity stratification while the shallower western side of the pass can be either stratified or well-mixed. This study also demonstrated that salinity and the degree of stratification vary during tidal periods and that the upper layer salinities within the pass are significantly related to river discharge.

Schroeder et al. (1990) have shown that stratification-destratification events within this broad, shallow estuary are not uncommon. They report that these events are related to the interaction of river discharge and the strength of the winds, not to the strength of tidal currents as has been observed in other estuaries. Furthermore, the river flow appears to be the dominant control, the winds being important only in the absence of large freshwater discharge. During the annual spring flooding season most of the salt can be flushed from the bay. At other times of the year the relative strengths of river discharge and the wind stress cycle the bay between

Figure 5. Time series of salinity (ppt) and river discharge ($m^3 sec^{-1}$) data for Mobile Bay, February-March, 1978 (A) and June-July 1978 (B). See Figure 6 for station locations. (From Schroeder and Lysinger 1979.)

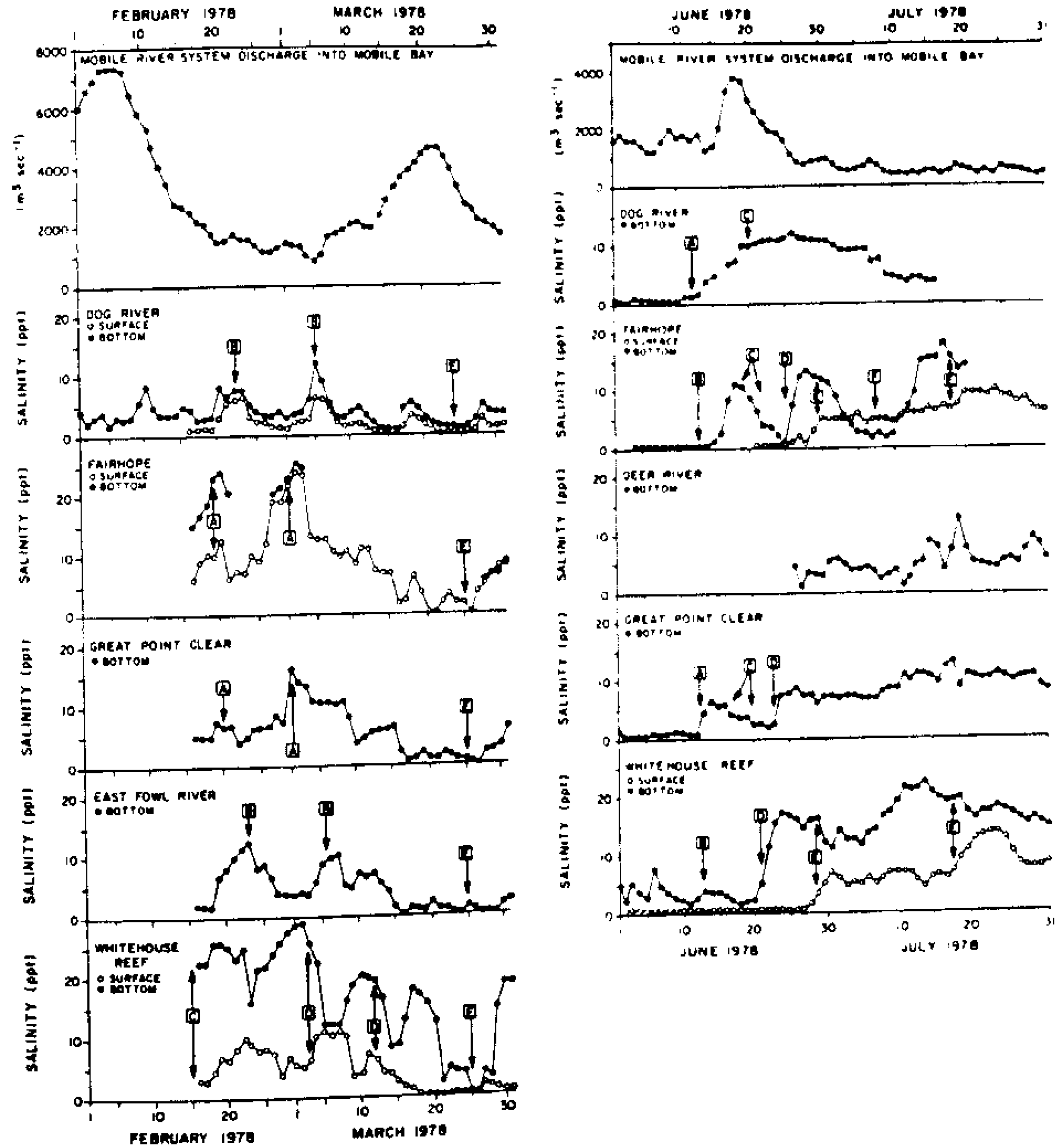
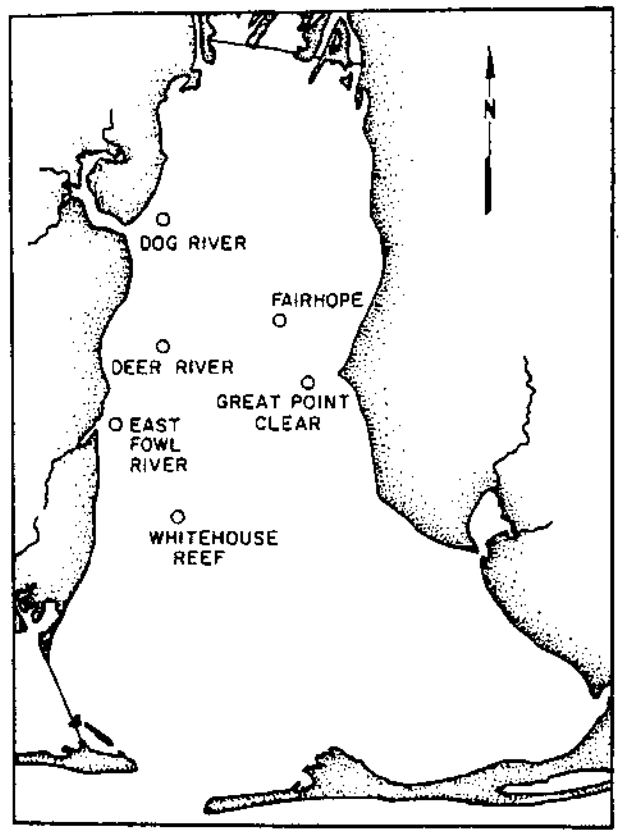


Figure 6. Station locations in Mobile Bay for salinity time-series data in Figure 5. (From Schroeder and Lysinger 1979.)



highly stratified and homogeneous on a variety of time scales ranging from daily to seasonal.

Subtidal variability is also important. The time series records depicted in Figure 5 suggest periods of 5 to 20 days to be particularly energetic. However, with the short records available it is difficult to identify the processes responsible for these fluctuations. Wind stress, river runoff and the fortnightly tides all vary on similar time scales.

Dissolved Oxygen. At the "Symposium on the Natural Resources of the Mobile Bay Estuary, Alabama," held in 1979, Schroeder (1979b) made the following observation: "The dissolved oxygen system in the Mobile Estuary remains essentially unknown." Specifically, he concluded that:

1. Some information was available on the quantitative annual cycle (Fig. 7) and macro-scale distribution patterns during oxygen depletion periods;

2. Unpublished research had recently provided the first look at oxygen-consuming processes; and

3. Virtually nothing was known about oxygen-producing processes, environmental factors responsible for the onset, maintenance and termination of oxygen depletion periods or meso- to micro-scale distribution patterns during oxygen depletion periods.

We are only slightly better off today with regard to our understanding of this system.

The most significant contribution since 1979 has been made by Turner et al. 1987. Their analysis of a number of historical data sets resulted in the substantiation of the following hypotheses:

1. Stratification inhibits reaeration and directly influences equilibrium oxygen concentration in bottom waters of Mobile Bay;

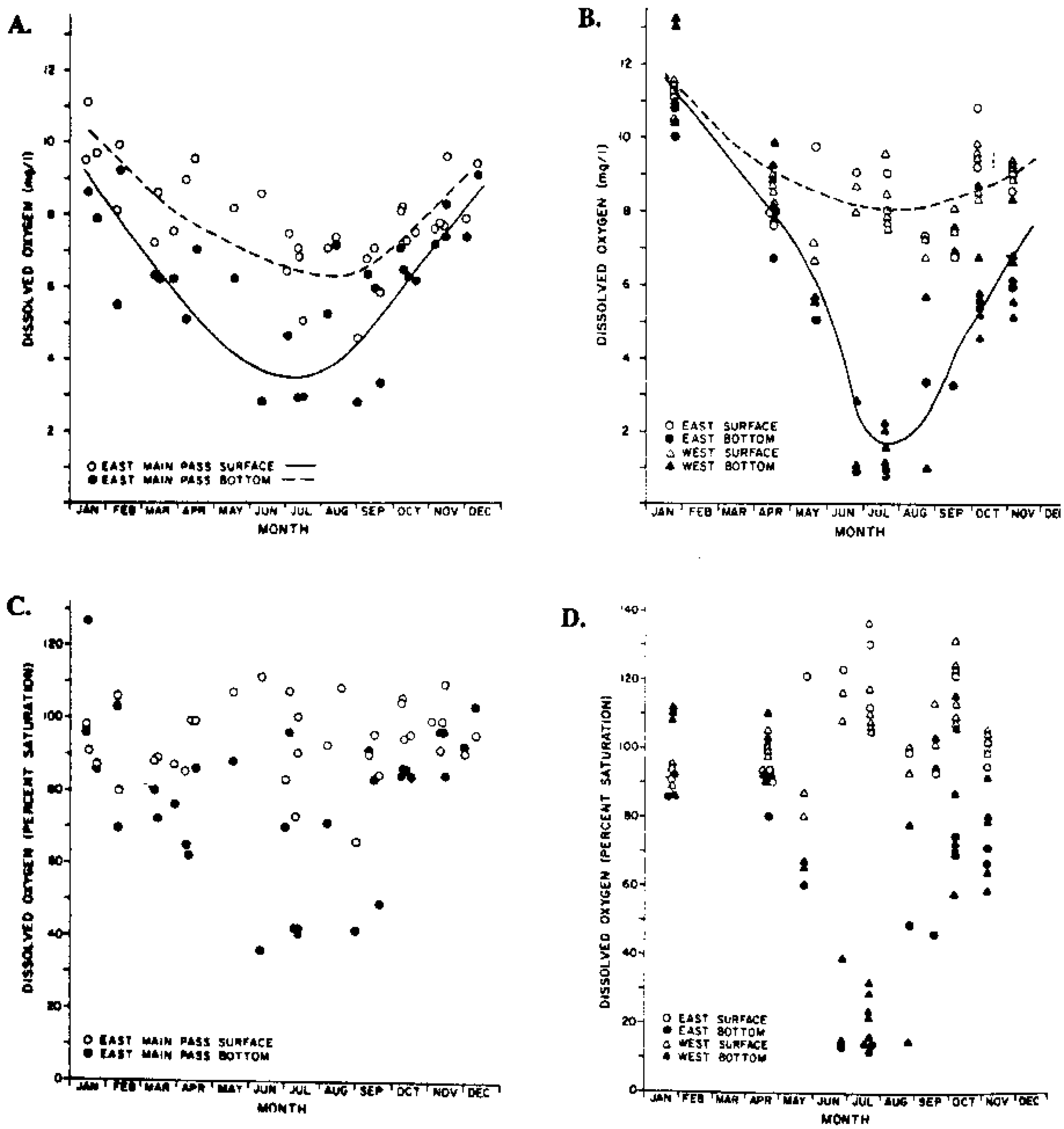
2. Net oxygen consumption (of benthos and water column combined) decreases with increasing depth;

3. Large oxygen reservoirs resist deoxygenation better than small reservoirs;

4. Recent, not relic, organic substrates influence short-term changes in oxygen concentration in Mobile Bay; and

5. Equilibrium oxygen concentrations are established in a matter of days, if not hours, in Mobile Bay.

Figure 7. Measured concentrations of dissolved oxygen at East Main Pass (A) and upper Mobile Bay (B) and calculated values of dissolved oxygen percent saturation for East Main Pass (C) and upper Mobile Bay (D). (From Schroeder 1979b.)



Hypoxia and Jubilees

"Jubilee" is the name given to the aperiodic shoreward movement of large numbers of fish and invertebrates, particularly along the eastern shore region of the bay. This phenomenon has been presumed to be associated with the occurrence and movement of hypoxic bottom waters (Loesch 1960; May 1973) but it was not until Schroeder and Wiseman (1988) analyzed a set of data that had been collected for other reasons that a documented relationship between a jubilee event and hydrographic and meteorological conditions was established. Their study examined the interactions of the bay's geomorphology, water column structure, circulation, biological activity, and man-made modifications relative to oxygen depletion and jubilees. The conclusions they reached are:

1. During summer months, strong haline stratification isolates the bottom waters of the bay from direct air-sea interaction. High temperatures increase metabolic rates and benthic consumption reduces near-bottom dissolved oxygen concentrations to levels that are stressful to the biota. This hypoxic water is moved by tides and wind-driven baroclinic (two-layer) motions. This movement appears to be responsible for the "jubilee" phenomenon in the bay.

2. Large areas of the bay are affected by hypoxic conditions. Strong wind, though, can rapidly dissipate these conditions. Hypoxia quickly redevelops following reestablishment of stratification after a wind event.

3. Hypoxic conditions are not generally found in winter. Presumably, this is because wind mixing is more frequent than in summer and lower temperatures result in reduced benthic oxygen consumption rates. Oxygen depletion has been reported during periods of spring river flooding episodes (Schroeder 1977a), but no "jubilee type" activity have been observed during these events.

Circulation

No definitive investigations on circulation patterns within Mobile Bay have been undertaken. Numerous small-to-medium spatial scale and/or short time period studies have approached the circulation question employing both direct measurement and remote sensing techniques.

Water Level and Current Measurements. Schroeder and Wiseman (1986), working with two years of data, determined relationships among water level, wind stress, river discharge and water flow through Main Pass and within Mobile Bay. They identify three forcing functions that are responsible for developing significant flow variations over three different time scales:

1. Strong north-south winds, particularly those accompanying winter cold front passages, were extremely effective in forcing water exchange between the Gulf of Mexico and Mobile Bay at periods of 2 to 10 days;

2. At periods longer than 3 days, the east-west wind stress also forced an exchange because of Ekman convergence and divergence at the coastline; and

3. Over periods longer than 40 days, river discharge at the northern end of the bay was coherent with water levels within the bay and thus with the total mass flow through Main Pass.

Wiseman et al. (1988), in a follow-up study utilizing one month of current meter data, demonstrated:

1. Shelf-estuarine exchange through Main Pass driven by north-south wind stress at periodicities longer than the tide; and

2. That river discharge fluctuations appear to readily modulate the strength of the gravitational circulation over time scales shorter than seasons.

They also concluded that the effects of tidal dispersion [as estimated from Austin (1954)], subtidal (long period) advection, and mean circulation appear to be of equal importance to dispersion of water through Main Pass.

For additional information on current meter measurements made during 26-hour anchor station surveys in Main Pass and 26-hour bridge station surveys at Grants Pass, in Pass aux Herons (the boundary between Mobile Bay and east Mississippi Sound), see Schroeder (1976, 1977b) and Schroeder and Lysinger (1979).

Drogue Studies. Twenty drogue tracking surveys, consisting of single and multiple drogue releases in the lower half of the bay, were conducted over the period of August 1975 to November 1977 (Schroeder 1976, 1977b). Pertinent information on eleven of these surveys is summarized in Schroeder and Lysinger (1979; see Table 5). From their analysis of these drogue surveys Schroeder and Lysinger (1979; see Figs. 20 and 21) make the following observations:

1. The surface circulation pattern in lower Mobile Bay is highly variable;

2. The maximum displacement of drogues released in or near Main Pass over one half of a tidal cycle (12 hours) ranged from 10 to 12 km (5 to 6.5 nautical miles);

3. Many individual drogue tracks depict a tendency for an "excursion" type drift pattern within the bay (e.g., a drift pattern with the same deployment-departure and recovery-return point);

4. Sustained winds can override astronomical tidal forces resulting, for example, in no direction reversals during the daily tidal cycle; and

5. Under flooding river discharge conditions, surface waters in the region of west Main Pass flow nearly continuously out of the bay.

Inferred From Salinity Distribution Patterns. Inferring circulation regimes from salinity distribution patterns is common practice. Large-to-medium-scale trends and in some cases medium-to-small-scale features can be defined by the use of this technique. Schroeder (1979a) summarizes the results of a two year field study on the influence of the Mobile River system on the salinity regime of Mobile Bay with the following observations:

1. During low river discharges, river water salinities (<1.0 ppt) and transitional water (salinities of 1.0 to 7.9 ppt) in the upper and middle bay form a surface lens over the more saline bottom waters and move to the south with no observable cross-bay pattern;

2. As river discharge increases into the moderate range, river and transitional waters at the surface and the bottom of the water column favor the western side of the bay as they move to the south; and

3. At higher river discharges the down-bay patterns of river and transitional water become less obvious at the surface because they tend to dominate the entire surface field, while at the bottom they still favor the western side of the bay.

High salinity water from the Gulf of Mexico has been observed to move northward into the bay as a broad bottom intrusion with a strong easterly component (flooding into Bon Secour Bay), as overflow from the main shipping channel or as a combination of both (Schroeder 1977a, 1978, 1979a; Schroeder and Lysinger 1979).

Inferred From Satellite Imagery. Surface circulation can be inferred from the distribution patterns of suspended sediments and sea surface temperatures observed on imagery obtained from Landsat (multi-spectral scanner) and NOAA-TIROS-N (Advanced Very High Resolution Radiometer) satellite systems. Major features such as strong, southward flow of turbid river waters along both the western and eastern sides of the bay; complex interactions of river, Mobile Bay and Gulf of Mexico waters within the bay; the formation of estuarine derived plumes in the nearshore waters of coastal Alabama, the significant role played by wind-wave induced resuspension of sediments on the "turbidity" regime of Mobile Bay and the impact of winter cold fronts on the thermal regime of the bay are but a few of the processes that have been studied utilizing satellite-based remote sensing (Schroeder 1977c; Schroeder and Lysinger 1979; Abston et al. 1987; Rucker et al. 1990).

Mathematical Models

Numerical models for simulation of Mobile Bay system waters have undergone a rapid development in the last ten years. Both improved model-formulation techniques and improved digital-computer capabilities have stimulated the increased use of, and confidence in, these models. The first-generation hydrodynamic models (e.g., April and Hill 1974; April and Liu 1975; April and Ng 1976a and b) were restricted to a constant spatial step size and fairly simple boundary conditions. For example, finite difference cells were either land or water with no provisions for "drying" or "flooding" of cells during the modeling process.

Second-generation hydrodynamic models (e.g., April et al. 1975; April and Hu 1979; Raney et al. 1984a) introduced improved boundary conditions for the finite difference cells, including an inundation capability. Sub-grid features also allowed a description of a geometric feature smaller than the selected grid size. For example, a sand bar, smaller than a grid cell, might be represented by a sub-grid barrier restricting flow through one or both faces of the cell. Current state-of-the-art third-generation hydrodynamic models (e.g., Raney 1984, 1985; Raney and Youngblood 1987; Raney et al. 1984b) introduce a variable spatial grid capability allowing a smaller spatial step, where required, for proper resolution of physical detail.

It is important to recognize that numerical modeling of hydrodynamic systems is not an academic exercise with little relationship to the physical world. The numerical hydrodynamic model, when properly applied and verified, is an extremely powerful predictive tool and a viable, cost effective alternative to physical (scale) modeling as has been done at the U.S. Corps of Engineers Waterways Experiment Station, Vicksburg, Mississippi for the Mobile Bay system. Table 1 presents mathematical representation and operational modes of Mobile

Table 1. Mathematical representations and operational modes of Mobile Bay mathematical models.

Name	Equation Form	Results	Modes
Continuity	$\frac{\partial Qx}{\partial x} + \frac{\partial Qy}{\partial y} + \frac{\partial H}{\partial t} = -(R + E)$	Tidal Height	Tidal Cycle Daily Avg. Monthly Avg. Seasonal
Momentum x-Component	$\frac{\partial Qx}{\partial t} + gD\frac{\partial H}{\partial x} = K\eta^2\cos\psi - fQQ_xD^{-2} + Qx(2W\sin\varphi) + D^{-1}(\frac{\partial(V_x^2)}{\partial x} + \frac{\partial(V_xV_y)}{\partial y})$	x-Component of System Current	Tidal Cycle Daily Avg. Monthly Avg. Seasonal
y-Component	$\frac{\partial Qy}{\partial t} + gD\frac{\partial H}{\partial y} = K\eta^2\sin\psi - fQQ_yD^{-1} + Q_y(2W\sin\varphi) + D^{-1}(\frac{\partial(V_y^2)}{\partial y} + \frac{\partial(V_xV_y)}{\partial x})$	y-Component of System Current	Tidal Cycle Daily Avg. Monthly Avg. Seasonal
Species Continuity	$\frac{\partial C}{\partial t} + Vx\frac{\partial C}{\partial x} + Vy\frac{\partial C}{\partial y} = E(\frac{\partial^2 C}{\partial x^2} + \frac{\partial^2 C}{\partial y^2}) + \frac{E}{D}(\frac{\partial C}{\partial z}(z_s) - \frac{\partial C}{\partial z}(z_b)) - \frac{1}{D}(CV_z(z_s) - CV_z(z_b)) + R_o$	Concentration of Species	
Salinity	$R_o = 0$	Salinity Concentration	Daily Avg. Seasonal
Coliform	$R_o = K_r$; where $K_r = f(\theta)$	Coliform Bacteria Concentration	Monthly Avg. Seasonal

Bay models based on the laws of conservation of mass and momentum. These include models describing the hydrodynamics as well as conservative and non-conservative species transport.

A standard finite difference grid used for Mobile Bay is shown in Figure 8. Figure 9 represents a typical output from the numerical model at a specific point in the system. Figure 10 illustrates graphical output from the same model showing overall tidal circulation patterns at a specific time in the tidal cycle.

HISTORICAL PERSPECTIVES AND FUTURE NEEDS

Estuaries are known to be ephemeral features (Schubel and Hirschberg 1979; Schubel 1986) which are slowly filling and Mobile Bay is no exception in that it has been filling at a rate of 0.50 m (1.65 ft) per century over the past 121 years (Hardin et al. 1976). On time scales of decades to centuries, these processes affect the circulation and store anthropogenic pollutants within the estuary. At the same time, dredging or deepening of shipping channels [currently the Mobile Bay Main Shipping Channel is being dredged from 13.5 m (45 ft) to over 15 m (50 ft)] and spoil disposal (in Mobile Bay as open water channel-side banks and in construction of an artificial island) alters the intrusion patterns of salt water and the large-scale seasonal circulation (Pritchard 1955, 1969), the small-scale circulation and mixing patterns, and re-exposes buried contaminants and other debris to the waters of an estuary.

Estuaries of the Gulf coast are nursery grounds for some of the most economically important fisheries of the U.S. In Mobile Bay, both large-and-small-scale circulation patterns undoubtedly play critical roles in the recruitment of these species to the shallow tributary rivers and creeks, pocket estuaries and marshes. Mixing processes within Mobile Bay are poorly understood, yet are important to the health of the bay and its biota. Expansion of the industrial complex within Alabama's coastal zone, including increased commercial shipping, as a function of the growth of the Port of Mobile (e.g., use of the Tennessee-Tombigbee Waterway and the U.S. Navy Homeport development), as well as petroleum recovery enterprises coupled with increased "people" pressures (e.g., shoreline development, recreational boating sewage disposal) will necessarily contribute potential contaminants to the system. Proper management decisions will require appropriate information bases concerning the advective-diffusive environment of the bay, i.e. its mixing/flushing characteristics.

SUMMARY AND RECOMMENDATIONS

1. Despite long periods of repetitious weather, especially during the summer, the climate of Mobile Bay region is quite variable. During severe weather, systems often dissipate or strengthen when approaching the coast. A monitoring program, consisting of both land and buoy observation stations, should be developed to allow prediction of the impacts of meso- and micro-scale systems, particularly on economically important aspects of the area.

Figure 8. A standard finite difference grid for Mobile Bay.

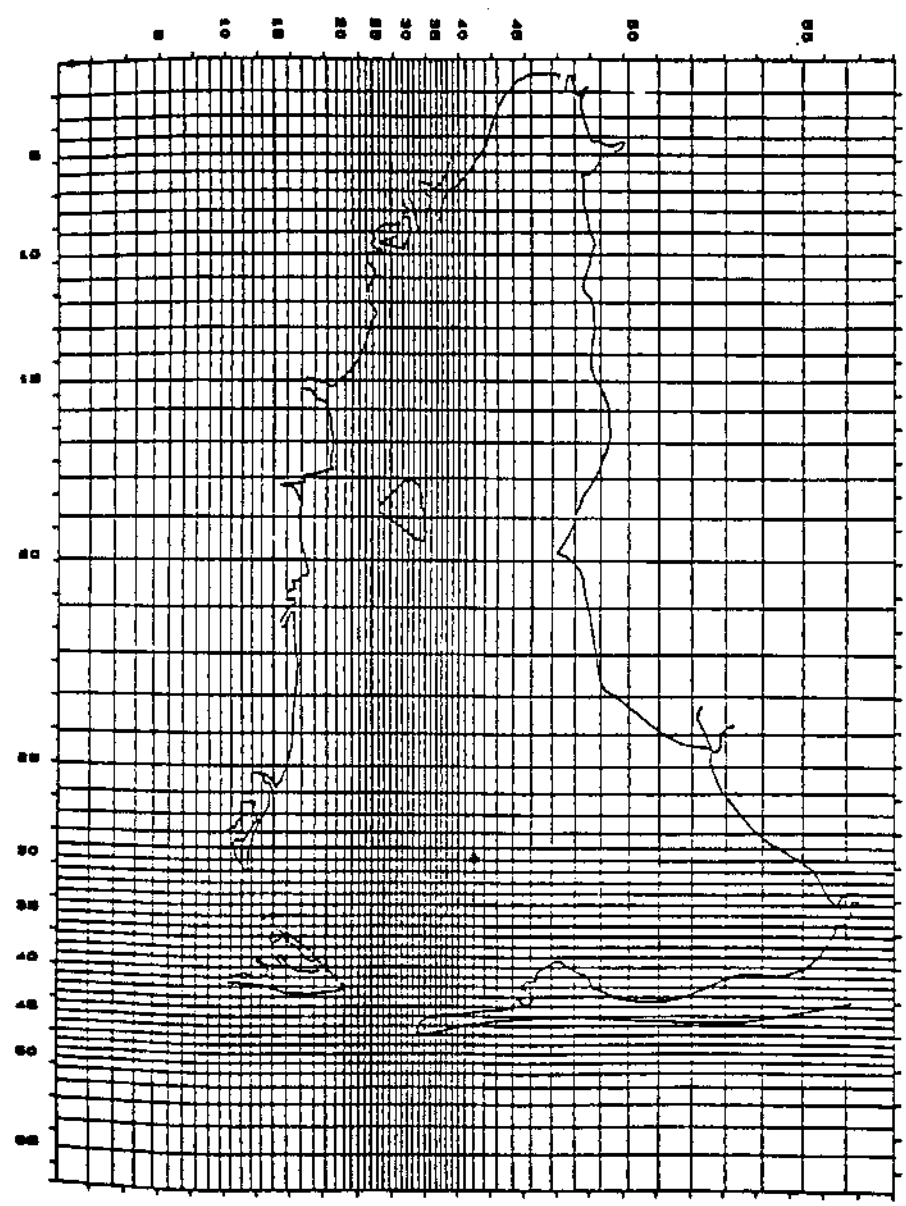


Figure 9. Typical model-generated tidal elevation output compared to prototype data for a station (Bon Secour Bay) in Mobile Bay.

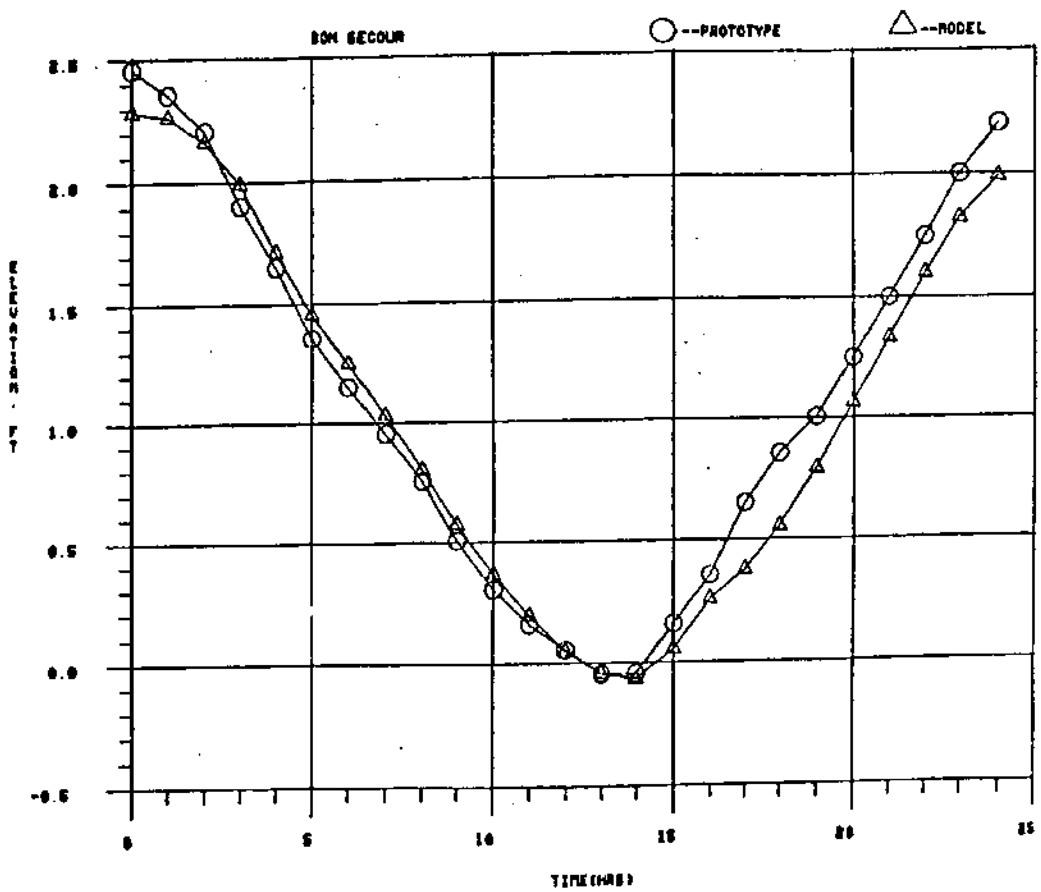
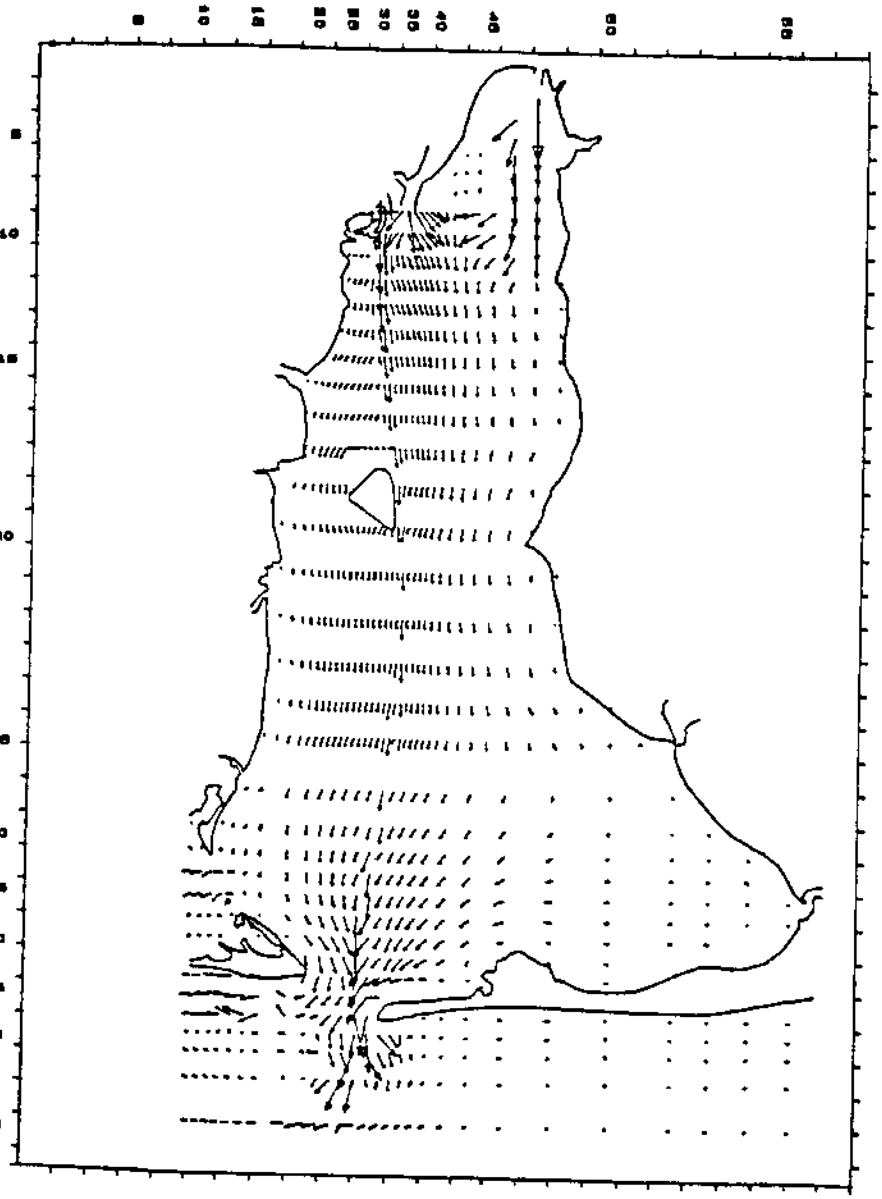


Figure 10. Typical model generated circulation pattern for Mobile Bay (ebb flow conditions).



2. Disconnected bits of historical information concerning Mobile Bay are available. Nevertheless, scientific investigations of the bay only date from the 1950's and no major, comprehensive study of either the climatic or oceanographic components, at a system-wide scale, has yet been undertaken. Also, while sophisticated two-dimensional models of transport within the bay exist, much of the data necessary to properly validate them still remains to be collected. Therefore, although we are still advancing our knowledge through the synthesis of existing observations, carefully designed field work should proceed even further, complimented by mathematical simulation studies.

All available data suggests the importance of seasonal and three-dimensional processes. A field program, ideally of 2 to 3 years, but of at least a one-year duration, designed to measure the three-dimensional fields of mass and motion within the bay, determine the important processes governing dynamics and validate models should be mounted in conjunction with the development of fully three-dimensional, primitive equation models.

3. In the Mobile Bay estuary the "State-of-the-Oxygen Regime" is an extremely useful tool in assessing the "State-of-the-Bay." Results from a comprehensive research program dealing with all aspects of the dissolved oxygen system would contribute to an immensely improved ability to gauge the "health" of the bay.

4. Continued research is needed to translate field and model results to a form useful by managers in land use/water use decision-making processes. This includes better documentation of the computer code, user-friendly access via desktop computational methods and the portrayal of results in computer graphics form that are visually descriptive.

ACKNOWLEDGEMENTS

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WATER QUALITY

by

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Mobile Bay, located at the southern extremity of Alabama, receives drainage through the Mobile and Tensaw River Systems from over 64 percent of the land area of the state.

Of the 67 counties in Alabama, part or all of 53 discharge by way of the Cahaba, Coosa, Tallapoosa, and Black Warrior Basins to the Alabama River System which combines with the Upper and Lower Tombigbee River Systems to form the Mobile River. The Mobile then splits into a smaller fork of the Mobile River and the Tensaw River, both of which enter Mobile Bay.

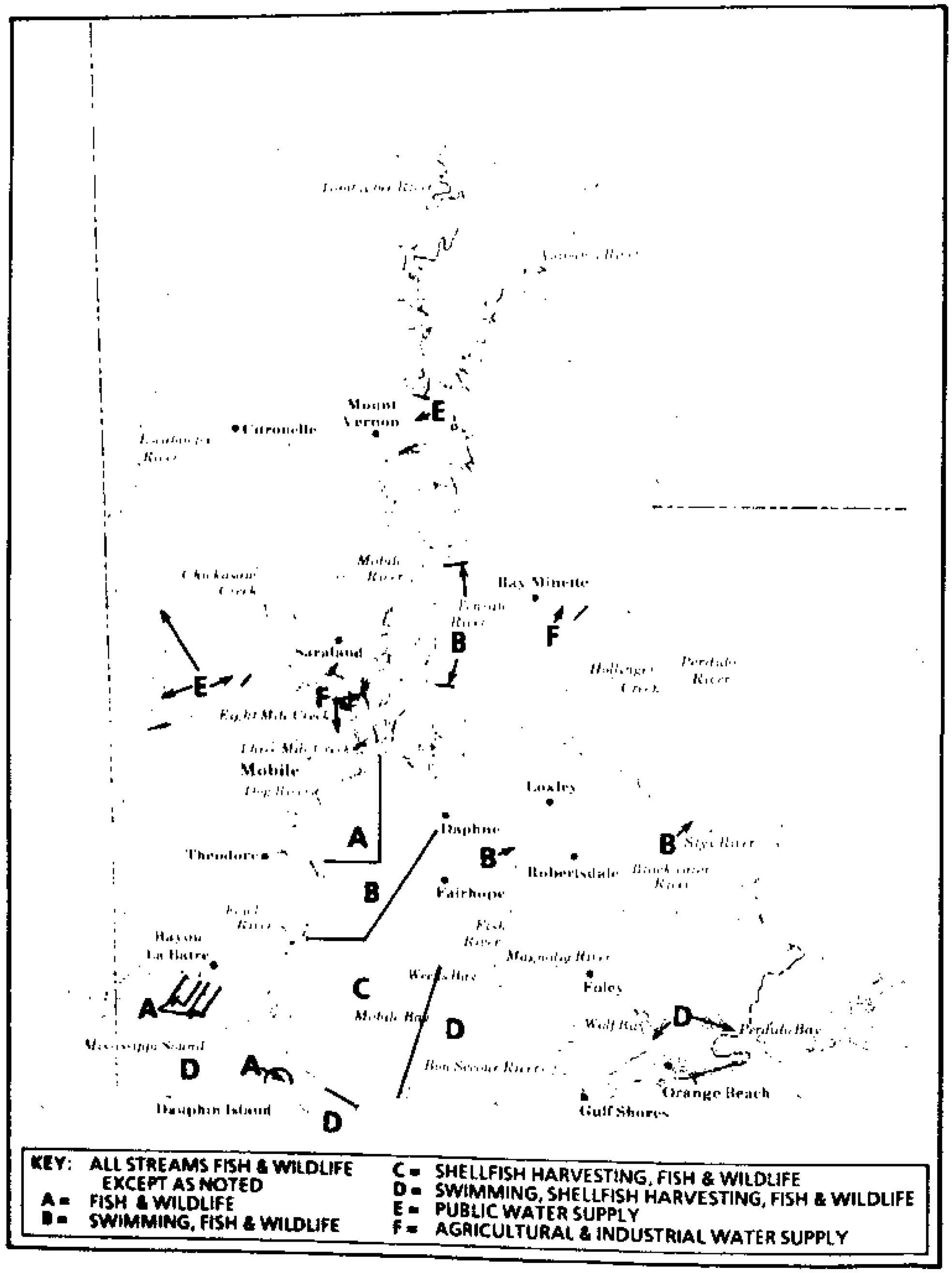
The water use classifications of Mobile Bay and tributary streams are high compared to the average of the remainder of the state due to the coastal nature of the area and to widespread usage for human contact activities and for shellfish growth and harvesting. Figure 1 illustrates the higher water quality classifications assigned to the Mobile Bay area.

Because Mobile has been a significant Gulf Coast port for years and due to the intensive growth and development of coastal areas, the water quality environment is experiencing considerable stress. Figure 2 indicates the wastewater sources by category which exist in the Mobile-Baldwin County areas. All of these dischargers (plus others which discharge indirectly through municipal treatment works) are under permit and provide treatment before discharge. Not illustrated and not managed to the degree needed are nonpoint source contributions (agriculture, forestry, construction, urban runoff, etc.). Add to this the rapid growth of the area (both in population and activity) and the importance of close and effective management is evident.

Much emphasis has been, and is being given to measuring water quality conditions and trends in the Mobile-Baldwin County area. A Departmental field office and laboratory are located in Mobile to respond to environmental needs of the area and to evaluate compliance. This office maintains an ambient water quality monitoring capability at 26 locations in the two-county area, representing 38 percent of the total statewide capability, which is indicative of the high priority and value assigned to coastal Alabama. These monitoring locations are shown in Figure 3 as ADEM Trend Stations and are supported by state, EPA, and NOAA funds.

Though generally good throughout the two-county area, existing water quality does not meet the higher standards in certain areas, as illustrated in Figure 1. Recent data suggests strongly, however, that standards are not met in much of the coastal area due to natural causes. The challenge, then, is to differentiate

Figure 1. Water classifications of Mobile Bay and feeder streams.



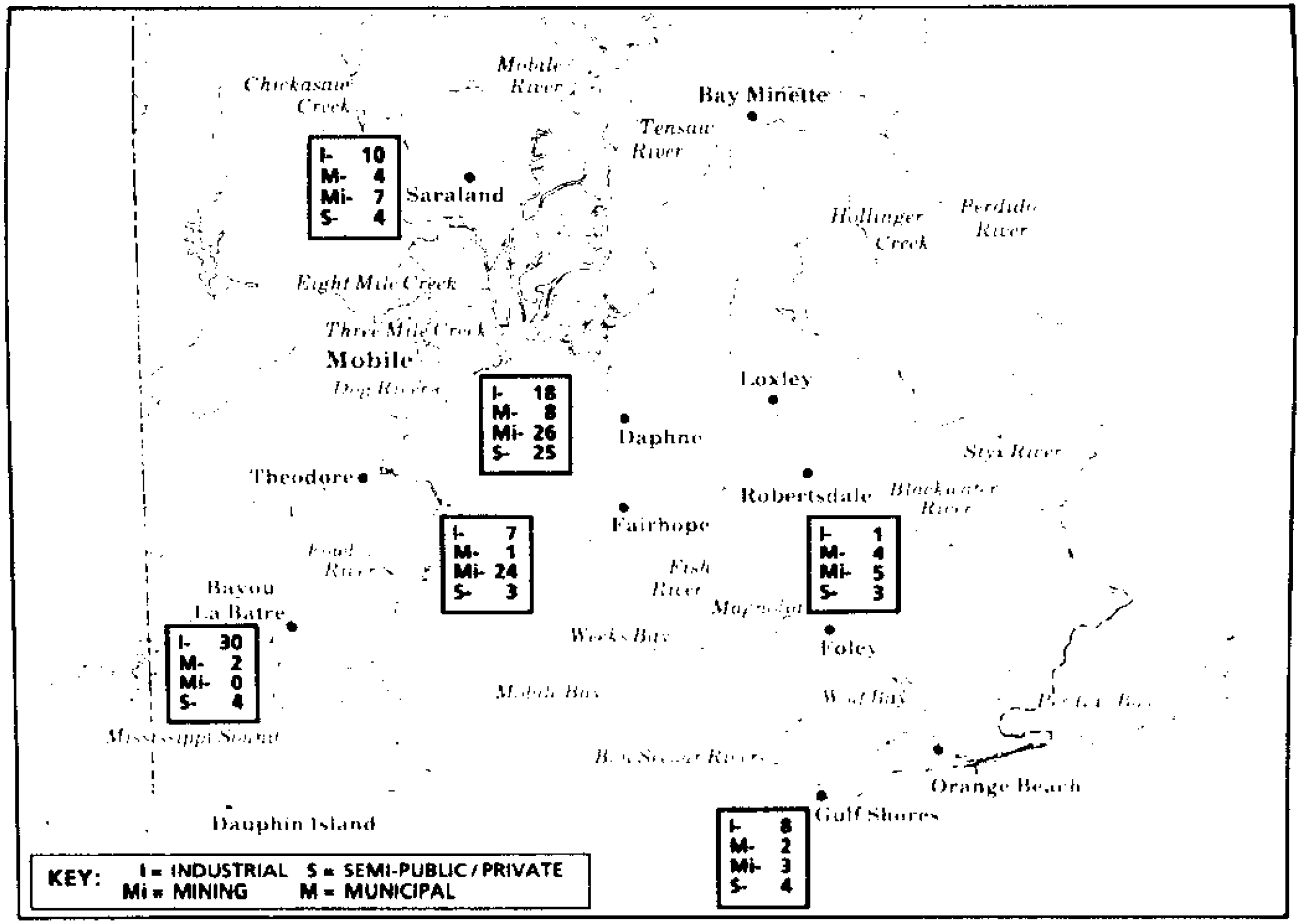
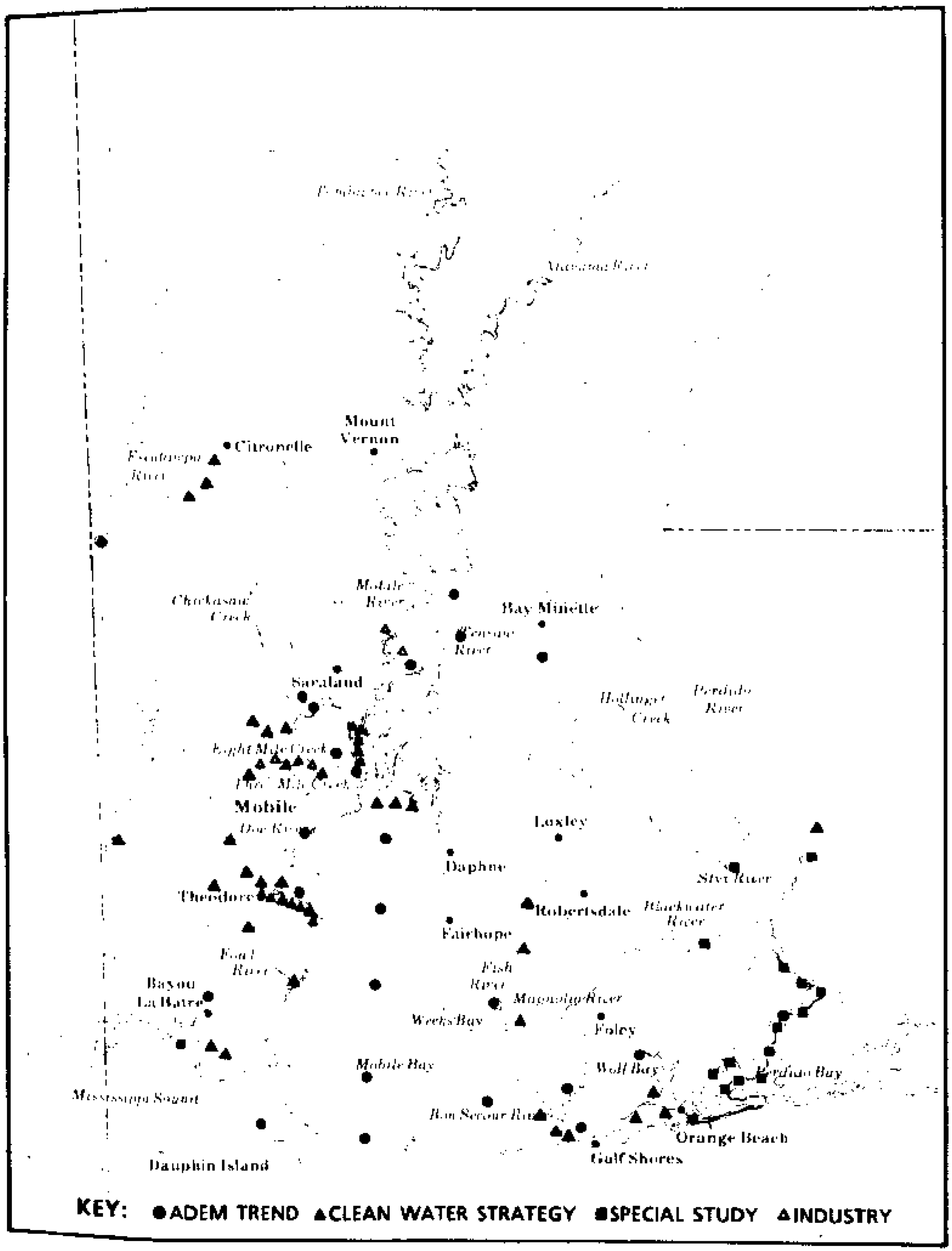


Figure 2. National Pollution Discharge Elimination System (NPDES) permit holders by catagory.

Figure 3. Monitoring programs.



between pollution-caused noncompliance and naturally occurring noncompliance. Constant effort is being directed to these areas to progress toward acceptable conditions. The few streams not having one of the higher use classifications are the lower Mobile River - Chickasaw Creek area, Three-Mile Creek, the Industrial Canal, and the upper portion of Hollinger Creek. Known stress conditions occur to some of the higher classifications at the northwest corner of Mobile Bay, in the Mobile River, near the Bayou La Batre area, in Baldwin County around the Bon Secour River - Oyster Bay area, and the Intracoastal Waterway. These stresses occur as the result of urban runoff, industrialized areas, septic tank failures, and combined wastewater discharges.

High growth or potential growth areas in Mobile County are the Navy Homeport Site, the Theodore Industrial Park, the Bayou La Batre area and residential growth west and northwest of Mobile. In Baldwin County, the Eastern Shore area (Daphne, Fairhope, etc.) is a growing residential area for people employed in Mobile; Gulf Shores is a growing residential and summer home community with tourism surges during the warmer months; and the Bon Secour area is developing commercially and residentially.

In addition, natural gas discoveries in lower Mobile Bay have resulted in a number of exploration and production wells by several major companies (Fig. 4). One field is in production with the processing plant near Bayou La Batre with a second to come on-line shortly in the same vicinity. Issues of drilling mud and cuttings disposal, and rig runoff/operational discharges have raised much public opposition, yet have demonstrated no evident environmental effects when properly managed.

Although increasing discharges and growth are occurring, water quality measurements of the past two years indicate that water quality standards in Mobile and Baldwin County have been met 86.7 percent of the time. This, while not at the 100 percent level preferred, is not unacceptable given the percentage of the state draining through Mobile Bay, the lower rainfall rates experienced in the southeast during the past four years (1986 represented a 100-year low), and the increased usage and growth that has occurred.

Several management plans are either existing, underway, or in the preliminary stages for Mobile Bay and surrounding Alabama counties. These plans, illustrated in Figure 5, are various combinations of state, federal, and local development and implementation.

The South Baldwin County EIS is a project with EPA lead to develop and assess various wastewater management alternatives for coastal Baldwin County, covering the area from U.S. Highway 98 to the coast.

A study and mathematical model was completed for the Intracoastal Waterway to define permit limitations for discharges to that tidally influenced water body which would protect the Waterway and Oyster and Wolf Bays. New discharges have occurred, and existing discharges have either upgraded treatment or terminated since the earlier sampling. Additional water quality work will be completed this year to update information.

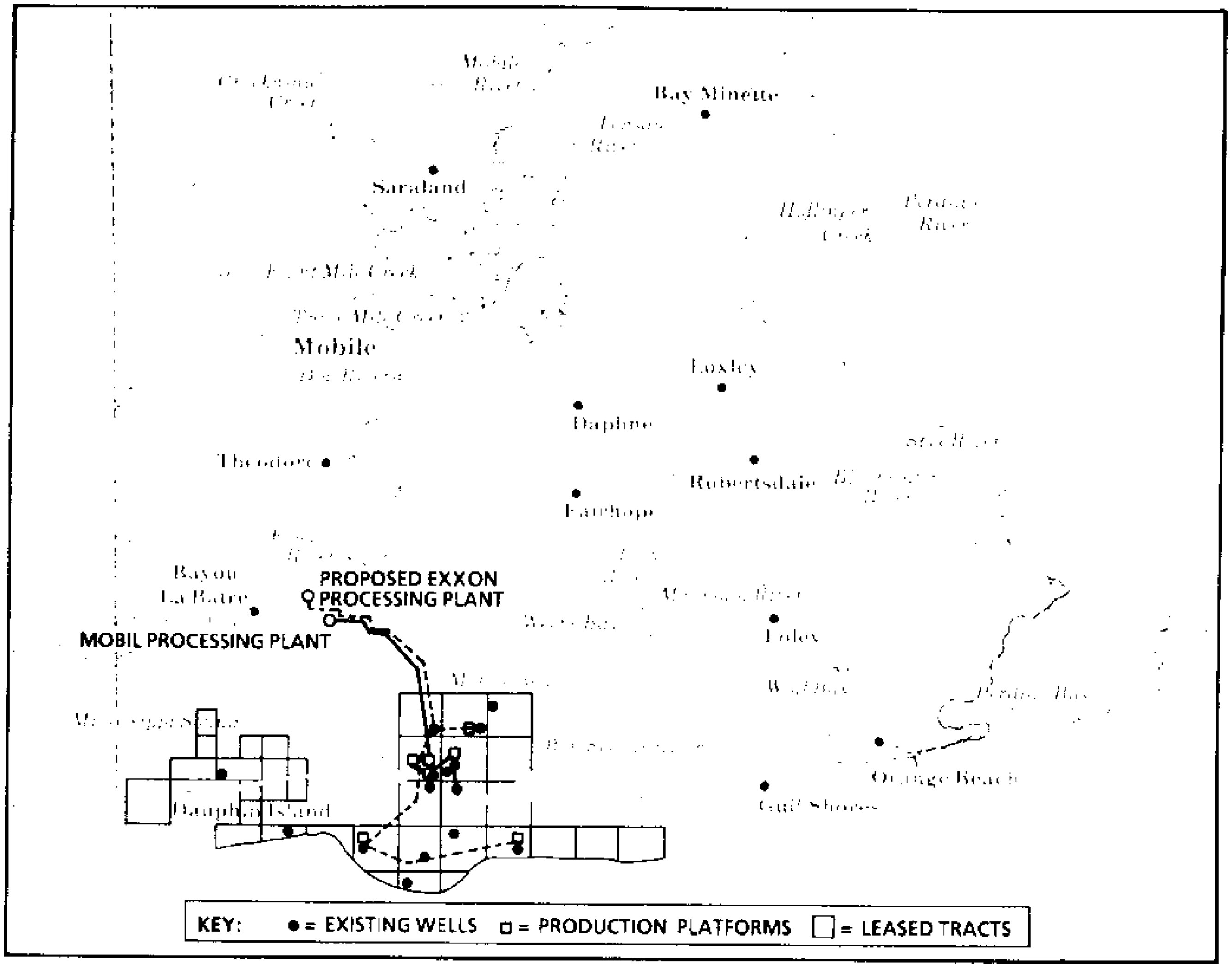


Figure 4. Lease tracts for gas exploration/production.

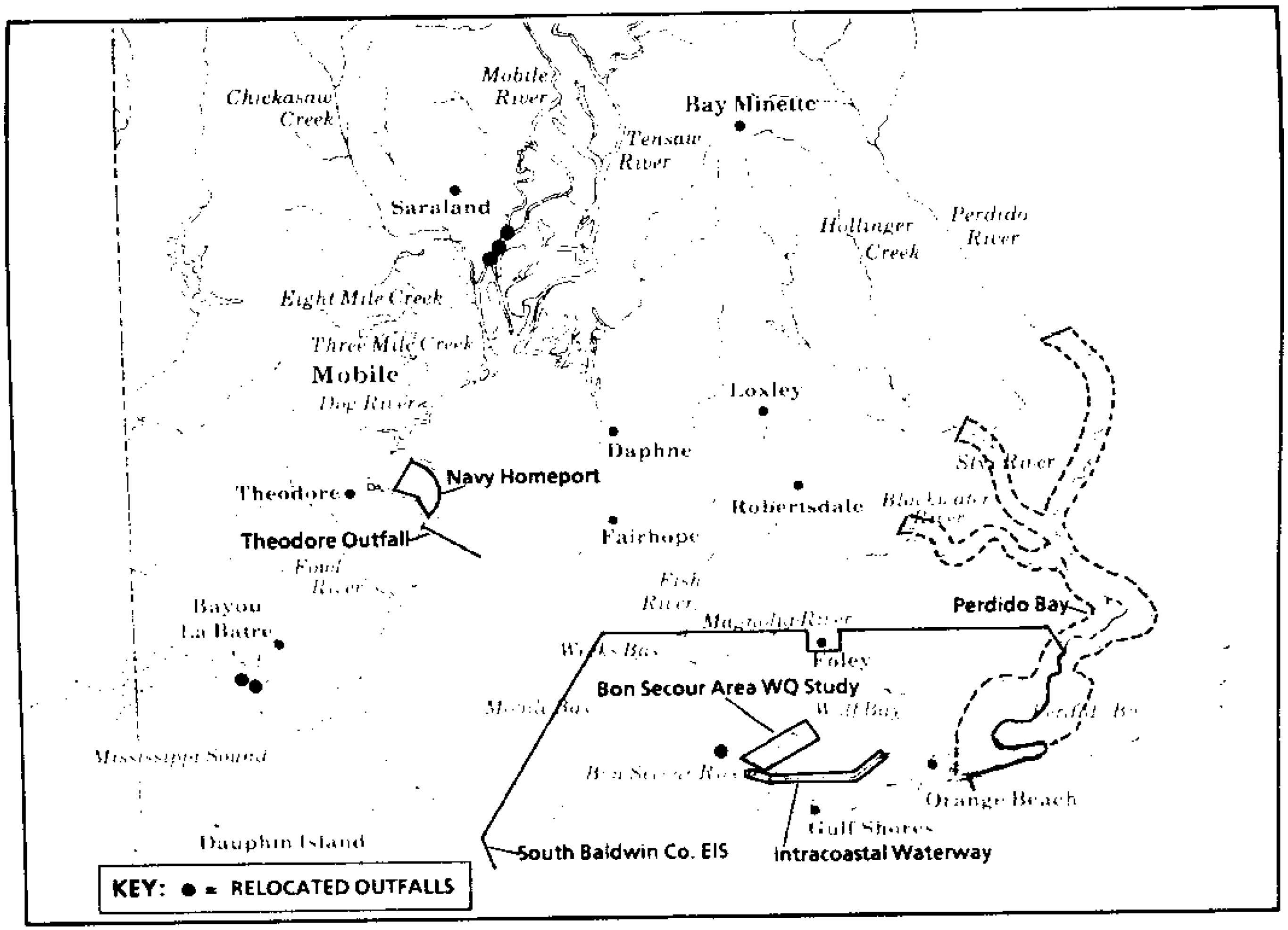


Figure 5. Ongoing Mobile Bay area management plans.

An extensive water quality study of Perdido Bay has been underway to evaluate a number of indicators of water quality and possible pollutant effects. This work involved NOAA and the States of Florida and Alabama with sampling locations indicated in Figure 6 as special study sites.

A fourth management effort related to water quality is the Weeks Bay National Estuarine Research Reserve. Managed by the State in a cooperative effort with NOAA, it serves as a field laboratory for studies of estuarine flora, fauna, circulation, hydrography, sediments and water characteristics.

In Mobile County several management actions which have been completed include: the relocation of two paper mill outfalls from Chickasaw Creek to the Mobile River, the relocation of the Prichard Municipal wastewater discharge; the alternative management of seafood wastewater at Bayou La Batre to restore the municipal plant to compliance; and an industrial wastewater management plan at the Theodore Industrial Park (Fig. 6) whereby each industry provides full treatment on-site and discharges to a subsequent treatment system operated by the Mobile Water Services System for further treatment (if required), blending and discharge to a point of optimum mixing and dispersion near the ship channel in Mobile Bay. The latter system has not been implemented beyond the on-site treatment phase due to public opposition to treated domestic wastewater in the overall plan.

Mobile Bay and the surrounding counties have been included in the State Clean Water Strategy (Fig. 7), which is a five-year plan to assess water quality, identify and target problem areas, and to develop implementation of corrective steps by 1992. The assessment phase consists of evaluating water quality at 32 locations in the two-county area shown in Figure 3 as Clean Water Strategy locations, representing 11 percent of the total effort in the State toward this purpose.

Over the longer term, two other efforts are planned. The first is the nomination of Mobile Bay as a candidate for the National Estuary Program upon some assurance there will be funding for this activity; and a second parallel effort is development of a long-range environmental plan for the state by the Environmental Planning Council, a body of 25 citizens appointed by the Governor, Lieutenant Governor, and Environmental Management Commission. A component of this plan will be goals, objectives, and actions for the long-term environmental management of coastal Alabama.

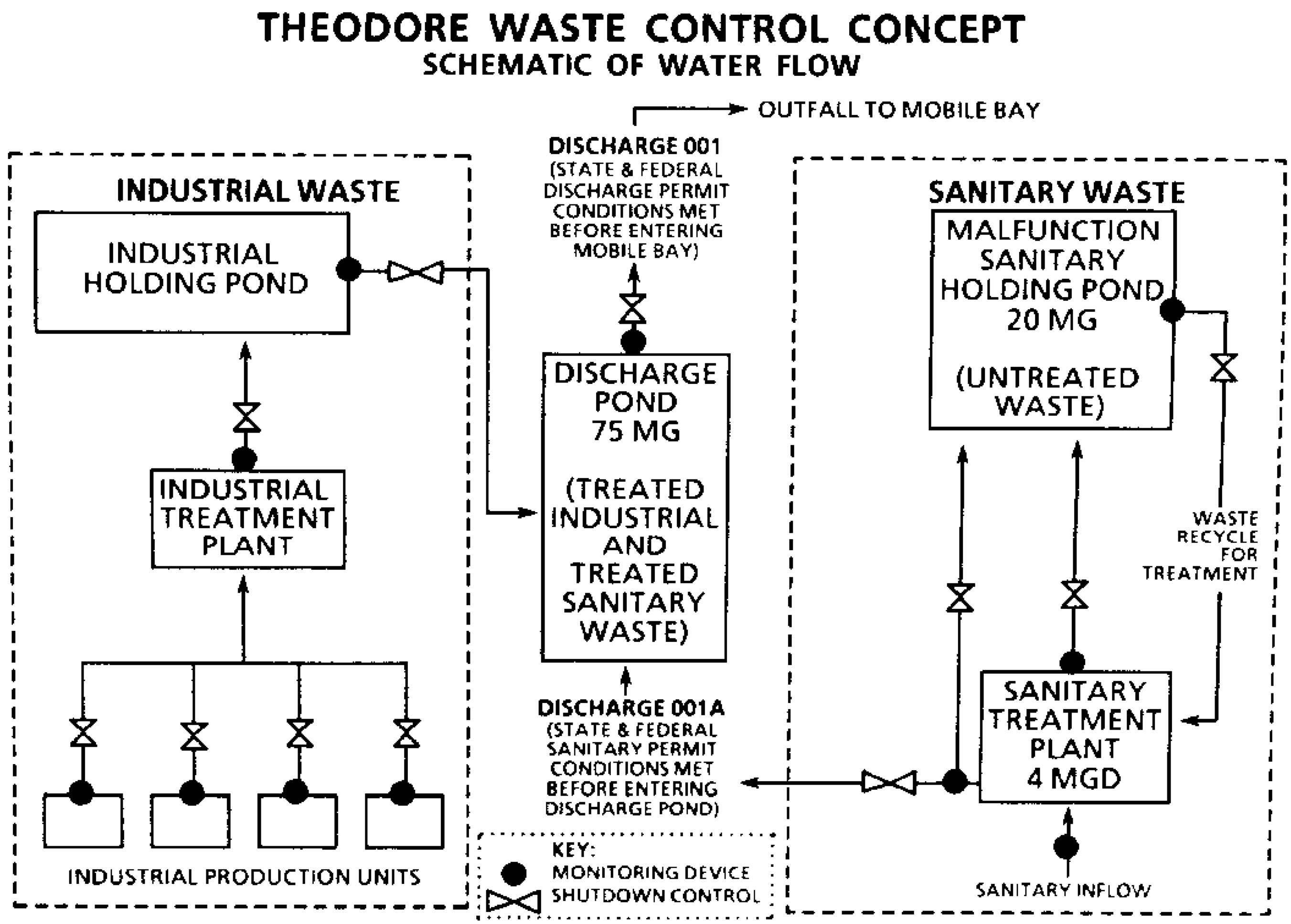
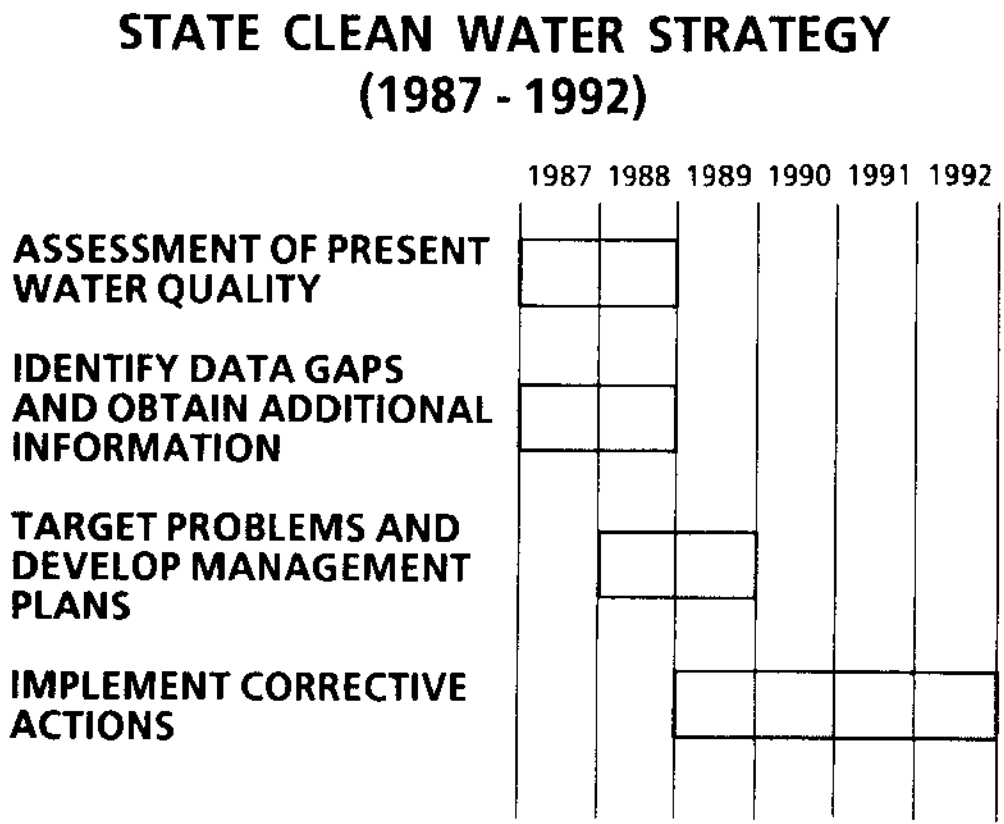


Figure 6. Theodore wastewater management plan.

Figure 7. Clean water strategy.



ESTUARINE HABITATS

by

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A critical attribute of any ecosystem is the nature, abundance and distribution of living spaces, habitats, available to the biota of the system. The continuum of interacting physical, hydrologic and chemical conditions present in an estuary create a diversity of distinct habitats which vary over short geographic distances and over seasonal time frames. The variety of habitat types is in large part responsible for the diversity and abundance of estuarine species.

Three broad habitat types will be discussed: 1) emergent wetlands - marshes and forested wetlands, 2) submerged aquatic vegetation, and hard substrates - clam beds and oyster reefs. Biota of unvegetated softbottom habitats are discussed by Dardeau, Shipp and Wallace in these proceedings.

EMERGENT WETLANDS

The Mobile Bay ecosystem includes over 142,382 acres of emergent wetlands (Table 1). These include non-fresh and fresh marshes which are either tidally flooded, or at least tidally affected, and forested wetlands from deep alluvial swamps to well-developed, seasonally flooded levee communities.

Wetlands have the capacity to store large quantities of water and thus serve as both recharge sites to surrounding areas and as natural flood control features. Those wetlands adjacent to coastal shorelines also serve as storm buffers when absorbing and slowing storm-driven floodwaters. Rooted wetland plants hold substrates against transport by moving waters. Erosion is thus reduced and turbidity level minimized.

The food web role of different wetland types varies, but in all cases they provide essential nutrients in the form of detritus and dissolved organics. In many cases, the food web impact of a wetland is complex and extends beyond the immediate habitat into adjacent ecosystems.

Description and Distribution

Marshes are emergent wetlands characterized by erect, rooted, herbaceous plants. The vegetation is usually dominated by perennial species. Marshes appear as wet grasslands occurring as extensive meadows, fringing margins of shorelines or isolated patches within other habitat types. The plant community is unique to

Table 1. Marshes, forested wetlands and submerged aquatic vegetation (SAV) acreage in the Mobile Bay ecosystem.

Location	Acres (percent of column total)							
	Marsh		Forested		SAV		Total	
Delta[1]	10,589	(57.5)	100,014	(80.7)	3,696	(66.5)	114,299	(77.3)
Mobile Bay Shores and Tributaries[2]	7,823	(42.5)	23,966	(19.3)	1,861	(33.5)	33,640	(22.7)
Total	18,402		123,980		5,557		147,939	

[1]From Stout et al. 1982
[2]From Stout and Lelong 1981

the marsh and may generally be typified for any geographic area. Community composition will vary depending upon the nature of the water - its salinity, its depth, daily and annual cycles of flooding and drought, and other edaphic factors. The currently accepted U.S. standard classification for wetlands can be found in Cowardin et al. (1979). Mobile Bay system marshes would be classified as Persistent Emergent Wetlands or Non-Persistent Emergent Wetlands. Marshes are further spoken of as freshwater or non-fresh, reflecting the significant influence of salinity on species occurrence. Fresh marsh includes emergent vegetation in the riverine, lacustrine and palustrine systems; non-fresh marsh is emergent herbaceous vegetation in the estuarine system (Cowardin et al. 1979).

Estuarine marshes occupy large expanses of the southernmost, younger portion of the Mobile-Tensaw River Delta. In addition, they may be found along margins of creeks and rivers upon recently emergent bottoms comprising approximately 15,111 acres or 82 percent of bay marshes (Stout and Lelong 1981; Stout et al. 1982) (Fig. 1). The marshes of the Delta and tributary rivers were considered "freshwater" by Stout and Lelong (1981) and Stout et al. (1982) based on species occurrence alone. However, these regions fall geographically in the Mobile Bay "estuarine system" as defined by the U.S. Fish and Wildlife Service (Roach et al. 1987). Consequently they were categorized as "non-fresh" in the National Wetlands Inventory. Similar confusion in terminology exists between surveys of different ages.

Sedges, grasses and rushes are often the dominant vegetation of the lower Delta and tributary marshes, including panic grass (*Panicum gymnocarpon*), wild rice (*Zizania aquatica* and *Zizaniopsis millacea*), and saw grass (*Cladium*

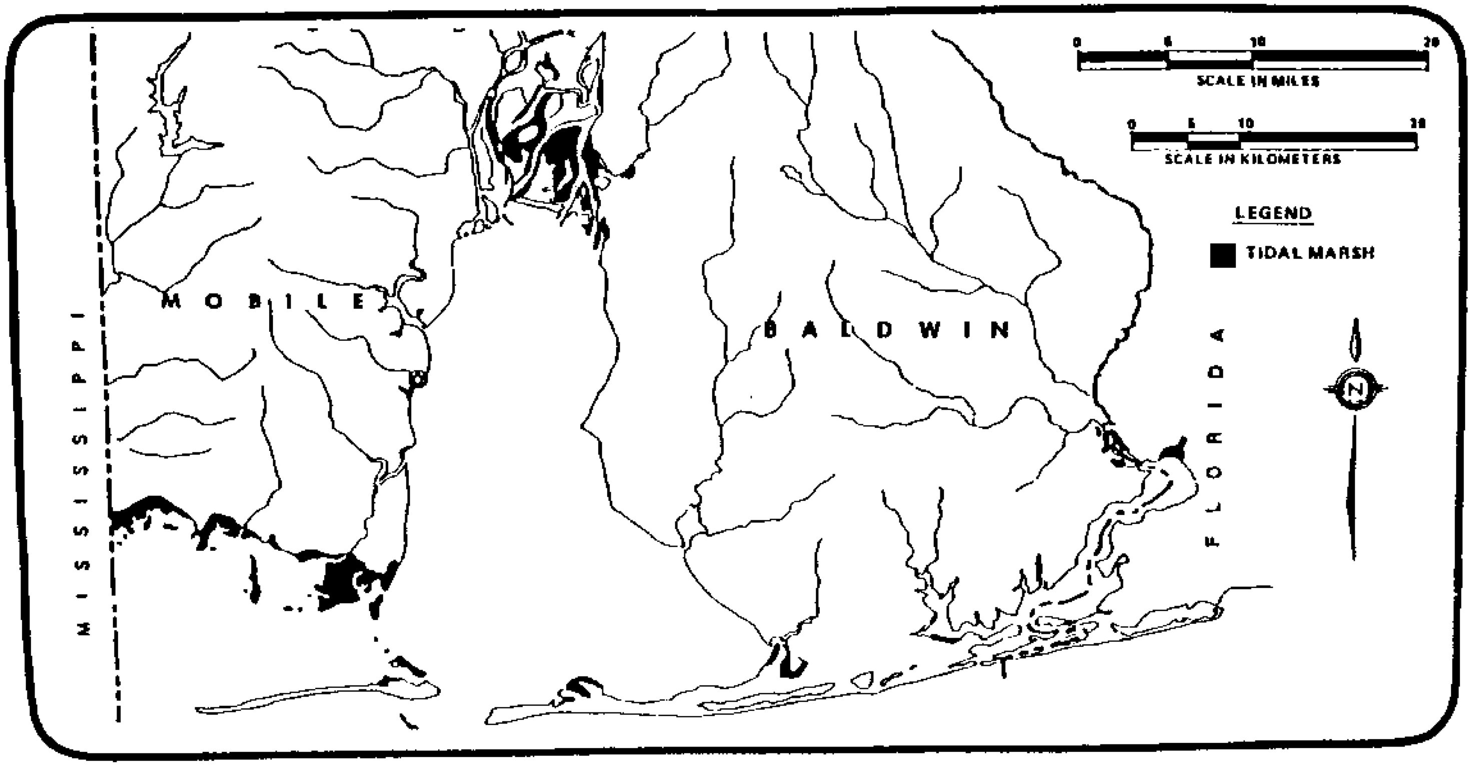


Figure 1. Location of Alabama coastal marshes. (From Chermock et al. 1974).

jamaicense), as well as numerous species of beak rushes (*Rynchospora* spp.), spike rushes (*Eleocharis* spp.), umbrella sedges (*Cyperus* spp.), and rushes (*Juncus* spp.). Occasionally other plants such as alligator weed (*Alternanthera philoxeroides*), arrowhead (*Sagittaria falcata* and *S. latifolia*) or cattails (*Typha latifolia* and *T. domingensis*) are the dominant vegetation.

As accretion of sediments continues in the low marsh, the elevation rises slightly and the marsh becomes dominated by less flood-tolerant herbaceous species. This high marsh may occur as a continuous zone between the low marsh and higher forested wetlands, as isolated patches of higher ground within the low marsh, or may represent the dominant marsh type on more stable, steeper shorelines. As in the low marsh, dominant vegetation is often grasses or sedges including common reed (*Phragmites australis*), cordgrass (*Spartina cynosuroides* and *S. patens*), switch grass (*Panicum virgatum*) and *Carex hyalinolepis* (Stout et al. 1982).

More saline marshes occur only in lower Mobile Bay nearest Main Pass and in the lower reaches of tidal rivers (Fig. 1). The marshes of Little Dauphin Island, the east end of Dauphin Island, Fort Morgan Peninsula, Oyster Bay and Weeks Bay have broad borders of smooth cordgrass (*Spartina alterniflora*) with interior, higher elevations covered by dense stands of black needlerush (*Juncus roemerianus*) (Sapp et al. 1975). Within less saline, brackish rivers and tributary bays a greater diversity of species occurs including the addition of giant cordgrass (*Spartina cynosuroides*), cattails, sawgrass and common reed. Approximately 3,291 acres of non-fresh marsh are found in lower Mobile Bay, south of the Delta (Stout 1979).

Dense and extensive forested wetlands occur along and between the major rivers and their tributaries throughout the entire Mobile-Tensaw River Delta. Significant coverage by this habitat is also found along the shores of Weeks Bay, and the Bon Secour, Fish and Magnolia Rivers. Forested wetlands are the most abundant emergent wetland habitat of the estuary, covering about 123,980 acres (Table 1).

The vegetation of forested wetlands varies, depending primarily on the frequency, depth and duration of flooding. Interactions between water level factors and soil characteristics may enhance or overshadow the impacts of flooding alone.

If flooding is frequent and extensive, pond cypress (*Taxodium distichum* var. *nutans*) and swamp tupelo (*Nyssa sylvatica* var. *biflora*) dominate the canopy. Areas where flooding is relatively constant are dominated almost exclusively by water tupelo (*Nyssa aquatica*) and bald cypress (*Taxodium distichum*). Usually, under moderate flooding the dominant trees are sweet bay (*Magnolia virginiana*) with red maple (*Acer rubrum*), swamp tupelo, and swamp bay (*Persea palustris*). Dense shade and extended hydroperiods inhibit subcanopy development. Herbaceous plants are generally patchy in distribution (Stout et al. 1982).

Forested wetlands provide high spatial and temporal diversity of habitats and food sources which may support a greater abundance and diversity of fish and wildlife than adjacent aquatic or terrestrial systems. They function as an integral part of surrounding systems, acting as an interface between river, upland and estuary.

Alterations and Changes

Using aerial photography, and the wetlands classification system of Cowardin et al. (1979), Roach et al. (1987) determined changes in wetland habitats in coastal Alabama during the 25 year period 1955 to 1979. Of the wetland types found in Mobile Bay, fresh marsh showed the greatest percentage loss (49 percent) while nonfresh marsh exhibited the greatest total acreage loss (6,680 acres = 35 percent) (Table 2). National trends over the same time period indicate a loss of 8 percent of nonfresh and 5 percent of fresh marshes (Frayer et al. 1983). Hefner et al. (1988) had similar results for southeastern Atlantic and Gulf coastal states; net losses of nonfresh marshes were 8 percent and losses of fresh marshes were 18 percent.

The causes for the loss of fresh marsh were primarily residential - commercial development (61 percent) and conversion to forest following drainage (27 percent), here termed silvicultural development (Fig. 2). Approximately 80 percent of losses of non-fresh marshes in the bay can be attributed to one of three causes industrial/navigation development, erosion/subsidence or natural succession. Stout (1979) itemized specific dredging projects contributing to loss of over 2,000 acres of estuarine marsh (Table 3). Surprisingly, commercial/residential development accounted for only 14 percent of the non-fresh marsh losses (Table 4) (Roach et al. 1987).

Of the total marsh losses, 48 percent could be attributed to human activity and 47 percent to "natural" processes such as erosion/subsidence and natural succession, although erosion/subsidence is probably exacerbated by human activities (Roach et al. 1987). The authors did not attempt to determine whether estuarine marshes are failing to be nourished and consequently subsiding, or whether substantial erosion is occurring. It is apparent, however, that the shoreline is retreating, particularly in the interior bays of the Mobile-Tensaw Delta. Hardin et al. (1976) determined a net erosional trend in Delta shorelines between 1953 and 1967. In an environment where increased sediment deposition and land-building should occur, net accretion would be expected. They suggest that losses may be due to a decrease in sediment supply because of upstream impoundments and/or erosion during increased velocity of flood waters during high discharge periods. Smith (1988) suggests that most bays in the delta terminus area are relict floodbasin areas that are undergoing drowning through rise in relative sea level. The implications of these losses are important since not all non-fresh marsh losses are under regulation via permitting agencies. Extending these trends into the future, unregulated causes of marsh loss could result in the loss of all non-fresh marshes within coastal Alabama with the next 125 years.

During the 25-year period 1955-1979, 547 acres of forested wetlands were lost (Roach et al. 1987) (Table 2). However, mapping errors in 1955 habitat designations resulted in an underestimate of actual loss of this habitat type. The conversion of forested wetlands to commercial/residential development and industrial/navigation development accounted for 68 percent of the reported losses (Fig. 3). Most of these losses occurred in the urban areas encompassing the cities of Mobile, Pritchard, Saraland and Chickasaw.

Table 2. Wetland habitat changes in upper Mobile Bay, 1955 to 1979 (data from Roach et al. 1987).

Habitat Type	Acreage Change	Percent Change
Non-fresh marsh	-6,680	-35
Fresh marsh	-587	-49
Forested Wetlands	-547	-1
Scrub-shrub wetlands	+2,146	+92

Figure 2. Fresh marsh losses in Mobile Bay, 1955-1979. (From Roach et al. 1987).

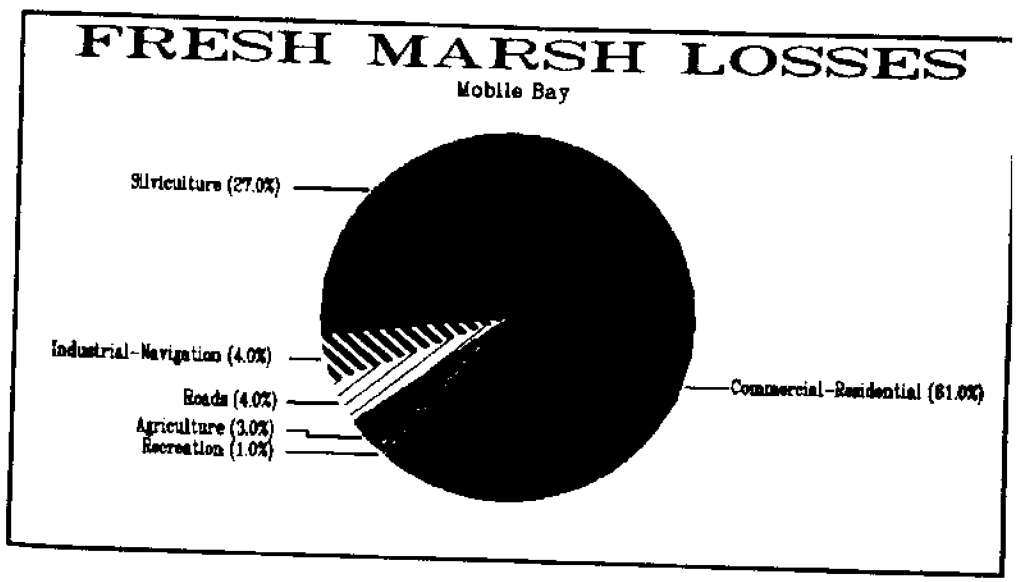


Table 3. Impact of dredging activities on Mobile Bay estuarine marshes (Stout 1979).

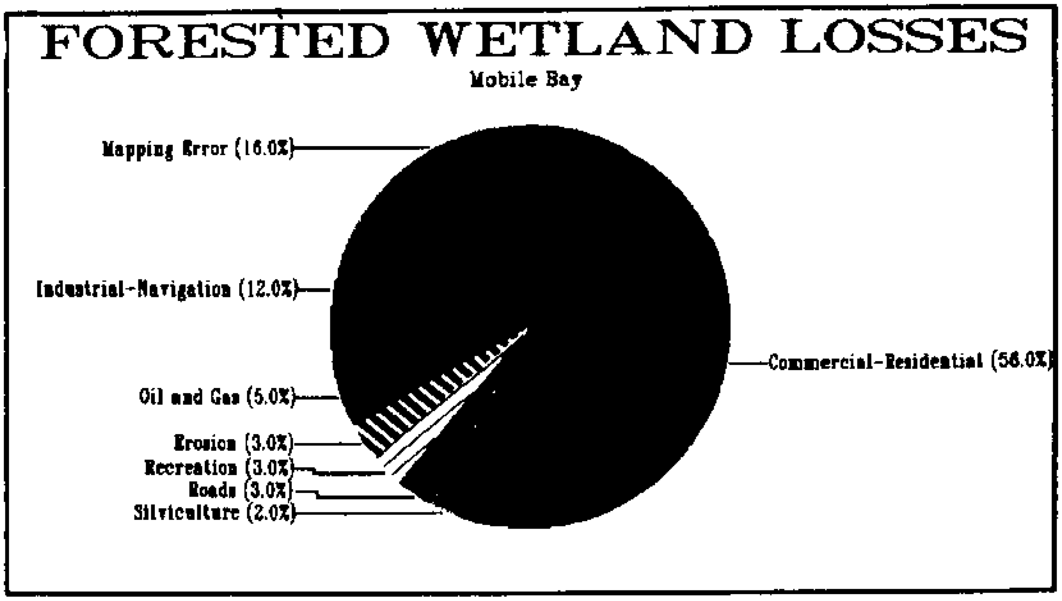
Location	Hectares	Acres
Loss to Spoil Deposition		
Bon Secour River	38	95
Blakeley Island	1,214	3,000
East Fowl River	69	172
Little Dauphin Island	4	10
Dog River	33	81
I-10 Highway	73	180
I-10 Twin Tunnels	5	13
Alcoa-Blakeley Island	121	300
Scott Paper Company Three Mile Creek	61	150
Private Projects	809	1,000
Total	2,427	6,002
Loss to Canal Dredging		
I-10	14	34
I-65	3	8
Theodore Industrial	20	50
Private Projects	20	46
Total	57	138
Creation by Spoil Deposition		
Blakeley Island	364	900
Polecat Bay	364	900
Pinto Island	157	387
Theodore Spoil Island	3	7
Total	888	2,194

Total Loss (2,484 ha) - Total Creation (888 ha) =
Net Loss (1,596 ha) = 22 percent Total Marshland

Table 4. Causes of nonfresh marsh losses (acres) in Mobile Bay, 1955-1979 (data from Roach et al. 1987).

	Upper		Southeastern		Southwestern		Total	
	Acres	Percent	Acres	Percent	Acres	Percent	Acres	Percent
Res./Comm. Dev.	340	7.0	162	16.9	411	70.6	913	14.3
Erosion/Subdiv.	1,165	24.0	120	12.5	128	22.0	1,413	22.1
Roads					18	3.1	18	2.8
Natural Suc.	1,456	30.0	520	54.3	25	4.3	2,001	31.3
Spoil			11	1.1			11	1.1
Indus./Nav.	1,650	34.0					1,650	25.8
Recreation	97	2.0					97	1.5
Other	49	1.0					49	0.8
Mapping Error	97	2.0	144	15.0			241	3.8
TOTAL	**4,854**		**968**		**582**		**6,404**	

Figure 3. Forested wetland losses in Mobile Bay, 1955-1979. (From Roach et al. 1987).



Scrub-shrub wetlands showed a substantial gain (92 percent) although 19 percent was attributed to misidentification of the habitat type in 1955 photos. The gains in scrub-shrub wetlands were primarily a result of natural succession (46 percent) and industrial/navigation development (27 percent) (Fig. 4). Most of the natural succession occurred in the Mobile-Tensaw Delta in non-fresh marshes used as diked disposal sites from industrial/navigation project dredging. Such sites, with raised elevation become vegetated with shrubs at the expense of non-fresh marshes (Roach et al. 1987).

Stout and Dowling (1982) inventoried 12,526 acres of Mobile-Tensaw River Delta wetlands impacted by land use practices. Impacts were categorized by type of land use and not wetland types. It was only possible to delineate areas which had been altered over the last 40-50 years. The largest impact was attributed to recent logging activities, about 60 percent of the impacted acreage (Table 5). The 1981-82 survey revealed over 7,400 acres which had obviously been recently logged. This estimate, however, falls far short of the actual acreage impacted since man began to exploit the abundant timber resources available. Mohr (1878) discusses the gigantic cypress of the Delta, up to forty feet in circumference, and their utilization as shingles, planks, cabinetry and increasing use as rot-resistant posts and pilings. By 1928, Harper reports for cypress:

> ...it does not constitute a large portion of the forest of any region except the Mobile Delta, ... (probably most of the original supply there has been cut out). It grows so slowly in the swamps that it does not have much chance to restore itself after logging operations. (p. 65)

Figure 4. Scrub-shrub wetland gains in Mobile Bay, 1955-1979. (From Roach et al. 1987).

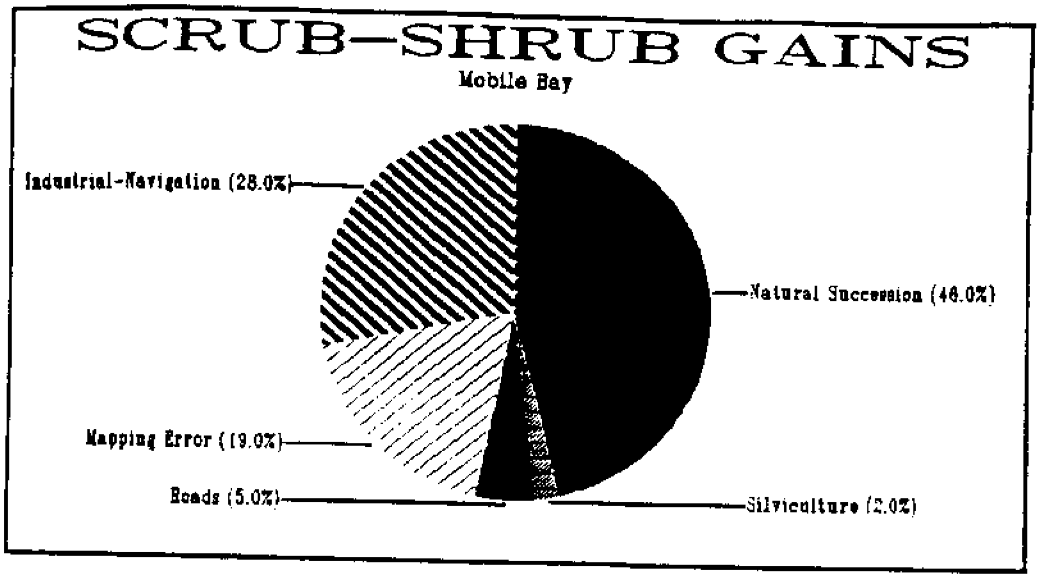


Table 5. Land use impacts on wetlands of the Mobile-Tensaw River Delta (from Stout and Dowling 1982).

Land Use	Acres Impacted
Transportation Corridors	322
Utility Corridors	801
Petroleum Exploration	42
Pipeline Corridors	151
Logging (Thru-1982)	7,488
Spoil Disposal (includes ALCOA)	1,124
Industrial Business	2,451
Other	147
TOTAL	12,526

Evidence of historical logging efforts is apparent in large stumps and, from the air, pull-boat trails along which logs were dragged to the navigable rivers are still visible. However, it is not possible to assess the extent of the historical impact of this activity on delta wetlands. Particularly impacted by recent logging are the easily accessible natural levees of the upper Delta. Additionally, evidence of extensive logging in the past can be found in wetlands of Weeks Bay and the eastern shore of Bon Secour Bay.

Alabama's Coastal Zone Management (CZM) program (revised in 1982) defines the 10-ft. elevation contour line as the inland boundary of the coastal zone. Wetlands within this zone are protected by various state and other regulations. However, Rathbun et al. (1987) found that approximately 28 percent (46,509 acres) of Alabama's coastal wetlands are above the 10-ft. contour coastal boundary and are thus excluded from CZM protection (Table 6). Most of the excluded wetlands are forested or fresh marsh types, with 35.8 percent and 49.5 percent respectively of each occurring above the 10-ft. contour. The ecological value and linkage of these wetlands with the estuarine system are not as well-known as non-fresh marshes. They are thought to be important in purification and wildlife habitat. It is important that the special vulnerability of these habitats be considered and revisions to CZM regulations should include them.

Table 6. Wetlands above and below the 10-ft. contour line in coastal Alabama (data from Rathbun et al. 1987).

Wetland Habitat Type	Total	Above 10-ft. Contour		Below 10-ft. Contour	
		Acres	Percent*	Acres	Percent
Forested Wetland	116,896	41,888	35.8	75,008	64.2
Fresh Marsh	8,806	4,358	49.5	4,448	50.5
Nonfresh Marsh	35,514	45	0.1	35,469	99.9
All Types	161,216	46,291	28.7	114,925	71.3

*Percentage of total for each habitat type.

Conservation, Preservation and Mitigation.

Concern over continuing loss and/or alteration of estuarine wetland habitats has provoked increasing efforts to preserve and restore them. Within the Mobile Bay estuary a few examples have been initiated in the last decade. Conservation efforts are discussed by Dyas, in these proceedings.

Habitat restoration or creation in Mobile Bay has been primarily as a result of mitigation requirements included in permits from the U.S. Army Corps of Engineers. Approximately 9.2 acres of fresh marsh and bay forest were established on Eight Mill Creek in mitigation for 8.36 acres of filled wetlands (1.1 to 1.0 ratio) (Dowling 1987). Native species utilized included arrow arum (*Sagittaria latifolia*), lizard's tail (*Saururus cernuus*), Virginia willow (*Itea virginica*), swamp cyrilla (*Cyrilla racemiflora*), sweet bay, swamp bay, bald cypress and swamp tupelo. The site will be monitored for two years.

To mitigate the loss of 23.5 acres of tidal marsh, on Mobile Bay, Vittor et al. (1987) have scraped down a moist pine forest adjacent to West Fowl River and created 40 acres of intertidal marsh. The non-fresh marsh will be two-thirds smooth cordgrass and one-third black needlerush.

The Mobile District, U.S. Army Corps of Engineers has created approximately 16 acres of tidal marsh on Gaillard Island, a man-made dredge disposal area on the western side of the ship channel, north of East Fowl River. This site has been used experimentally to evaluate planting and anchoring methods for smooth cordgrass (Allen et al. 1986).

In addition to preservation and restoration of habitats, a unique cooperative agreement between local industry, private, state and federal organizations has been accomplished to minimize impacts on delta wetlands. Scott Paper Company, the Coastal Land Trust and the ADCNR have designated over 58,000 acres (respectively 27,000 acres, 18,500 acres and 13,000 acres controlled by each) as the "Delta Project" of the Gulf Coast Joint Venture, part of a United States and Canadian project known as the North American Waterfowl Management Plan. The acreage includes shallow bays, fresh marshes, hardwood forests and swamps. The management plan is designed to enhance habitats necessary to restore North American waterfowl populations to historical levels.

The agreement involves the following management features within the designated acreage (Windish 1988):

- use of helicopters to haul logs in timber cutting operations
- restriction of the size of clearcuts
- staggering cut areas with mature forest to maintain diversity
- leaving a buffer of uncut trees along water courses
- retention of snags and dead trees as wildlife habitat
- construction and installation of waterfowl nest boxes
- limited control burning on state lands
- food plot establishment on state lands

SUBMERGED AQUATIC VEGETATION

Submerged aquatic vegetation (SAV) may be found in the shallow flats of bays, small tributaries and in quiet pockets along the margins of large rivers. These areas are not normally emergent at low water, but remain covered by water. Plant species present are diverse, but require surface water for optimum growth and reproduction. Grassbeds may be monotypic in species composition or mixed, with two or more species occurring. Water salinity, clarity and depth are important environmental factors affecting community composition, though substrate types also play a role.

Description and Distribution

Surveys of Mobile Bay SAV's were completed in 1980 and 1981 (Stout and Lelong 1981; Stout et al. 1982). Twenty-four species of submerged plants were identified. Most beds were composed of mixed communities, usually, however, exhibiting strong dominance by one of several species. Five species, Eurasian milfoil (*Myriophyllum spicatum*), bushy pond weed (*Najas quadalupensis*), charaphytes (not identified to species), slender pondweed (*Potamogeton pusillus*) and wild celery (*Vallisneria americana*) occurred most frequently and covered the majority of the acreage mapped. Of these species, Eurasian milfoil was the most abundant.

Milfoil is an introduced (not native) species and is considered a "pest species" or "obnoxious weed" in the United States. Its lush and complex growth form overshadows and outcompetes other more desirable waterfowl food species. In addition, boaters find it almost impossible to navigate for any distance through beds of milfoil without choking the motor.

Approximately 5,557 acres of submerged vegetation were located, mostly in the lower Delta and upper bay (Table 1). The most extensive coverage was in the large shallow bays (Chacaloochee Bay, Big Bateau, Justin's Bay, Bay Minette Basin, Delvan Bay and Big Bateau) and the shallow flats at the mouths of the Tensaw, Blakeley and Apalachee Rivers. These areas have been steadily filling due to sedimentation and provide ideal habitat for submerged vegetation. Additionally, large patches of wild celery were found in Weeks Bay and middle Fowl River.

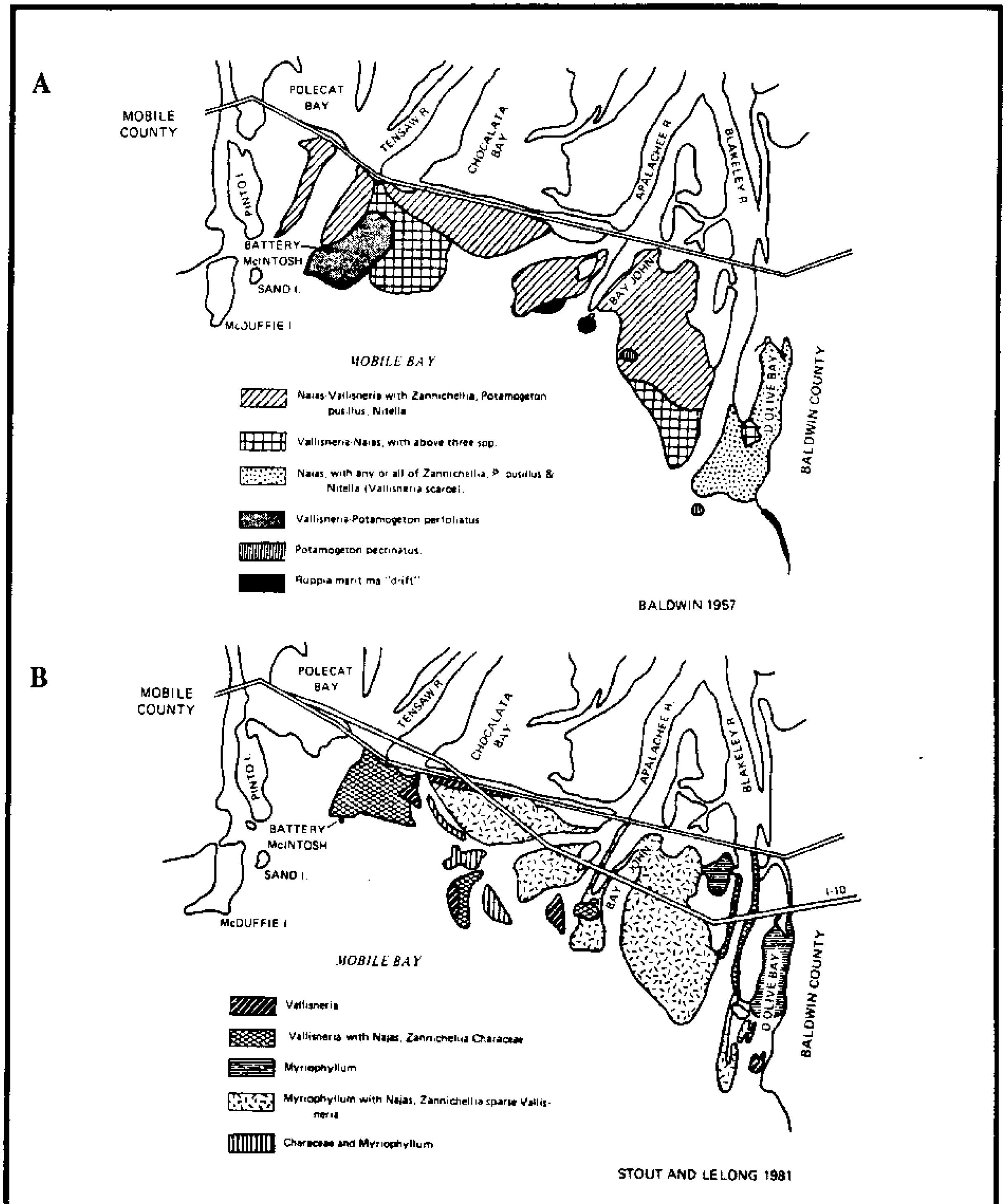
The larger rivers of the bay system are too deep and fast moving for the establishment of submerged species. However, quiet bends, where velocities slow and sedimentation occurs, may support small patches of aquatic plants. Small tributary rivers and creeks often are lined by a marginal band of submerged vegetation. Map scales have not allowed accurate portrayal of these beds and the total acreage figures are consequently underestimates which do not include the narrow marginal beds.

Comparison with Past Conditions

Prior to 1980, no comprehensive survey of submerged aquatics of coastal Alabama had been completed. Alabama Department of Conservation and Natural Resources (ADCNR) studies have been oriented toward waterfowl, encompassing the lower delta only. Baldwin (1957) and Lueth (1968) prepared rapid assessments of submerged vegetation in the Mobile Delta and northern portions of Mobile Bay for wildlife and waterfowl management planning. Baldwin compared his findings to those of Lueth, whose field work was actually done in the late 1940's, and found an extension of wild celery beds approximately one mile further south in the intervening ten years. He predicted a continued increase in the coverage of this species as natural shoaling created favorable water depths to the south. Although distribution of wideongrass (*Ruppia maritima*) was not determined, he predicted an increase in this species with shoaling in high salinity waters. However, Borom (1975) found a great reduction in coverage, especially along the eastern bay shore. Once extensive submerged beds were found to exist only as small patches. Personal communications with knowledgeable local citizens confirm the decline and disappearance. Accompanying the decline in submerged vegetation have been reports of declines in sport and commercial fish and invertebrate species associated with the vegetation. In addition, an invasion of Eurasian milfoil has been noted in the upper bay (Borom 1979; Powell 1979). Figures 5A and 5B demonstrate changes which had taken place between Baldwin and the 1980-81 surveys. Community diversity had decreased, in some areas to single species beds. Eurasian milfoil had become the predominant species for greater than 50 percent of the beds, but was not observed in the area by previous workers. Notable areas of invasion are lower Chacaloochee Bay, Bay John, and D'Olive Bay. This species is considered a "pest" plant by waterfowl managers and boaters.

Changes in aerial coverage by submerged beds has also occurred. Channel dredging and filling between Pinto Pass and Battery McIntosh along the causeway have resulted in the complete loss of submerged vegetation in that area. Some loss can be seen along both sides of the Blakeley Bar and in D'Olive Bay. This is probably due to increased turbidity from shoreline development. A shift in bed locations in lower Chacaloochee Bay has probably not resulted in any net change in acreage. It is not possible to quantify the changes in species distribution or coverage since boundary determinations and map scales of earlier reports were of undetermined accuracy. Surveys by Lueth (1968) and Baldwin (1957) were accomplished without photography to assist in boundary delineations. Plant inventories of these studies were only a minor portion of the study scope and thus did not include seasonal variations or complete geographic coverage in the field. The slightest errors in grassbed delineations, as portrayed on the small maps of each report, would result in large errors in acreage determinations made from the maps. Thus, specific acreage comparisons with the 1980-81 situation would be misleading and should not be attempted.

Figure 5 A,B. Comparison of submerged aquatic vegetation along the lower Mobile Delta from 1957 (A) to 1981 (B). Modified from Baldwin 1957 and Stout and Lelong 1981.



In order to better portray long-term changes and provide an additional baseline for future comparisons, the Mobile District U.S. Army Corps of Engineers (COE) in cooperation with the Game and Fish Division of the Department of Conservation and Natural Resources, resurveyed SAV's of the lower delta and portions of the upper bay in August 1987. Results of the survey and changes detected are being prepared for 1989 publication (J. Zolczynski, ADCNR, personal communication).

Restoration Efforts

Several pilot projects have been initiated to restore SAV habitats of Mobile Bay to previous natural species composition and coverage. The COE has conducted a program of selective spraying of herbicides to clear patches and navigation channels of milfoil in small harbors and major sport fishing areas and to encourage the regrowth of native SAV species. Over 1,500 acres (including multiple treatments at many sites) have been sprayed since 1982 (M. Eubanks, COE, personal communication). From 1979 through 1986 the area of milfoil infestation remained fairly constant, but spraying appeared to have reduced the density of growth. The abundance of native species also seemed to have increased (Zolczynski 1987).

Scientists of the Marine Environmental Sciences Consortium (MESC), with support from the Alabama Department of Economic and Community Affairs (ADECA) and the Gulf Coast Conservation Association (GCCA), have planted test plots of wild celery in the upper bay to evaluate restoration methods and success. Transplants were made in May 1988 and success and function are currently being monitored.

HARD SUBSTRATES

Within Mobile Bay hard substrates consist of living and dead bivalve mollusc beds and artificial substrates such as jetties, seawalls and pilings. Oyster reefs (*Crassostrea virginica*) and clam beds (*Rangia cuneata*) comprise the greatest acreage of exposed hard bottoms in the bay.

Living and dead shell reefs represent a unique habitat in a system otherwise devoid of natural hard substrates for associated macrofaunal and algal communities. The complexity of the available living space in a reef provides a diversity of microhabitats. Bahr (1974) calculated that at least 50 m^2 of habitat surface area is available for every square meter of horizontal reef area. Over 300 species of animals were identified by Wells (1961) in subtidal oyster reefs.

The large surface area of a reef also provides extensive substrates for aerobic bacteria and cyanobacteria. Reefs, consequently, release plant nutrients, ammonia and phosphorus compounds into the water.

Oyster and clam reefs can effect local turbidity levels by filtration and biodeposition. They result in stabilization and gradual elevation of sediments.

Rangia Clam Beds

Living *Rangia* clams may be found in waters of salinities from freshwater to 25 ppt. (Castagna and Chanley 1973) however they are most abundant in salinities from less than 1 to 15 ppt. (Moore 1961; Godwin 1968). The foremost economic value of the clam is the use of shells for road building material, oyster cultch and as a source of calcium carbonate for industrial use (Tarver and Dugas 1973). Though potentially valuable as a food resource, harvesting shellfish from estuarine waters within the preferred low salinity range of the clam is prohibited due to bacterial contaminations.

Swingle and Bland (1974) surveyed 159 sites in coastal Alabama to determine the distribution and abundance of *Rangia*. The clam was found from the 12 ppt. bottom isohaline inland some 25 miles (40 km) in Delta rivers. Clams were most abundant within Mobile Bay around the mouths of tributary rivers and were densest on compacted sandy clay bottoms. Beds with clam densities 5-10 m^{-2} occurred at the mouth of East Fowl River on the western shore and from Fairhope north to Gravine Island in the eastern portion of the estuary. Higher density beds, 10-15 m^{-2}, were located along the eastern shore from D'Olive Bay to Fairhope and at the mouth of Dog River to the west. Mean live clam density of all sites was 8.9 m^{-2}. Total acreage was not calculated.

Distribution of *Rangia* is quite dynamic and strongly influenced by fluctuating salinity regimes. Periodic inland intrusions of brackish water into the Mobile Delta region have provided conditions suitable for spawning and spat establishment (Cain 1972). Surveys for oyster distribution in August 1988, revealed significant mortality of *Rangia* beds with limited distribution south of the Highway 90 causeway. Low rainfall for three successive years (1986, 1987,1988) resulted in elevated estuarine salinities limiting *Rangia* success (M. Van Hoose, ADCNR, personal communication). Net changes in bed densities and areal coverage are not known.

Oyster Reefs

Carbon-14 dating indicates that oysters became established in the head of the bay, in the area of the present delta, between 5,000 and 6,000 years ago and have progressively migrated down bay. Dead reefs are currently buried under 3-25 feet of sediment with shallow younger beds in the lower bay. As evidence of historical productivity, over 40.3 million cubic yards of dead shell was removed for industrial use from 1947-1968 with an estimated additional 46.2 million cubic yards remaining (May 1971).

Total acreage of living oyster reefs remained relatively stable from 1894 (1,241 ha = 3,066 ac) to 1968 (1,211 ha= 2,992 ac) (Table 7) (Eckmayer 1979). The only intensive survey of oyster reefs was compiled by May (1971), shown in (Fig. 6).

Up until 1979, environmental factors resulted in shifts of living reefs southward in the bay. However, drought conditions since 1985 have caused a subsequent reintroduction of oysters into upper reaches of the bay and heavy

Table 7. **The area in hectares of the oyster reefs in Mobile Bay and Bon Secour Bay, Alabama, reported from various surveys. The net changes in area from the earliest to the most recent are listed (from Eckmayer 1979).**

	1894[a]	1910[b]	1943[c]	1951[d]	1968[e]	Net Change
Mobile Bay Reefs						
Hollingers					3.2	0
Fowl River	40.5		0			-40.5
Whitehouse	356.5			282.9	183.2	-173.3
Kings Bayou		33.2		81.3	27.8	-5.4
Buoy	164.3	164.3		84.6	84.1	-80.2
Cedar Point	180.1	489.7	70.4	588.8	562.3	+382.2
Sand	329.0	265.1		202.8	15.5	*-313.5
Dauphin Island Bay	12.1	306.0		69.2	3.5	-8.6
Heron Bay		85.8			44.1	-41.7
Great Point Clear	21.5			48.6	83.2	+61.7
Little Point Clear			16.2		0	-16.2
Bon Secour Bay Reefs						
Klondike				78.9	65.0	-13.9
Fish River	33.6			56.7	42.7	+9.1
Bayou Cour	27.5			39.7	27.1	-0.4
Bon Secour			15.4	11.3	12.0	-3.4
Shell Bank	76.1			26.3	60.3	-15.8
TOTAL	**1,241.2**	**1,344.1**	**102.0**	**1,571.1**	**1,210.8**	

[a]Ritter 1896
[b]Moore 1913
[c]Engle 1945
[d]Bell 1952
[e]May 1971
*May reflect construction of Gulf Intra-Coastal Waterway through reef area.

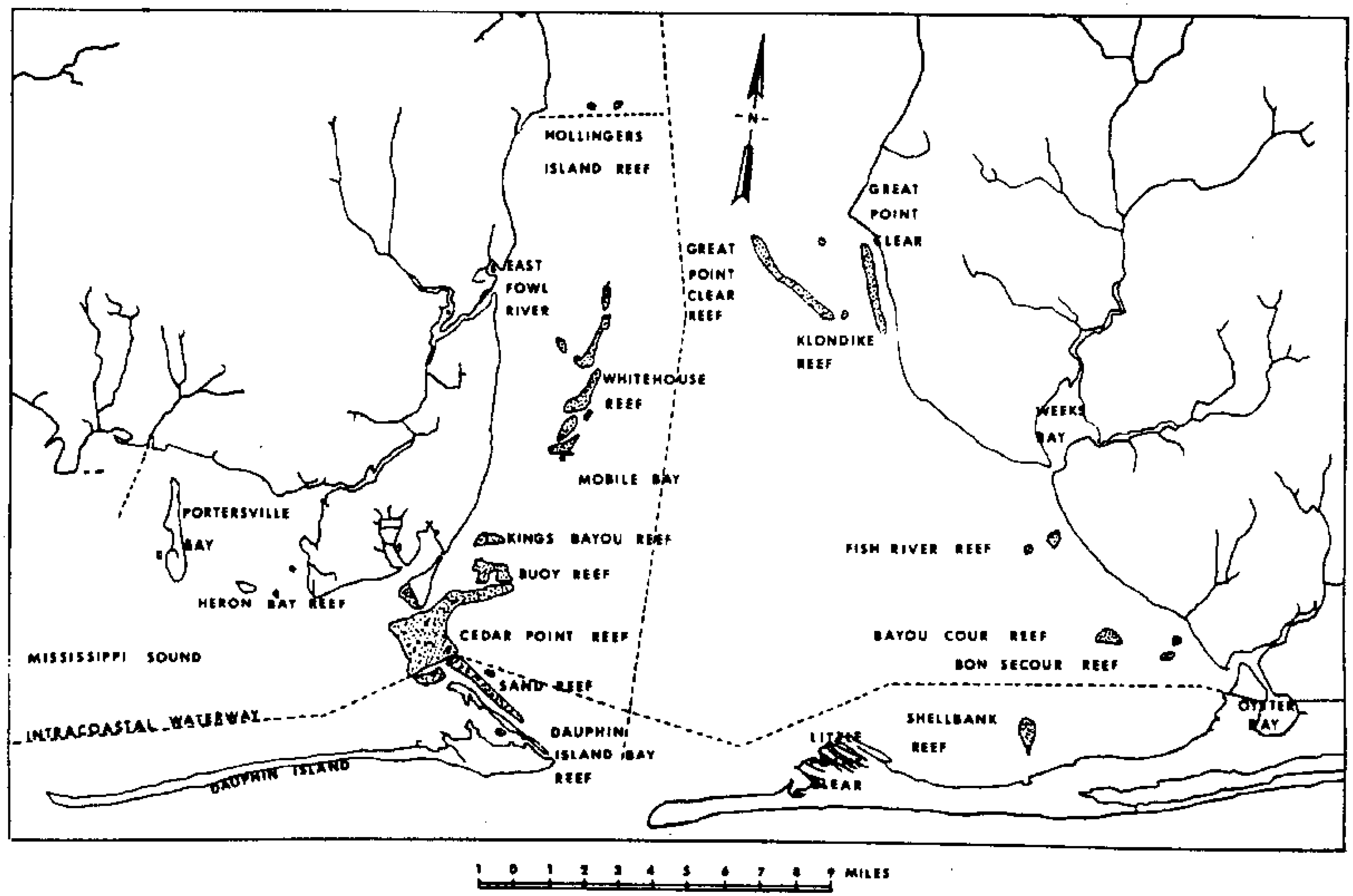


Figure 6. Location of living oyster reefs in coastal Alabama. (From May 1971).

mortality in the lower bay. The August 1988 bed survey by Marine Resources Division personnel located abundant oysters as far north as Brookley Field and the Battleship U.S.S. Alabama. Many young oysters were attached to cultch of recently dead *Rangia* shells (M. Van Hoose ADCNR, personal communication). Salinities were high enough in 1988 to allow encrusting of the marine coral, *Astrangia danae*, on dead oysters of Buoy Reef (T. Hopkins, Dauphin Island Sea Lab, personal communication).

Oysters are found in waters with a wide range of salinity but are more successful in waters ranging from 10 to 20 ppt. Though seasonal variation in salinity is characteristic of estuarine environments, prolonged periods of flood induced low salinity may seriously affect mature oysters and annual recruitment success. See Table 8 for frequency and impact of floods.

Floods affect oyster survival in several indirect ways. Suspended sediments transported by flood waters may smother reefs and cause high mortality. May (1971) notes that several reefs were severely impacted by sediment from summer floods of 1970. Although floods may cause mass mortality, there has been little long-term damage to oysters in Mobile Bay. Losses may be balanced by the reduction of diseases and predators by freshwater conditions. Oyster abundance may also be enhanced by nutrient input via flood water. Additional cultch material is provided by breakdown of dead oysters into half-shells.

A major oyster predator, the oyster drill (*Thais haemastoma*), does not enter areas of the estuary with salinities lower than 18 ppt. Predator pressure increases in years of low rainfall and elevated salinities. In August 1988, very few oysters were found on Kings Bayou Reef, Cedar Point Reef or Buoy Reef. Only scattered patches were found on Whitehouse Reef (M. Van Hoose, ADCNR, personal communication). Evidence of oyster drills was abundant. New reefs in the upper bay (mentioned previously) were in salinities low enough to exclude the drill. Similar predator outbreaks have been documented in the past (Table 8). Additional *depressus* and *Panopeus herbstii*), stone crab (*Menippe adina*), blue crabs (*Callinectes sapidus*) and black drum (*Pogonias cromis*) (Eckmayer 1979). Predators impact adult oyster survival as well as spat success.

The most destructive disease to Alabama oysters is the protozoan pathogen, *Perkinsus marinus*, formerly referred to as "dermo" for the suspected fungus, *Dermocystidium marinum*. The protozoan causes high mortalities during periods of high salinity and high water temperatures (Overstreet 1978; Soniat 1985). Hoese (1964) concluded that mud crabs may be important as a vector in transmitting the disease after eating weak or dying infected oysters. Otherwise unexplained die-offs of oysters have been blamed on pathogens at various times (Table 8). Isolation of pathogenic organisms has not been possible on most occasions.

A three-year drought, beginning in 1986, caused a combined outbreak of oyster drill predation and fungus infection. Conservation Department officials predict that 1988 production of oysters may be the worst in Alabama since records have been kept (Sweatt 1988), unless significant areas in the closed upper bay can be cleared for harvest by the Alabama Department of Public Health. This appears doubtful.

Table 8. Changes in live oyster bottoms of Mobile Bay due to natural (floods, predators and disease) and manmade causes (dredging and overfishing).

Source	Year	Comment	Reference
Floods	1912	Majority within bay killed	Nelson 1914
	1929	Upper bay - 100 percent mortality Lower bay - 54-88 percent mortality	Galtsoff 1930
	1953	Cedar Point	Ala. Dept. Conserv., Ann. Rept. 1952-1953
	1961		Ala. Dept. Conserv., Ann. Rept. 1960-61
	1970	26-76 percent overall mortality	May 1972
	1972-73	42 percent average mortality	Eckmayer 1979
	1983	32 percent overall mortality	U.S. Army COE 1983
Predators	1967	80-90 percent loss	May 1968
	1968	85 percent of spat loss	May and Bland 1970
	1987	No live oysters on lower reefs	ADCNR-MRD 1987
Diseases	1942		ADC 1944
	1955		ADC 1955
	1967	Whitehouse Reef, Eastern shore from Pt. Clear to Bon Secour R.; 73-90 percent mortality	May 1968
	1968	Buoy Reef-99 percent mortality; Cedar Pt. - 10-20 percent mortality	Beckert et al. 1972
Dredging	1827	E. Fowl River and Whitehouse Reef due to Mobile Ship Channel	Ritter 1896
	1838	Grants Pass	May 1971
	Others	Cedar Point and Sand Reef dredging of Pass aux Huitres, Pass aux Herons and Dauphin Island Bridge	May 1971
Overfishing	pre-1896		Ritter 1896
			Nelson 1914
		Oyster dredging	Engle 1936
	1966, 1967		May 1971
	1979	Cedar Pt.	Eckmayer 1979

Dredging activities damage or destroy oyster reefs directly through removal or burial by sedimentation. Ritter (1896) attributed the loss of Fowl River Reef and a portion of Whitehouse Reef to the deposition of spoil from the Mobile Ship Channel, initiated in 1827. Navigation and construction channels dredged at Grants Pass, Pass aux Huitres and Pass aux Herons, as well as during construction of the Dauphin Island bridge, either destroyed or altered an undetermined amount of oyster bottoms. Dredging may also indirectly effect oyster survival through alteration of salinity regimes. Examples include various deepenings of the Mobile Ship Channel, the Gulf Intracoastal Waterway and the Theodore Ship Channel.

Overfishing removes both living oysters and cultch for future spat fall. Earliest reports of fishing depletion of reefs were by Ritter (1896) in Bon Secour Bay, eastern Mobile Bay and Cedar Point reef. Similar reports of overfishing are found in Nelson (1914), Galtsoff (1930), Engle (1936), May (1971), and Eckmayer (1979) (see Table 8). The only instance where objective evidence indicates that Alabama reefs were overfished was 1966-1967 when size limits were reduced from 3" to 2 5/8" and undersize allowances were increased from 5 percent to 25 percent for a steam oyster operation in Mississippi. Due to severe impacts on oyster abundance, these changes were rescinded after four months. Given favorable growing conditions, harvestable size oysters will continue to be produced despite harvest pressures if oystermen are restricted to hand tongs and size limit and proper culling practices are observed (M. Van Hoose, ADCNR personal communication).

Periodic tropical storms and hurricanes kill living hard bottoms and bury both live and dead shell reefs under sediments. Eckmayer (1980) reported a 64 percent loss of spat and a 90 percent loss of oysters in 1979 due to Hurricane Frederic. Winds drove water across the reefs rolling larger oysters off the reefs and into the muds. Attached spat and small immature oysters were crushed by the tumbling action or were smothered when the oysters were buried in the mud. When the eye moved ashore and wind direction changed, reefs were covered with sand and mud.

If allowed to recover on their own from burial, it would take the reefs over two and one-half years, with favorable conditions. Consequently the Alabama Department of Conservation and Natural Resources, Marine Resources Division has a long history of shell planting to artificially reestablish a hard substrate for community development and cultch for spat colonization. Over 800,000 cubic yards of shell have been "planted" in lower Mobile Bay since 1975 to provide substrate for developing oysters.

Because of extreme sensitivity to environmental and biological conditions, living hard bottoms, oysters and clams, represent a locally ephemeral, but temporally persistent habitat in Mobile Bay. Management strategies applied to these habitats are of only limited effectiveness, since natural conditions cannot be controlled. Restrictions on dredging and filling activities, within and adjacent to living reefs, help minimize sedimentation and burial. Gear specifications, size limits and seasonal controls on fishing efforts have some effect on maintaining population levels. However, a continuation of historical patterns of loss, reappearance and relocation of these habitats should be anticipated.

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Marine Environmental Sciences Consortium Contribution Number 163.

FAUNAL COMPONENTS

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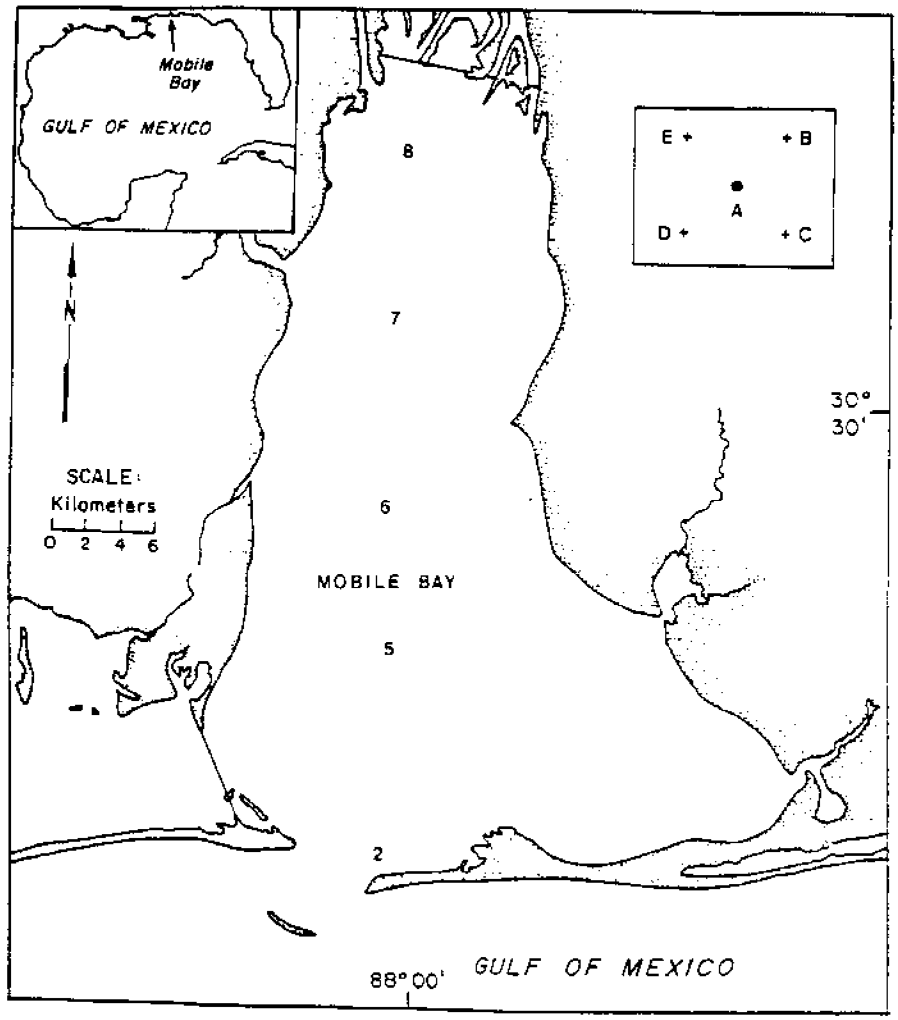
The fauna of Mobile Bay can be conveniently subdivided into three categories for consideration: benthic infauna or those organisms which live in the sediment, water column animals, and fisheries. Although these have inherent overlapping components, this organization lends itself to summary treatment, and is employed here for the benefit of general readership.

BENTHIC INFAUNA

Despite the utility of benthic communities as a means of monitoring the relative health of an estuarine ecosystem (Armstrong 1987), few data on infaunal populations in Mobile Bay have been published. Vittor (1979) summarized the published and unpublished studies conducted during the 1970's noting that of ten studies, only two examined seasonal trends. Neither of these two studies, a U.S. Army Corps of Engineers (USACOE) sponsored study of the Theodore Ship Channel project and a Mobil Oil Corporation test-well environmental monitoring program, were complete at that time. Results of these projects have since been made available in the form of a student project, a master's thesis, and several final reports (Gulf Universities Research Consortium 1979; USACOE 1979; Johnson 1980; TechCon 1980; Marine Environmental Sciences Consortium 1983; Ranasinghe 1983). In addition, two other USACOE sponsored projects examined benthic communities at sites within Mobile Bay (USACOE 1982; USACOE 1987). However, the only study to examine seasonal changes in infaunal populations along the entire north-south axis of the bay was conducted in 1980-81 under the auspices of the Alabama Coastal Area Board (CAB). The results of this survey have never been published, although several syntheses have been made available (Blancher 1982; Hopkins 1988). This report will draw on these syntheses as well as the original data base in order to provide an overview of benthic infaunal populations of Mobile Bay.

Six stations, selected from the CAB data base to represent the range of hydrographic conditions present in Mobile Bay, had been sampled 14 times at approximately monthly intervals between April 1980 and April 1981 (Fig. 1).

Figure 1. Station locations occupied during benthic macroinfaunal surveys of Mobile Bay. Distribution of subsampling sites around each station is shown in the inset.



Each station consisted of a central site (A) surrounded by four sites (B-E) equidistant from each other on the perimeter of a circle with a 105 m radius (See inset, Fig. 1). Six 0.1 m^2 Peterson grab samples were taken at each site and washed through a 0.5 mm sieve, a total of thirty replicates per station.

Annual means of the sediment characteristics of each station are displayed in Table 1. Station 2, located at the mouth of the bay, had more sand, less organic carbon and was deeper than any other station. The middle bay stations (5, 6) were roughly equivalent in depth, sediment composition and total organic carbon and had predominantly clay-sized particles. The upper bay stations (7, 8) had relatively more silt-sized particles and higher but more variable amounts of total organic carbon than the lower bay stations.

Mobile Bay is a river-dominated estuary with mean annual salinities decreasing from the lower bay to the upper bay, even on the bottom (Fig. 2). Species richness likewise decreased from south to north, however, annual mean densities were generally highest at the stations most influenced by river discharge.

The polychaete, *Mediomastus ambiseta* and the bivalve, *Mulinia lateralis* were numerical dominants throughout most of the bay (Fig. 3). Other species present in substantial numbers included the polychaetes, *Leitoscoloplos robustus* and *Pseudeurythoe ambigua*, at station 5 and the bivalve, *Mulinia pontchartrainensis*, at stations 7 and 8. Of the 15 species present at abundances greater than one percent at station 5, five species, the polychaetes *Glycinde solitaria* and *Sigambra tentaculata*, the gastropods, *Haminoea succinea* and *Tornatina canaliculata*, and the shrimp, *Ogyrides alphaerostris*, did not assume this degree of relative importance at any other station. Several polychaetes (*Leitoscoloplos robustus*, *Pseudeurythoe ambigua*, *Cossura soyeri* and *Paraprionospio pinnata*) contributed most to communities in the polyhaline to mesohaline reaches of the bay. The relative contribution of other species, including the polychaetes, *Capitella capitata* and *Neanthes succinea*, the bivalves *Macoma mitchelli*, *Mulinia pontchartrainensis*, *Rangia cuneata*, and the gastropod *Texadina sphinctostoma*, was greatest in the mesohaline to oligohaline range.

Table 1. Sediment characteristics of benthic stations. Sediment sand-silt-clay percentages and total organic carbon (TOC) values are annual means.

Station	Depth(m)	Sediments				TOC(mg/kg±s.d.)
		Gravel	Sand	Silt	Clay	
2	6.0	0.5	40.6	15.8	43.1	13.8 ± 4.7
5	3.5	0.1	6.9	23.6	69.3	14.9 ± 1.4
6	3.8	0.1	3.3	25.5	71.1	16.2 ± 1.8
7	3.5	-	3.7	32.5	63.8	16.9 ± 6.5
8	3.5	-	4.4	45.5	50.1	17.0 ± 5.2

Figure 2. Mean annual salinity, species richness and macroinfaunal density at five stations along the midline of Mobile Bay.

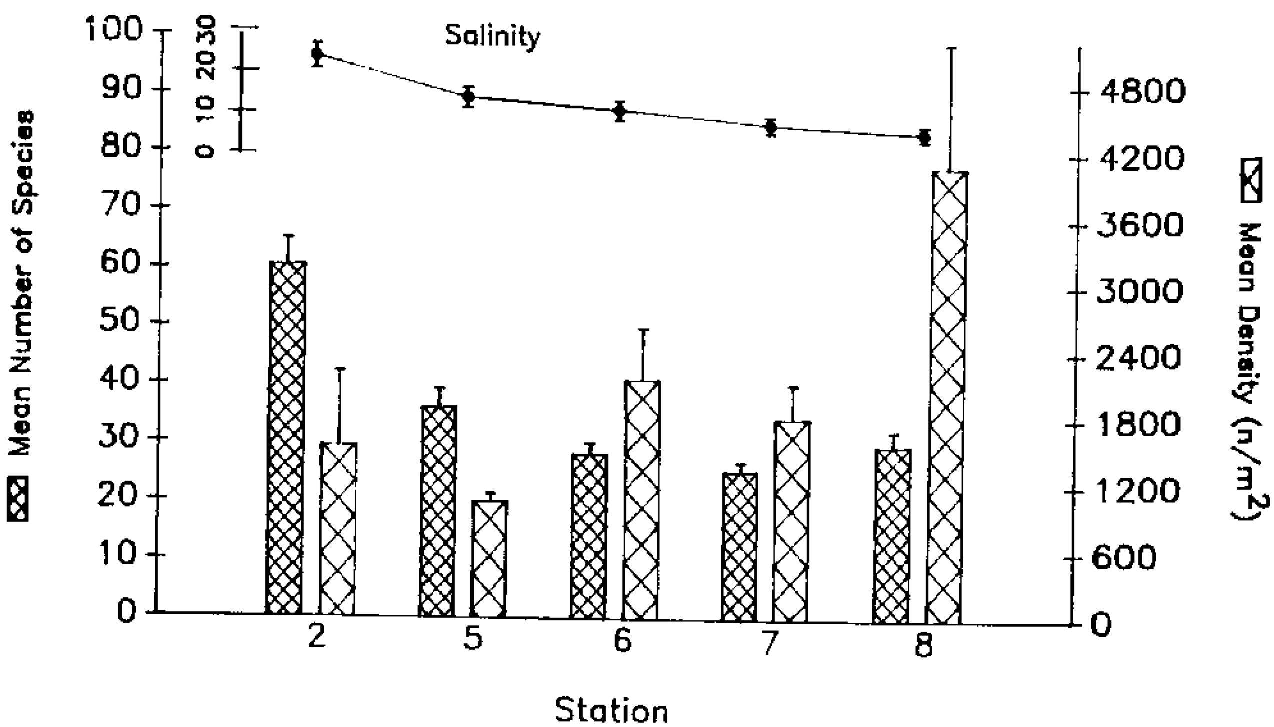


Figure 3. Distribution, life mode (D=deep, S=surface, B=burrower, T=tube builder) and feeding strategy (C=carnivore, H=herbivore, SF=suspension feeder, DF=deposit feeder, SC=scavenger) of dominant benthic macroinfaunal species (P=polychaete, M=mollusc, A=arthropod) in Mobile Bay.

	SPECIES	STATION 2	STATION 5	STATION 6	STATION 7	STATION 8	LIFE MODE	FEEDING GUILD
(M)	*Mulinia lateralis*	■	□	■	■	▩	SB	SF/DF
(P)	*Mediomastus ambiseta*	▩	■	■	■	■	SB	DF
(P)	*Paraprionospio pinnata*	□	□	□	□		ST	SF/DF
(P)	*Leitoscoloplos robustus*	□	▩	□			DB	DF
(P)	*Pseudeurythoe ambigua*	□	□	□			S	C/SC
(P)	*Cossura soyeri*	□	□				DB	DF
(P)	*Lumbrineris verrilli*	□					SB	DF/C
(P)	*Magelona sp. A.*	□					SB	DF
(P)	*Glycinde solitaria*		□				B	C
(P)	*Sigambra tentaculata*		□				B	C
(M)	*Haminoea succinea*		□				S	C/H
(M)	*Tornatina canaliculata*		□				B	C
(A)	*Ogyrides alphaerostris*		□				SB	DF/SF
(P)	*Hobsonia florida*		□			□	ST	DF
(P)	*Sigambra bassi*		□	□	□		B	C
(M)	*Macoma mitchelli*			□	□	□	S	SF/DF
(P)	*Parandalia americana*		□			□	DB	C
(P)	*Streblospio benedicti*		□		□	□	ST	SF/DF
(M)	*Mulinia pontchartrainensis*				▩	■	SB	SF/DF
(P)	*Capitella capitata*				□	□	SB	DF
(P)	*Neanthes succinea*					□	SB	DF/SC
(M)	*Rangia cuneata*					□	B	SF
(M)	*Texadina sphinctostoma*					□	S	DF

% OF TOTAL ABUNDANCE

□	▩	■
1 - 10	11 - 20	> 20

Seasonal distribution patterns of the total infaunal community (Fig. 4) were generally driven by polychaete population dynamics, except during the spring, at stations 6, 7, and 8 where recruitment by molluscs resulted in significant increases in infaunal abundance. Late summer and fall abundances were reduced at all stations (Fig. 4), a common pattern in southeastern estuaries. Temporal comparisons of selected polychaete communities at two representative stations are shown in Figures 5 and 6. Seasonal groupings consistent with hydrographic regime are exhibited at each station. The high flow, upper bay stations (7, 8) showed three groups (Fig. 5): a warm water group from April to July, a fall group (September through November) when water temperatures are falling and a winter group (December through March). The lower bay stations generally clustered in four groups (Fig. 6): a wet spring group from April to May, a summer group from June to September, a fall group from October to December and a dry winter-spring group from January to April.

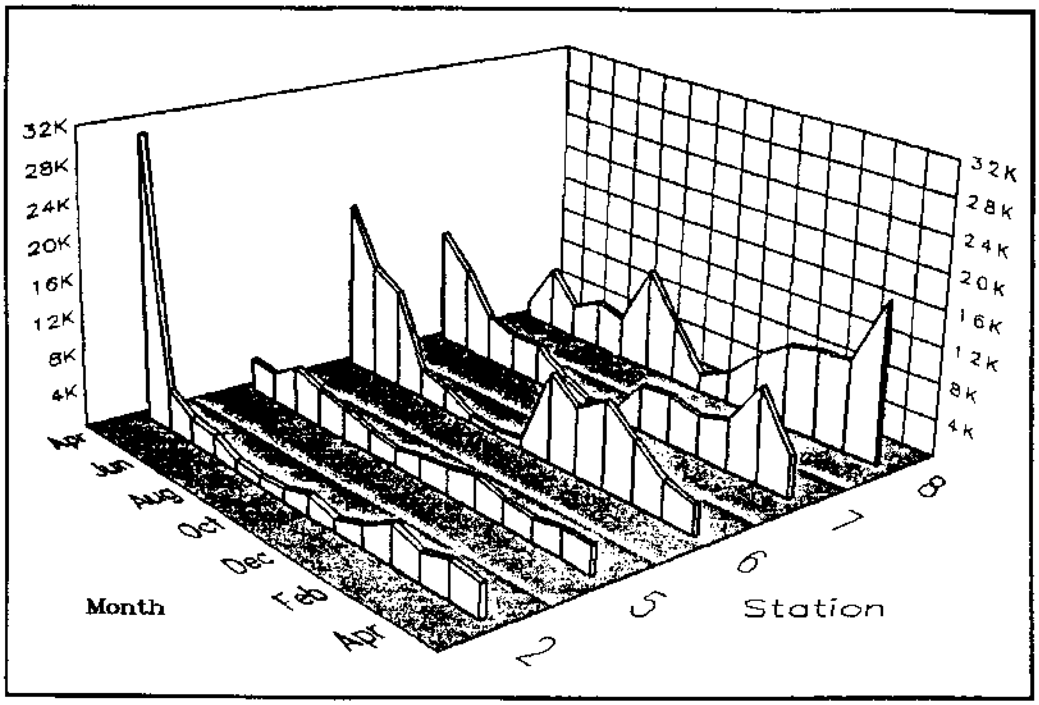


Figure 4. Monthly total abundances of macroinfauna in Mobile Bay by station.

Figure 5. Seasonal relationships of macroinfaunal communities at station 8 as determined by cluster analysis of selected polychaete assemblages (after Blancher, 1982).

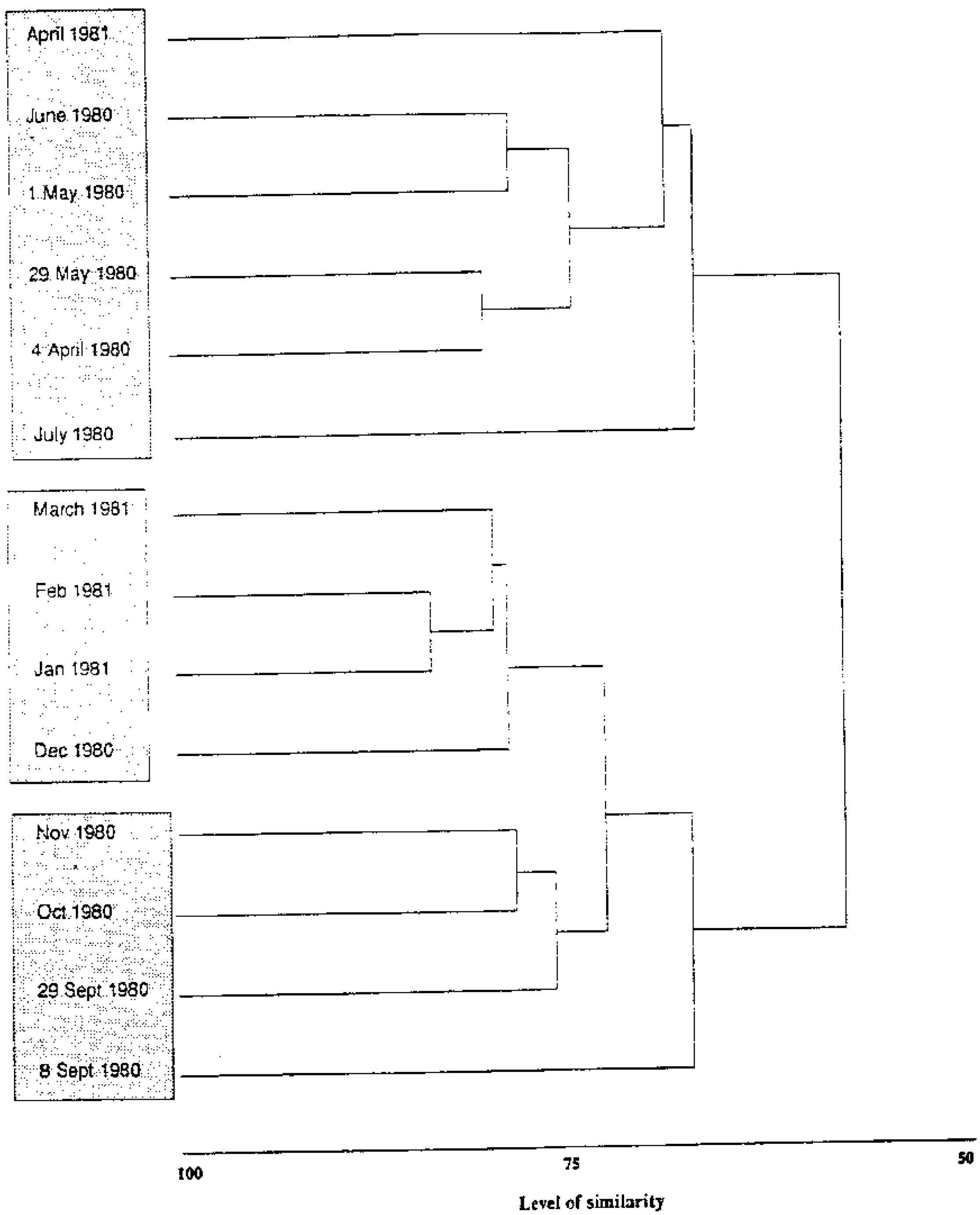
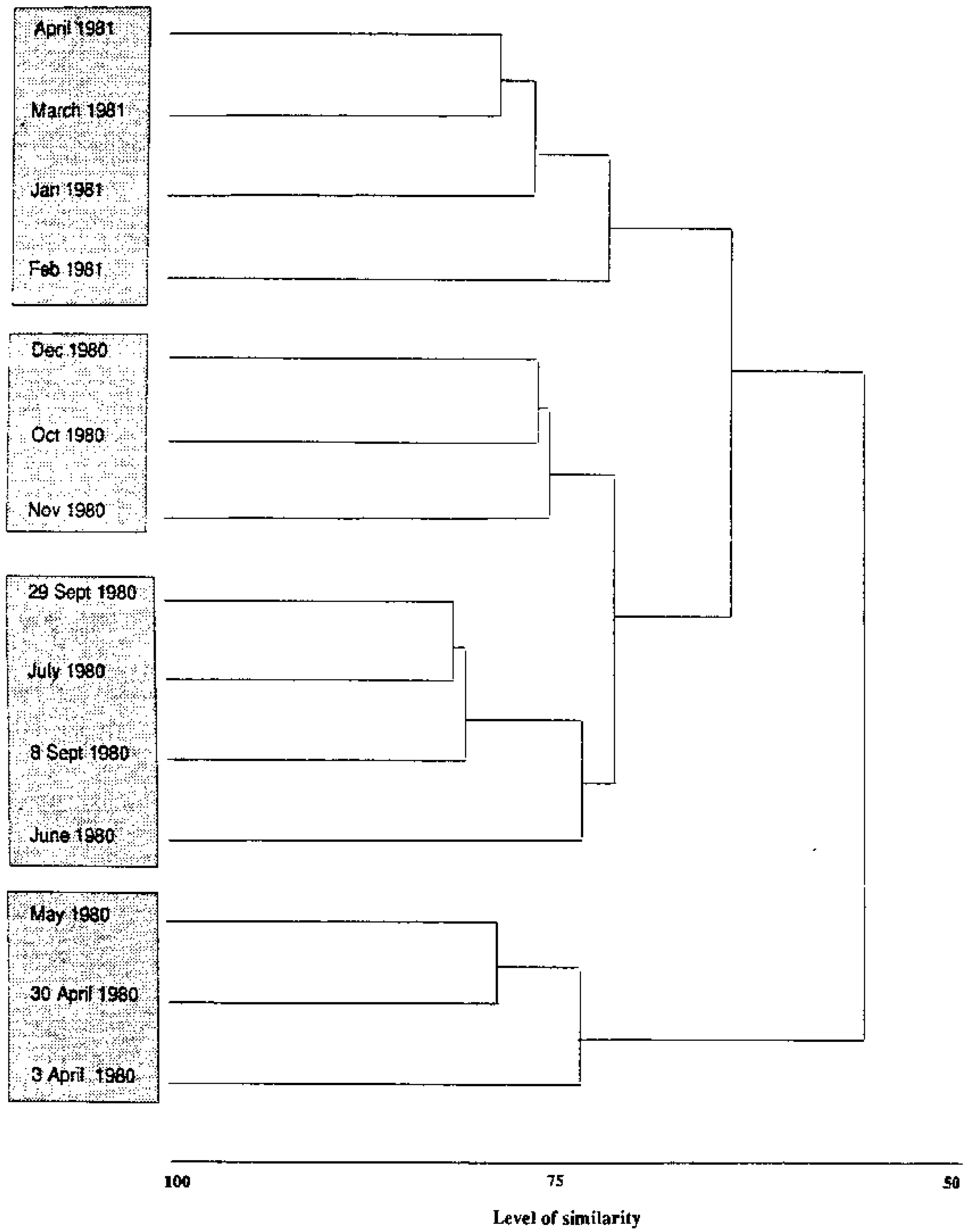


Figure 6. Seasonal relationships of macroinfaunal communities at station 2 as determined by cluster analysis of selected polychaete assemblages (after Blancher, 1982).



Densities of infaunal species in Mobile Bay fall within the range of those reported from mud bottoms of other southeastern estuaries and many of the dominant species are also common in other southeastern estuaries. Although several of these species, for example, the polychaetes *Mediomastus ambiseta* and *Streblospio benedicti*, and the bivalves, *Mulinia lateralis* and *M. pontchartrainensis*, have been characterized as indicators of organic enrichment (Wass 1967), they are ubiquitous in southeastern estuaries because of their ability to withstand chronic disturbance and stressful conditions (Simon and Dauer 1977; Flint and Younk 1983). *Mediomastus* is a burrowing deposit feeder which feeds near the sediment surface (Fauchald and Jumars 1979). The spionid worms, *Streblospio benedicti* and *Paraprionospio pinnata*, occupy shallow, fragile tubes and, like *Mulinia*, feed at the sediment-water interface, utilizing particles both from the sediment surface and in suspension (Dauer et al. 1981). Sedentary, surface-feeding species like these have a negligible effect on subsurface sediments, and therefore contribute little to sediment oxygenation and nutrient regeneration (Dauer et al. 1981; Flint and Kalke 1986a, b). Their short life cycles and high reproductive rates allow them to rapidly colonize disturbed habitat (Watling 1975; Dauer and Simon 1976; Simon and Dauer 1977) and to persist in spite of constantly changing conditions (Flint and Younk 1983; Dauer 1984). As surface dwellers, these species are readily available as prey for higher order consumers (Virnstein 1977).

Other polychaete species, such as *Leitoscoloplos robustus* and *Cossura soyeri*, are subsurface deposit feeders. *Leitoscoloplos* feed in a head-down position, ingesting particles as deep as 13 cm in the sediment column and egesting them upon the sediment surface (Myers 1977; Rice et al. 1986). Deposit feeders utilizing relatively deep sediment vertically mix particles in the top several centimeters of sediment, with profound effects on the redox potential discontinuity, microbial distributions and benthic nutrient regeneration (Aller 1978; 1982; Aller and Yingst 1985; Flint and Kalke 1986a). Maldanid worms, another group of subsurface deposit feeders, were present at all stations but in relatively low numbers. "Conveyor belt" deposit feeders are often characteristic members of a late successional stage, a stage not well represented in Mobile Bay. Rhoads and Germano (1986) have suggested that the metabolism of labile detritus by these species prevents its accumulation. Dense tube mats of surface feeders, on the other hand, may trap and store organic matter, contributing to hypoxic events upon its decomposition.

A third group of species are middle level carnivores. *Gycinde solitaria*, *Parandalia americana*, *Sigambra* spp. and *Lumbrineris verrilli* are predatory burrowing polychaetes, while another polychaete, *Pseudeurythoe ambigua* and the gastropods, *Haminoea succinea* and *Tornatina canaliculata*, scavenge and hunt on the surface of the sediment. These species were especially prominent at station 5 and were much less important at stations to the north and south. Predatory infauna provide an additional level of trophic complexity to infaunal communities (Commito and Ambrose 1985).

In summary, stations in the upper bay and those in the lower bay supported distinct benthic communities which differed in species composition (Fig. 3), abundance (Figs. 2, 4) and taxa number (Figs. 2, 7). Temporal variation in community structure followed seasonal trends in temperature and salinity. Stations

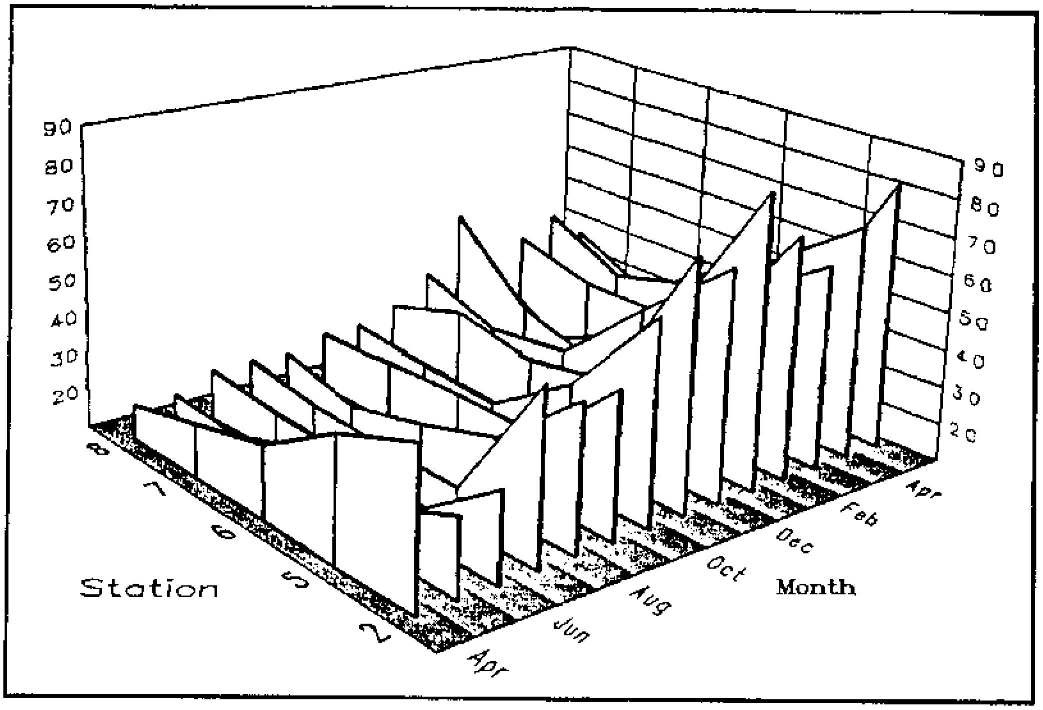


Figure 7. Monthly species richness of macroinfaunal communities in Mobile Bay by station.

closest to fluvial input were most affected by reduced salinities but extraordinary discharges influenced even the stations at the mouth of the bay. Although a few members of late successional stages were present, many of the dominant species were opportunistic pioneers capable of withstanding stressful conditions. Intermediate predators were found in substantial numbers only at Station 5, suggesting more stable conditions in the middle reaches of the bay.

From the standpoint of resource management, two of the most important features of benthic communities are the trophic support they provide to epibenthic predators and their ability to integrate and reflect environmental stress. However, information on biomass, nutrient regeneration, and carbon production necessary to evaluate the relationship between the benthos and other system components is sadly lacking. Furthermore, taxonomic discrepancies and differences in sampling gear make comparisons to prior studies of the benthic infauna difficult. Because no long-term, bay-wide, seasonal study comparable to the CAB study has been carried out, changes in community composition in response to increased development cannot be assessed.

In addition, despite the extensive spatial coverage, the frequent sampling and the many replicates, the CAB data base may not be an ideal baseline against which to measure the impacts of anthropogenic stresses. Sampling began only seven months after the passage of a major hurricane over the estuary. The massive resuspension of sediments resulted in changes in particle size distribution and alteration of habitat that may have affected benthic communities, encouraging the appearance of opportunistic species (Boesch et al. 1976; Johnson 1980). Furthermore, river discharges during the spring of both 1979 and 1980 far exceeded the 55 year average for those months (Schroeder and Wiseman 1986). The effects of dramatically reduced salinities within the estuary are not clear. Numbers of individuals decreased, especially at stations 2 and 6 (Fig. 4) and populations of many species were severely reduced or extirpated (Modlin and Dardeau 1987) in a fashion similar to that reported by Boesch et al. (1976). Flint (1983) and Armstrong (1987), however, reported that four months after record freshwater input to Corpus Christi Bay, total abundance and biomass of benthic infaunal communities increased dramatically, presumably as a result of nutrient and detrital inputs associated with the freshet. Without a long-term data set for comparison, it is impossible to determine if Mobile Bay, a relatively wet locale, responds in a fashion similar to Corpus Christi Bay with its semi-arid climate. A long-term monitoring program which includes not only the structural components but the functional aspects of the benthic communities of Mobile Bay is needed to resolve the effects of natural disturbance and aid resource managers in decision making.

WATER COLUMN BIOTA

Invertebrate Plankton

Water column animals within the bay system are comprised of planktonic and nektonic groups. Planktonic organisms are either holoplankton (those that spend their entire life as plankton) or meroplankton (those whose planktonic stages are transitory or larval phases during the maturation process). The bay is nutrient rich due to river discharges that empty into it (Riley 1967; Lamb 1979; Schroeder and Lysinger 1979), and the planktonic communities reflect this abundance of nutrients. Knowledge of the holoplankton and planktonic stages of meroplankton, especially commercially important species such as penaeid shrimp and portunid crabs, are well studied in nearby estuaries, including the contiguous Mississippi Sound (Perry and Christmas 1973), and nearby shelf waters (Subrahmanyam 1971). However, noting the lack of larvae of *Crassostrea virginica*, these authors suggested inadequate sampling for this commercially important oyster species. Similar comprehensive studies of zooplankton from Mobile Bay are lacking. However, Swingle (1971) presented a summary of plankton samples taken throughout the bay during 1968-69, in which he noted the predominance of the copepod *Acartia tonsa*, as well as fish and penaeid zooplankters.

Jones (1974) in his monograph of the Protozoa of Mobile Bay, listed and described more than 250 species of protozoans taken from stations throughout the bay. Although, many of these may be considered primarily benthic, the majority spend part of their life in the water column. His studies indicated a confusing picture of typically freshwater and marine species of protozoans living in the same estuarine environment.

L. Shipp (1977) reported on the vertical and horizontal distribution and abundance of larval stages of decapod crustaceans from West Fowl River, a tributary of Mobile Bay/Mississippi Sound. She demonstrated numerical abundance of four species of *Uca*, representing 86% of the total meroplankton collection of some 84,000 individuals. Only about 2% were older larval stages, which suggested a high mortality rate in the earlier developmental stages, or movements to other areas of the estuarine system (Table 2). Later (1979), she presented a summary of knowledge of zooplankton studies in Mobile Bay.

Finfish Eggs and Larvae

The first systematically collected data on occurrence of finfish larvae in Mobile Bay were reported by Swingle (1971). Species dominant in these collections were clupeid (menhaden), engraulid (anchovy), and sciaenid (drum) species. However, this was based on fewer than 300 individuals.

Marley (1983) reported on the spatial distribution patterns of planktonic fish eggs in lower Mobile Bay. His study was conducted over a twelve month period, during which 110 samples were taken, containing more than 100,000 eggs. His data indicated the presence of fourteen taxa, with eight taxa numerically dominant. Ninety percent of all eggs were of the bay anchovy *Anchoa mitchilli*. In addition, he noted that during periods of high river discharges, essentially all eggs were retained in the demersal portions (higher salinity) of the water column. During periods of moderate discharge, there was mixing of the eggs throughout the water column in the lower (channel) bay stations, but few eggs near the surface in other stations. Greatest egg abundance as well as most uniform mixing throughout the water column at all stations occurred during periods of low river discharge.

R. Shipp (1987) summarized data on fish egg and fish larvae concentrations in the lower bay as well as in nearshore waters just outside the bay based on plankton collections, taken during the previous decade, representing more than a half million eggs and larvae. His data indicated that relatively little actual spawning of finfishes occurred within the bay proper. The exception was the bay anchovy, which spawns both inside and around the mouth of the bay. Most other species apparently spawn outside the bay, and the larvae are moved or actively swim back into the bay. This conclusion was based on the relative abundance of fish eggs and larvae at numerous sampling sites within the lower bay. For example, during all of 1982, a total of approximately 3000 sciaenid (drum family: sea trouts, red fish, croakers, etc.) eggs were taken at interior bay stations. However, single sampling cruises in open Gulf locations frequently contained several thousand sciaenid eggs, and in one instance more than 10,000 were taken during a single August 1983 collection cruise.

Although the transport mechanism enabling certain zooplankton organisms to reenter the interior nursery grounds of the Mobile Bay system has not been the focus of past studies, work by Weinstein and co-workers (1988) indicate numerous behavioral mechanisms whereby larval finfishes and other plankters selectively enter estuarine systems. This is apparently especially relevant to the Mobile Bay system, due to the extremely restricted pass between the bay and the open Gulf. For this reason studies are presently underway which will give indication of these transport mechanisms, especially in regard to finfish.

Table 2. Total abundance of each larval stage of each species of plankter in West Fowl River, Alabama (Dec. 1974-Nov. 1975) (from Shipp 1977).

	LARVAL STAGE									
SPECIES	I	II	III	IV	V	VI	VII	VIII	MEG	TOTAL
Palaemonetes spp.	334	18	4	2	0	1	6	X[a]	1	336
Alpheus sp. *("heterochaelis?")*	6	11	0	0	0	-	-	-	0	17
Ogyrides limicola	2	2	4	0	0	0	0	0	0	8
Callianassa sp. *("jamaicense?")*	56	25	X	X	X	X	X	X	0	81
Upogebia affinis		0	0	0	X	X	X	X	0	4
Sesarma cinereum	1,262	2	0	0	X	X	X	X	1	1,265
Sesarma reticulatum	3,115	33	1	X	X	X	X	X	0	3,149
Uca spp.	72,067	18	0	0	0	X	X	X	0	72,085
Rhithropanopeus harrisii	4,660	825	247	141	X	X	X	X	0	5,783
Eurypanopeus depressus	483	1	0	1	X	X	X	X	0	485
Panopeus herbstii/ Eurytium limosum	335	0	0	0	X	X	X	X	0	335
Callinectes sapidus	1	0	0	0	0	0	0	0	100	101
										83,770

X[a] - Stage does not occur for this species.

FISHERIES

Forage and Non-Commercial Species

In regard to forage fish species, and species of little to no commercial or recreational value, R. Shipp (1979) summarized available data and previous studies. He included data on sixty-two species commonly taken during trawling and fish faunal surveys in the bay. These were divided into three ecological categories: 1) nearshore/marsh, 2) demersal estuarine, and 3) pelagic estuarine. Dominant species of the nearshore/marsh habitat are livebearers (Poeciliidae), killifishes (Cyprinodontidae) and silversides (Atherinidae). The former two families contain hardy species, resistant to environmental extremes and exposure, while the latter family includes species exhibiting little resistance. The demersal estuarine species are dominated by drums (Sciaenidae), and the most important forage group is the pelagic estuarine (Table 3), dominated by anchovies (Engraulidae) and herrings (Clupeidae). Earlier studies (Sheridan 1978) have demonstrated the dependence of the bay anchovy, *Anchoa mitchilli*, on zooplankton and its place in the food chain.

Relative abundance tables indicate that where comparative data are available, most northern Gulf of Mexico estuaries support similar forage fish faunas. Information on early life history is recognized as the most critical need for this group of fishes, whereas information on species composition, seasonality, and frequency of occurrence appears adequate. However, indications of stress on the bay ecosystem may be detectable by long-term changes in these parameters.

Commercial Fishing

The Mobile Bay Estuary supports several valuable commercial fisheries. Total commercial landings for the period 1978 - 1987 averaged 28.7 million pounds with a dockside value of $42.9 million (U.S. Department of Commerce). Average landings for the previous 10 years (1968 - 1977) were 33.5 million pounds. Only a portion of the Alabama landings can be attributed to Mobile Bay, but the trends seen in Figure 8 probably approximate landings from the bay since the 1880s.

The primary components of commercial landings are shrimp, finfish, crabs and oysters. Three species of estuarine-dependent shrimp are found in the commercial catch. Brown shrimp (*Penaeus aztecus*) dominate during early summer, followed by white shrimp (*P. setiferus*) in the fall. Pink shrimp (*P. duorarum*) are sometimes an important part of an early spring fishery that also depends on white and brown shrimp that were not caught in the previous year. Shrimp account for 65-75 percent of the total landings in Alabama and 85-95 percent of the value. Shrimp landings closely parallel the total landings except that the most recent 10-year average has not declined (Fig. 8).

Table 3. Pelagic estuarine forage fish species listed in descending order of abundance for several northern Gulf of Mexico estuaries (from Shipp, 1979).

MISSISSIPPI SOUND	MOBILE BAY		ESCAMBIA BAY	ST. ANDREW BAY	APALACHICOLA BAY, FLORIDA
	Mid Bay	Watercourses			
Anchoa mitchilli	*Anchoa mitchilli*	*Anchoa mitchilli*	*Anchoa mitchilli*	*Anchoa mitchilli*	*Anchoa mitchilli*
Brevoortia patronus	*Anchoa hepsetus*	*Brevoortia patronus*	*Brevoortia patronus*	*Harengula jaguana*	*Harengula jaguana*
Peprilus burti	*Brevoortia patronus*	*Dorosoma petenense*	*Anchoa hepsetus*	*Anchoa hepsetus*	*Chloroscombrus chrysurus*
Anchoa hepsetus	*Dorosoma petenense*	*Anchoa hepsetus*	*Chloroscombrus chrysurus*	*Brevoortia patronus*	Not Available
Harengula jaguana	*Peprilus alepidotus*	*Oligoplites saurus*	*Harengula jaguana*	*Peprilus burti*	Not Available
Chloroscombrus chrysurus	*Vomer setapinnis*	*Chloroscombrus chrysurus*	*Peprilus alepidotus*	*Chloroscombrus chrysurus*	Not Available

Over 50 kinds of finfish are landed in Alabama. This generally represents 15 to 25 percent of the total landings and 5 to 8 percent of the value. Flounder (*Paralichthys sp.*), black drum (*Pogonius cromis*), several species of kingfish (*Menticirrhus*), sheepshead (*Archosargus probatocephalus*) and striped mullet (*Mugil cephalus*) are the most important inshore components. Recently, the striped mullet has become the focus of a significant roe fishery. In 1986, 644,000 of the 1.4 million pounds of mullet landed were caught during the spawning run (November - December). Historically, the mullet catch has fluctuated widely with greater average catches in previous decades than are currently being made (Fig. 9).

Blue crabs (*Callinectes sapidus*) are an often overlooked resource with landings usually in the 1.5 to 3 million pound range and values between 0.5 and 1.3 million dollars. Average landings for the last 10 years are above previous decades, mostly on the strength of a record 4.2 million pound catch in 1984 (Fig. 9). Alabama has a small but growing soft shell crab industry that is largely undocumented.

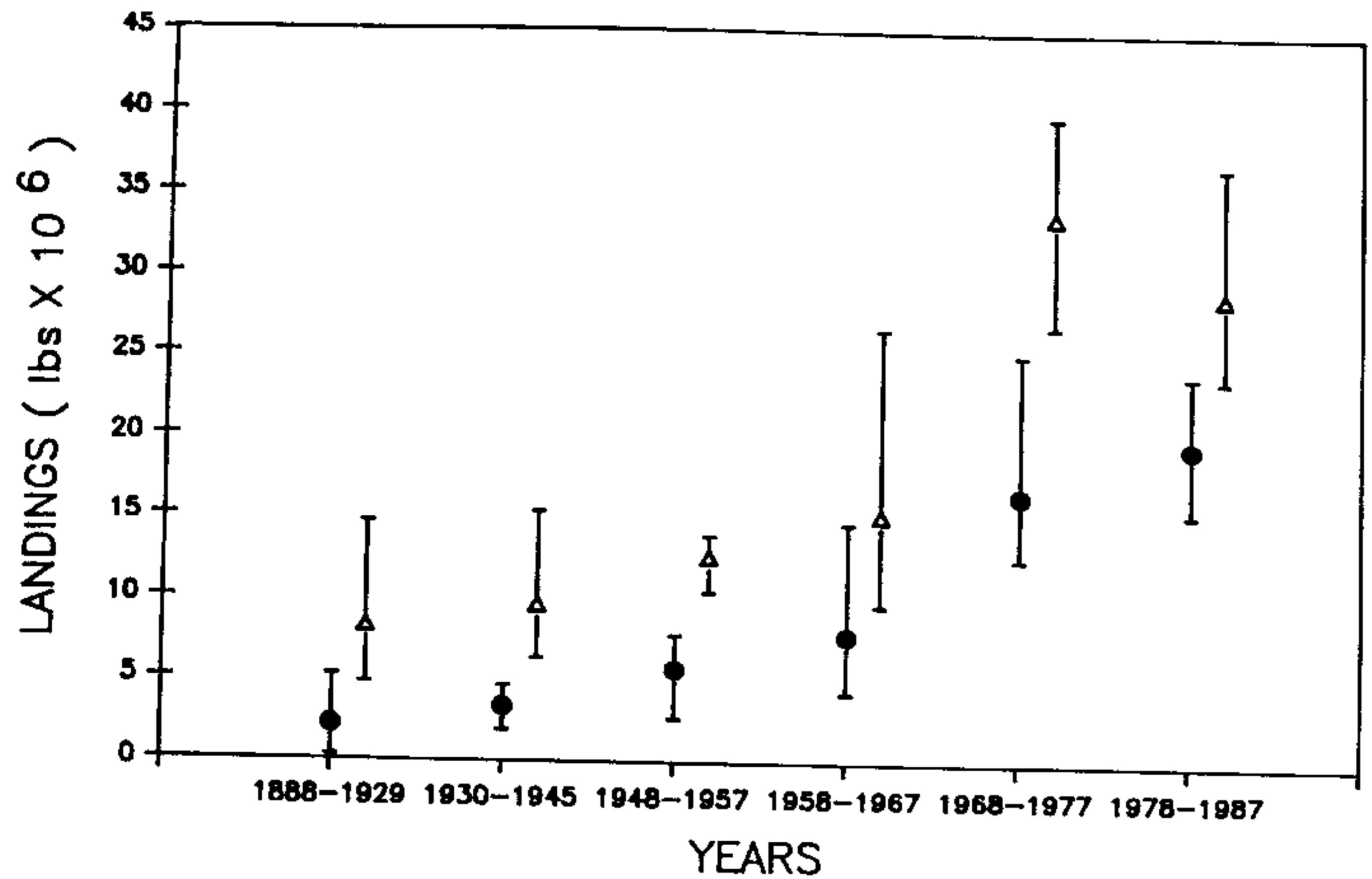


Figure 8. Ranges and means of total Alabama landings (Δ) and shrimp landings (•) at 10-year intervals for years in which data is available (derived from U.S. Department of Commerce).

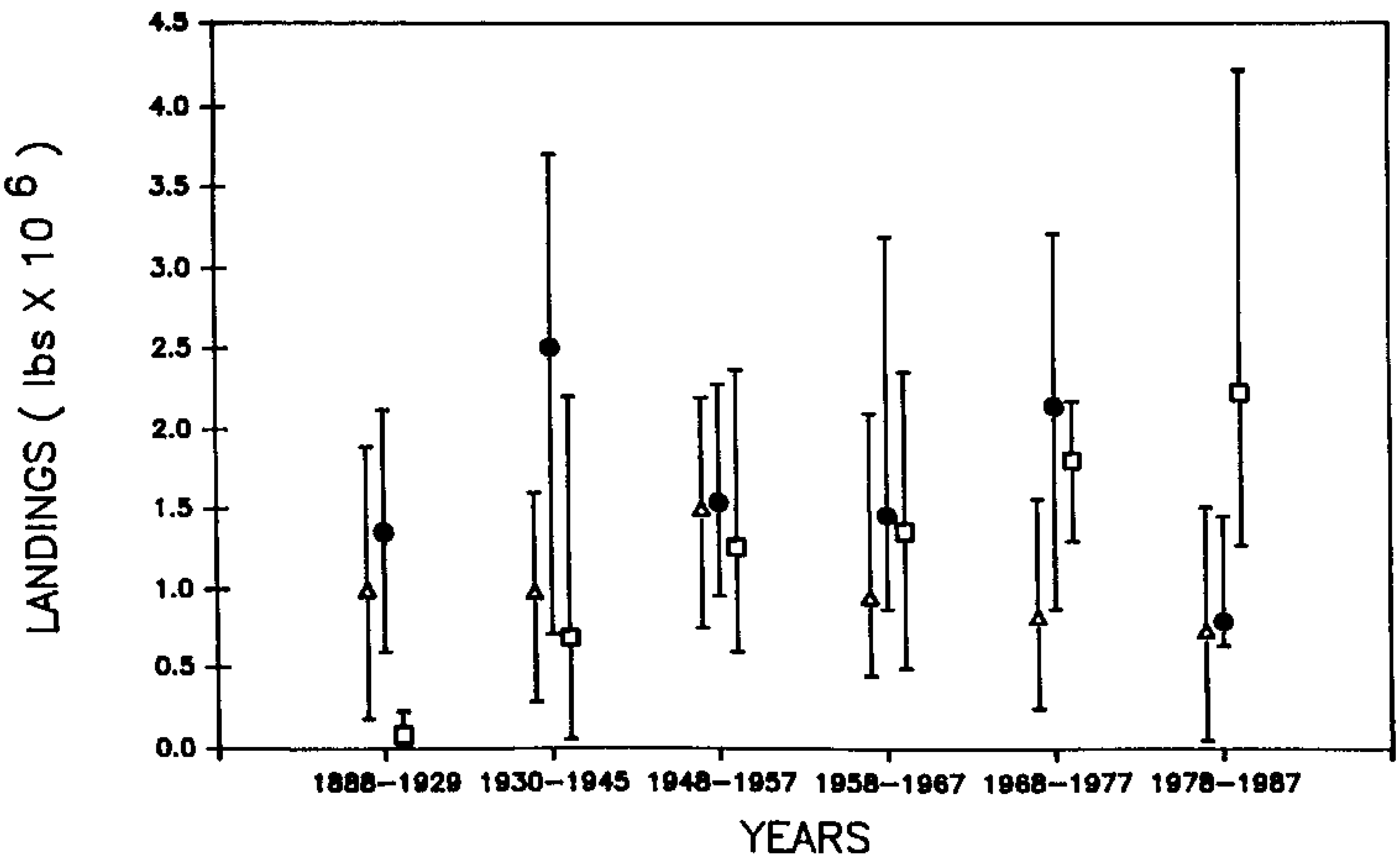


Figure 9. Ranges and means of Alabama oyster (Δ), mullet (•) and crab (□) landings at 10-year intervals for years in which data is available (derived from U.S. Department of Commerce).

Oysters (*Crassostrea virginia*) have the longest record of exploitation of any bay resource with shell middens dating back 3,500 years (Friend et al. 1982). Oyster landings reached their peak in the 1950s (average 1.5 million pounds) and appear to have declined in the last three decades (Fig. 9) to a current average of 0.7 million pounds per year, while showing fluctuation similar to crab and mullet. The value of recent oyster landings is between 0.25 million and 2.2 million dollars.

Recreational Fishing

Numerous leisure time opportunities are found on Mobile Bay. Recreational fishing is probably foremost, and this multi-million dollar industry is dependent on the same renewable resources as commercial fishing. Unfortunately, there are no time series of data on the recreational catch available to examine trends. However, several studies in the 1970's can provide some information as can a recent creel survey.

Recreational shrimpers caught an average of 257,000 pounds of shrimp between 1972 and 1974 (range = 204-290 thousand pounds). Swingle et al. (1976) estimated that this amounted to between 15 and 25 percent of the total catch from Alabama inside waters. It is reasonable to assume that the current recreational catch is the same or greater and that it varies in magnitude with the commercial catch.

Wade (1977) reported that approximately 3.3 million pounds of finfish were harvested from Alabama inshore waters by recreational fishermen in 1975. The five most important species by weight were spotted seatrout (*Cynoscion nebulosus*), sand seatrout (*C. arenarius*), red drum (*Sciaenops ocellatus*), Atlantic croaker (*Micropogonias undulatus*), and bluefish (*Pomatomus saltatrix*). Inshore fishermen spent about 1.8 million dollars on their fishing trips. A recent survey of recreational fishing indicated that inshore recreational fishermen caught 537,000 pounds of fish during fiscal year 1985 (Malvestuto 1985). The five most important species by weight were seatrout (primarily *C. arenaruis*, but may include some *C. nothus*), Atlantic croaker, mullet, flounder and gulf kingfish (*Menticirrhus littoralis*). These fishermen spent approximately 3.1 million dollars on trip costs and 34.8 million dollars on durable goods. Differing methodology, changing fishing regulations and fishermen attitudes make comparison between the studies problematic.

Blue crabs are a popular target for recreational fishermen. Tatum (1977) conservatively estimated that the recreational catch is about 20 percent of the commercial catch. This would amount to about 440,000 pounds per year during the last decade.

Alabama law allows a recreational harvest of 100 oysters per day. The extent or value of this catch is unknown.

Mobile Delta

The Mobile Delta is artificially separated from Mobile Bay by Interstate 10 for management purposes. Hydrologically and biologically, the Delta is an integral part of the Mobile Bay Estuarine System. A 1980 - 1981 survey of recreational and commercial fishing in the Delta revealed a total harvest of 14 million pounds (55 percent recreational). The value of this fishery in terms of expenditures, market value of the harvest and willingness to pay by the fishermen was estimated at 13 million dollars (Malvestuto 1987).

The Delta also provides numerous opportunities for waterfowl hunters. Beshears (1979) and Hayden (1987) both report declining duck and coot populations. Duck populations have decreased from counts of over 20,000 in the 1950's to less than 10,000 in the 1980s. Coots have shown a similar but less drastic decline. With nesting grounds in Canada and long migratory flights, it is difficult to correlate local conditions with duck populations. However, Beshears (1979) expressed concern over the losses of submerged aquatic vegetation (an important source of food) throughout the Delta and the effect on overwintering waterfowl populations.

Environmental Effects

Mobile Bay fish and shellfish are adapted to survive the wide range of water temperatures and salinities that are normally encountered in the estuaries. However, extreme conditions in either of these two factors can have severe effects on some species. Heavy spring rains often result in bay salinities less than 10 parts per thousand and water temperatures less than 20°C during March, April, and May. Postlarval brown shrimp, which are migrating into the bay during this time period show low survival under these conditions and this is reflected in the summer shrimp harvest (Heath 1979). Similarly, spring floods accompanied by heavy siltation have periodically destroyed 29 to 85 percent of the oysters in Mobile Bay (Eckmayer 1979). In contrast, under prolonged conditions of high salinity, predators such as oyster drills and a disease called "dermo" (actually a protozoan infestation) flourish and destroy significant amounts of oysters (May 1971).

The effect of temperature and salinity extremes on the bay fish populations are not as well known. Poor survival of spotted seatrout eggs and larvae is reflected in subsequent year class strength which is correlated with spring flooding (Tabb 1966; and Walter Tatum, personal communication). Extreme low water temperatures are known to cause mortality in red drum, spotted seatrout and other fishes (Johnson and Seaman 1986; Reagan 1985).

Areas of Mobile Bay periodically experience low oxygen, particularly in summer (Schroeder 1979). This results in crabs dying in traps and eliminates areas from commercial production (Tatum 1979). An oyster kill in 1971 was attributed to low dissolved oxygen and it is suggested that other unexplained oyster die-offs are a result of low oxygen (Eckmayer 1979). Furthermore, periodic low oxygen along with other factors may prevent establishment of oyster reefs in certain areas.

The consequences of catastrophic events such as hurricanes are not well understood. Fishermen often report good shrimping in the weeks following a hurricane. Likewise, recreational fishermen caught thousands of pounds of gag grouper (normally rare) in the nearshore areas of Alabama after Hurricane Elena in 1985. On the other hand, after Hurricane Frederic (1979) oyster production fell from 460,000 pounds to 54,700 pounds. In 1985, the Alabama Marine Resources Division surveyed the oyster reefs immediately following Hurricane Elena and found a 90 percent loss of harvestable oysters and an 89 percent loss of all oysters.

Environmental extremes probably account for most of the variations seen in the commercial landings of shrimp (Fig. 8), and oyster landings (Fig. 9). Fluctuations in crab and mullet landings (Fig. 9) are less well understood.

User Group Problems

User group problems revolve around traditional conflicts among and between commercial and recreational fishermen competing for similar common property resources. Conflicts (particularly in reference to fishermen expectations) are made worse from a management standpoint by a lack of information on catch-per-unit effort by various users, an incomplete understanding of environmental effects on stocks as discussed above, incomplete information on year class strengths, and the cumulative impacts of habitat loss and deteriorating water quality on the exploited stocks. In the absence of rational explanations for fluctuating stocks and possibly declining stocks, competing users tend to blame one another for perceived shortages. As a result, inshore shrimpers squabble with offshore shrimpers and both quibble with bait and recreational shrimpers. Similarly, gill netters are at odds with recreational fishermen and both see shrimpers as a threat to "their" resources.

Allocation of resources to these competing groups remains somewhat a political decision influenced by available biological data. Ideally, managers should have sufficient information to determine safe harvest levels of the various resources and then the political allocation process could proceed within the prescribed biological limits.

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NATURAL RESOURCE CONSERVATION

by

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The wetland composition of south Alabama incorporates five (5) primary geographic areas. These areas include (1) the Mobile-Tensaw Delta, (2) Mobile Bay, (3) barrier islands, (4) the Mississippi Sound, and (5) the interior bays and bayous of south Baldwin County, including Oyster Bay, Wolf Bay, and Perdido Bay. These wetland systems have experienced tremendous developmental pressures over the years and have undergone substantial acreage and water quality reductions.

History of Natural Resources Conservation

Prior to 1970, conservation in the state of Alabama was largely limited to development and maintenance of the living resource - primarily wildlife game species. The attitude of "unlimited" natural resources permeated the consciousness of most citizens, business and political leaders.

Mobile Bay, with approximately 264,000 acres of open water, seemed quite limitless in its ability to absorb the mounting developmental pressures. These pressures resulted from industrial and municipal waste discharges and the maintenance of the Mobile Bay Ship Channel and Harbor. Substantial wetland acreages were eliminated through the disposal of dredge spoil from the maintenance projects.

Conservation, in these early years, was a relatively new term in south Alabama. The environmental and conservation organizations were comprised of Mobile County Wildlife and Conservation Association, the Audubon Society (the only activist organization at that time), Baldwin County Wildlife and the Alabama Department of Conservation.

In the mid to late 1960's numerous catastrophic events significantly impacted the estuary of south Alabama. Fish kills were common throughout many of the local rivers and tributaries. Water quality declined drastically and grassbeds disappeared almost completely. Several rivers became too polluted for swimming or fishing. The general population took these events in stride as the price paid for economic vitality.

The decade of the 1970's began with a further deterioration of the estuary. This rapid decline began to cause alarm within certain spheres of the community. The gradual awakening of a conservation ethic was not welcomed in a community that was concerned first and foremost with generating a dollar through economic activity. Environmental regulations were viewed as deterrents to progress. The eminent collapse of the entire system was dismissed as purely scare tactics.

The lack of a long-term plan for development in south Alabama became more obvious as the 1970's ended. The impact of the effects of unchecked and unregulated growth in coastal Alabama became very obvious immediately after Hurricane Frederic in September 1979. The economic chaos and loss as a direct result of the storm was a small amount when compared to the ultimate environmental damage caused by the rampant redevelopment of the Gulf Shores beach area. A once tranquil single family resort was transformed almost overnight into a major tourist facility.

The Gulf Shores beach area was substantially impacted by the elimination of a large segment of the primary dune system as developers of high rise condominium complexes attempted to locate their structures as close as possible to the water's edge. Future storms will obviously result in tremendous economic losses as a result of this activity. Sewage demands have far exceeded capacities with water quality suffering as a result. Ground water reserves are being rapidly depleted as a result of the demand, with salt water intrusion of the primary aquifers expected in the near future. Warnings of this problem are presently being voiced by local experts.

In addition to the environmental impacts resulting from the rebuilding after Hurricane Frederic, other major development projects were and are being planned in south Alabama without a determination being made as to the cumulative effect of these various projects on the estuarine system. There are six (6) major projects planned or presently being implemented in Alabama coastal waters:

(a) Deepening of the Mobile Bay Ship Channel to 55 feet with the open water disposal of hundreds of millions of cubic yards of dredge spoil. Initially, 2,000 acres of shallow bay bottoms and grassbeds were to be destroyed as a result of this project. Through the cooperative effort of local, State and Federal agencies, this portion of the project was eliminated.

(b) Completion of the Tennessee-Tombigbee Waterway, with no plan developed for the fleeting of thousands of barges, which were projected to travel to and from the Port of Mobile.

(c) The proposed construction of the Theodore Outfall Line, which would dump up to 20 million gallons per day of treated municipal and industrial effluent into Mobile Bay.

(d) Continued Mobile Harbor maintenance dredging and ultimate disposal of millions of cubic yards of material.

(e) Discovery of a major natural gas field in Mobile Bay and the immediate Gulf waters, resulting in the possible discharge of millions of gallons of drilling waste into these waters.

(f) Surge in disposal needs for treated sanitary waste by the many municipalities in south Alabama. Population growth projections indicate that Baldwin County alone will increase by 47 percent by the year 2000. Most of those new residents will locate along the eastern shore of Mobile Bay and the tidal areas of Gulf Shores and Orange Beach in the south part of the county. Presently, the disposal of treated waste involves discharging the effluent into our bays, rivers and streams due to convenience as opposed to developing other disposal alternatives.

In the late 1970's and early 1980's, the conservation ethic in south Alabama finally took hold. The public began to realize that public agencies and local organizations were not adequately addressing the needs of the resource. Environmental quality was being taxed to the limit.

Present Status of Natural Resources Conservation

The current conservation "popularity" has taken many years to develop in south Alabama and can be attributed to the efforts of several concerned individuals. Public attitudes have begun to change with more individual involvement taking place.

The conservation-minded businessperson in south Alabama has begun to realize and understand the true definition of conservation - the <u>wise</u> use of our natural resources. The environment can easily be classified as a <u>primary</u> industry in this area.

Four major south Alabama industries rely almost exclusively on a functioning viable wetland system. These industries are:

(1) Commercial seafood industry - the south Alabama seafood industry employs 1,000-1,500 workers directly and generates upwards of $100 million per year in revenues. The many seafood restaurants can also be included here.

(2) Recreation industry - this industry is comprised of the boat builders, sporting goods stores, bait shops, hunters, fishermen, birdwatchers, etc.

(3) Timber industry - the Mobile-Tensaw Delta supplies a substantial volume of raw material for the local pulp and paper industry and hardwood lumber industry. Today, a portion of this timber is being marketed overseas. The timber industry in the four counties along the river system employs approximately 13,000 people.

(4) Tourism - this industry relies almost exclusively on a clean, healthy environment. Tourism is rapidly becoming one of the largest industries in south Alabama. The white sand beaches of the area are favorite tourist attractions in both the summer and winter months.

Together, by our best estimates, these four industries employ roughly 50,000 persons and generate three-quarters to a billion dollars in annual revenues. The realization of the impact that a healthy environment has on the local economy is just now beginning to be absorbed by our local leaders. The philosophy that south Alabama can have a truly unique quality of life by maintaining the integrity of our natural resources, while accommodating and encouraging quality economic development is slowly being acknowledged. Great strides are being taken today to develop this philosophy. For the first time, business, industry, government and private concerns are attempting to work toward a common goal of long -range planning for a "total well balanced community." Mr. Jack Friend, a local management consultant, has coined the phrase best - "Jobs and Income plus Quality of Life equals Prosperity." A community without one or the other is doomed to stagnation and economic blight.

The 1980's have seen public awareness and involvement in conservation surge. In this relatively short period of time, local conservation organizations and public agencies (State and Federal) have taken an interest in the unique Mobile Bay estuarine system.

Local active conservation organizations include:

1) Mobile County Wildlife
2) Audubon Society
3) Coastal Environmental Alliance
4) Gulf Coast Conservation Association
5) Sierra Club
6) Alabama Wildlife Federation
7) Baldwin County Wildlife
8) Fowl River Protective Association
9) The Nature Conservancy
10) Coastal Land Trust
11) Perdido Bay Environmental Coalition
12) Commercial Seafood Industry
13) Many smaller, single-issue groups concerned with their particular areas.

Public agencies which have focused on the needs of the south Alabama estuaries include:

1) Alabama Department of Conservation and Natural Resources
2) Alabama Department of Environmental Management
3) U. S. Army Corps of Engineers
4) U. S. Environmental Protection Agency
5) U. S. Fish and Wildlife Service
6) National Marine Fisheries Service, NOAA
7) Gulf of Mexico Fisheries Council
8) Baldwin and Mobile County Commissions
9) Mississippi-Alabama Sea Grant Consortium
10) Marine Environmental Sciences Consortium
11) Various university research centers

Accomplishments of Resource Conservation in South Alabama

Natural resource conservation has experienced several major accomplishments in south Alabama in the recent past. Although these successes are vitally important, it should be noted that they are relatively small when compared to the total size of the estuary and the present and projected future populations of south Alabama.

In 1980, the Bon Secour National Wildlife Refuge was established along the Fort Morgan Peninsula in Baldwin County. Largely through the initial efforts of The Nature Conservancy and several private individuals, this program was initiated and is presently managed and monitored by the U. S. Fish and Wildlife Service. The refuge presently totals 4,000 acres of this fragile barrier island and wetland systems. The goal of a 10,000 acre refuge has been slow to materialize due to private landowner interests. The objectives of the refuge are to preserve this critical habitat for the flora and fauna that depend on it, provide a living laboratory to scientists and students of the area and provide for wildlife-oriented recreation for the public.

The Weeks Bay National Estuarine Research Reserve was established in April 1986 as a protected education and research site. The sanctuary is dedicated to the educational research of brackish estuaries nationwide. The initial boundaries encompassed 2,668 acres of land and water around Weeks Bay. The Alabama Department of Conservation and Natural Resources is responsible for overall management of the reserve. The estuary is a field laboratory for scientists and students and a place for the public to learn about estuarine ecology in a natural setting. Participants in the development of this important project include the National Oceanic and Atmospheric Administration, Faulkner State Junior College, The Nature Conservancy, Baldwin County Board of Education, University of South Alabama, the Mississippi- Alabama Sea Grant Consortium, and the Marine Environmental Science Consortium.

The Coastal Land Trust has been the first attempt to incorporate private, state and federal assistance and management into one concept. The Trust is a private initiative designed by a group of local concerned conservation-minded businessmen whose primary agenda is to protect a large segment of the Mobile-Tensaw Delta. Coastal Land Trust, a private, non-profit corporation, purchased an 18,000 acre tract of tidal marsh and bottomland hardwoods adjacent to the city of Mobile in May 1983. The proposed program includes the ultimate acquisition of at least 50,000 acres of critical habitat in order that a wildlife management area can be established in this area. The Trust has undertaken a $10 million private fund raising campaign in order to generate needed acquisition monies. The anticipated acquisition of 20,000 acres in the Mobile-Tensaw Delta by the Corps of Engineers as a part of the mitigation requirement for the construction of the Tennessee-Tombigbee Waterway will add another piece to a well-designed program. The designation by the Alabama Department of Conservation, of approximately 10,000 acres of State held lands in the Delta as a State Wildlife Management Area illustrates the fact that Federal, State and private interests can function together to accomplish a common conservation objective. To date, however, the Corps of Engineers has not moved forward with their Congressionally mandated acquisition.

Currently, the proposed Grand Bay National Wildlife Refuge is being studied by the U. S. Fish and Wildlife Service. The location of this much-needed refuge will be along the northern shore of the Mississippi Sound and incorporate a portion of the States of Alabama and Mississippi. The purpose of the refuge would be to protect rapidly disappearing pine savannahs and pitcher plant bogs while incorporating the protection of adjoining wetlands. There is also the potential of expanding the endangered Sand Hill Crane population into this area.

Conclusions

The Mobile Bay Estuary is a very complex and critically important system to the State of Alabama and the nation. It has one of the last virtually untouched delta systems in the nation. However, there are many proposed programs which could affect the vitality of the system if not addressed adequately.

The estuaries of this nation are in need of public education as to their importance and function. There should be incentives developed for private landowners to protect critical coastal wetland systems.

A united effort should be initiated between Federal, State and private sources for the acquisition of critical habitat acreages for conservation purposes.

Federal assistance is needed to develop cumulative impact assessments within a major ecosystem, such as the Mobile Bay Estuary, through documented research by professional organizations and agencies. Planning for the long-term maintenance of a healthy system is paramount. We need planning which will assure the wise use and maintenance of our natural resources.

The rapid decline in the health of our estuaries is tragic and in some instances irreversible. We must act now to insure the maintenance and health of the last few critically important estuaries in this country.

ECONOMIC ASPECTS

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INTRODUCTION

Mobile Bay is an estuary rich in natural resources. As the State and the region have developed, these resources have attracted increasingly large numbers of business, industrial, and residential interests. All these human users are competing for these natural resources and as this competition for finite resources increases, conflicts intensify. Individual, corporate, and governmental decisions that affect use in one sector often create changes that affect all aspects of the bay.

Current decisions and the cumulative impact of earlier decisions that altered the estuarine environment often create natural resource losses and economic modifications. The history of civilization is a litany of change. Changes are usually considered as progress, but progress in one respect often results in losses in other areas, frequently negatively impacting the environment.

Change is inevitable, but change does not have to be environmentally destructive. Compromise, communication, and cooperative effort to preserve a healthy balance of use and conservation of the area's resources is not only possible, but currently occurring.

Our positive assertion is not intended to imply that conflicts between groups with differing viewpoints and objectives on appropriate policies and actions in the Mobile Bay Estuary do not occur. Conflicts do occur with some degree of regularity. However, both in Mobile Bay and in other sections of the nation, increasing numbers of people are acknowledging that a healthy economy can exist only in a healthy environment.

In previous sections of this publication, specific aspects of the natural resources of the Mobile Bay Estuary have been addressed. In general, these presentations have tended to indicate that both positive and negative factors exist. The existence of several viewpoints has caused disagreement and often conflict. The balance of this discussion is intended to present some of the types and kinds of interactions that exist in the Mobile Bay Estuary. An overview of Mobile's economic base and then more detailed information on specific industrial and commercial sectors is provided. It is not possible to discuss in detail all factors which impinge on the economy and environment of the Mobile Bay area. However, attempts have been made to include those deemed to be most significant in their impact on the area.

MOBILE'S ECONOMIC BASE: AN OVERVIEW

The Mobile Bay Area enjoys a diversified economy with two major paper mills (Scott Paper and International Paper) and seven chemical companies listed among the area's top twenty manufacturers. Among these are such nationally-known names as DuPont, Olin, and Ciba-Geigy. Our "high tech" industries include QMS, manufacturers of laser printers and electronic peripheral computer equipment, and Teledyne Continental Motors, manufacturers of the engine used in the Voyager.

Mobile is headquarters for approximately fifteen companies, including Morrison, Inc., which was recently named one of the top 1,000 U.S. companies ranked by stock- market value. Small business is also an integral part of Mobile's economy. Of the 10,476 business establishments in our metropolitan area, 95 percent are classified as small business. Mobile is Alabama's major port and has approximately 20,000 people employed in port-related businesses. There are twenty-eight foreign-based manufacturing investments in the Mobile Area, some representing joint ventures with internationally-known companies such as BASF and Mitsubishi.

In addition to the usual government offices, the U.S. Army Corps of Engineers has a district office in Mobile with over 700 employees and the U.S. Coast Guard has an aviation training base with 1,100 employees. Mobile will be the homeport for five Navy vessels in 1991-1992.

The Mobile County Public School System, with 6,300 employees, is the area's largest employer. The University of South Alabama, (the fourth largest university in the State) and its teaching hospital, the University of South Alabama Medical Center, have a combined employment of 3,800, the second largest in the Mobile area. Other major employers include Scott Paper Company, the Mobile Infirmary Medical Center and Providence Hospital.

Tourism is a leading industry in Mobile employing thousands of people as a direct result of visitor activity. Services and retail trade employment in the Mobile area represents almost 50 percent of the total number of jobs. Oil and gas exploration, seafood processing and shipbuilding are other areas of great importance to Mobile's economy.

It should be noted that some of the industrial and commercial activities discussed in the preceding paragraphs do not require access to water. However in these instances, either water access is extremely desirable or the amenities associated with the waters of Mobile Bay were instrumental in selecting the initial site of the industries discussed.

Amenities also play a major role in the population growth in the areas adjacent to the Mobile Bay Estuary. Population growth in Alabama's two coastal counties, Mobile and Baldwin, has increased at a faster rate than total State population. Population increases in the surrounding area exert additional pressures and demands on the Mobile Bay Estuary, both in terms of land for residential use and in increased demand for commercial and industrial development to provide employment for the growing population.

Commercial and residential development has spread throughout the bay's drainage basins and provides the dominant land use extending southward along the east and west shores. More recently, second-home and condominium development have exerted intensive pressure on the Fort Morgan Peninsula and Dauphin Island at the mouth of the bay. An indication of both the positive and negative aspects of increasing population is given in the discussion on strategic homeporting and Mobile Bay which follows.

STRATEGIC HOMEPORTING AND MOBILE BAY

With the U.S. Navy moving forward to a full 600 ship fleet capability, a need existed to locate additional ships in new geographic areas. To meet this need, a "national competition" to locate homeports in the Northeast, Northwest Pacific, Western Pacific and Gulf Coast was undertaken. The result is a strategic homeporting plan that will disperse existing and new ships to homeports in New York, Puget Sound, San Francisco and seven Gulf Coast Ports.

Mobile will be home for five ships of the 15th Carrier Battle Group with the remainder of the ships of this Battle Group scheduled for Gulf Coast Ports located in Pensacola, Florida and Pascagoula, Mississippi. These ships are scheduled to arrive in 1991-1992. Development of a Navy homeport will have effects not only in the immediate Mobile- Baldwin region but State-wide as well.

The State of Alabama has provided $30,000,000 for waterfront construction and dredging and the City of Mobile and Mobile County have provided a 212-acre homeport site at no cost to the Navy. Cost of land was $7.6 million and access improvements by the County will cost more than $800,000. These investments of public funds are expected to generate the local impacts discussed below.

The Navy homeport will provide approximately 2,000 Federal jobs and an additional 1,600 civilian jobs in the area. The total Federal and civilian payroll is expected to exceed $70 million per year and represent an annual economic impact of $175 million, not including the $100 million investment at Naval Station Mobile.

This increased population will generate a $55 million increase in annual retail sales volume. Nearly 1,300 units of off-base housing will be required for these new residents. The Navy homeport will ultimately result in $82 million in new government revenues including aid to school districts, county, and city governments. Because of the location of the Navy vessels in Mobile and the surrounding area, increased shipyard activity and jobs are expected that could generate substantial additional revenue.

Although the positive impacts on the region are quite obvious and economically significant, certain changes and, in effect, tradeoffs will be required to accommodate this beneficial development. In greater or lesser degree, the same scenario is replayed every time any major economic development activity occurs. The discussion that follows is intended to illustrate some of the concerns that must be addressed when changes in the economy of Mobile Bay area occur. The same general logic applies to all of the remaining topics discussed. However, the expansion of this thought process to the other industrial sectors is left to the reader.

Perhaps the most striking change that will occur with the implementation of naval homeporting in Mobile will be in terms of additional demands posed by the increased population. The impacts in terms of increased school attendance and increased demand for housing have been quantitatively addressed above. These new residents will also need and demand adequate police, fire, and general safety services which require additional employees in these departments. The additional vehicles will increase traffic congestion to some extent and may require new or improved roads and other transportation networks.

The influx of new residents will undoubtedly wish to take advantage of the area's many natural resources for recreation purposes, including the beaches, saltwater and freshwater recreational fishing, and opportunities to enjoy nature at State parks and federal wildlife refuges. Increased usage of the bay and surrounding waters for recreational boating, a greater demand for fresh seafood provided by the commercial seafood industry, and increased sales and revenue in many retail and service sectors of the economy are also expected to occur.

Increased population will also place greater demands on the estuary to assimilate residential and commercial treated waste discharges, change drainage patterns, increase the need for solid waste disposal facilities, and cause changes in numerous other factors that could be construed to be detrimental to the natural resources of the Mobile Bay Estuary.

The most important factor to be considered is the need to maintain a balance; a balance of use and conservation of the natural resources of the Mobile Bay Estuary. The authors contend that such a balance is possible, but difficult and sometimes even painful to attain.

RECREATIONAL ASPECTS

Mobile's location on the sunny Gulf Coast and a clean, safe city, with traditional Southern Hospitality to visitors has made it an increasingly popular destination for convention delegates and tourists. The historical and culturally diverse city is currently experiencing unprecedented media attention in travel sections of newspapers across the country as one of the last truly beautiful and quintessentially charming southern cities.

Recreational travel has a significant impact on the Mobile Bay/Gulf Coast economy. The annual Alabama travel survey (Adams and Boyce 1986) revealed that the direct travel expenditure for the State in 1986 was $4 billion. Of the total, 25 percent or $1 billion was spent in the general Mobile Bay/Gulf region. Because of the unique features of the region, most of that expenditure was attributed to Mobile Bay and Gulf of Mexico attractions.

Estimates of the Alabama travel survey indicate that the employment and income multipliers for travel expenditures is 0.2. Thus, the $1 billion spent in 1986 generated $200 million in wages and salary income and 19,000 jobs for the region.

A separate 1980 study (Nelson and Hardy 1980) of the Alabama-Mississippi coastal economy provided estimates of expenditures and purchases for various economic sectors. Two sectors, "Hotel, Personal, and Repair Service" and "Other Services" representing the recreation industry had type II output, income, and employment multipliers of approximately 4.9, 2.8, and 2.4, respectively. These multiplier levels indicate a high degree of sectoral interdependence and impact on the area economy.

In fact, these sectors, stimulated heavily by recreational activity in the Bay environs, ranked fifth and sixth respectively among 30 sectors considered with respect to economic impact. Only "Education/Medical and Non-profit," "Wholesale/Retail Trade, Forestry" and "Fishery Products" ranked higher in economic impact. The same study evaluated the environmental interdependence associated with economic changes. As expected, the recreationally related sectors had far less negative environmental effect than other sectors.

The combined areas of Mobile Bay and the Mobile Delta contain approximately 285,000 acres of open water capable of supporting 1.7 million recreational fishing occasions per year. Most of the Delta is fresh or brackish water and the Bay, salt water. The 1990 statewide demand for saltwater fishing is projected to be 2.1 million occasions. Although a significant portion of the demand will be for offshore Gulf fishing, Mobile Bay is likely to receive at least a fourth to a third of that demand. Thus, 500,000 to 750,00 recreational fishing occasions pressure from an additional 0.5 - 1.0 million fisherman days is expected by 1990.

Boating also is an important recreational activity in Mobile Bay. The 35-mile-long bay provides excellent sailing, windsurfing, power boating, and, to a lesser extent in the upper reaches, canoeing. Public access to Mobile Bay and the Delta is provided by approximately 35 boat ramps. Within the immediate area of Mobile Bay, there is a projected demand in 1990 for 1.6 and 2.4 million freshwater boating and fishing occasions, respectively. Since there is limited freshwater in the area other than Mobile Delta, much of that demand will fall in Delta rivers and waterways. The Alabama travel survey also showed that boating and fishing parties spent an average of $204 per trip in 1986. Assuming 0.6 million fishing occasions and, conservatively, 1.5 million boating occasions per year (2.1 million total), the direct expenditure for the two activities could generate $428 million for the Bay area alone in 1990. This level of recreational spending would generate $85 million in wages and salary and 8,500 jobs.

Thus, the economic impact of recreation on and around Mobile Bay is significant. Protecting the environmental resources of the Bay used for recreational activity is important for both environmental and economic reasons. And, based on the economic model of the Alabama-Mississippi coastal economy, the importance of the Bay exceeds that of most manufacturing and resource extraction industries in the region.

OIL AND GAS EXPLORATION AND PRODUCTION IN MOBILE BAY

Leasing and drilling for oil and gas in Alabama's coastal waters was initiated in 1951 on a limited scale but has been greatly accelerated in recent years. The State has leased oil and gas rights for 37 blocks or tracts in Alabama waters and has received nearly $800 million in bonuses for the leased areas since 1969.

Test wells have been drilled or are currently being drilled on approximately 15 leases and have provided encouraging results. Although oil is present, the volume of natural gas available shows the greatest economic potential. A modern gas production plant was completed in South Mobile County in mid-1988. This facility will be used to process gas produced from several tracts owned by a number of different firms.

Primarily because of environmental concerns, the time lag between the start of the first leases and the actual initiation of drilling activities spanned nearly a decade. Permission to drill was finally granted, but the State required that drilling activities be conducted under strict "no-discharge" regulations. Initially, even rainwater runoff from the drilling platform had to be collected and transported by barge to either upland disposal sites or discharged in open-water locations. Either of these options greatly increased the costs of drilling in Mobile Bay.

The primary concern was focused on the disposal of drilling muds into the relatively shallow and confined environment of Mobile Bay. Although the mud is dense and tends to sink to the bottom without prolonged dispersion in the water column or much spreading from the disposal point, the potential to destroy bottom dwelling microorganisms and filter feeders such as oysters has been questioned.

Concerns have also been expressed that disposal of muds may alter salinity, temperatures, or currents within the disposal areas. Although a stringent biological monitoring program had been established and to date had not shown critical adverse effects, permission to dump drilling muds in the Bay was not granted until early 1988 and then only after a prolonged legal battle.

By lifting the requirement for "no discharge" conditions and hence reducing the costs of drilling operations, additional exploration activities have been encouraged. The bulk of the income received by the State from drilling activities has primarily been bonus revenue received from oil companies solely for the right to drill. The royalty income that the State will receive from production is also expected to be substantial. However, the employment impact of the oil industry is primarily concentrated in initial drilling and construction of production facilities with a dramatic decrease in the number of long-term employment prospects after the initial phases are completed.

Although the commercial seafood industry produces a significant economic impact both in terms of employment and income, it provides only a fraction of the dollar impact of the oil and gas industry. However, the commercial fishing industry is based on a renewable natural resource while hydrocarbon extraction consumes the resource.

By carefully guarding and preserving the wetlands, embayments, and coastal waters, the commercial and recreational fishing industries can be expected to continue in some form into the foreseeable future. In summary, it is important that both the oil and gas industry and the seafood industry be able to co-exist with minimal adverse effects on each other. Continued studies need to be conducted to achieve this objective.

TRANSPORTATION

The transportation industry of Mobile is comprised of railroads, highways, motor carriers, interstate bus, air, and water transportation. Each of these segments of the transportation industry is briefly described with special emphasis on water transportation.

Four railroads serve the Mobile area: Burlington Northern, Illinois Central Gulf, Norfolk Southern, and Seaboard System Railroad. All four railroads provide piggyback service. There is no passenger train service at this time. Two interstate highways (I-10 and I-65) pass through Mobile and five U.S. highways provide additional highway service. There are over 60 motor freight lines certified to transport interstate shipments to and from Mobile. Nine of these carriers provide container services. Interstate bus service is provided by Greyhound Bus Lines and Colonial Trailways. Six scheduled airlines serve Mobile: American Airlines, Delta Airlines, Eastern Airlines, Continental Airlines, Northwest Airlines, and Royale Airlines.

The Port of Mobile is one of the 10 most active ports in the nation. The port is served by a 36.5 miles of ship channel with a depth of 40 feet. The Port of Mobile is the terminal port to the Gulf of Mexico for the Tennessee-Tombigbee Waterway, known as the Tenn-Tom Waterway. Tenn-Tom connects Mobile to about 16,000 miles of the nation's inland waterways. The Tenn-Tom was completed for traffic in January 1985 and first year projected tonnage was much lower than anticipated. However, tonnage has been gradually increasing and is expected to reach a steady level of approximately 10 million tons annually by 1990-1991.

The Port of Mobile is equipped with one of the largest coal-exporting facilities in the nation with a maximum capacity of about 23 million tons per year.

However, the latest annual tonnage of coal loaded at the McDuffie Terminal was only 7 to 8 million tons. It is anticipated that the relatively low price of crude oil will continue to depress coal exports through the Port of Mobile for many years to come.

Early in 1988 the first phase of deepening the ship channel from 40 feet to 45 feet began at a total cost of $30 million. The first phase is expected to last about 3 years. Two additional phases are planned to eventually deepen the ship channel to 56 feet so that super colliers can visit the McDuffie Terminal. Varying stages of ship-channel deepening projects have also begun on several smaller ship channels in Mobile Bay. These include Bayou La Batre Channel, Bayou Coden, Dauphin Island, Dog and Fowl River Channels, Perdido Pass Channel, and Fly Creek.

Two additional activities relating to water transportation merit consideration but are not discussed in detail because of lack of data or projections. The Mobile Foreign Trade Zone is located in the Brookley Industrial Complex, but is not currently utilized to its full potential. As discussed earlier, the U.S. Navy is scheduled to establish a naval base at a 212-acre site on Mobile Bay in 1991-1992 and this homeporting is expected to increase traffic in Mobile Bay considerably.

So far as we know, no systematic study has been made to determine the impact of increasing ship traffic on the Mobile Bay Estuary. Perhaps, the most serious problem is the long-term nature of the impact. Studies, if available at all, deal with the fishery industry. The real impact, however, takes such a long time that studies concentrating on short-term impact are not likely to capture the full impact of Bay activities on the estuary. Systematic studies are needed to reconcile conflicting interests of different industries that utilize the same resource known as Mobile Bay.

COMMERCIAL SEAFOOD INDUSTRY

Alabama has a relatively short coastline in terms of miles. However, our location in the central portion of the Gulf of Mexico, makes Alabama processors and facilities important to both Alabama registered vessels and to large numbers of transient vessels with home ports in other states.

Seafood products landed in Alabama had a dockside value of $64 million in 1986. Shrimp is the mainstay of Alabama's commercial fishery and has historically provided approximately 90 percent of the value of all seafood products landed. Oysters, crabs, and finfish are also taken by Alabama fishermen. Based on an earlier study sponsored by the Mississippi-Alabama Sea Grant Consortium, it is estimated that Alabama seafood landings have an economic impact on the State that normally ranges between $125 and $150 million annually. Because of the high value of 1986 landings, the economic impact well exceeded $200 million.

Nearly 600 modern vessels ranging in length from 50 to 85 feet make up Alabama's offshore fishing fleet. In addition, several hundred smaller vessels operate in Mobile Bay harvesting shrimp, oysters, crabs, and mullet. Approximately 3,000 fishermen are employed on these two groups of vessels.

Based on dockside value of landings, the two major fishing ports, Bayou La Batre and Bon Secour ranked 7th and 35th nationally in 1986.

However, the dockside value of Alabama landings does not begin to tell the complete story. Because of the relatively large seafood processing sector that exists in Alabama, large processors must rely heavily upon seafood landed in other areas and trucked into the State. Foreign-produced shrimp is also imported for further processing. Major Alabama processors frequently send trucks into other states to bring products back to Alabama and routinely buy seafood from fishermen and dealers in states as distant as Texas and Virginia. Alabama seafood landings totaled slightly less than 37 million pounds during 1986, but total seafood processed in the State exceeded 121 million pounds.

Seafood landings and seafood from out-of-state support over 60 Alabama processing plants that provide employment for some 1,600 year-round workers. Alabama processors add a substantial amount to the value of the imported product they process. When this fact is considered in combination with the economic impact on the State derived from Alabama landings, the total 1986 economic impact of the commercial seafood industry is estimated to be in excess of $400 million.

SUMMARY

Alabama's coastal areas and marine resources are a major asset of the State. It is generally acknowledged that the Port of Mobile at the terminus of the Tennessee-Tombigbee Waterway is economically significant. Recreation and tourism is also an important aspect of the economy in coastal regions. The 1986 Alabama travel survey indicated a direct travel expenditure for the State of $4 billion, approximately 25 percent or $1 billion in the Mobile Bay/coastal region. A large portion of the coastal expenditure was attributable to the unique marine and coastal resources of the region. Announcing the selection of Mobile for the 1990 National Governors' Association Meeting, Governor Guy Hunt suggested that, "that the lure of fishing and Mobile's famous seafood could have been major points in the final decision for the location of the conference."

Earlier studies to identify water-related concerns of coastal area residents provide a strong correlation between concerns expressed by members of the commercial fishing industry and the recreation/tourism industry. The recreation/tourism interests indicated that fishing and/or fresh seafood provided a large portion of the impetus for individuals to visit the Alabama coastal area.

Many of the opportunities and challenges facing the Alabama coastal area are directly related to our marine and coastal resources. Significant changes will occur as additional oil and gas exploration and production intensify, as the Strategic Homeporting Plan for Mobile Bay is implemented, and as shipping traffic increases with greater utilization of the Tenn-Tom Waterway and channel deepening and widening.

Many groups, agencies, and organizations have a strong interest and a responsibility in the Alabama coastal area. Agencies of State government including the Alabama Department of Conservation and Natural Resources, the Alabama Department of Economic and Community Affairs, the Alabama Department of Environmental Management, the Alabama Department of Health, and numerous other State agencies which have sometimes overlapping and even conflicting responsibilities in coastal lands and waters. NOAA, particularly the Office of Sea Grant, the Estuarine Programs Office, the National Marine Fisheries Service, and other U. S Department of Commerce agencies also have a major role in the Alabama coastal region. Other Federal agencies and organizations including the U.S. Army Corps of Engineers, the U.S. Fish and Wildlife Service, the U. S. Coast Guard, the U.S. Environmental Protection Agency, the U.S. Department of Agriculture, and many others have certain additional responsibilities.

Coastal Alabama also has a number of State-supported educational institutions including the University of South Alabama, Faulkner State Junior College, the Marine Environmental Sciences Consortium, and outreach arms of both Auburn University and the University of Alabama. Many public and environmental organizations are also extremely active in Alabama's coastal area, including the Audubon Society, the Nature Conservancy, the Sierra Club, and many other local environmentally-oriented groups.

The groups, agencies, and organizations listed above and many others have all contributed to the growing general commitment to utilize the natural resources of the Mobile Bay Estuary with care. Few, if any, individuals or organizations are in total opposition to all developmental activities or change; conversely, economic development activities are seldom, if ever, conducted without due regard for environmental effects.

Although the environmental situation in the Mobile Bay Estuary is much better than in the past, improvements must still be made. Significant strides have been made in developing educational materials and programs that inform the public about the importance of the natural resources of Mobile Bay. However, additional efforts will be necessary for citizens to become even better informed. Decision-makers must know more about the system so that we do not unwittingly damage the environment or reduce the opportunity for economic progress.

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COASTAL RESOURCE MANAGEMENT IN ALABAMA: PAST EFFORTS AND FUTURE NEEDS

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INTRODUCTION

Coastal resource management is an extremely important topic in Alabama, as well as throughout the rest of the nation. Coastal systems are complex, and as the population of our coastal areas increases, the impacts of land and water uses on coastal resources also increase. Many feel, the author included, that the ability to manage the interaction of natural and economic resources will determine the long-term quality of life in Alabama's coastal area as it will in other coastal areas throughout the nation.

Coastal Alabama possesses a vibrant mix of land and water uses, and it is fast-growing. Baldwin County is the second fastest-growing county in the State of Alabama, and its growth rate rivals similar counties in Florida. When a move is made in coastal Alabama, there is contact, and in many cases, conflict with natural resources.

Over 250,000 acres of waters in the Mobile Bay Estuary provide recreational opportunities for thousands of boaters and fishermen each month - a superb recreational resource for residents and visitors alike. Coastal Alabama is blessed with over 120,000 acres of wetlands. These wetlands and waters provide the essential nurseries and habitat areas for commercial and recreational fish and shellfish species of the Mobile Bay Estuary and the Gulf of Mexico.

There are significant aspects of Alabama's coastal area which sets it apart from the other coastal areas of the United States. Baldwin County's coastline consists of over 30 miles of the most beautiful white sand beaches imaginable. Fort Morgan Peninsula begins a special 150-mile crescent of sugar white sand beaches that stretch to Panama City on the Florida panhandle.

The Mobile Bay Estuary is situated atop one of the largest natural gas finds in the continental United States, and exploration and development create continuing pressures on coastal resources.

Between 1979 and 1985, condominium units in the unincorporated beachfront areas of Baldwin County increased from 32 units to over 3000 units. This condominium boom has been the source of substantial controversy, and, in some cases, serious damage to the dune systems (Baldwin County Commission, 1986). Despite this increase, beachfront development has lagged behind that of many other coastal areas. This provided breathing room in which to bring on-line a series of land management controls designed to protect beachfront resources. Lateblooming development has also allowed the State agencies to provide excellent public access to the gulf beaches.

The tourist industry has never been more important to the coastal economy; over 5 million visitors come each year to their shores (Gulf Coast Area Chamber of Commerce, 1988).

The shallow estuarine waters combined with the shipping requirements of the ninth largest port in the United States leave coastal Alabama with channel maintenance requirements which are staggering. Maintenance disposal requirements are measured each year in the millions of cubic yards of spoil material.

These partially make Baldwin and Mobile Counties special. Without these resources, the coastal counties would be like any other county in Alabama. These resources - always special and often fragile - are the reason Baldwin County enjoys the highest quality of life in Alabama.

With such precious resources pressured by extensive water-related growth, there can only be one mission in managing the coastal resources. It is our responsibility to develop innovative techniques to manage the impacts of economic development activities so that the unique and fragile resources are protected.

RESOURCE MANAGEMENT PROGRAMS IN COASTAL ALABAMA

Modern coastal resource management began in earnest in Alabama in 1976 with the passage of the Alabama Coastal Resource Management Act. This hallmark legislation established the Alabama Coastal Area Board, and it empowered the Board to develop and implement a Coastal Area Management Program. The Alabama Coastal Area Management Program (ACAMP) adopted in October 1979 has been the basis for much of Alabama's progress in managing its coastal resources.

The ACAMP established as its fundamental goal the preservation of the "present levels" of coastal resources. The Board specifically wanted to prevent any further degradation of Alabama's coastal resources. This policy lead to a thorough examination of the methods available to measure resource degradation, and a series of pioneering studies to provide needed baseline information (Alabama Coastal Area Board, 1979).

The Board was a small state agency with limited staff, resources and capabilities. The ACAMP was framed, therefore, to allow the Board to concentrate on those few issues that it could effectively address. The regulatory structure was designed to piggyback on the State and Federal regulatory structure that existed at the time of program adoption.

In 1983, the Coastal Area Board was supplanted as the State's coastal resource management agency by the Alabama Department of Environmental Management (ADEM) and the Alabama Department of Economic and Community

Affairs (ADECA) which currently share responsibility for the implementation of the ACAMP.

GENERAL REQUIREMENTS FOR SUCCESSFUL RESOURCE MANAGEMENT

Before we consider several programs which we believe fairly characterize coastal resource management efforts in Alabama, let us look at general requirements for successful resource management: political commitment, commitment of financial and technical resources, sound technical programs, and effective regulatory programs (Fig. 1). These are fundamental to any successful management program and no less important for managing the interactions of complex environmental and economic systems.

Political Commitment

In reviewing those factors that have determined successes and failures in coastal resource management, it is apparent that the bulk of recent progress is tied to a commitment and follow-through by top management. Without a commitment by U.S. Representative Jack Edwards, for instance, the Bon Secour National Wildlife Refuge could never have materialized. Similarly, a joint commitment of the beachfront communities, the two coastal counties, and the Coastal Area Board was needed to institute beachfront development controls.

Without the commitment and support of political leadership, we can expect to witness the gradual disappearance of the natural resources - regardless of the quality and magnitude of the resources that are available to the agencies.

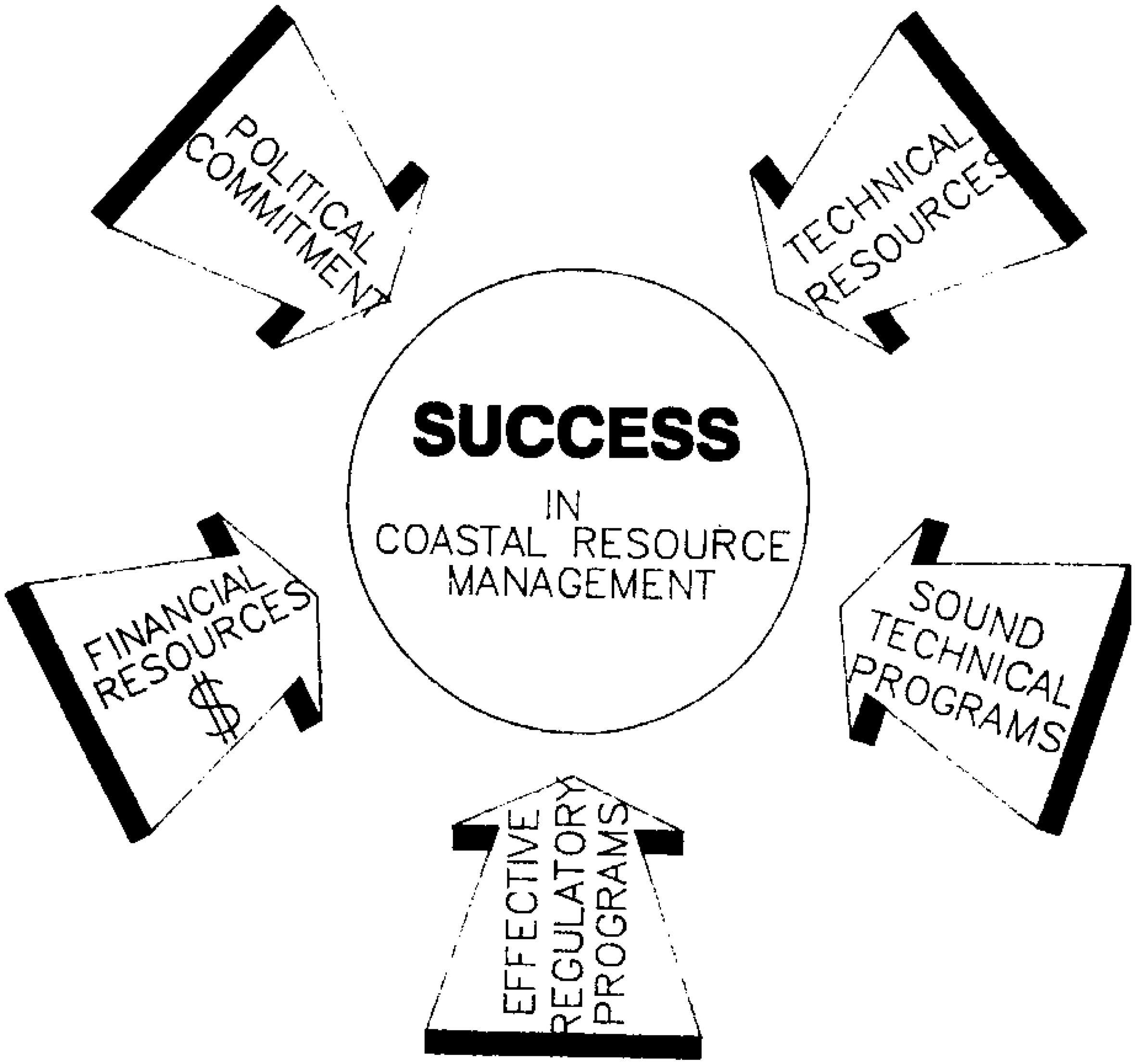
Commitment of Resources

Clearly, financial resources are needed for successful management of coastal resources. Coastal issues are, by their very nature, complex. The variations in the natural systems and the magnitude of the issues involved (in terms of both the dollars at stake and the value of the resources themselves) require long-term scientific study of natural systems in order to support competent regulatory decisions. If funding is pulled away in mid-stream, the important research efforts needed to protect coastal resources can be crippled. Stable levels of funding are essential for long-term progress.

Sound Technical Programs

Strong scientific underpinnings are required for competent regulatory decision-making. Inadequate technical information consistently leads to regulatory decisions that do not protect environmental resources, as well as to vacillations in regulatory policy that can have severe adverse economic repercussions. In either case, the public ultimately bears the cost through environmental degradation or higher prices for goods and services. Although strong science requires deep pockets, the results are well worth the investment.

Figure 1. Success in coastal resource management.



Solid Regulatory Programs

As regulatory efforts move beyond the simple coastal issues to the more complex, it is increasingly important to move beyond simple water quality standards to represent the health of the environment. The public is much more aware, interested, and sophisticated in its attitude toward environmental protection than at any other time in history. As a result, the public is increasingly intolerant of regulatory agencies hiding behind standards that do not necessarily protect living resources! In coastal Alabama, this intolerance is manifest by mounting criticism of the Alabama Department of Environmental Management for its regulatory decisions on a series of major issues affecting the coastal area. This criticism is often accompanied by lawsuits and always by controversy.

In my view, the Clean Water Act of 1987 is an important step forward in our efforts to manage the nation's estuaries. Ten years ago the Coastal Area Board initiated a comprehensive approach to managing the resources of the Mobile Bay Estuary - a program designed to monitor the long-term health of the estuary through direct measurement of the living resources in the sediments and water column. This approach is remarkably similar to the approach outlined by Ms. Rebecca Hamner, EPA's Acting Assistant Administrator for Water (Sea Technology, 1988). EPA's move toward a program of comprehensive estuarine management is particularly important for several reasons.

First, a comprehensive approach is required to successfully address the complex issues and competing demands for resources of the estuarine system. Second, the state water quality agencies can be expected to follow EPA's lead - willingly or unwillingly. Third, we are hopeful that EPA and the State agencies will commit sufficient financial and technical resources to resolve estuarine resource management issues. Fourth, if EPA will make a long-term commitment to sound scientific research on coastal issues - issues that are common to the Mobile Estuary and other estuaries in the country - the management decision-making process can benefit greatly. Adequate technical information concerning the effects of economic activity may reduce the rhetoric and hyperbole surrounding resource management decisions.

Successful Resource Management Efforts in Coastal Alabama

During the early 1980's, several efforts were undertaken by the Coastal Area Board and other environmental groups in coastal Alabama: biological research, land management, and habitat preservation and restoration. These efforts were innovative, effective and provided lasting benefits to the coastal community.

Present Level Studies

As mentioned earlier, the Coastal Area Board, in developing the Coastal Area Management Plan, established the goal of preserving present levels of coastal resources. To reach this goal, it became necessary for the Board to determine what those present levels of coastal resources were. It became quickly apparent that there was little reliable, quantified documentation of the levels of living resources in Alabama's coastal area. In addition, techniques for determining these levels of resources were untested.

Thus, the Coastal Area Board commissioned a series of baseline studies which provide an excellent foundation for the evaluation of changes in the natural systems and the living resources of the Mobile Bay Estuary (Table 1). The philosophical foundation for these studies was quite simple. The staff and the Board felt that effective long-term biological resource management requires the direct measurement of living resources rather than reliance on water quality standards or other surrogate measurements of environmental health.

We agree with Lewis who wrote, independently, in 1976, "I have argued elsewhere and now simply repeat my conviction that recruitment, especially in communities with a "key-species" organization, deserves priority study because this phase is often most sensitive to both natural variables and to pollutants, and because the ability to repopulate is the ultimate criterion of biological health and well-being."

The present levels studies are important for several reasons. They provided a reliable, comprehensive view of the resource base during several seasons. These studies were comprehensive not only in terms of the breadth of the resource base, but also in geographic coverage. All of the major provinces of the estuarine system were studied during the same time period. The baseline studies tested and proved a set of statistically valid sampling and analytical techniques that are available for further studies.

The present levels studies provided the baseline to track population fluctuations of the coast's living resources. This should allow the long-term monitoring of the health of the estuary as well as the detection of cataclysmic events in the resource base. However, no follow-up is planned, scheduled or funded!

Table 1. Present level studies.

- Geochemical Analysis of Mobile Bay and Mississippi Sand Sediments
- Benthic Analysis of Eight Regions of Mobile Bay and Mississippi Sound
- Benthic Study of Discharges into Mobile Bay Estuary
- Fish Larvae Studies
- Wetland and Submersed Grassbeds Studies
- Physical Characteristics: Sediments, Salinity, Temperature, Current, Water Quality
- Birds and Mammals of Alabama Coastal Area
- Statistically Valid Sampling Techniques for Benthic and Fish Population Sampling
- Land Use Study of Mobile River Delta

By the mid-1980's, the Federal Flood Insurance Program was encouraging Gulf-front property owners to place their dwellings far forward of the historical norm. Since the Federal government obligingly paid for storm damage from hurricanes, homeowners became far more ambitious in the type of dwelling constructed and far braver in challenging the surf.

One of the preliminary efforts of the Coastal Area Board was to implement a program to manage beachfront development (Table 2). The initial program consisted of several components (Savage, 1985). First, a coastal setback line was adopted. Second, a program of patrols by the Baldwin County Sheriff and the Alabama Department of Marine Resources was instituted to keep vehicles off the beaches and dunes. For the past four years, vehicular traffic on Baldwin County beaches has been minimal.

Hurricane Frederic, which came ashore in Alabama's coastal area in 1979, taught us some very valuable lessons about the ability of the existing construction techniques to withstand the wind and storm surge forces of a hurricane. Following Hurricane Frederic and the devastation caused by the combination of heavy storm surge, high winds, and poor construction techniques, the Coastal Area Board commissioned the development of improved standards for Gulf-front construction. These standards were adopted by each of the coastal counties and the beach communities to supplement the Southern Standard Building Code (Baldwin County, 1980). These standards remain in effect today, and although they have yet to be tested, fortunately, there should be far less destruction in future hurricanes than witnessed during Hurricane Frederic.

After six years of struggle, controversy and turmoil, a comprehensive zoning ordinance was adopted during 1988 for Baldwin County's coastal areas, including the Gulf-front and the eastern shore of Mobile Bay (Baldwin County, 1988). This zoning ordinance carries with it several key components, not least of which is a comprehensive erosion control ordinance for the eastern shore of Mobile Bay. We expect this erosion control ordinance to significantly reduce suspended solids entering Mobile Bay from the eastern shore.

Table 2. Land management controls.

- Coastal Construction Setback
- Dune Patrol
- High Hazard Building Code
- Zoning Ordinance - Baldwin County
- Erosion Control - Baldwin County

The ordinance also makes building permits and zoning certificates contingent upon the successful completion of environmental permitting systems. We expect this combination of land management controls to pay long-term dividends.

Habitat Preservation and Restoration

One of the more successful programs to manage coastal resources has been the effort by environmental groups to purchase and preserve important habitat areas within the coastal area (Table 3).

U.S. Representative Jack Edwards and environmentalists from the coastal area succeeded in establishing the Bon Secour National Wildlife Refuge. This Sanctuary consists of 5 miles of Gulf-front property in Baldwin County and, at the present time, 1500 acres of wetlands that have already been acquired. Three thousand additional acres of wetlands are planned for future acquisition (Carroll, 1988).

In 1985, the Weeks Bay National Estuarine Research Reserve was dedicated following several years of effort by the Coastal Area Board, the Alabama Department of Economic and Community Affairs and the Alabama Department of Environmental Management to obtain this Sanctuary through NOAA and the Nature Conservancy. The Weeks Bay Reserve currently consists of approximately

Table 3. Land acquisitions.

Bon Secour Wildlife Refuge	
Beachfront	5 miles
Wetlands	1,500 acres
Wetlands Planned	3,000 acres
Weeks Bay	
Wetlands Purchased	1,000 acres
Wetlands Planned	300 acres
Delta	
Coastal Land Trust	18,000 acres
State of Alabama	13,000 acres

1000 acres of wetlands surrounding Weeks Bay with another 300 acres of land planned for future acquisition (Tatum, 1988). In the early 1980's, the Coastal Land Trust initiated a program with the aid and assistance of the Nature Conservancy to purchase large amounts of acreage in the Mobile-Tensaw River Delta. So far, this effort has resulted in the purchase of 18,000 acres of Delta wetlands. The Alabama Department of Conservation and Natural Resources also owns 13,000 acres of Delta wetlands (Dyas, 1988).

Over the years, the State of Alabama has made major acquisitions of land on the Gulf-front in Baldwin County. At the present time, 11 of the 22 miles of Baldwin County beaches are held in public ownership; 5 miles are owned by the Department of the Interior in the Bon Secour Wildlife Refuge; the remaining 6 miles are owned by the State of Alabama at Fort Morgan State Park, Gulf State Park, Perdido Key State Park and other small tracts along the coast (Baldwin County, 1986).

During the past three years, the feasibility of restoring dunes and wetlands has been field tested with some success (Table 4).

In 1986, a 500-foot dune was planted in front of Phoenix Condominiums on sand placed upon the beachfront from foundation excavations. This joint effort of the Boy Scouts, the Baldwin County Commission and the U.S. Department of Agriculture has successfully withstood three seasons of storm surge and several small hurricanes.

Several wetland restoration projects have been undertaken through the U.S. Army Corps of Engineers permitting process. These wetland projects have provided mixed results. Some of the wetlands are flourishing, others have not survived as well. The Corps of Engineers built Gaillard Island in the middle of Mobile Bay from dredge spoil material amid some skepticism. This island has developed into a fine pelican rookery given high marks from local U.S. Fish and Wildlife staff members (Goldman, 1988).

Table 4. Habitat preservation and restoration.

- Gaillard Island Pelican Rookery
- Manmade Dunes in Baldwin County
- Submersed Grassbeds Project
- Wetland Creation Project
- Beach Mouse Habitat
- Reduced Loss of Jurisdictional Wetlands

Although much work remains to be done in determining the biological productivity of artificially created wetlands and dune systems, important steps have been taken to develop and prove the technologies needed for environmental restoration.

The three programs which have been briefly discussed represent important progress in the management of coastal resources in Alabama.

ON THE BRIGHT SIDE

The coastal program since its inception has been a forum for the discussion of the major issues affecting the coastal environment, and a catalyst for initiatives to address these issues (Table 5).

Increased Public Awareness.

Beachfront development, drill mud discharges, the Theodore outfall to Mobile Bay, discharge of dredge spoil into coastal waters, the Vulcanus incineration ship, zoning and many other issues have surfaced through the coastal program. The public is more aware of the issues and increasingly concerned that they be addressed properly. Specifically, there is ever-increasing support for environmental protection. A recent poll in Alabama indicated that 58 percent of the population supported stronger environmental controls even if they required higher taxes. This support reflects a feeling in the population that their resources are important but not managed properly.

Baseline Data

The complication of comprehensive baseline data of biological and physical parameters in the coastal area of Alabama was a broadbased effort to initiate a system of direct monitoring of coastal resources. This effort accomplished two important goals. It resulted in the first comprehensive study of baseline environmental conditions in Alabama's coastal area. During the course of the study, pioneering techniques were developed to obtain statistically valid data on the health of biological populations in the benthic community and in the water column. These studies provide not only important information about the coastal area but also the basis for determining trends in the health of the ecosystem.

Table 5. On the bright side.

- Increased Public Awareness
- Comprehensive Approach to Resource Management
- Excellent Biological and Physical Baseline Data
- Land Management Programs
- Extensive Habitat and Restoration
- Improved Wastewater Treatment
- "Clean" Sediments

Although this effort has lain dormant for the past several years, ADEM is making an effort to continue some of this work in Mobile Bay. Perhaps more significantly, the U.S. Fish and Wildlife Service is continuing efforts to implement a comprehensive approach to coastal resource management through its cumulative impact assessment efforts.

Land Management

Prior to the Coastal Program, the environmental impacts of land use had been largely ignored. This has been changed, fortunately, during the past decade with the introduction of a series of land management programs: coastal construction setback, dune patrols, high-hazard building codes in most coastal communities, zoning ordinances, erosion controls, and a link between land use permits and other environmental permits in the high growth areas of Baldwin County. These additions are important measures that will allow the control of impacts on coastal resources from land-based activities.

Habitat Preservation and Restoration

In addition to placing over 20,000 acres of environmentally sensitive lands in the public trust, regulatory programs have become markedly more efficient in reducing the loss of jurisdictional wetlands. It appears that the filling of regulated wetlands has slowed to a trickle. The focus of discussions is shifting to the definition of jurisdictional wetlands. There appear to be substantial disagreements among several agencies and environmental groups concerning which areas should be protected.

Several wetland and dune restoration projects have been undertaken with mixed results. Over 400 feet of dunes planted in Baldwin County have survived several hurricanes in three storm seasons. There is some controversy concerning the environmental productivity of the artificial marshes that have been created under the mitigation policies of the Corps of Engineers and ADEM. There is also substantial concern that the Corps is losing valuable opportunities to study artificial marsh creation projects. The submersed grassbeds program of the Marine Environmental Sciences Consortium is providing exceptionally good information on the feasibility, value, and ecological value of planting submersed grassbeds in the upper Mobile Bay area. The Corps of Engineers has developed an artificial island in the middle of Mobile Bay which has developed into an important pelican rookery. These programs are important for they may provide the basis to correct some of the environmental problems created in the past by taking an active role in restoring natural areas to productivity.

Wastewater

We have witnessed substantial improvements in wastewater treatment in the Alabama coastal area during the past ten years, both in the private and public sectors. In addition to improved treatment technologies, most of the growth areas have been provided with sewer service, eliminating septic tank inflows to surface waters.

"Clean Sediments"

Geochemical studies in the early and mid-1980's have shown low levels of pesticides, heavy metals and other potentially toxic materials in Mobile Bay sediments. Although there may be a few isolated "hot spots" the estuarine sediments of Mobile Bay are generally "non-toxic."

ON THE OTHER HAND

Despite the progress that has been made with the limited resources at hand, there are some serious problems facing coastal resource management in the coming years (Table 6).

Lack of Public Trust

Among the most difficult issues faced by the regulatory and management agencies is a lack of public trust of the agencies themselves and the industries that they regulate. The public is much more sophisticated these days about environmental issues, and they are much more aware of the consequences of environmental mismanagement. Rising cancer rates throughout the country are making the public extremely nervous about their health, and the impact of air, water and groundwater pollution on their lives. The public is increasingly aware of the depletion of the natural resource base. As a result, the public is demanding higher standards of environmental protection, and is less likely to accept at face value agency and industry claims.

A cursory look at some of the events of the past decade show the reason for public skepticism concerning the intentions of industry and the ability of the agencies to protect the public interest. High quantities of Kepone, an extremely toxic chemical, were found flowing down the James River. The Emelle Landfill, a hazardous waste landfill in north Alabama, is constantly in the news with permit violations and controversy concerning polluted groundwater supplies. PBB's in dairy cows and in milk required the destruction of large herds of dairy cattle in Michigan. Radioactive emissions were found to have been emanating from the Fernold Weapons Plant for many year. The Rocky Mountain Arsenal near Denver will require expenditure of up to a billion dollars in Superfund clean-up costs. The Environmental Protection Agency was prepared to issue permits for the Vulcanus

Table 6. On the other hand.

- Lack of Public Trust
- Cumulative Impact Analysis
- Lack of Oil and Gas Development Plan
- Rapid Growth
- Poor Environmental Cost Allocation
- Aging Coastal Management Program

incineration ship to take PCB's and other toxic substances through Alabama ports for incineration in the Gulf of Mexico. A groundswell of public opposition in Texas and Alabama ultimately forced the EPA to reconsider, and Jack Raven (EPA, Region IV Administrator) made a courageous decision to deny the permit and study the issue thoroughly. Mobil Oil illegally dumped tons of drilling muds into Mobile Bay in the early 1980's in violation of their permit requirements. Infectious wastes were washed ashore on long stretches of New Jersey and Long Island beaches (Table 7).

Each time a similar incident of environmental degradation occurs, the public trust in industry and government suffers. Good science, independent monitoring of discharges, a comprehensive approach to resource management and tougher enforcement appear to be important elements most needed to earn the public trust.

Cumulative Impact

The natural variations and stresses of the coastal environment create difficulties in isolating the uses or products that are impacting living resources. The relative low water flow through the estuary, relative to a river system, allows contaminants to remain in contact with estuarine resources for much longer periods of time. The estuary acts much like a sink by retaining pollutants brought in from upstream.

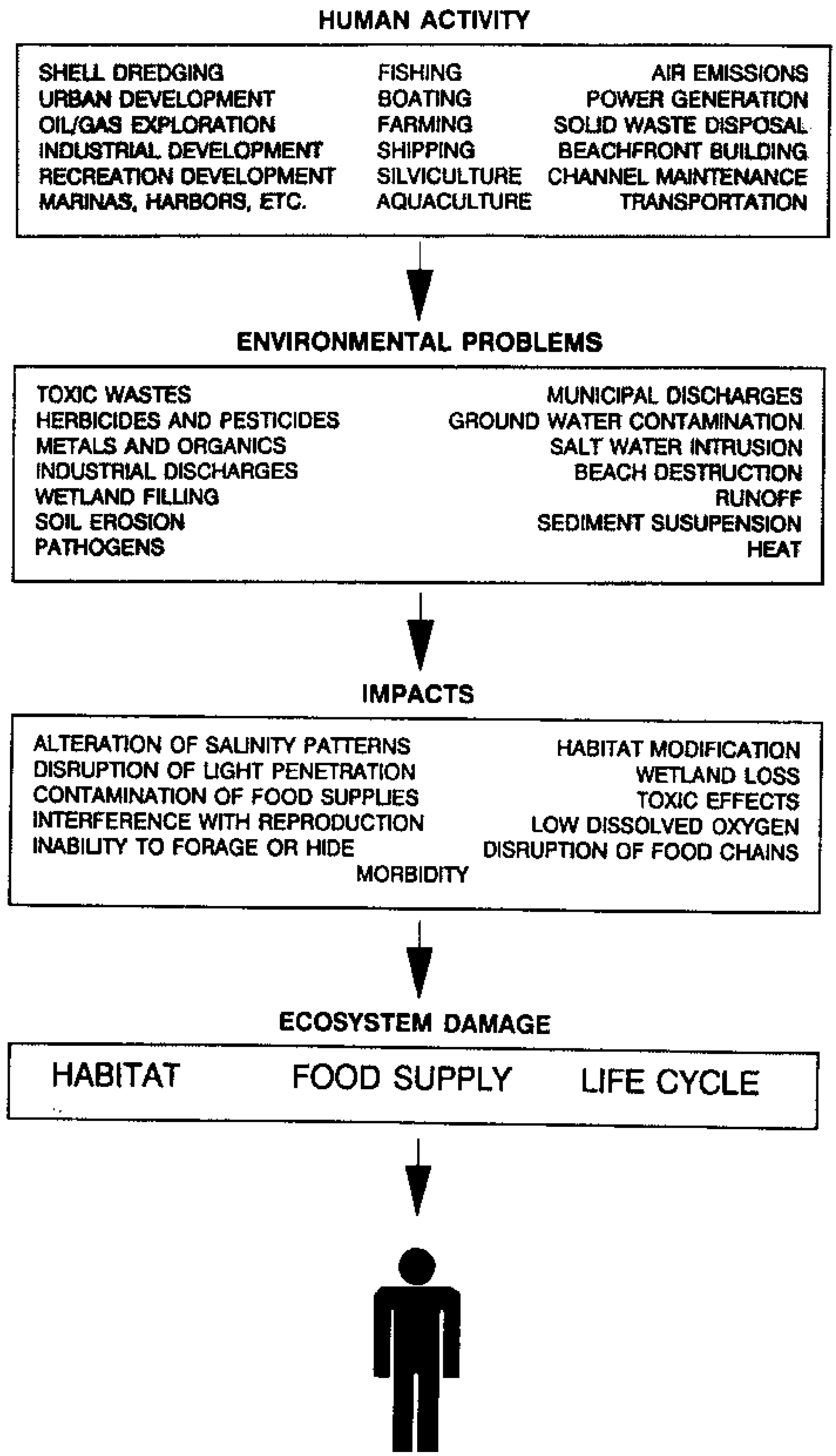
Because of the complexity of natural systems, as well as the fact that the estuary acts as a sink for pollutants, the potential for cumulative impacts from a wide range of discharges and uses is a serious concern. Let us look at a conceptual framework which has been developed recently to facilitate efforts to understand and deal with coastal issues (Fig. 2).

At first glance, this figure may appear complicated. However, upon close inspection, it provides a logical, consistent and simplified method for viewing the activities within the coastal area and their impacts upon the environment and the organisms which the programs are designed to protect.

Table 7. Reasons for public skepticism.

Emelle Landfill
Kepone on the James River
Contamination of Milk and Dairy Cows
Illegal Discharge of Drill Muds into Mobile Bay
Radioactive Emissions of Fernold Weapons Plant
Infectious Wastes on Long Island Beaches
Superfund Sites
Ocean Incineration
Waste Treatment Plant Failures

Figure 2. Coastal resource management cumulative impact hierarchy.



The first box depicts the major types of human activities occurring within the coastal area. These include farming, marinas, harbors, piers and others. All of the different activities that are seen in the first box create environmental problems shown in the second box. Marinas, farming, and urban and industrial development have caused substantial wetland filling during the past decades. Runoff, soil erosion and suspended sediments are produced from industrial plants; toxic waste from farming. Each of these problems in sufficient quantity or at the wrong time of the year can produce substantial impacts within the coastal area - shown in the third box. Wetland loss, habitat modification, disruption of light penetration, contamination of food supply, direct toxic effects, disruption of the food chain and increased mortality are all common examples of the impacts of coastal uses.

The fourth box shows the three major elements of the environment of any living organism, including man: habitat, food supply and the natural life cycle of the organism. Any severe disruption of these three major components of the organism's environment will affect the long-term survivability and the quality of life of the organism, in this case man.

The complexity of the interaction of uses and living resources underline the importance of a comprehensive approach to resource management. The Clean Water Act of 1987 and recent efforts by the U.S. Fish and Wildlife Service to develop "cumulative impact" programs are encouraging signs that the original Coastal Area Board philosophy of direct biological measurement and comprehensive resource management is spreading. This renewed attention can only bring beneficial improvements, funding, technical capabilities and improved regulatory programs.

Oil and Gas Development

One of the largest natural gas finds in the continental United States is located in the Mobile Bay Estuary. The oil companies will be producing from these formations for the next thirty to forty years. There is significant concern on the part of many scientists, regulatory and public individuals that there will be a cumulative impact on coastal resources from the discharge of drilling muds and cuttings into the near-shore Gulf of Mexico and estuarine areas. One of the major challenges facing resource managers is to develop a way to satisfactorily assess the potential impact of these discharges and to protect the coastal resource base.

Rapid Growth

Baldwin County faces tremendous growth on the eastern shore of Mobile Bay and in the south part of the county along the Gulf front. The water, wastewater runoff and wetland issues that surround this development will have to be managed.

Cost Allocation

Another important issue is the equitable allocation of the economic costs of pollution. At the present time, since a substantial amount of the cost is passed on to the public at large, there is an economic benefit for discharging into the waters and the air. An important step was taken recently with the passage of the Ocean

Dumping Ban Act. The Ocean Dumping Ban Act not only removed the incentive of inexpensive tipping fees for ocean dumping, it placed an economic burden on ocean dumping that will encourage industry to seek land-based alternatives. One cannot overstate the importance of economic factors in pollution control. In our society, most of our decisions, and all business decisions, are directed by economic considerations.

Aging Coastal Management Program

The original coastal area management program has been in place for ten years, and several of its provisions deserve reconsideration based on the experience of implementation. With a careful rewrite and an infusion of commitment, the coastal program can once again be an effective tool for resource management.

SUMMARY

With small amounts of funding, the application of talented minds, and persistence by a number of talented scientists and professional resource managers, a series of creative programs have been put in place to manage Alabama's coastal resources.

The list of projects range from boardwalks over the dunes at a State parking lot to pioneering research into the direct measurement of biological resources. From wetland mitigation to land management controls, the leadership of the Coastal Area Board, the Baldwin County Commission and others have pushed us forward, step-by-step, toward our goal of melding economic development with resource protection.

The programs of the Coastal Area Board, however, have run out of steam. The successor agencies have neither embraced these pioneering efforts, nor have they substituted a well-conceived agenda of their own! This failure to embrace the goals and the spirit of ACAMP is widely recognized in the coastal area, and this is undoubtedly one of the underlying factors in the public relations problems suffered by these agencies in Mobile and Baldwin Counties.

If further progress in coastal resource management is to occur, ADECA and ADEM must revitalize the coastal program. They must make the commitment of political resources to design and implement sound technical programs, improve monitoring and enforcement actions, and move beyond water quality standards to direct biological monitoring. If these steps are not taken, very little progress can be expected in the future in the State's efforts to manage our fragile and important coastal resources!

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