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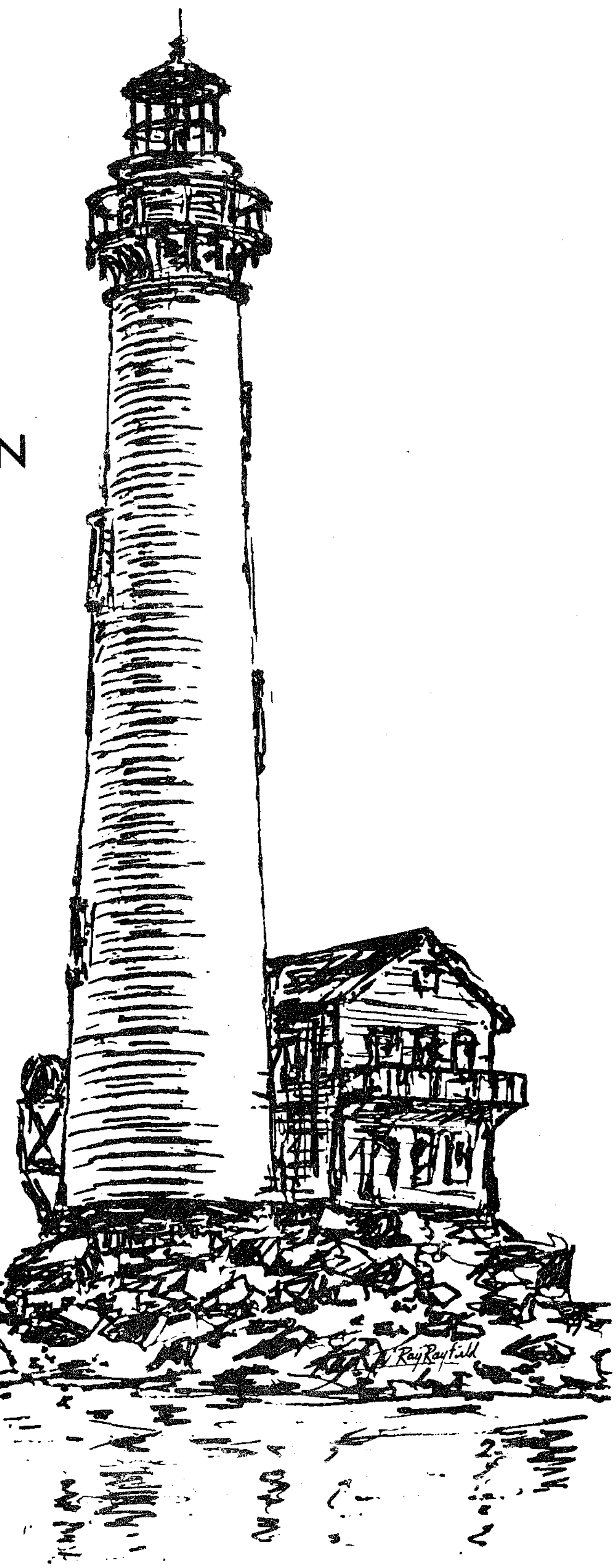
June 1982

ALABAMA COASTAL REGION ECOLOGICAL CHARACTERIZATION

Volume 2

A Synthesis of Environmental Data



Bureau of Land Management

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U.S. Department of the Interior

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ALABAMA COASTAL REGION ECOLOGICAL CHARACTERIZATION
VOLUME 2
A SYNTHESIS OF ENVIRONMENTAL DATA

Edited by

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ERRATA

p. 206 - delete *Rhododendron austrinum* from Federal list

p. 207 - delete *Sarracenia psittacina* from Federal list

NOTE: All plant species listed in table 58 under Federal list are only candidate species and are not on the official Federal list of endangered and threatened species.

p. 137 Under PLANKTONIC ALGAE

- First paragraph - delete sentence "In more complete compilations of the Gulf of Mexico Gulf Surveys (table B-1, Appendix B)."
- Second paragraph - add to beginning of first sentence - "Several dinoflagellates are widely recognized as producing red tides. In the Gulf of . . ."

p. 175 - replace figure

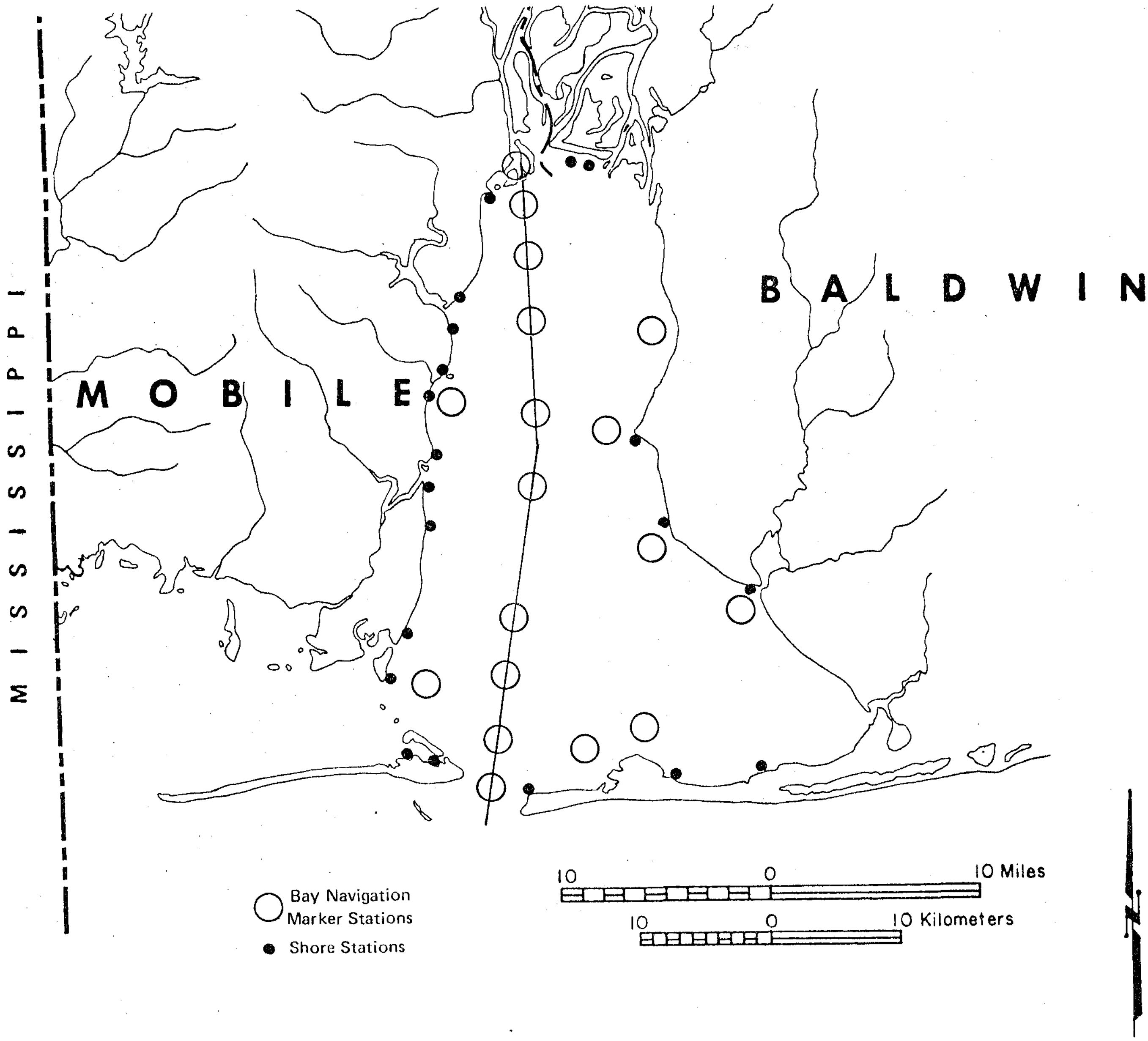

Figure 73. Protozoa collecting stations in Mobile Bay, Alabama (Jones, 1974).

PREFACE

Coastal Alabama, comprising Mobile and Baldwin Counties and adjacent waters, is an important industrial, recreational, and seafood production area in the northern Gulf of Mexico. Contributing factors to its present status include the development of a large port facility and industrial complex, abundant natural resources, numerous recreational opportunities, a substantial transportation network including highways, railroads, and the intracoastal waterway and significant estuarine areas that produce an abundance of seafood. These conditions, enhanced by discoveries of gas and oil in and around Mobile Bay, the development of state-owned and outer continental shelf fossil fuel reserves, and the completion of the Tennessee-Tombigbee Waterway, should provide a prosperous future for this area and Alabama.

Continued urban and industrial expansion in coastal Alabama will necessarily place increased demands on the natural resources of Mobile and Baldwin Counties. One habitat that could be adversely affected by this growth, especially in the immediate coastal area, is the estuary. Estuaries are extremely important to Alabama for several reasons. They provide a nursery ground for many sport and commercial species of animals upon which the seafood industry and sizeable recreational and tourism businesses depend. Estuaries offer a unique habitat for many species of plants and animals that otherwise would not exist in Alabama. Many residents and nonresidents travel to coastal Alabama just to observe these organisms annually, particularly the spring bird migration. One vital but nevertheless often overlooked role of estuaries is waste assimilation. Microscopic organisms collectively known as decomposers chemically break down both organic and inorganic natural and manmade products in the estuary to release essential nutrients that are reused and cycled by estuarine plants and animals including man. Failure to recognize the ecological and hence the economic significance of estuaries in Mobile and Baldwin Counties and to protect their integrity during future growth could result in their irretrievable modification or elimination from Alabama shores.

Recognizing the need for comprehensive resource planning, the U.S. Fish and Wildlife Service initiated the ecological characterization program for selected coastal areas of the United States. These programs, by analyzing all available environmental and socioeconomic data, attempt to describe the important components of coastal ecosystems and the forces that control their internal processes. Recognition of the physical, chemical, and biological systems that exist in our coastal areas and the relationships between them should provide State and local planners, industry, and interested citizens with vital information necessary to conscientiously manage these areas to the future benefit of all who reside there. Copies of this report may be obtained by writing to either of the following addresses:

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SUMMARY

Coastal Alabama contains a variety of natural resources that have contributed to the development of this area into an important industrial, shipping, commercial fishing, and recreational center in the northern Gulf of Mexico. As growth continues, however, supplies of some of these finite resources will diminish in both quality and quantity. Future efficient utilization of these remaining supplies is essential, therefore, and will require conscientious planning by government officials, industry, and local citizens.

The purpose of this report is to summarize all available information on the natural resources of coastal Alabama. Data included herein will be used by the U.S. Fish and Wildlife Service and Bureau of Land Management, Outer Continental Shelf (OCS) office to plan for the development of outer continental shelf oil and gas reserves offshore of Alabama.

The report is divided into two sections. The first section contains a detailed description of the geology and geography, hydrology, climate, plant and animal life, and threatened and endangered species of coastal Alabama. The second section of the report presents a conceptual model and supporting text on four natural ecosystems (freshwater, upland terrestrial, estuarine, and continental shelf) and two manipulated (urban-industrial and agricultural) systems in Mobile and Baldwin Counties. Also included are individual models for the estuarine ecosystem and one of its components, the marsh.

CONTENTS

CONTENTS

CONTENTS

FIGURES

FIGURES. Continued.

TABLES

TABLES. Continued.

TABLES. Concluded.

ABBREVIATIONS AND SYMBOLS

ATP	adenosine triphosphate
BOD	biochemical oxygen demand
°C	degrees Celsius
ft^3/s	cubic feet per second
$ft^3/s/mi^2$	cubic feet per second per square mile
cm	centimeter
°F	degrees Fahrenheit
f/s	feet per second
ft	feet
ft^2	square feet
ft/mi	feet per mile
gcal	gram-calories
$gcal/cm^2/min$	gram-calories per square centimeter per minute
g/m^2	grams per square meter
gal/min	gallons per minute
ha	hectare
h	hour
kg/cm^2	kilograms per square centimeter
kg/m^2	kilograms per square meter
km	kilometer
km^2	square kilometer
km^3	cubic kilometer
km/h	kilometers per hour
lb/ft^2	pounds per square foot
l/min	liters per minute
l/s	liters per second
m	meter
m^2	square meter
m^3	cubic meter

ABBREVIATIONS AND SYMBOLS. Concluded.

m/km	meters per kilometer
Mgal/d	million gallons per day
mg/l	milligram per liter
mg/m^2	milligrams per square meter
mg/m^3	milligrams per cubic meter
$\mu g/g$	micrograms per gram
$\mu g/l$	micrograms per liter
$\mu g/m^3$	micrograms per cubic meter
mi	mile
mi^2	square mile
mi^3	cubic mile
mm	millimeter
mi/h	miles per hour
MPN	most probable number of colonies
m/s	meters per second
MSL	mean sea level
NPP	net primary productivity
ppt	parts per thousand
ppb	parts per billion
ppm	parts per million
sp.	species (singular)
spp.	species (plural)
ssp.	subspecies
var.	variety
yds^3	cubic yards
$>$	greater than
$<$	less than

ACKNOWLEDGMENTS

Various agencies and individuals contributed information for use in this report. The Alabama Department of Conservation, Marine Resources Division, Marine Environmental Sciences Consortium, and the Coastal Area Board were particularly helpful in furnishing data or assisting in manuscript review. Scott Schomer of Tallahassee, Florida, was instrumental in developing the conceptual models of energy flow in coastal Alabama.

INTRODUCTION

Coastal Alabama is composed of Mobile and Baldwin Counties and associated State waters. Although small in area compared to other gulf states, coastal Alabama possesses a diverse network of natural and manmade ecosystems. Four natural ecosystems (coastal terrestrial, stream and freshwater, estuarine, and continental shelf) and two developed (urban-industrial and agricultural) systems are identified within a simplified model of energy flow in coastal Alabama (Figure 1). Climatic energy sources include sunlight, winds, tides, and precipitation and are collectively known as forcing functions because they drive ecosystems through energy transformations and transfers. Upstream inputs include among other things dissolved nutrients, organic matter, sediments, and flow. Although the urban-industrial and agricultural systems are controlled in part by natural ecosystems in the area, they are primarily subsidized by imported goods and services. Examples of these energy sources include fossil fuels, fertilizers, transportation (cars, trucks, ships, trains), clothes, pesticides, paper, foods, and other manufactured products to mention a few. Within each ecosystem exists a number of interacting components such as ground water and surface water.

Energy received or produced within a particular ecosystem may be consumed wholly or in part by the system or it may be transferred as an energy input to another system. As an example, water borne nutrients in freshwater drain into the estuarine ecosystem where they are partially used or cycled by plants in their primary productivity role. Ultimately, some of these nutrients will enter the continental shelf ecosystem where they may remain indefinitely or they may be utilized as food by microscopic plants known as phytoplankton. Phytoplankton are eaten by microscopic animals collectively known as zooplankton and these organisms are in turn preyed upon by large fishes who are eaten by larger fishes. Many of these fishes spawn in the gulf and their larval offspring enter Alabama estuarine areas to spend the early stages of their lives. Other transient and permanent estuarine species actually spawn in the estuaries proper. During this time, these organisms are subject to predation by larger animals, including man, or they may die of natural causes. In any case, nutrients that originated from freshwater input were moved to the estuarine and subsequently the continental shelf ecosystems, then recycled back into the estuarine and freshwater ecosystems. Recognition of these energy utilization and recycling pathways in each ecosystem affords a clearer understanding and appreciation of how adverse environmental impacts may be received by one system and, in turn, will affect another.

This report has been organized into two major sections: (1) a descriptive text on the geologic, hydrologic, and climatic conditions of Mobile and Baldwin Counties and (2) an indepth discussion of the plant and animal life and endangered species that occur in the area. The second portion of the paper is devoted to a synthesis and analysis of the various structural components of the model shown in Figure 1. Included within this portion are more technical descriptive models of the entire coastal area of Alabama, the estuarine ecosystem and the marsh component of the estuary. Indepth discussions of some environmental parameters have been limited due to a lack of data. Notations of these data deficiencies are made in the individual sections.

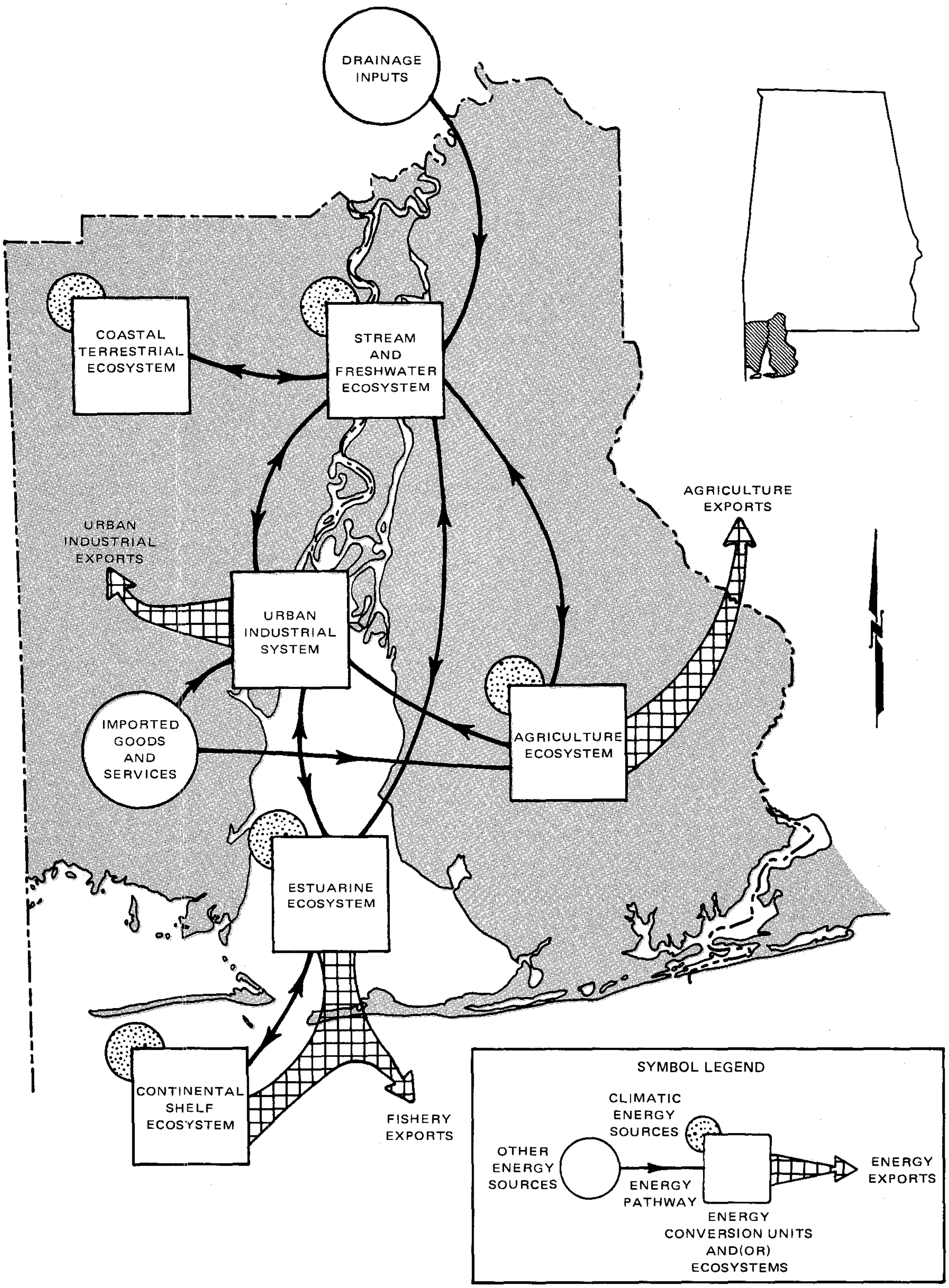


Figure 1. Simplified energy-flow diagram for coastal Alabama.

GEOLOGY

By Charles W. Copeland

GEOGRAPHY

Coastal Alabama lies within parts of two major physiographic provinces: the East Gulf Coastal Plain section of the Coastal Plain province and the Mississippi-Alabama shelf section of the Continental Shelf province. Land areas in coastal Alabama are within the Southern Pine Hills and the Coastal Lowlands subdivisions of the East Gulf Coastal Plain section (Figure 2). Offshore Alabama lies within the Mississippi-Alabama shelf section of the Continental Shelf province. Material presented in this description of the geography of the coastal area has been modified from Boone (1974) and Hardin et al. (1976).

SOUTHERN PINE HILLS

The Southern Pine Hills are a moderately dissected, southward-sloping plain developed on gravelly sands and clays of Miocene to Pleistocene age. Sediments of the Miocene Series, undifferentiated, crop out in the northern part of the subdivision and sediments of the Citronelle Formation of Pliocene age crop out in the southern part.

In coastal Alabama, the Southern Pine Hills comprise the elevated interfluves between the Escatawpa, Mobile-Tensaw, and Perdido Rivers. The Southern Pine Hills range in altitude from about 30.4 m (100 ft) near the coast to about 91.4 m (300 ft) in the northern parts of Mobile and Baldwin Counties. Relative relief from valley floors to hill crests is greatest in the northern part of the counties where stream valleys are incised as much as 61 m (200 ft). In the southern parts of Mobile and Baldwin Counties, the topography is more subdued and relative relief from valley floors to hill crests is generally less than 30.4 m (100 ft). Numerous shallow, saucer-like depressions, which hold water most of the year, are scattered over the nearly level interfluves. These depressions are underlain by compacted clayey sediments in the Citronelle Formation and are more abundant in Baldwin County.

COASTAL LOWLANDS

The Coastal Lowlands (Figure 2) is an essentially flat to gently undulating plain extending along the coast adjacent to Mississippi Sound and along the margins of Mobile, Bon Secour, and Perdido Bays (Cooke 1939). The Coastal Lowlands merge inland with the alluvial-deltaic plains of the Mobile-Tensaw and Perdido fluvial systems and smaller streams of the area and extend northward along the Tombigbee and Alabama Rivers. The lowlands range in altitude from sea level to about 9.1 m (30 ft) and in width from almost 0 to approximately 16.1 km (10 mi). The Coastal Lowlands belt in the alluvial-deltaic plains of the Mobile and Tensaw Rivers is from 11.3 to 16.1 km (7 to 10 mi) wide. To the south, the lowlands undulating plain along the western side of Mobile Bay and north shore of Mississippi Sound is from 3.2 to 8 km (2 to 5 mi) in width. On the eastern side of Mobile Bay between the Battleship Parkway and Point Clear, the lowlands is a narrow strip of land from 61 to 305 m (200 to 1,000 ft) in width. From Point Clear southward, along Mobile Bay and the margins of Bon Secour Bay, the lowlands strip is a more pronounced topographic feature ranging in width from 0.8 to 2.4 km (0.5 to 1.5 mi). Along the southern boundary of

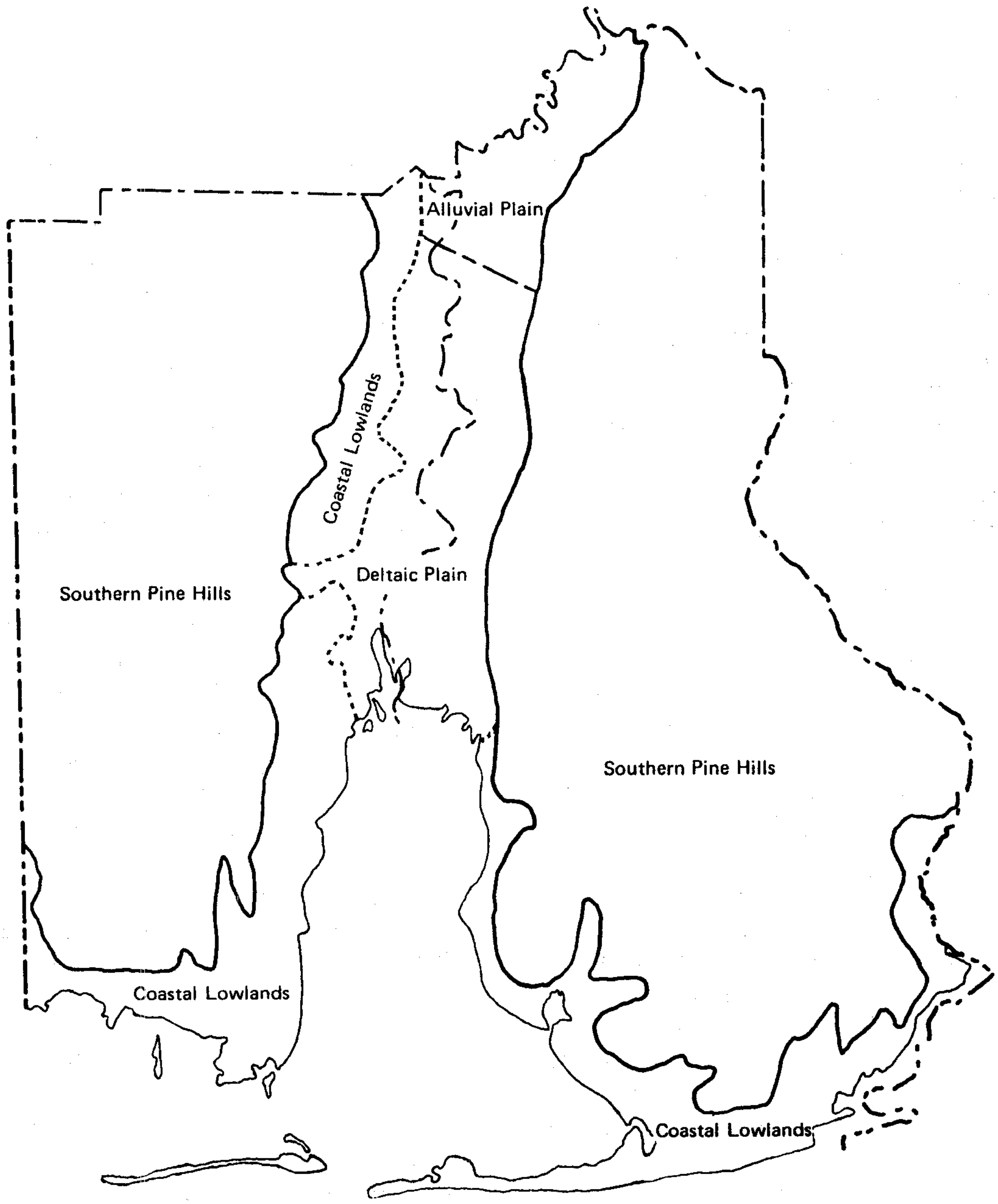


Figure 2. Physiographic subdivisions of coastal Alabama.

Baldwin County that parallels the Gulf of Mexico, the Coastal Lowlands subdivision is from 3.2 to 8 km (2 to 5 mi) in width.

The lowlands are indented by many tidewater creeks, rivers, and estuaries and are fringed by tidal marshes, all of which are subject to inundation at high tide. Fresh-water swamps border the tidal marshes along the north side of Mississippi Sound. Alluvial, deltaic, estuarine, and coastal deposits of Pleistocene and Holocene age underlie the Coastal Lowlands.

The Southern Pine Hills and Coastal Lowlands are separated by erosional escarpments with relief up to 30.4 m (100 ft). The escarpments generally coincide with the geologic contacts of resistant Tertiary sediments with the less resistant Pleistocene and Holocene sediments that underlie the Coastal Lowlands. At their seaward margin, the escarpments are parallel to Mississippi Sound and the Gulf of Mexico. Throughout the coastal area and particularly along the eastern side of Mobile Bay north of Point Clear, the erosional escarpment is a pronounced topographic feature. The erosional escarpments northward from the gulf curve and extend inland forming subparallel-facing escarpments that parallel the streams of the area. Carlston (1950) has interpreted the southern part of these erosional escarpments as marine wave-cut scarps of Pamlico (Pleistocene) age.

BARRIER ISLANDS AND SPITS

Dauphin Island, Mobile Point-Fort Morgan peninsula, and Perdido Key are islands or spits of the Mississippi Sound barrier-island system and western Florida barrier-spit-and-island system. Dauphin Island has a broad, well-developed beach backed by dunes on the gulf side. Beach and intermittent marsh backed by dunes occur on the mainland side of the island. Dunes average 3 to 6 m (10 to 20 ft) in altitude with a maximum of 12.2 m (40 ft) on the eastern end (Boone 1973). Dauphin Island is 24.35 km (15.13 mi) long and varies from 305 to 549 m (1,000 to 1,800 ft) wide across the western sandy spit to 2.6 km (1.6 m) wide across the forested main body of the island near the eastern end.

Dauphin Island is being elongated primarily by the accretion of sediment to its western end. Accretion has extended the western end of the island about 6.4 km (4 mi) in the last 100 years (May 1971a). Erosion is active on the eastern end but has not caused significant westward migration of that part of the island. Marsh deposits and tree stumps exposed in the surf zone indicate significant erosion on the gulf side of the island.

Mobile Point-Fort Morgan peninsula is a large spit attached to the mainland on the east and extends westward, forming part of the southern margin of Mobile Bay. The western part of the peninsula consists of broad, well-developed beaches backed by lines of discontinuous dunes that reach a height of 6 m (20 ft). Several large lagoons and marsh areas lie between the gulf beaches and the mainland in the eastern part of the peninsula. Several sets of intersecting dune ridges indicate a complex depositional history for this spit.

Perdido Key is a narrow peninsula connected at about its midpoint to the mainland. Dunes are as much as 6 m (20 ft) high in the central part and decrease in height and frequency toward each end (U.S. Army Corps of Engineers 1971).

The surface of the shelf is relatively smooth in the west, but it becomes irregular east of Mobile Point. Ridges and valleys with relief up to 9.1 m (30 ft) occur on the sea floor in the area. These ridges and valleys are relict features of subaerial erosion resulting from lower stands of the sea during the Pleistocene. Linear valleys, off the mouths of rivers in the area, cross the shelf and probably represent the partly filled valleys these streams occupied during lower stands of the sea.

MISSISSIPPI-ALABAMA SHELF

The Mississippi-Alabama shelf is a triangular area, on the seaward side of the barrier islands, extending from the Mississippi River delta on the west side to DeSoto Canyon on the east side (Figure 3). The shelf is about 128.7 km (80 mi) wide in the west and narrows to about 56.3 km (35 mi) in the east. The shelf is an extensive, almost flat plain bounded on the landward side by the relatively steep but narrow shoreface of the Mississippi Sound and western Florida barrier systems. The break in slope between shoreface and shelf occurs at a depth of about 6 m (20 ft) along the Mississippi Sound barrier-island system and as far east as Pensacola Bay.

The shoreface has a gradient of from 9.4 to 11.3 m/km (50 to 60 ft/mi). The shelf has a gradient of 0.6 m/km (3.2 ft/mi) off Dauphin Island and 1.6 m/km (8.5 ft/mi) off Pensacola Bay. At a depth of approximately 54.9 m (180 ft), the slope increases to about 5.9 m/km (31 ft/mi) (Upshaw et al. 1966).

INSHORE WATER BOTTOMS

Water and water bottoms within the coastal area of Alabama include Mobile Bay, Mississippi Sound, and Perdido and Wolf Bays (Figure 4) and all tributaries of these larger water bodies. Descriptions of navigation channels in the inland waters and their physical dimensions are included in Table 1.

MOBILE BAY

Mobile Bay is a submerged river valley about 49 km (31 mi) long from Battleship Parkway at the northern end to the Gulf of Mexico at the southern end. The bay is about 37 km (23 mi) across at its widest portion between Mississippi Sound and the eastern shore of Bon Secour Bay. The average width is 17.4 km (10.8 mi). The bay is relatively shallow, with an average depth of 3 m (9.7 ft) in areas outside the Mobile ship channel, which has an average depth of 11.3 m (37 ft) (Crance 1971). The opening of Mobile Bay into the Gulf of Mexico between Dauphin Island on the west side and Mobile Point on the east side is slightly more than 4.8 km (3 mi) wide. Mobile Bay is connected to Mississippi Sound through Pass aux Herons, which is about 1.6 km (1 mi) wide. The exchange of water between Mobile Bay and Mississippi Sound is affected by bridges and auxiliary structures that connect the mainland and Dauphin Island.

Several rivers, which are distributaries of the Mobile River system, flow into the northern part of the bay. Dog River and Fowl River also drain into the bay from the western side, and Fish River and Magnolia River drain into the bay from the eastern side.

MISSISSIPPI SOUND

The Alabama portion of Mississippi Sound is 25.7 km (16 mi) long as measured from the former Dauphin Island bridge westward to the Mississippi-Alabama boundary. The sound is bounded on the south side by Dauphin Island. Mississippi Sound opens directly into the Gulf of Mexico west of Dauphin island through Petit Bois Pass which is 8.3 km (5.1 mi) wide. Mississippi Sound connects with Mobile Bay on the east side through constricted openings in the Dauphin Island bridge, presently being reconstructed.

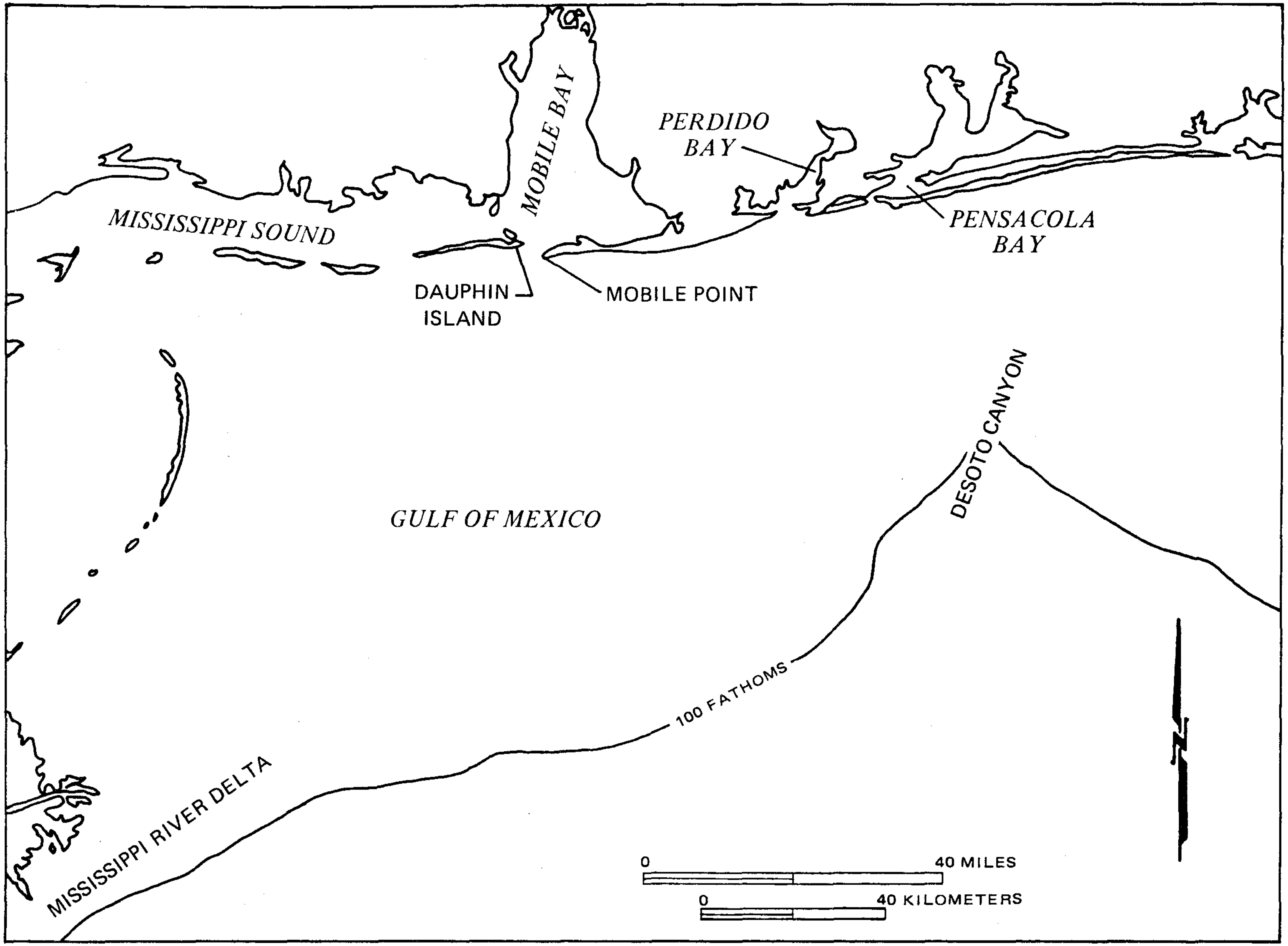


Figure 3. Mississippi-Alabama Shelf section of the Continental Shelf province (Boone 1973).

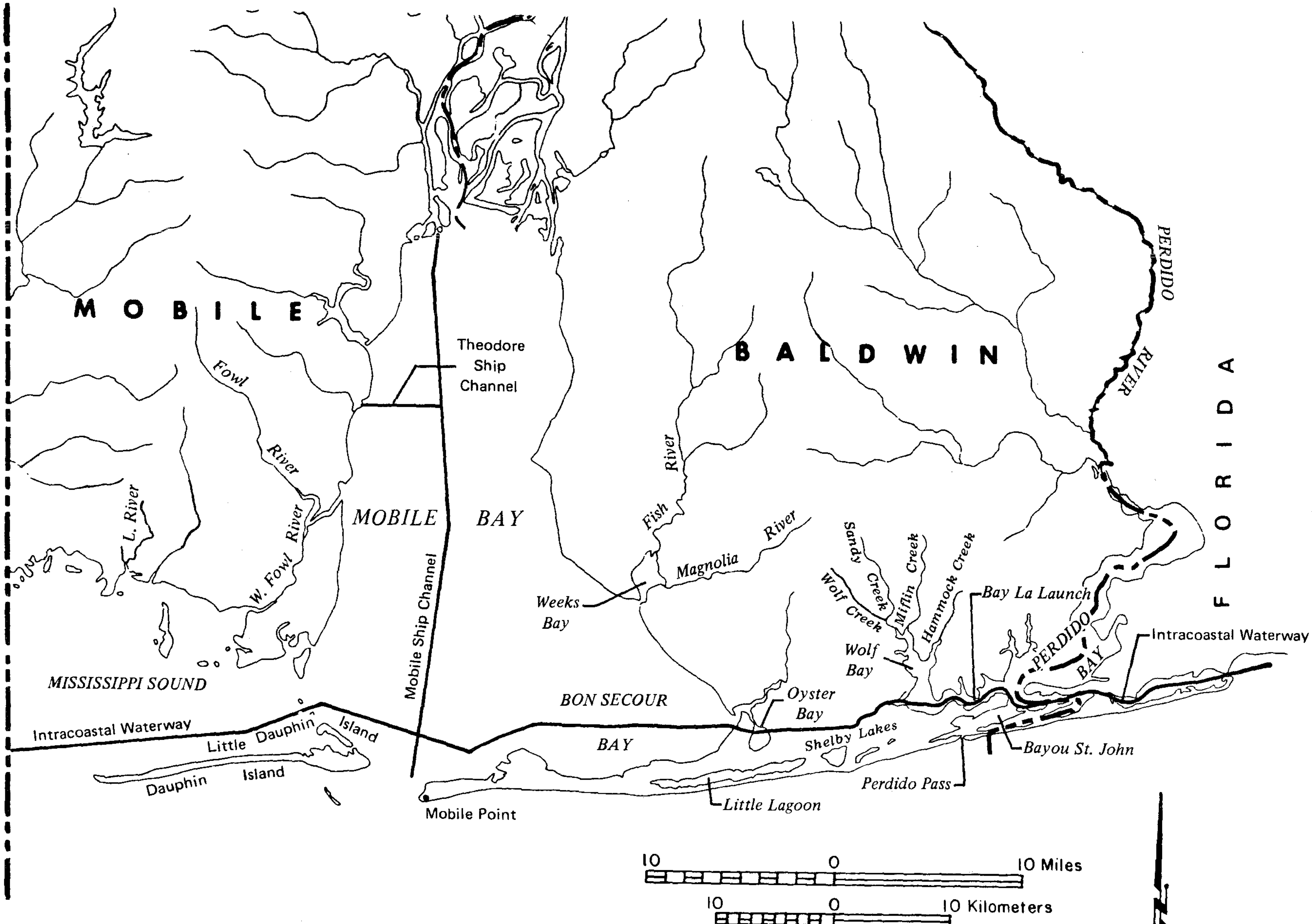


Figure 4. Inshore water bottoms.

Table 1. Navigation channels in Alabama estuaries (Crance 1971).

Estuary and channel	Length (mi)	Width (ft)	Surface area (acres)	Controlling depth (ft)	Stage of completion	Agency
Mississippi Sound						
Intracoastal Waterway	8.5	150	155	12.0	C[a]	CE[b]
Bayou La Batre	7.8	75-100	82	11.2	C	CE
Coden	2.9	60-100	28	8.0	C	CE
Aloe Bay	1.6	100	19	6.5	C	CE
Government Cut	1.2	40-150	15	4-7	C	CE
Dauphin Island Bay	3.0	40	15	7.0	C	LI
Graveline Bay	0.8	40	4	7.0	C	LI
Alabama Marine Science Institute	1.5	40	7	5.0	C	LI
Subtotal	27.3		325			
Mobile Bay						
Mobile Ship Channel	29.0	400	1,409	37.0	C	CE
Intracoastal Waterway	15.1	125-150	251	12.0	C	CE
Arlington Channel	1.4	150	26	21.5	C	CE
Garrows Bend	1.1	150	20	21.5	C	CE
Garrows Bend Turning Basin	0.2	600	15	21.5	C	CE
Hollinger Island	4.0	175	85	11.0	C	ASD
Deer River (Theodore Barge Canal)	1.9	150	35	12.0	C	ASD
Fly Creek	0.4	80-100	4	6.0	C	CE
Bon Secour River	4.5	80	44	6-10	C	CE
Dog River	7.8	100-150	118	6- 8	P	CE
Fowl River	2.6	100	32	8.0	P	CE
Theodore Ship Channel	7.2	300-400	306	40.0	UC	CE
Subtotal	75.2		2,345			
Mobile Delta						
Mobile Ship Channel to Chickasaw Creek	4.9	500-1,000	446	38.0	C	CE
Chickasaw Creek	2.6	250	79	17.0	C	CE
Three Mile Creek	1.0	150	18	12.0	C	ASD
Industrial Canal	1.2	150	22	12.0	C	ASD
Mobile River	14.0	200	340	9.2	C	CE
Subtotal	23.7		905			
Perdido Bay						
Intracoastal Waterway	17.9	125	272	120	C	CE
Perdido Pass	1.9	100-125	29	6.3-9.0	C	CE
Subtotal	19.8		301			
Total	146.0		3,876			

[a] C--completed, P--proposed, UC--under construction.

[b] CE--Corps of Engineers, LI--local interests, ASD--Alabama State Docks.

The average depth of the sound is 3.6 m (11.7 ft) at mean high water (Crance 1971). The width of the sound in Alabama gradually increases from east to west and is about 8 km (5 mi) wide near the eastern end and 20 km (12.5 mi) wide near the Mississippi-Alabama boundary.

PERDIDO AND WOLF BAYS

Perdido and Wolf Bays are apparently drowned river and stream valleys, respectively. Wolf Bay is located in the southeastern part of Baldwin County and Perdido Bay occurs along the boundary between Baldwin County, Alabama, and Escambia County, Florida (Figure 4). Wolf Bay is connected to Perdido Bay by Bay La Launch, a narrow body of water essentially parallel to the coastline and about 5.1 km (3.2 mi) long. Both bays are connected to the Gulf of Mexico through Bayou St. John and Perdido Pass.

The long axis of Perdido Bay trends approximately N.40°E., and the bay including Bayou St. John is about 27 km (17 mi) long. The widest point of the bay, southeast from Red Bluff, is about 5 km (3 mi). The average water depth according to Crance (1971) is 2.4 m (7.9 ft). Water depths slightly in excess of 4.9 m (16 ft) occur in areas near Perdido Beach in the western part of the bay. Marshy areas of the bay are mainly confined to the northwestern part near where the Perdido River flows into the bay.

The long axis of Wolf Bay trends approximately N.10°W. The bay, excluding Bay La Launch, is about 7 km (4 mi) long and the widest point near the southern end is 3.8 km (2.4 mi). Water depths in the bay are shallow and the deepest parts are slightly in excess of 2.7 m (9 ft). Wolf, Sandy, Miflin, and Hammock Creeks flow into Wolf Bay at the northern end. Tidal flats and marshes occur in the northern part of the bay and along the western side.

SUBSURFACE STRATIGRAPHY

The coastal and offshore regions of Alabama are underlain by sediments that range from pre-Jurassic to Holocene (Figure 5). These rock units possibly are more than 7,620 m (25,000 ft) thick at the coast (Moore 1971) and dip southward at 1.9 to 9.4 m/km (10 to 50 ft/mi) except where affected locally by structural features. This thick section of sedimentary rock lies unconformably upon metamorphic and igneous rocks of unknown age. Thicknesses offshore are not known but should be similar.

Generalized representations of the stratigraphy in southern Mobile and Baldwin Counties are shown on Figures 6 and 7 that have been compiled from the sample descriptions of oil test wells in the area.

PRE-COASTAL PLAIN BASEMENT COMPLEX

The lithologic character and relative ages of rocks comprising the igneous and metamorphic basement complex underlying the Coastal Plain sediments are poorly known. Two wells drilled in southern Mobile County have penetrated the basement complex. One of the wells, drilled in sec. 24, T.3S., R.4W., penetrated chlorite schist of the basement complex at a depth of 6,054 m (19,862 ft) below land surface; and the other, drilled in sec. 11, T.6S., R.4W., penetrated quartz mica schist at a depth of 5,743 m (18,842 ft) below land surface. The basement complex has not been penetrated by oil test wells in Baldwin County.

JURASSIC SYSTEM

Rocks of Jurassic age in coastal Alabama are about 1,524 m (5,000 ft) thick. At the base of the Jurassic rock are mainly salt, sandstone, dolomite and limestone with interbedded evaporite deposits of salt and

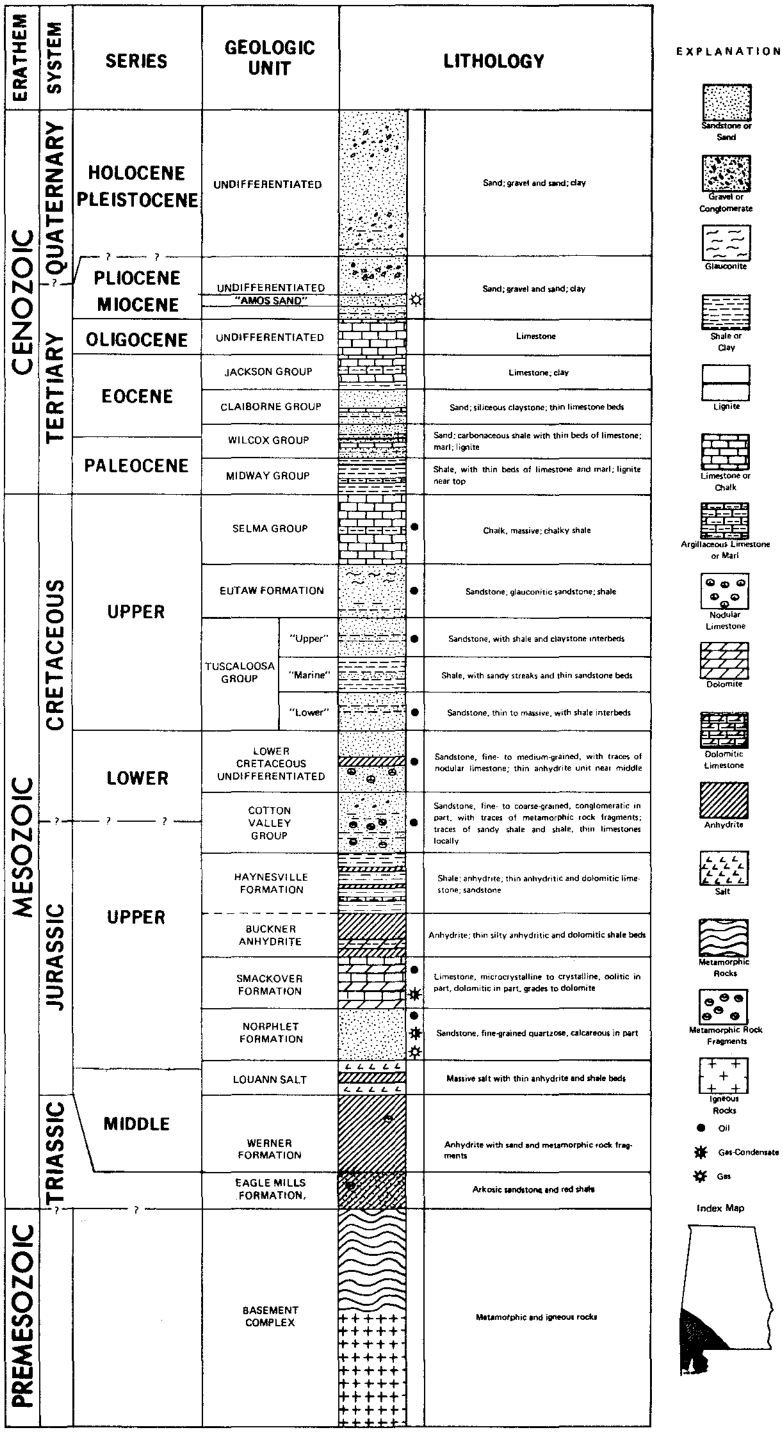


Figure 5. Generalized stratigraphic column in oil and gas producing areas in southwest Alabama.

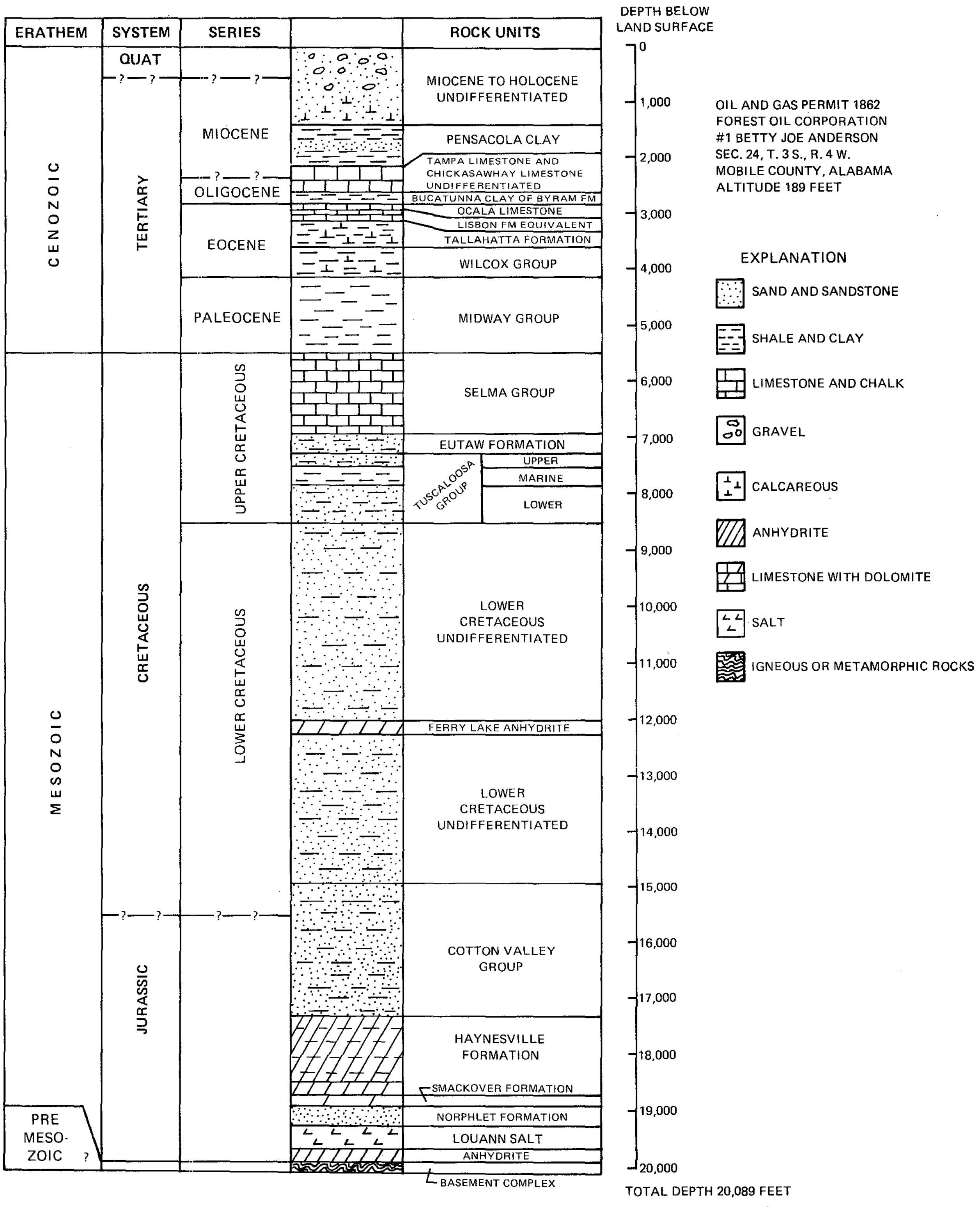


Figure 6. Columnar section of well in Mobile County.

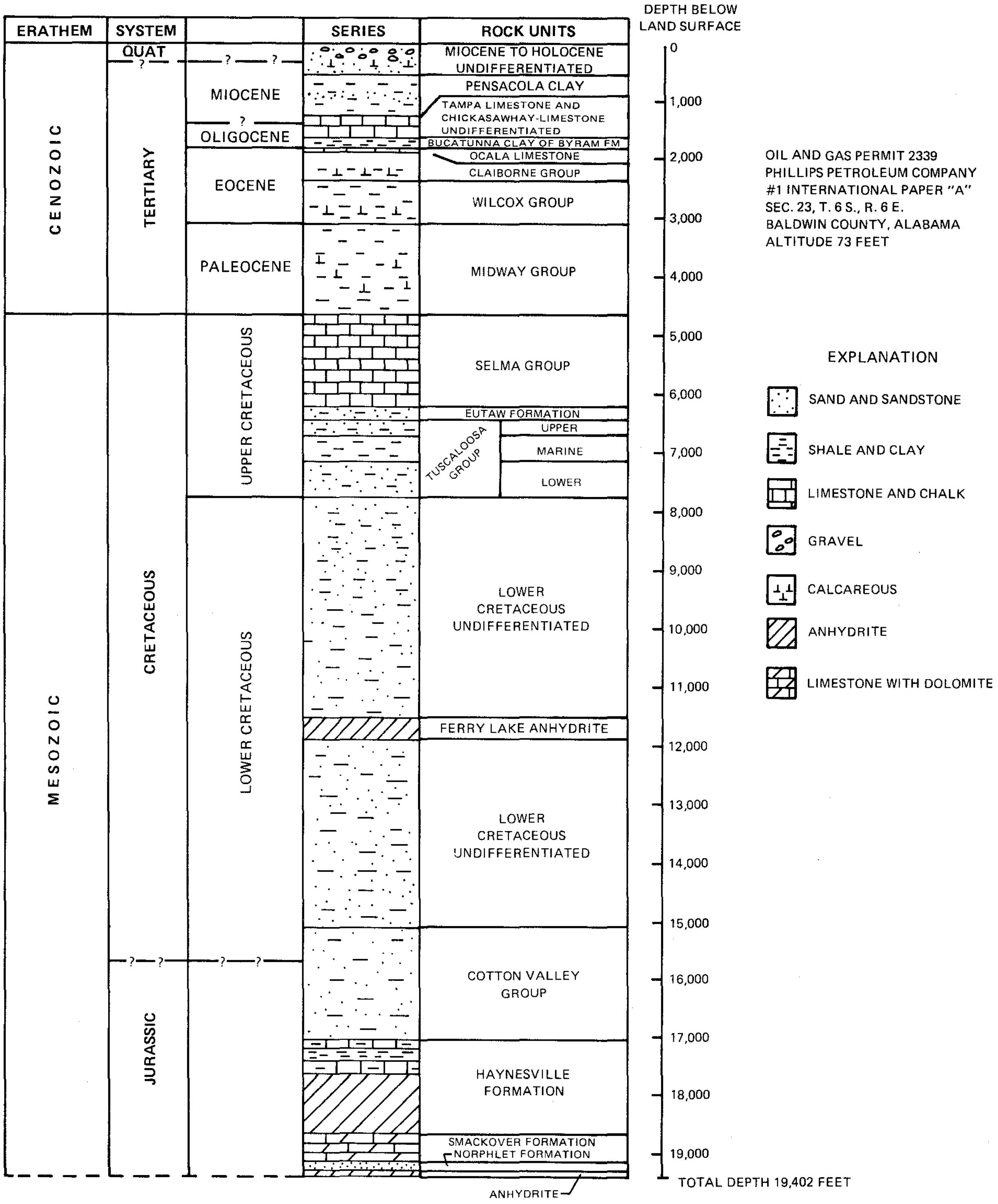


Figure 7. Columnar section of well in Baldwin County.

anhydrite. The upper part of the Jurassic consists mostly of terrigenous clastic deposits of shale and sandstone. In south Alabama, rocks of Jurassic age are assigned, in ascending order, to the Louann Salt, the Norphlet, Smackover and Haynesville Formations, and the Cotton Valley Group. Gas, gas condensate, and oil are produced from the Norphlet and Smackover Formations.

CRETACEOUS SYSTEM

LOWER CRETACEOUS SERIES

Lower Cretaceous sediments in coastal Alabama are mainly terrigenous clastics and consist mostly of interbedded sandstone and shale with pink nodular limestone and red and green shale in the upper part. An evaporite sequence consisting of anhydrite and limestone occurs near the middle of the section. The sediments are about 1,219 to 1,524 m (4,000 to 5,000 ft) thick in coastal Alabama. The Lower Cretaceous Series generally is not subdivided in south Alabama outside the Citronelle oil field. Oil is produced from the Lower Cretaceous in Mobile County, and minor quantities of oil were produced from the Lower Cretaceous in an abandoned field in Baldwin County.

UPPER CRETACEOUS SERIES

The Upper Cretaceous formations include beds of chalk, clay, and sand deposited as shelf and near-shore sediments in marine environments; and beds of gravelly sand, sand, and clay deposited in marine, transitional, and non-marine environments that include estuarine and fluvial-deltaic deposits of regional extent. The strata are 914 m (3,000 ft) thick and dip southward at 9 to 13.7 m/km (30 to 45 ft/mi) except where affected locally by structural features. In south Alabama deposits of Late Cretaceous age are assigned in ascending order to the Tuscaloosa Group, the Eutaw Formation, and the Selma Group. Oil is produced from the lower part of the Tuscaloosa Group in an eastern extension of the South Carlton field in northwestern Baldwin County.

TERTIARY SYSTEM

In coastal Alabama the Tertiary formations consist predominantly of marine and estuarine clastic rocks with interbedded marine carbonates. The section is about 1,524 m (5,000 ft) thick and, in ascending order from oldest to youngest, is composed of the Midway Group of the Paleocene Series; the Wilcox, Claiborne, and Jackson Groups of the Eocene Series; the Vicksburg Group and the Chickasawhay Limestone of the Oligocene Series; the Miocene Series that includes the Tampa Limestone and Pensacola Clay near the coast which intertongue with and are overlapped northward by undifferentiated coarse clastics; and the Citronelle Formation of the Pliocene-Pleistocene Series.

The Quaternary System in coastal Alabama includes terrace deposits of the Pleistocene Series and fluvial, fluvial-deltaic, estuarine and beach, dune, and other coastal deposits of the Pleistocene and Holocene Series. Due to subaerial erosion of the exposed Tertiary units that occurred during sea level fluctuations of the Pleistocene Epoch, prior to and during deposition of the Quaternary units, the Quaternary units at places in Baldwin and Mobile Counties unconformably overlie much older stratigraphic units (Figure 8).

SURFACE STRATIGRAPHY

Surface geologic units of the coastal and offshore areas consist of unconsolidated sand, gravel, silt, and clay of Miocene through Holocene ages. The Miocene Series and Citronelle Formation crop out in bands that strike northwest and dip southwest. The Miocene strata generally dip 1.9 to 9.4 m/km (10 to 50 ft/mi) and strata in the Citronelle, 0.9 to 2.3 m/km (5 to 12 ft/mi). Lesser dips may be associated with folding that is present in the subsurface. Terrace deposits are generally parallel to the Mobile River system and Mobile Bay and slope gently toward the Gulf of Mexico. The alluvial and coastal deposits are relatively flat lying.

Strata are disrupted by faulting in the subsurface in the northern part of the area; however, evidence of faulting at the surface is obscured by deep weathering or the lithologic similarity of displaced beds.

MIOCENE SERIES UNDIFFERENTIATED

The Miocene Series overlies the Oligocene Series in the subsurface and crops out in the central and northern parts of Mobile and Baldwin Counties (Figure 8). It generally ranges in thickness from 122 m (400 ft) in the northern part of the area to about 914 m (3,000 ft) at the coast. The Tampa Limestone and Pensacola Clay described by Marsh (1966) are confined to the subsurface and are readily recognizable on electric logs of oil test wells that were drilled along the coast and northward for a distance of about 19.3 km (12 mi) in both Mobile and Baldwin Counties. In the outcrop the Miocene Series undifferentiated consists of laminated to massive marine and estuarine fine and coarse clastic deposits. The deposits consist of gray, orange, and red, very fine- to coarse-grained sand; red ferruginous sandstone; and gray, olive, blue, and green sandy silty clay. Locally, the sand contains very fine to medium quartz pebble gravels and silicified and carbonized plant material. Carbonized leaf remains occur at places in the clay beds.

In Mobile and Baldwin Counties, the upper part of the Miocene Series is a principal source of ground-water supplies. Natural gas has been discovered in sand beds within the Pensacola Clay in southern Baldwin County. The wells are shut-in at present pending completion of a pipeline.

PLIOCENE AND PLEISTOCENE SERIES—CITRONELLE FORMATION

The Citronelle Formation overlies the Miocene Series and crops out in the central and southern parts of the area; in the northern part of the area, it caps high hills and ridges as outliers. The formation ranges in thickness from around 30 m (100 ft) in updip areas to 60 m (200 ft) in the southern parts of Mobile and Baldwin Counties (Reed 1971b).

The Citronelle Formation consists chiefly of brown, red, and orange gravelly sand that locally contains clayballs and partings, and gray, orange, and brown lenses of sandy clay. Gravels in the formation are mainly very fine to medium subangular to rounded quartz and chert pebbles. The base of the formation is generally marked by a ferruginous sandstone that contains quartz and minor amounts of chert gravel. The Citronelle is difficult to map and is easily confused with the underlying Miocene deposits and the terrace deposits that occur along the major streams. However, the terrace deposits dip southward much less steeply at a rate of only 0.2 to 0.4 m/km (1 to 2 ft/mi) and careful mapping procedures facilitate differentiation of the units.

PLEISTOCENE SERIES—TERRACE DEPOSITS

Gravelly sand fluvial deposits underlie relatively flat surfaces or terraces in northern Mobile and Baldwin Counties that formed during the Pleistocene Epoch when beds of ancestral rivers of the Mobile River system occupied higher levels than at present. As the streams eroded downward, additional terrace surfaces formed and deposits of alluvium accumulated. Two levels of high terrace deposits are prominent in Mobile and Baldwin Counties. The oldest or highest terrace in Mobile County is at an altitude from 58 to 61 m (190 to 200 ft) and has been mapped in areas northwest of Mount Vernon. The

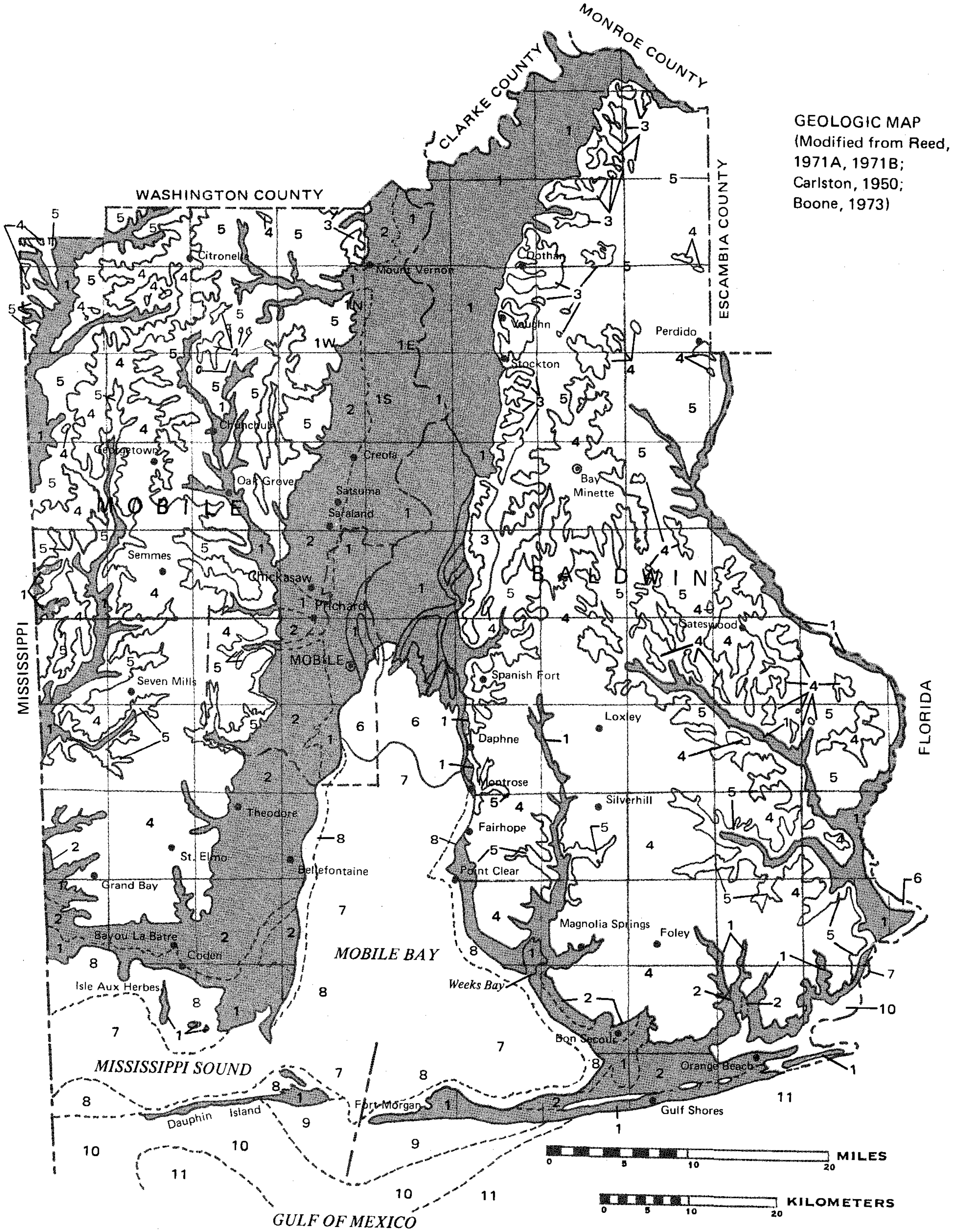


Figure 8. Geologic map of Baldwin and Mobile Counties and generalized distribution of offshore sediments (modified from Carlston 1950, Reed 1971a, and Boone 1973).

		ONSHORE	Number on map	OFFSHORE	Number on map
QUATERNARY	Holocene	Alluvium and coastal deposits	1	Subaqueous sediments: Deltafront and prodelta sand and clay Estuarine clay and silt Bay margin sand Tidal delta Nearshore fine-grained facies	 6 7 8 9 10
QUATERNARY	Holocene	Low terrace deposits	2		
QUATERNARY	Pleistocene	High terrace deposits	3		
QUATERNARY	Pleistocene			Mississippi—Alabama sand facies	11
TERTIARY	Pliocene	Citronelle Formation	4		
TERTIARY	Miocene	Miocene undifferentiated	5		

——?——?——?—— uncertain time boundary

Figure 8. Concluded. Explanation for geologic map.

former flat surface has been well dissected by the present streams. In Baldwin County this terrace is also well dissected and occurs 8 km (5 mi) southeast of Tensaw at altitudes ranging from 64 to 67 m (210 to 220 ft). The youngest and lowest of the high terrace surfaces is quite extensive and has been mapped approximately parallel to the Mobile River system from Bay Minette Creek in the south to Wolf River in the north, a distance of about 69.2 km (43 mi). The altitude of the terrace surface in the north is 42.7 m (140 ft) and at the southern end is at an altitude of 19.8 m (65 ft). The terrace deposits are generally 6 to 9.1 m (20 to 30 ft) thick but locally reach thicknesses of 15.2 m (50 ft). The deposits underlying the terrace surfaces consist of white, gray, red, and orange fine- to coarse-grained gravelly sand and orange sandy clay.

PLEISTOCENE AND HOLOCENE SERIES—COASTAL AREA AND FLOODPLAIN DEPOSITS

Low terrace and alluvial deposits occur as a belt from 11.3 to 16.1 km (7 to 10 mi) wide in the delta complex at the head of Mobile Bay and extend northward beyond the confluence of the Tombigbee and Alabama Rivers. Where the Mobile River system joins Mobile Bay, sediments of the delta have been described by Boone (1974) as deltafront and prodelta sand, silt and clay, interstratified fine-grained sand and silt and interstratified silt and clay. In the Mobile River basin these deposits are of fluvial, estuarine, and marine origin and are as much as 46 m (150 ft) thick.

Low terrace and alluvial deposits also occur parallel to and in the floodplains of the smaller streams in the area and contain gravelly sand, sand, silt, and clay derived from the weathering of the Miocene Series, Citronelle Formation, and terraces. Gray and orange, sandy, carbonaceous clay are present in some areas. These deposits are generally less than 15.2 m (50 ft) thick.

The Coastal Lowlands, at altitudes ranging from sea level to 9.1 m (30 ft) are underlain by low terrace and alluvial deposits that, in places near the central and southern margins of Mobile Bay and the southern ends of the mainland, contain marine beds with shells and shell debris and layers of peat formed in pre-existing swamps and marshes.

The beach and dune deposits of the barrier islands and spits consist of well-sorted, medium-grained quartzose sand having a heavy mineral suite rich in staurolite and kyanite. Concentrations of heavy minerals occur in thin laminae along the beaches of the gulf and mainland sides of the barrier system, primarily in the silt to fine-sand fraction. Sediments capping Dauphin Island, Mobile Point, and Perdido Key consist of coarse-laminated dune sand and marsh deposits that have been stirred and burrowed by organisms (Boone 1973).

OFFSHORE OR BOTTOM SEDIMENT DISTRIBUTION

The distribution and generalized lithologies of sediment in the offshore area are shown by numbers on the geologic map (Figure 8). Sediments in the northern part of Mobile Bay consist of prodelta silt, clayey silt, deltafront sand, and silty sand that have been transported into the bay by the rivers to form a broad delta complex. Sediments in the southern part of the bay consist of estuarine silty clay and clay. Bay-margin sands and clayey sands occur around the periphery and can be further described as fine- to medium-grained quartzose sand with local concentrations of shell fragments, clay clasts, or heavy minerals. The bay-margin sands are a contrast to the estuarine silty clay and the clay that occupies most of the bay floor. The bay-margin sands persist because they are swept free of finer particles by the winnowing or washing action of the waves. Locally within the bay, the accumulation of oyster shell is significant. Holocene sediment thicknesses range from about 4.6 to 6.1 m (15 to 20 ft) in the western part of the bay to about 12.2 m (40 ft) in the eastern part. Sediments are up to 38 m (125 ft) thick in the ancient Mobile River valley in the mouth of the bay (Boone 1973). Holocene sediments in the bay overlie sand and relatively massive clays of probable Miocene age.

The rate of sediment accumulation in the bay has been described by Ryan (1969), Hardin et al. (1976), and Lamb (1979) and is averaging approximately 0.5 m (1.6 ft) per century. Hardin et al. (1976) divided the bay into an upper and lower portion and showed that the rate of accumulation in the two areas was different. Bathymetric evidence indicates that the rate of filling for the upper bay was 0.58 m (1.9 ft) per 100 years between 1852 and 1920 and showed that this rate decreased to 0.3 m (1 ft) per 100 years between 1920 and 1973. In the lower bay Hardin et al. (1976) estimated the rate of filling was 0.41 m (1.3 ft) per 100 years from 1852 to 1920, and that it increased to 0.71 m (2.3 ft) per 100 years from 1920 to 1973. As pointed out by Lamb (1979), the change may have resulted from decreased amounts of sediments being discharged into the upper bay from rivers and some of the upper bay sediment being redistributed by currents and deposited in the lower bay area. The construction of dams along the Tombigbee and Alabama Rivers has reduced the amount of sediment previously discharged into the bay by the Mobile River system. As a result, the rate of sediment accumulation in Mobile Bay will probably show a marked decline when further studies are made.

Sediments in Mississippi Sound consist of estuarine silt and clay in the central part and bay-margin sand around the periphery (Upshaw et al. 1966). The estuarine facies of Mississippi Sound is characterized by variable lithology, general lack of stratification, abundance of bioturbation, and irregular lenses of differing lithology. The bay-margin sands along the mainland are fine grained and include silt and clay. Bay-margin sand along the Dauphin Island beach facing the sound is mainly medium to coarse sand. Holocene sediments range in thickness from about 1.5 m (5 ft) in the northern part of the sound to 12.2 to 18.3 m (40 to 60 ft) at the barrier islands (Ludwick 1964). The sedimentation rate in Mississippi Sound has not been definitely established, but the rate estimated by Ludwick (1964) was 0.24 m (0.8 ft) per 1,000 years and by Rainwater (1964) was 1.2 m (4 ft) per 1,000 years.

Sediments in Perdido and Wolf Bays consist of estuarine clayey silt and silty clay in central deeper parts of the bays and clean, well-sorted, bay-margin quartz sand around the periphery. The northern part of Perdido Bay is floored by deltafront silty sand, silt, and sand which are discharged into the bay by the Perdido River and its minor tributary streams. The gross mineralogy of the sediments, as described by Parker (1968), in order of abundance, is quartz, kaolinite, montmorillonite, and calcite. Mollusk shell fragments, mainly of gravel size, account for the majority of the calcium carbonate content in the Perdido Bay area. Bayou St. John and Old River are floored mainly by sand with some silty sand and clayey silt (Parker 1968). Sedimentation rates in Perdido and Wolf Bays have not been determined.

A large tidal delta extends from the mouth of Mobile Bay seaward, consisting of a clean, well-sorted quartz sand similar to the sand that occurs in the beach and dune deposits. The tidal delta does not seem to be a delta related to the Mobile River system but rather has formed from the transportation of large quantities of sediment through the passes in the barrier island complex in response to tidal fluctuations (Shannon 1977).

Immediately south of the Mississippi Sound barrier-island system and the tidal delta is a nearshore, fine-grained facies similar in lithology to that of Mobile Bay and Mississippi Sound. Sand, muddy sand, sandy mud, and mud occur in water depths less than 18.3 m (60 ft) in a zone about 11.3 km (7 mi) wide. Tidal flushing of the estuaries moves turbid waters seaward where the suspended silt and clay are deposited to form this facies. The fine sediments move southward from the high energy environment existing at the mouth of the bay to the quiet waters further out to sea.

The Mississippi-Alabama sand facies (Figure 9) covers most of the western part of the shelf area (Boone 1973). It consists predominantly of well-sorted, fine-grained, clean quartz sand. Shelly sands occur locally. This facies occurs in an area of very slow deposition or slow erosion where sands deposited during a lower stand of the sea are being reworked by marine processes but not buried by normal shelf deposits.

SOILS

Soil formation is the result of the interaction of many factors including climate, plant and animal life, chemical and mechanical weathering of the parent underlying geologic formation, topography, and time. Soil properties are important variables which must be considered when determining the suitability of land for a particular use. Thickness, permeability, composition, ph, bearing capacity, available water capacity, and liquid limit are all factors to be considered in determining the suitability of a soil type for a specific use. Soil associations in Mobile and Baldwin Counties as determined by the Soil Conservation Service (1974) are shown on Figure 10. Descriptions of the soil associations and their particular characteristics are shown in Table 2.

Soil associations in the two counties exhibit relatively close relationships to the underlying parent stratigraphic unit from which they are mostly derived. It is apparent from examining Figure 11, which shows soil limitations for light construction, and the geologic map (Figure 8) that the areas with severe limitations are those soil types derived from the Miocene Series, alluvial deposits, and the coastal deposits. All but the coastal deposits contain appreciable quantities of clay with the associated problems of moderate to high shrink-swell potential and poor drainage characteristics.

The alluvial deposits in the floodplain of the Mobile River system and the coastal area deposits are mainly in the Cahaba-Chewacla-Myatt, Dorovan-Plummer-Tidal Marsh, and Osier-Johnston Associations, with construction limitations due to location, elevation, and drainage characteristics or composition.

The preferred agricultural land use in the area is shown on Figure 12. The areas most suitable for cropland are underlain mainly by the Citronelle Formation consisting of sand and gravel with minor lenticular beds of clay.

Existing constructed facilities near the coast in the two-county area indicate that the Citronelle Formation and coastal deposits are generally suitable for most types of construction, provided proper engineering practices are followed. The only areas apparently not used for construction are alluvial deposits, coastal marshes, and temporary swamp areas of the coastal deposits. The alluvial areas are subject to flooding and are generally only of use for agricultural and recreational purposes, and seasonally high water tables associated with the marsh and swamp areas severely limit other uses.

According to Szabo (1975) sediments of the Citronelle Formation have a high load-bearing capacity, a low shrink-swell potential, and high to moderate permeability and are suitable for most construction. Construction or modification of areas underlain by the Citronelle should provide for proper drainage and septic field percolation. These sediments should not require special treatment to support most structures.

Sediments of the coastal deposits, excluding the swamp and marsh areas, have fair load-bearing capacity, moderate to low

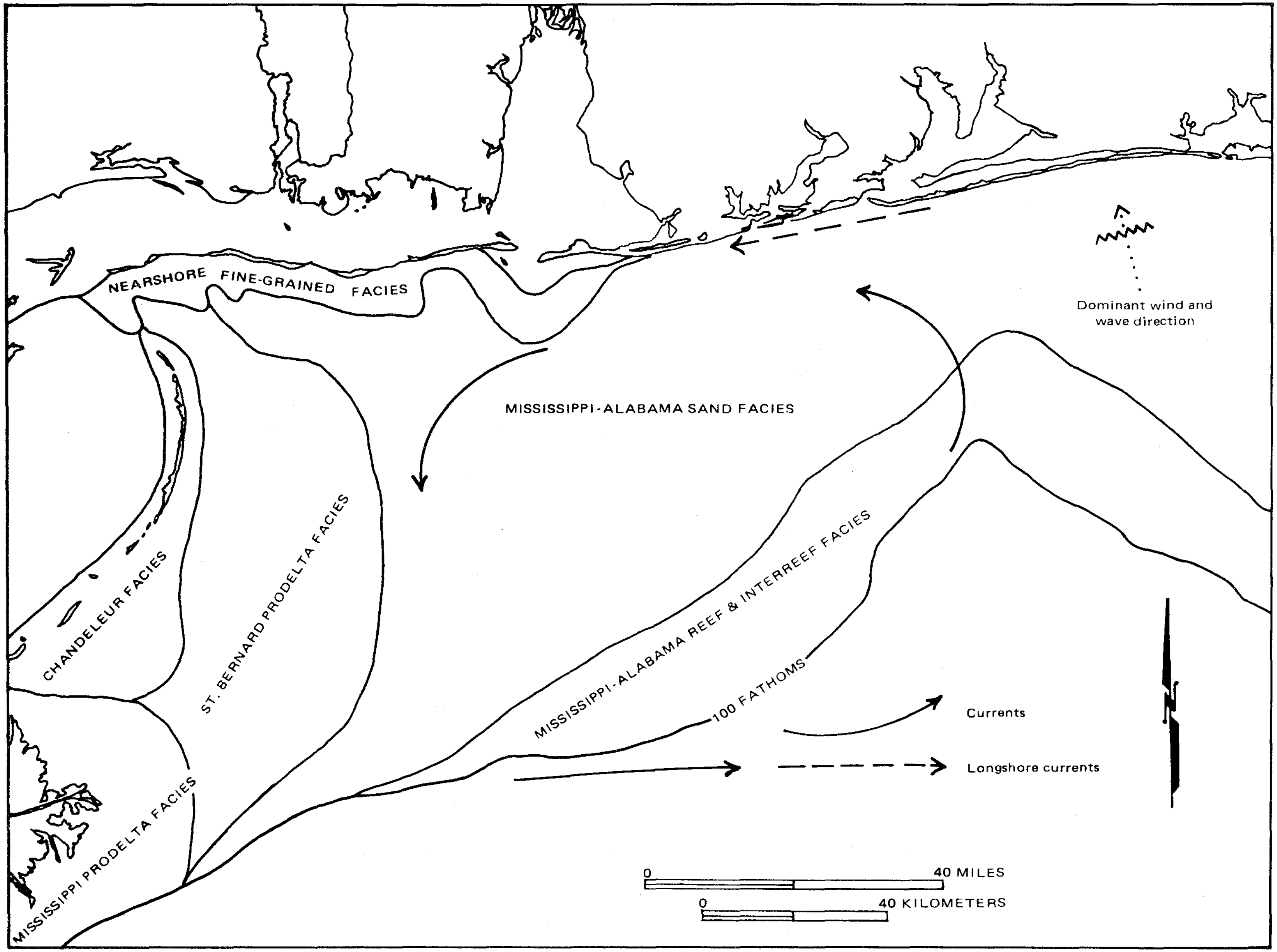
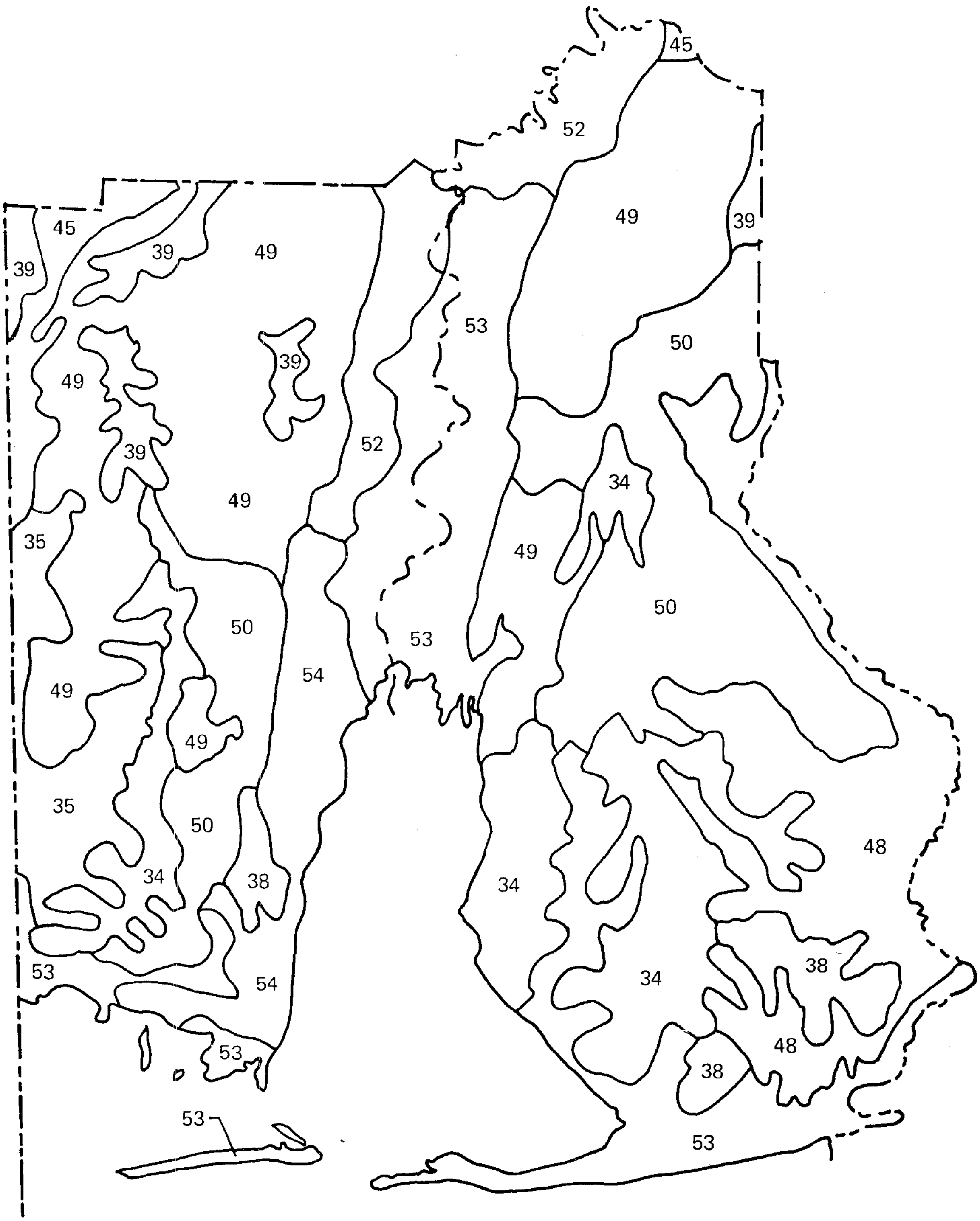


Figure 9. Mississippi-Alabama shelf-sediment facies (Boone 1973).



34 Malbis-Orangeburg-Pansey
35 McLaurin-Troup-Ruston
38 Poarch-Benndale-Escambia
39 Lucedale-Ruston-Greenville
45 Smithton-Escambia-Troup
48 Troup-Plummer-Escambia
49 Troup-Smithdale-Esto
50 Troup-Smithdale-Escambia
52 Cahaba-Chewacla-Myatt
53 Dorovan-Plummer-Tidal marsh
54 Osier-Johnston

Figure 10. Soil associations (modified from Soil Conservation Service 1974).

Table 2. Soil characteristics of Mobile and Baldwin Counties (Soil Conservation Service 1974).

Map symbol	Soil associations	Percent slope	Drainage	Dominant texture	Reaction	Erosion	Limitation for light construction	Desirable agricultural use
34	Malbis-Orangeburg Pansey	0-5	Moderate	Sandy clay loam	Strongly acid	Slight	Slight to severe	Cropland
35	McLaurin-Troup-Ruston	2-10	Good	Sand clay loam	Strongly acid	Slight	Slight	Cropland
38	Poarch-Benndale-Escambia	0-5	Good	Loam	Very acid	Slight	Moderate	Cropland
39	Lucedale-Ruston-Greenville	0-5	Good	Sandy clay loam	Strongly acid	Slight	Slight	Cropland
45	Smithton-Escambia-Troup	0-5	Moderate	Sandy loam	Very acid	Moderate	Slight to severe	Pasture
48	Troup-Plummer-Escambia	0-5	Moderate	Sandy loam	Very acid	Slight	Slight to severe	Forest
49	Troup-Smithdale-Esto	2-25	Good	Sandy clay loam	Strongly acid	Severe	Severe	Forest
50	Troup-Smithdale-Escambia	0-12	Good	Sandy clay loam	Strongly acid	Moderate	Moderate	Pasture
52	Cahaba-Chewacla-Myatt	0-5	Moderate	Loam	Strongly acid	Slight	Severe	Cropland
53	Dorovan-Plummer-Tidal marsh	0-1	Very poor	Organic	Extremely acid	Slight	Severe	Forest
54	Osier-Johnston	0-2	Very poor	Loamy sand	Very acid	Slight	Severe	Forest

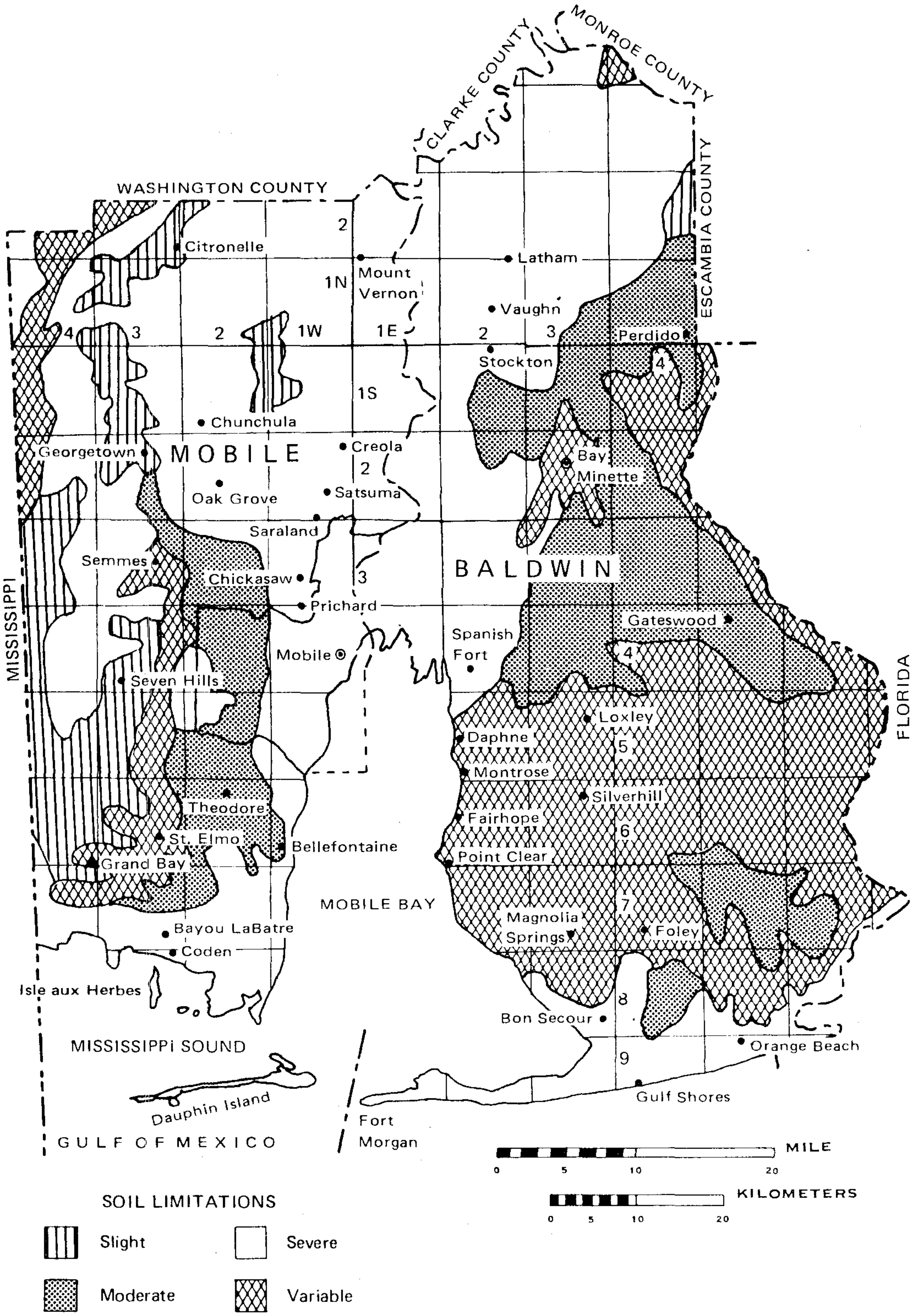


Figure 11. Soil limitations for light construction (Moser and Chermock 1977).

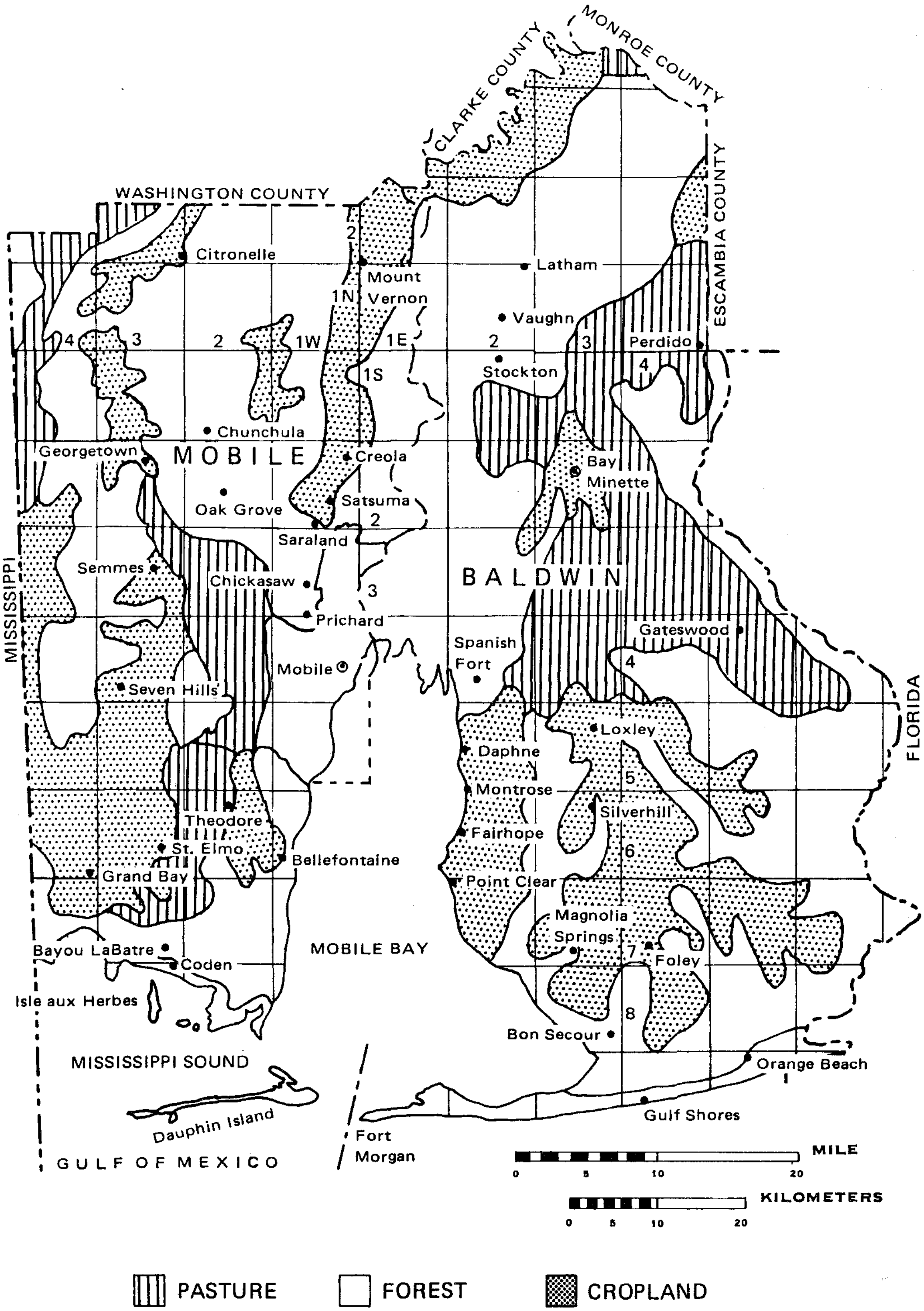


Figure 12. Preferred agricultural land use based on soil association (Moser and Chermock 1977).

permeability, and moderate to high shrink-swell potential. The shrinking and swelling of this material may weaken foundations, and the permeability is important as it relates to proper drainage and septic field percolation. These areas probably would require remedial treatments to prevent foundation damage, to remove surface water, and process sewage other than by septic tanks. Test data supplied by the State Highway Department of Alabama (Szabo 1975) indicate that the material will support a uniform loading of approximately 10,240 kg/m^2 (3,000 lb/ft^2) and may require pilings to a depth of 8 to 21.3 m (30 to 70 ft) for support of greater loads.

STRUCTURAL GEOLOGY

Major faults and folds of economic importance are present in southwest Alabama. Some of these structures adversely affect the ground-water resources in this vicinity. Regionally, Mesozoic and Cenozoic formations in coastal Alabama form a broad homocline dipping approximately south toward the Gulf of Mexico. The Mesozoic sediments dip from 5.7 to 8.5 m/km (30 to 45 ft/mi) and the Cenozoic sediments dip from 0.2 to 9.4 m/km (1 to 50 ft/mi). The following discussion is modified from Joiner and Moore (1966), Moore (1971), and Boone (1974).

THE SALT BASIN

Southwest Alabama is situated in the easternmost extension of the Mississippi interior salt dome basin. Most of the geologic structures observable in Jurassic, Lower Cretaceous and younger sediments in the basin are the result of movement of the underlying Louann Salt. Salt at depth responds as a plastic medium and will move into zones of weakness in response to sediment loading. Structures formed as positive features by salt swells or domes and as collapse-type features such as grabens where salt was removed occur in southwest Alabama. Salt movement associated with these structures was sporadic with alternating dormant and active periods. Stratigraphic units thicken where subsidence resulted from salt removal, and units thin where positive or domal movement occurred.

The most prominent structural features within the salt basin with a bearing on coastal Alabama include the peripheral faults, the Mobile graben, the Citronelle domal anticline, and the Wiggins uplift (Figure 13). Additional unnamed structural anomalies in the form of minor faults and folds have been mapped in the area (Reed 1971a, 1971b; Moore 1971).

PERIPHERAL FAULTS

The Gilbertown, Coffeeville-West Bend, Walker Springs, Pollard, and Bethel fault zones occur near the updip limit of the Louann Salt and probably represent the periphery of the salt basin. The faulting formed a series of relatively narrow grabens, with subsequent faulting occurring between the two major faults. The dominant fault in most of the graben structures is the northernmost one, which is downthrown to the southwest.

In coastal Alabama, fault zones can be detected only in the subsurface, or, at best, with very subtle surface indications. Northward in Choctaw and Clarke Counties, faults can be observed on the surface, and movement along some of the faults has occurred recently enough to cause the grabens to be topographic lows. Displacement at the surface of these faults generally ranges from about 15.2 to 91.4 m (50 to 300 ft).

A possible extension of the Walker Springs-Pollard fault zone may cut across the northeastern corner of Baldwin County (Figure 13). Two wells drilled near Little River in the northeastern part of the area are cut by faults with displacements from 94.5 to 103.6 m (310 to 340 ft). Insufficient control is presently available to confirm the existence of the Walker Springs-Pollard fault zone extension into Baldwin County as a graben structure of the peripheral fault zone.

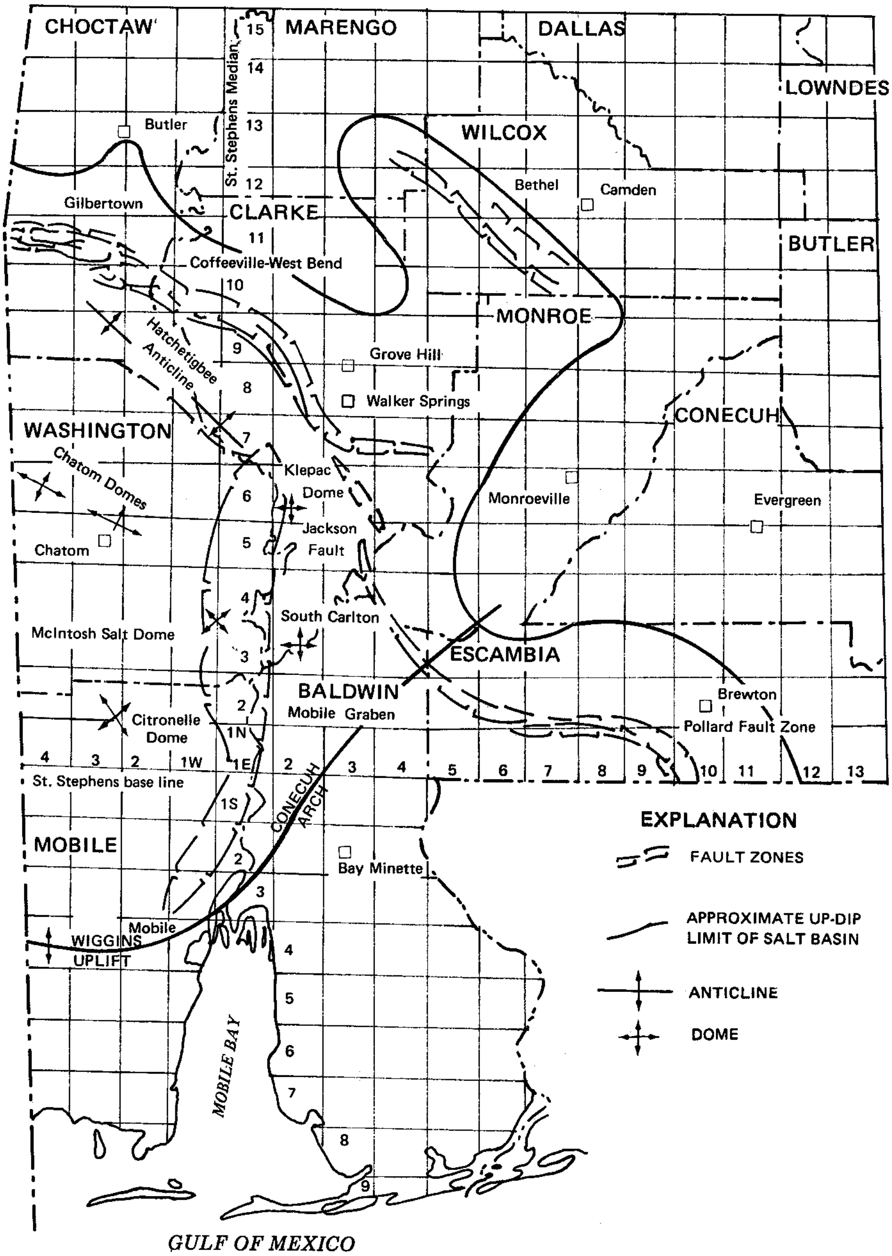


Figure 13. Structural features in southwest Alabama (modified from Moore 1971).

MOBILE GRABEN

In the subsurface the Mobile graben, a complex north-south fault system, extends from near Jackson in southern Clarke County southwestward to near Satsuma in northern Mobile County. The Jackson fault, and extensions that form the eastern boundary of the graben, occur near the eastern limit of thick Louann Salt (Jurrasic) in Alabama. Vertical displacement of the Jackson fault at the surface ranges from 15.2 to 42.7 m (50 to 1,400 ft) (Causey and Newton 1971). In the subsurface in Clarke County the displacement of the fault at a mapping horizon in the lower part of the Tuscaloosa Group is 1,524 m (5,000 ft) or more. A probable extension of the Jackson fault was penetrated by an oil and gas test well in irregular sec. 8, T.1S., R.1E., and displacement along the fault, apparently downthrown to the west, is 1,158 m (3,811 ft) at a depth below surface of 3,490 m (11,450 ft).

The Mobile graben shown on Figure 13 decreases in width to the southwest. The western boundary fault of the Mobile graben that is downthrown to the east has been intersected by gas wells in the Hatter's Pond field and by a wildcat well located to the northeast. A wildcat well located in irregular sec. 9, T.1N., R.1E., Mobile County, intersects the fault at a depth of 3,819 m (12,530 ft) and the relative displacement is 1,417 m (4,650 ft). Gas wells in the Hatter's Pond field intersect the western boundary fault zone of the Mobile graben at depths ranging from about 122 to 5,182 m (400 to 17,000 ft) and the relative displacement ranges from 24.3 m to 853 m (80 to 2,800 ft) (G. V. Wilson, Geologist, Geological Survey of Alabama, personal communication, 1978). The displacement of faults forming the Mobile graben increase at depth and abnormal thicknesses of stratigraphic units occur within the graben, indicating that faults composing the graben system have been active since late Mesozoic time. Many structures favorable for petroleum accumulation occur in the highly mobile zone and will be a target for exploration in years to come.

CITRONELLE

The Citronelle oil field in Mobile County is on a slightly elongated, northwest-trending domal anticline that has 122 m (400 ft) of vertical closure. Gravity maps show a subtle minimum over the anticline, which probably has a nonpiercement salt core. One deep well in the area was reported by the operators to have encountered the Louann Salt at the total depth of 5,854 m (19,206 ft). Indications of the Citronelle dome can be observed on the surface. Much of the area is topographically high and is a classic example of radial drainage.

WIGGINS UPLIFT

The trend of the Wiggins uplift in Alabama shown on Figure 13 is based on the low gravity values extending from Louisiana into Mobile County that continues northeast into central Conecuh County. According to Wilson (1975), the Wiggins uplift was probably a positive feature throughout Jurassic time that subsided at a much slower rate than the remainder of the Gulf Coast basin. Along the trend of the uplift, the Smackover and Haynesville Formations of Jurassic age are much thinner than in areas to the north and southwest. The full significance of this subtle feature and its relationships to potential accumulations of petroleum are unknown. Two wells drilled near the crest of the uplift in southern Mobile County have encountered what may be the basement complex at shallower depths than was expected.

UNNAMED STRUCTURAL FEATURES

Minor faults have been intersected at depths above 2,438 m (8,000 ft) in drill holes in southeastern Baldwin County in T.7S., R.5

and 6E. (Moore 1971). An anticline of low relief is interpreted to extend from the southwest corner of T.1S., R.4W. to the northwest part of T.3S., R.2W. in Mobile County.

A geophysical anomaly occurs near Bay Minette in Baldwin County. This anomaly is not reflected in the overlying sediments and possibly represents an inactive basement high that was gradually onlapped and covered by Jurassic or later sediments.

TECTONIC HAZARDS

The term "tectonism" is used to describe the action of forces that violently deform the earth's crust and cause folding and faulting of rocks, earthquakes, and volcanoes. Such events on the North American continent are presently confined to areas near the west coast of the United States and Canada where crustal plates are colliding. Tectonic hazards resulting from these events are obviously of great concern in the areas affected, but events of this nature are not a potential problem in coastal Alabama. There are no known active faults in Alabama, and information presented on Figure 14 indicates that earthquakes are not expected to affect south Alabama.

More conventional hazards that may affect the coastal region are certain naturally occurring or man-induced geologic conditions that present a risk or potential danger to life or property. Examples of geologic hazards include but are not restricted to flooding, salt water intrusion into ground water, coastal and beach erosion, land subsidence, pollution, and waste disposal. These problems are common to most coastal areas and generally pertain to Alabama but can be managed to some extent with the proper geologic information and with sound engineering practices.

OIL AND GAS POTENTIAL

Oil and gas production is well established in Mobile and Baldwin Counties and probably will increase in the near future. The presently developed fields are Citronelle, Chunchula, Hatter's Pond, and South Carlton (Figure 15). New fields have been discovered east of the Chunchula Field in Mobile County and in Baldwin County near Foley, Gulf Shores, and Blacksher. Confirmation wells for a potential new gas field presently are being drilled near the mouth of Mobile Bay. Production statistics from the established fields have been published by Masingill and McAnnally (1980).

The Citronelle oil field is the largest field in Alabama with 447 producing wells. The field was discovered in 1955 and has produced approximately 130 million barrels of oil and 11.7 billion cubic feet of gas. The wells are completed in a series of sands in the Lower Cretaceous at depths ranging from 3,052 to 3,300 m (10,014 to 10,827 ft).

The Chunchula field was discovered in 1974 and gas and gas condensate are produced from 34 wells completed in the Smackover Formation (Jurassic) at a depth of approximately 5,486 m (18,000 ft). The Cold Creek field with two wells and the South Cold Creek field with one well join the Chunchula field on the east and produce oil from the Smackover at a depth of about 5,639 m (18,500 ft).

The Hatter's Pond field is located southeast of the Chunchula field and was also discovered in 1974. The 11 wells in the field produce gas and gas condensate from the Smackover and Norphlet Formation at a depth from 5,486 to 5,639 m (18,000 to 18,500 ft). Cumulative production from the Chunchula and Hatter's Pond fields is approximately 11.5 million barrels of condensate and 32.6 billion cubic feet of gas.

The South Carlton field is located along the Alabama River in southeastern Clarke County and northwestern Baldwin County. The field has 50 producing wells; 44 of these are in Clarke County and 6 are in Baldwin County. The wells are completed in the lower part of the Tuscaloosa Group (Late Creta-

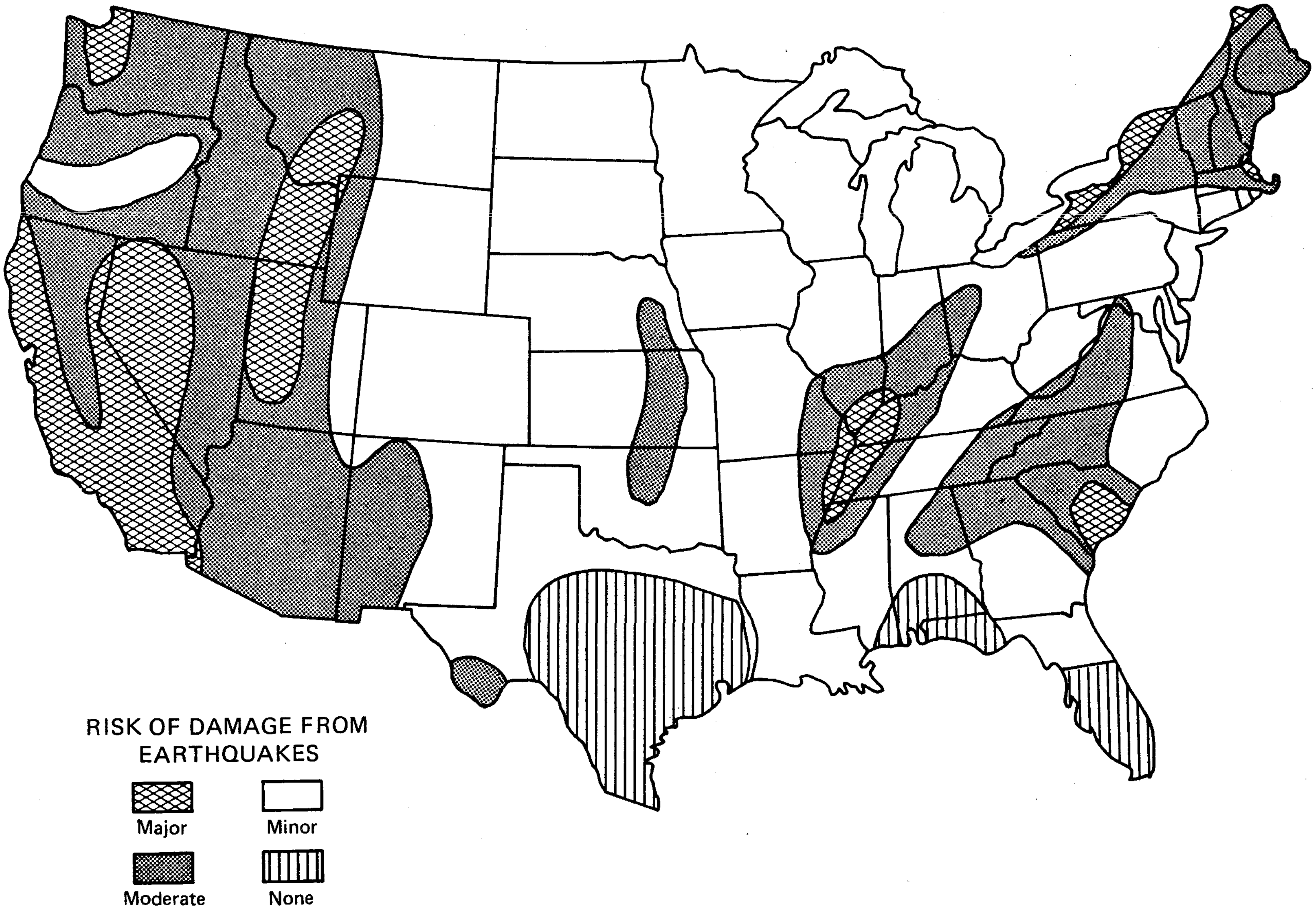


Figure 14. Earthquake risk in the United States (U.S. Department of Commerce 1970).

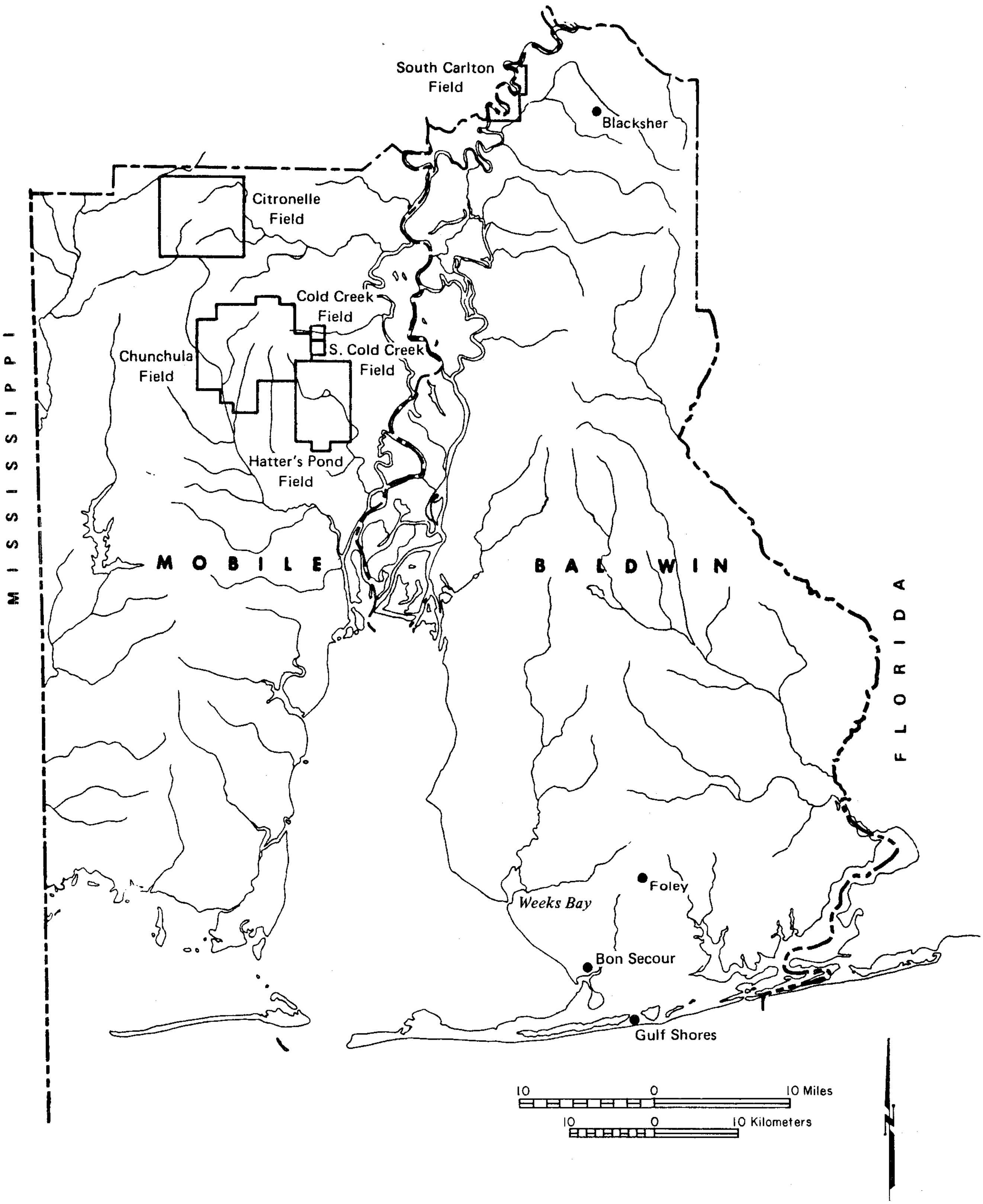


Figure 15. Oil and gas fields in Mobile and Baldwin Counties.

ceous) at a depth of approximately 1,676 m (5,500 ft). Since its discovery in 1950, the field has produced about 4.4 million barrels of oil.

New gas fields are being developed in sand beds in the Pensacola Clay (Miocene) at depths of approximately 396 to 549 m (1,300 to 1,800 ft) in the vicinity of Foley, Alabama. Five wells are presently confirmed in the Foley field and one has been completed in the newly named West Foley field. The Foley field was first discovered in 1979 and development wells are presently shut-in pending completion of a pipeline. The initial test results from these shallow wells range from 0.9 to 7.5 million cubic feet of gas per day. The productive sands in the Miocene have not been fully explored but may extend beneath Mobile Bay. New discoveries of shallow gas from the Miocene have also been made in the past few months near Bon Secour, Weeks Bay, and Gulf Shores, indicating that production limits from the Miocene sands may be extended throughout southwestern Baldwin County.

The Blacksher field in northern Baldwin County was discovered by Shell Oil Company in 1980 and is presently being developed. The wells are being completed in the Smackover Formation at a depth of approximately 4,877 m (16,000 ft) and are the first discovery wells in the Smackover Formation in Baldwin County. The initial tests indicate that the wells will produce both oil and gas. The discovery well in the field flowed at the rate of 104 barrels of oil per day and 123,000 cubic feet of gas. Gulf Oil Corporation has also made a new discovery (1981) northeast of the Blacksher field and development is in progress. The discovery well flowed at the rate of 147 barrels of oil per day and 170,000 cubic feet of gas.

Mobil Oil Exploration and Producing Southeast, Inc., in November 1979, discovered a potential new gas field about 3.2 km (2 mi) east of Dauphin Island near the mouth of Mobile Bay in lease block 76 (Figure 16). The well flowed dry gas through perforations between 6,289 to 6,365 m (20,634 to 20,883 ft) in the Norphlet Formation (Jurassic) at a rate of 12.2 million cubic feet per day. Mobil was awarded leases on blocks 76, 77, 94, and 95 and is now drilling confirmation test wells in lease blocks 76 and 95. The well being drilled at a surface location in tract 76 will actually bottom in lease tract 94.

A lease sale of submerged State lands was conducted in March 1981, and five-year leases for 13 lease tracts were awarded to the companies shown on Figure 16. The tracts are located in Mobile Bay, Mississippi Sound, and areas offshore within the 3-nautical-mile outer limit of State waters. Applications for drilling permits have been submitted, and the coastal waters will be an area of extensive drilling activity for the next few years.

HYDROLOGY

By Phillip F. Dark and Frank Hinkle

Coastal Alabama contains a dynamic hydrologic system that changes with every season and with the use of that system. The focal point of this system is the Mobile River and the 1,070-km^2 (413-mi^2) Mobile Bay into which it flows. As fresh water from the Mobile River, or any stream, mixes with saline waters of the Gulf of Mexico, unique hydrologic and water-chemistry zones develop. During an average year, the streams of this region discharge more than 50 km^3 (12 mi^3) of fresh water into the Gulf of Mexico. A volume of fresh water equivalent to several years of runoff occurs in the subsurface, stored in ground-water reservoirs that underlie the area (Riccio et al. 1973). Defining the interactions of the surface water, embayments, Gulf of Mexico, and the ground water will be the objective of this section.

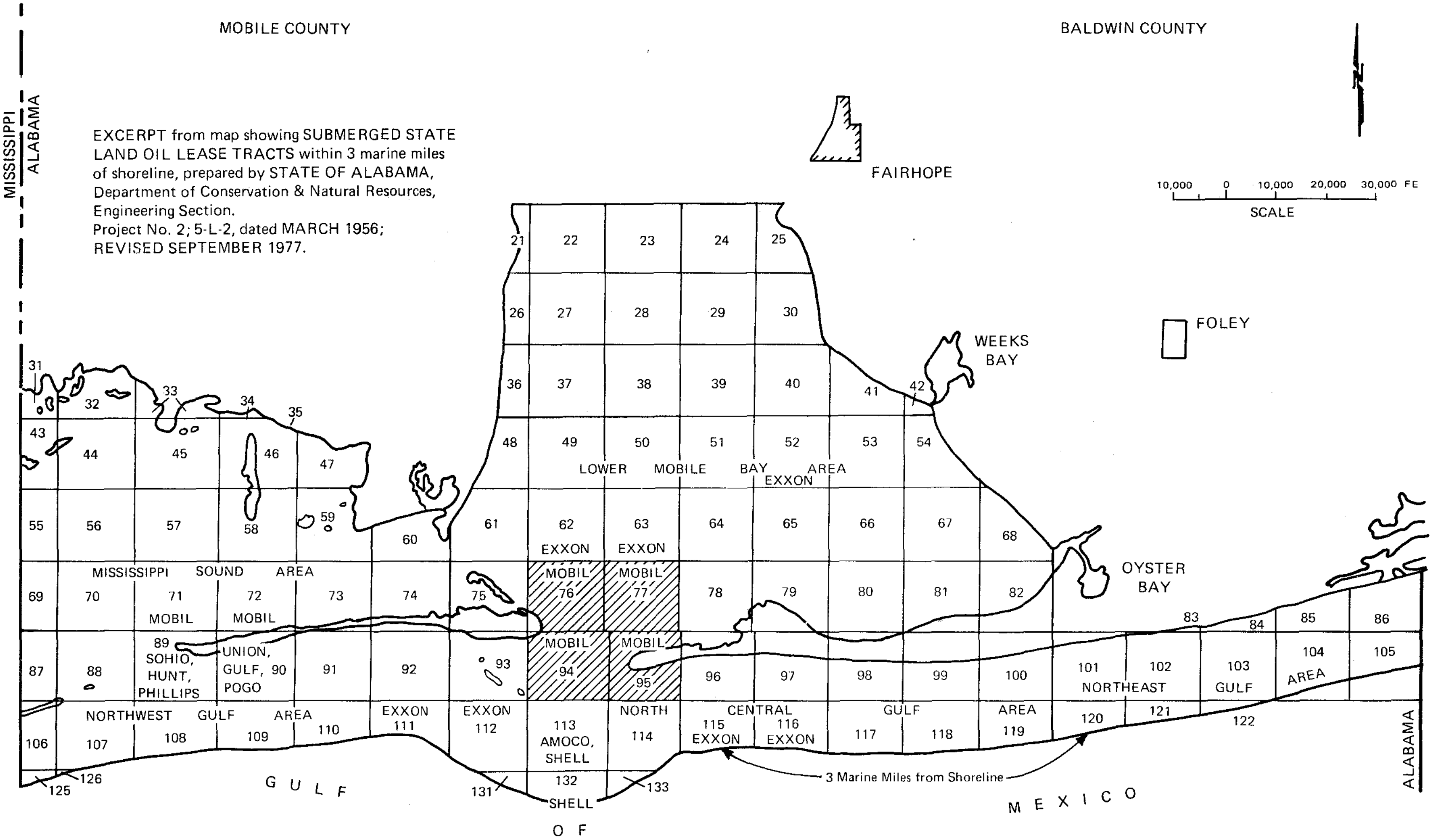


Figure 16. Offshore State lands leased for oil exploration (Alabama Department of Conservation and Natural Resources 1977).

STREAMFLOW AND SURFACE WATER

Streamflow plays an important role in the hydrologic processes of coastal Alabama. The interrelationships between various factors influencing streamflow are complicated. The following discussion is based on Reed and McCain (1971, 1972), Riccio et al. (1973), and Chermock (1974).

FACTORS INFLUENCING STREAMFLOW

Factors that control streamflow may be classified as (1) meteorologic factors that determine the total amount of water available, and (2) land factors that determine the amount of water that reaches the streams.

Meteorologic factors are precipitation, temperature, and wind; land factors include the physical characteristics of the land surface and the underlying rocks, as well as the various topographic and cultural features of individual watersheds. The most important land factors include rock and soil type, watershed area, shape, slope, and land use.

Some of the factors that govern streamflow cannot be classified as above. For example, the type and density of vegetation strongly influence the amount of rainfall that becomes available to streamflow.

Factors influencing streamflow do not act independently. Some have greater influence over high flows, some over low flows, whereas the effects of other factors may vary seasonally. This interplay of meteorologic, topographic, and geologic factors determines the hydrologic environment of the area.

The Mobile-Baldwin County area does not represent a self-contained hydrologic system inasmuch as stream characteristics are also influenced by other geographic areas. Consequently, streamflow characteristics of the major rivers are modified, but not completely controlled, by hydrologic factors operating in the area.

Precipitation is the basic source of all streamflow. In any year, much of the streamflow may occur as direct runoff immediately following severe storms. For runoff to occur, rainfall must exceed the amount that vegetation and soil will absorb or retain. Often, very little of the rainfall from light or moderate storms will run off to streams. During major flood-producing storms, rainfall greatly exceeds retentive demands, and the intensity, duration, and areal extent of rainfall are important factors.

The manner in which runoff reaches the streams, either by surface or subsurface means, and the amount of runoff following each course is mainly governed by the underlying geology and characteristics of the land surface. Some of the land factors affecting runoff rate are drainage basin area, land surface slope, and permeability of the ground surface.

COMPONENTS OF RUNOFF

Direct runoff occurs during or immediately following storms when rainfall intensity exceeds the combined rates of evaporation and infiltration. It includes surface runoff, which reaches the stream by moving over the land surface; and interflow, which reaches the stream by moving at shallow depths without reaching the ground-water table.

Runoff reaching the stream by the subsurface route (ground-water discharge) is derived from subsurface storage and sometimes is separated into two components depending upon whether the water is from basin or bank storage. Basin storage represents ground water stored in aquifers as a result of rainfall that percolates downward to the water table. Bank storage represents water within the banks of a stream resulting from a rise in stream level above the water table. This water is stored temporarily and is readily released as the level of the stream recedes. There also can be drainage from surface storage in lakes or swamps that accumulate water during wet periods and release it slowly in dry periods.

In a perennial stream, the basin-storage component of base flow is continuous, increasing to some extent in wet periods and decreasing in dry periods. Discharge from bank storage occurs only when the stream is below the level of its saturated banks. At any one time, the amount of bank storage may be considerably less than that of basin storage. However during the year, the entire bank-storage reservoir may be filled and emptied several times, whereas only a part of the basin-storage reservoir is used.

The dominant factor that determines variability of natural streamflow is the source of supply. If the principal source is from surface runoff, streamflow tends to fluctuate widely, with high rates of flood runoff and low rates of dry-weather flow. Ground water from storage tends to stabilize streamflow, both by increasing low flows and by decreasing high flows.

SURFACE-WATER AVAILABILITY

Basic records of streamflow in Alabama are compiled and published for each water year (October 1 to September 30) by the U.S. Geological Survey in the annual bulletin, "Water Resources Data for Alabama Surface Water Records." Prior to the 1961 water year, records of streamflow for southwestern Alabama were published annually in the U.S. Geological Survey Water Supply Papers, Part 2-B South Atlantic Slope and Eastern Gulf of Mexico basins, Ogeechee River to Pearl River (U.S. Geological Survey 1960).

Gaging stations and partial-record stations in the study area for which significant records of streamflow are available are listed in Table 3. The availability of surface water in selected streams in the study area is shown on Figure 17.

Table 3. Streamflow gaging stations.

Gaging station number	Stream and location	Gage	Drainage area (mi^2)	Period of record
	PERDIDO RIVER BASIN			
3765.00	Perdido River at Barrineau Park, Fla.	WS[a]	394	June 1941-Present
3775.00	Styx River near Loxley, Ala.	WS	93.2	Oct. 1951-Sept. 1969
	FISH RIVER BASIN			
3785.00	Fish River near Silverhill, Ala.	WS	55.1	July 1953-Present
	MOBILE RIVER BASIN			
4295.95	Little River near Uriah, Ala.	WS	99.2	Oct. 1968-Sept. 30, 1979
4710.01	Chickasaw Creek near Kushla, Ala.	WS	125	Oct. 1951-Present
	PASCAGOULA RIVER BASIN			
4795.00	Escatawpa River near Wilmer, Ala.	WS	506	Aug. 1945-1973

[a]WS - Water Stage recorder.

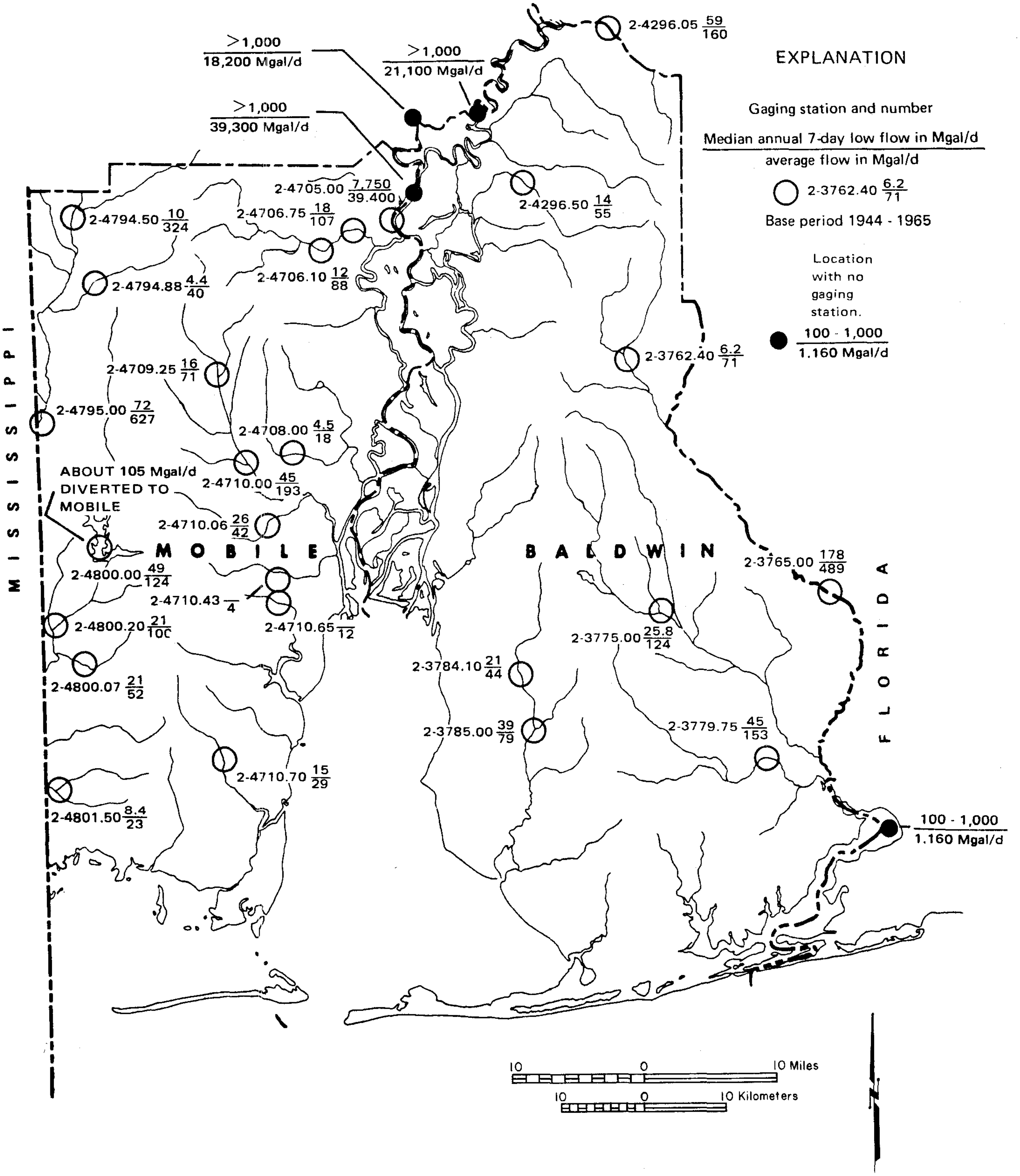


Figure 17. Surface water availability map of Mobile and Baldwin Counties (modified from Riccio et al. 1973).

AVERAGE DISCHARGE

The average flows of streams at gaging stations in this area are listed in Table 4 both as discharge (ft^3/s) and as unit runoff in cubic feet per second per square mile ($ft^3/s/mi^2$). The latter is the average number of cubic feet of water flowing per second from each square mile of area drained, assuming that runoff is distributed uniformly with regard to time and area. The figures of unit runoff are useful for comparing discharges of streams draining basins of unequal size because it reduces runoff from all basins to a common base, one square mile. Average unit runoff varies from less than 2 $ft^3/s/mi^2$ to less than 2.5 $ft^3/s/mi^2$ in south Alabama. The mean annual discharges of streams draining into Alabama estuaries is given in Table 5.

FLOW-DURATION CHARACTERISTICS

One of the most effective means for evaluating streamflow variability is the flow-duration curve. A cumulative frequency curve shows the percentage of time in which discharges were equaled or exceeded during a given period. Many years of streamflow data are concentrated into a graphic presentation that indicates the general character of the stream. The flow-duration curve is a useful tool to compare the runoff characteristics of different streams.

Because streamflow is the result of the combined effects of climate, geology, and topography, the profile of the flow-duration curve is determined by these characteristics of a drainage basin. The lower part of the profile of the duration curve is an indication of the natural storage in the basin, including ground-water storage. A flat or concave upward slope indicates a large amount of storage; a steep slope indicates a negligible amount. Figure 18 shows the duration of daily flows ($ft^3/s/m^2$) for four streams of this area in 1953-62. The lower part of the flow-duration curves for Fish and Styx Rivers are relatively flat, indicating that ground water contributes to the discharge of the river. These rivers have cut through sand and gravel aquifers which allow water outflow to the streams, therefore providing high base flows.

LOW-FLOW INDEX

The median annual 7-day low flow of a stream may serve as the low-flow index (Figure 17). The annual 7-day low flow of a stream is the lowest mean discharge for seven consecutive days during a year. The index, representing the discharge, allows a rapid evaluation of the normal dry-weather capability of a stream to dilute wastes. Changes in the chemical characteristics of selected streams can result from changes in stream discharge.

FLOODS

Flooding, one of coastal Alabama's greatest natural hazards, is a result of storm surges and heavy rainfalls associated with hurricanes and other tropical storms, convective thunderstorm activity, and frontal passages. Base elevations of the 100-year flood (the common name for a flood which has a 1% chance of occurring annually) are shown in Figure 19.

Hurricane Frederic was one of the most intense hurricanes of record to enter the United States mainland (12-13 September 1979). Flooding and water-related damages were most severe in coastal Alabama, particularly at Dauphin Island and Gulf Shores. Maximum prevailing flood-tide elevations were about 3 m (9.7 ft) at Dauphin Island, about 3.1 m (10.3 ft) at the U.S. Highway 98 causeway across Mobile Bay, and about 4.4 m (14.3 ft) at Gulf Shores. The approximate flood boundaries of Hurricane Frederic were compiled from U.S. Geological Survey atlas maps and are delineated on Figure 20. The effects of Hurricane Frederic ranged from

Table 4. Duration of daily flow and average discharge (ft^3/s) at gaging stations in the study area (Discharge which was equaled or exceeded for indicated percentage of time) (Riccio et al. 1973).

	U.S.G.S. station number and location				
Percent of time	3765.00 Perdido River at Barrineau Park, Fla. (1942-62)	3775.00 Styx River near Loxley, Ala. (1952-62)	3785.00 Fish River near Silverhill Ala. (1954-62)	4710.00 Chickasaw Creek[a] near Whistler, Ala. (1952-62)	4795.00 Escatawpa River near Wilmer, Ala. (1946-62)
1	4,500	1,300	550	1,900	8,400
2	3,300	970	400	1,400	6,000
5	2,200	580	270	800	3,700
10	1,400	400	200	550	2,500
20	970	250	140	350	1,400
30	740	170	110	260	960
40	600	130	100	210	680
50	510	97	90	170	500
60	440	76	81	140	360
70	380	62	70	120	250
80	330	49	61	92	180
90	290	36	52	62	130
95	260	30	47	48	100
98	250	24	44	37	72
99	240	23	42	29	60
99.5	230	21	40	25	49
99.9	210	19	38	23	40
Average Discharge					
ft^3/s	773	181	119	285	1,041
$ft^3/s/mi^2$	1.96	1.94	2.16	2.32	2.06

[a]Published now as "near Kushla."

Table 5. A summary of the watershed area and mean annual discharge of streams draining into Alabama estuaries (modified from Crance 1971).

Estuary and U.S.G.S. Station Number	Mean discharge (ft^3/s)	Watershed area (mi^2)	Year of record
Mississippi Sound	unknown	[b]100	
Mobile Bay			
Montlimer Creek 02471065	18.6	8.57	5
Fish River 02378500	107.0	55.1	15
Additional	[a]600	[b]300	
Total	725.6	463.36	
Mobile Delta			
Alabama River 02429500	31,870	22,000	38
Tombigbee River 02470000	36,230	19,100	32
East Basset Creek 02470100	276	188	12
Chickasaw Creek 02471001	269	125	30
Additional	[a]3,715	[b]2,239	
Total	72,360	43,650	
Perdido Bay			
Perdido River 02376500	740	394	38
Jacks Branch 02376700	27.1	23.2	3
Styx River 02377500	170	93.2	17
Additional	931	507.6	
Total	1,868.1	1,018.0	
Totals	74,953.7	45,233.7	

[a]Estimated discharge.

[b]Area estimated by Crance.

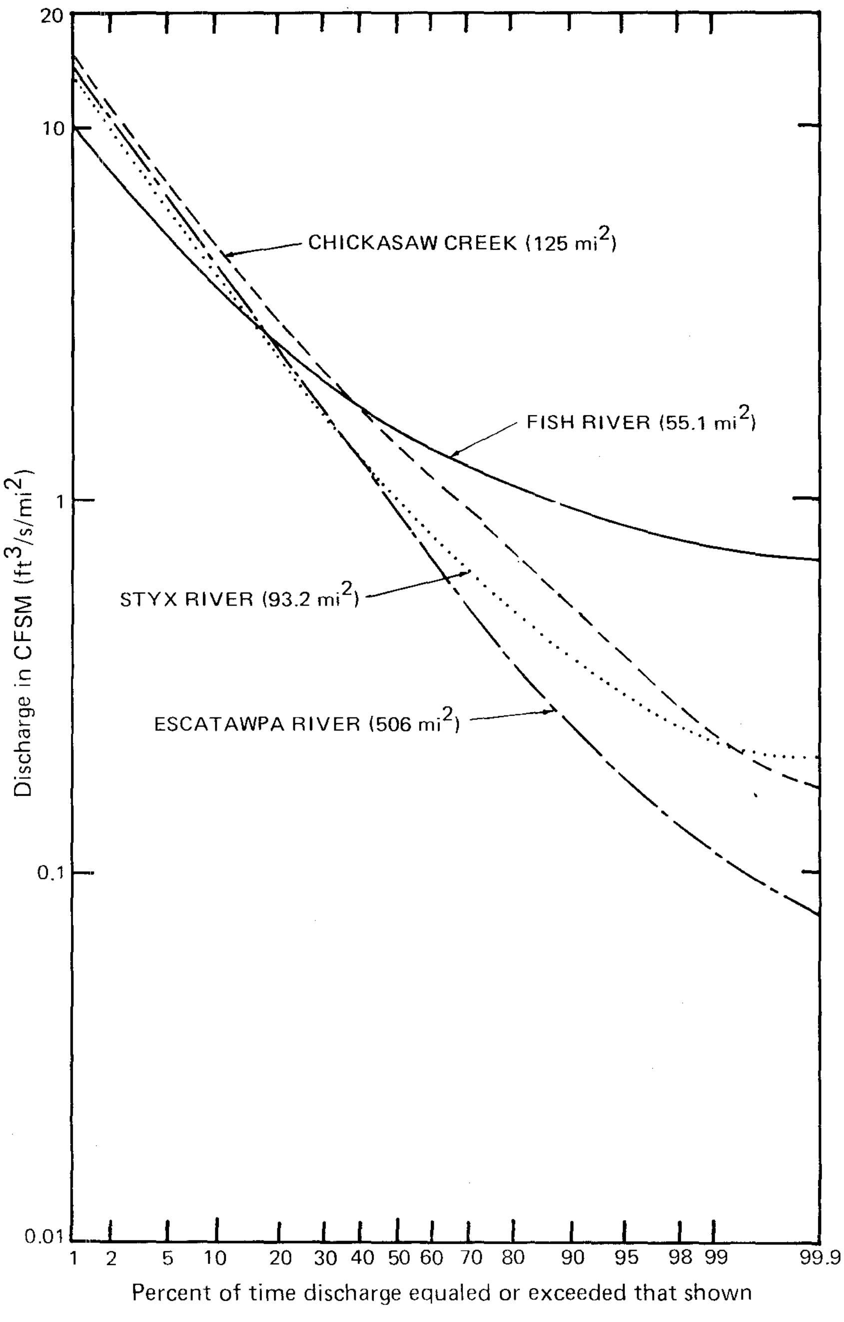


Figure 18. Flow duration curves for four streams in Mobile and Baldwin Counties, 1953 - 62 (Riccio et al. 1973).

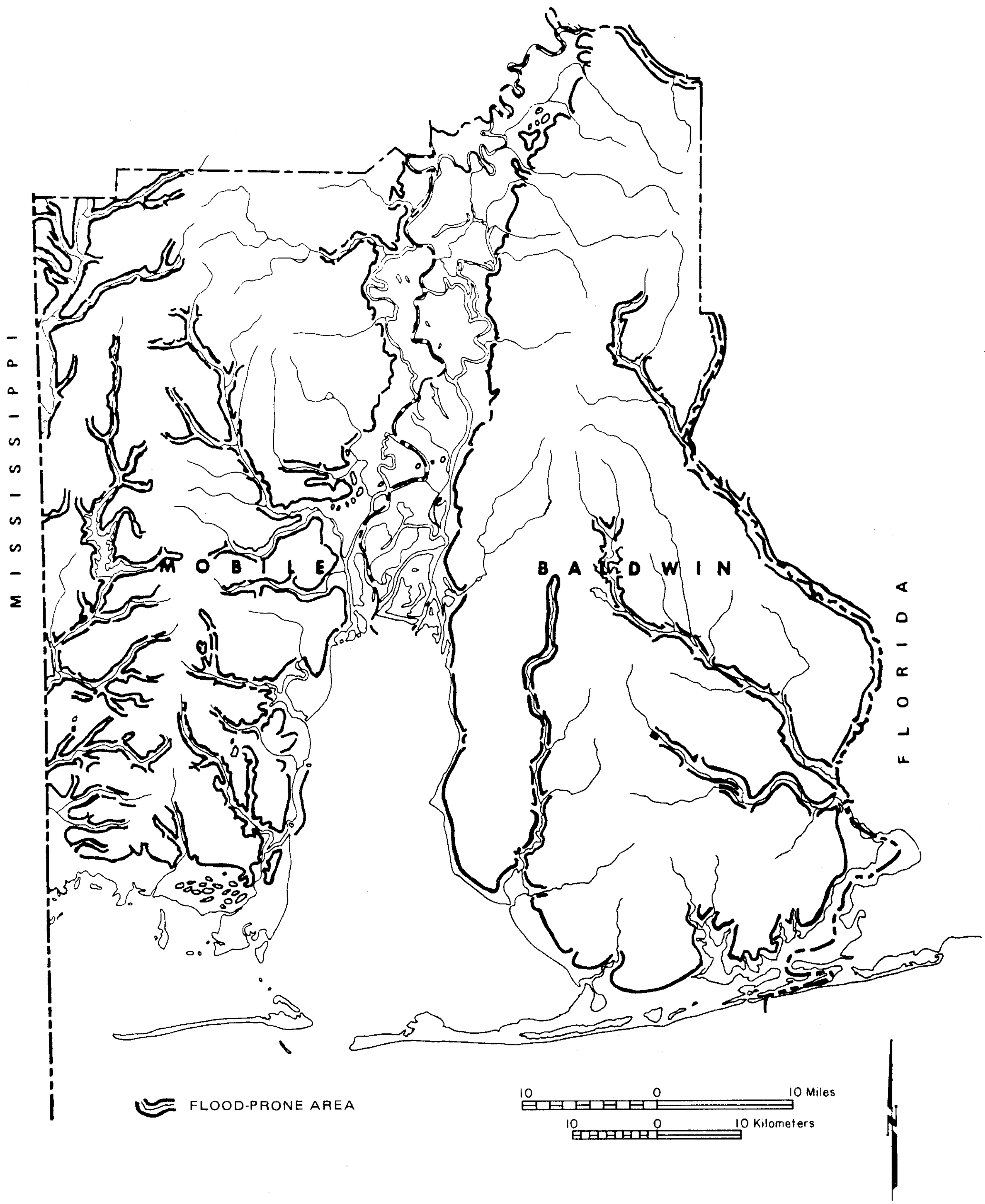


Figure 19. Map of flood-prone areas in Mobile and Baldwin Counties (Riccio et al. 1973).

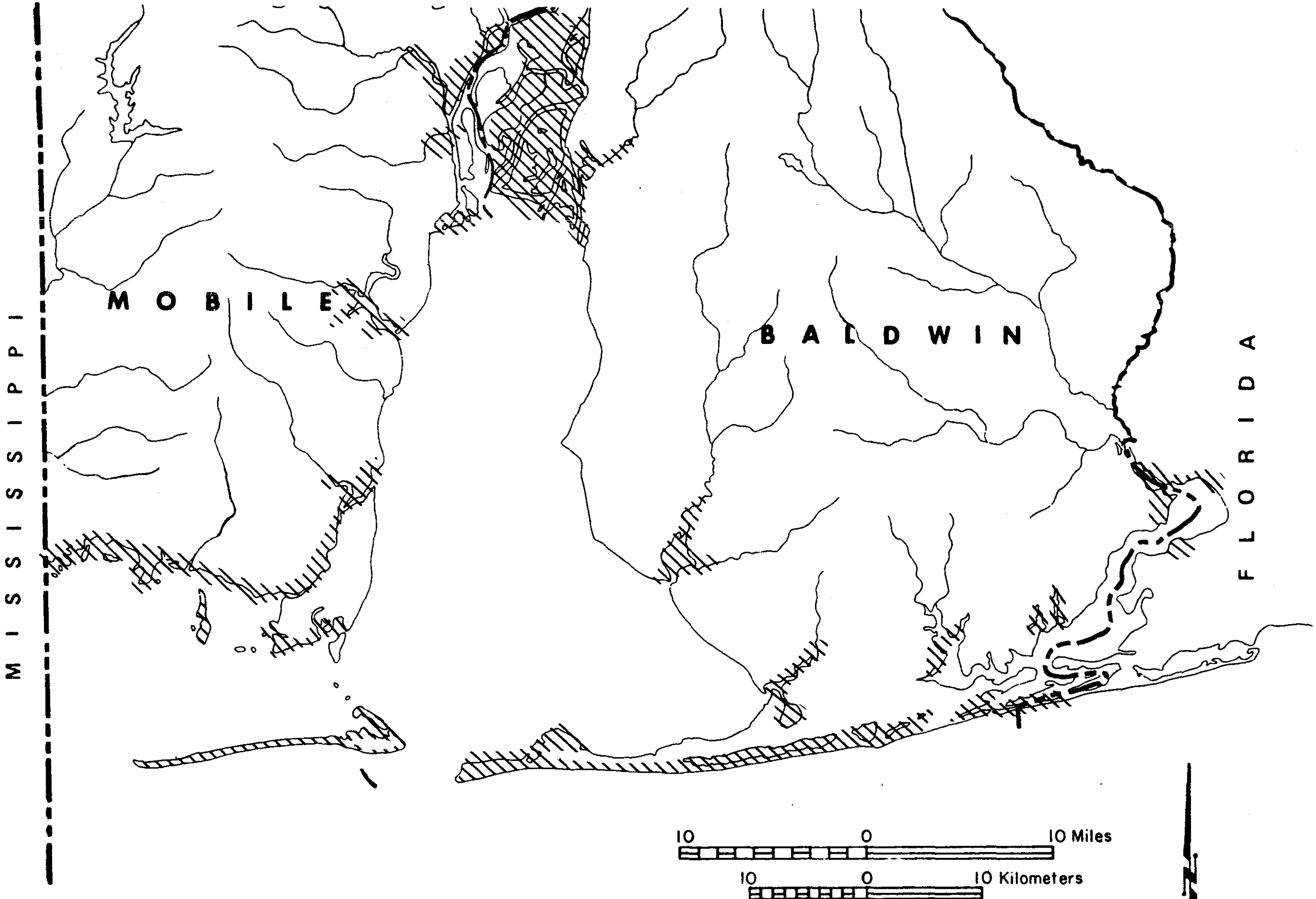


Figure 20. Zones of land covered by storm tides of Hurricane Frederic (modified from Bohman and Scott 1980).

structural damage of buildings to alterations of topography by wind and high water.

When circumstances permit, the simplest and most effective method of protecting against floodwaters is to remain beyond their reach. A flood profile is useful for appraising the elevation necessary to provide security against floods. It is constructed by drawing lines between known flood-crest elevations plotted in their respective locations along the stream. It closely indicates the highest elevation reached by a particular flood. Used with topographic maps, the probable extent of flooding at a particular locality along the stream can be determined.

Data collected during the flood of 1961 (Barnes and Somers 1961; U.S. Army Corps of Engineers 1963) are used to illustrate a flood profile (Figure 21). This is the greatest known flood on the Mobile River, having an estimated recurrence interval of about 200 years. The flood profile shows this flood produced a crest stage of only about 2 ft above mean sea level near the mouth of the river and along the head of Mobile Bay. Information from the flood of 1979 revealed similar flooding conditions.

Flood discharges have a pronounced effect on estuarine salinities. Even in the southernmost parts of Mobile Bay, high river discharges can depress salinity values to very low levels.

HYDROLOGIC UNITS

Seven U.S. Geological Survey hydrologic units (drainage basins) or parts of units have been recognized in Mobile and Baldwin Counties (Figure 22). These units include parts of the Escatawpa and Perdido River basins, a small portion of the Alabama-Tombigbee River basin, essentially all of the Mobile River floodplain, the Mobile Bay drainage basin excluding the Mobile River floodplain, and the coastal basins in Mobile and Baldwin Counties that drain directly into the Gulf of Mexico. Approximately 83% of the Escatawpa and 61% of the Perdido drainage basins are within the Mobile-Baldwin County area. The Mobile River basin covers several states, thus being influenced by hydrologic factors that are sometimes hundreds of kilometers from the study area. Table 6 lists characteristics of the three major stream basins—the Escatawpa, Mobile, and Perdido—in the study area.

MOBILE RIVER BASIN

The Mobile River is the dominant fresh-water resource in coastal Alabama. The river, formed by the confluence of the Alabama and Tombigbee Rivers, flows as a single channel for 8 km (5 mi), and then branches into four major distributary streams and numerous smaller ones. This complex braided network of streams flows through the old deltaic floodplain for about 56 km (35 mi) until it enters into Mobile Bay.

The stream network of the lower Mobile River basin is composed of the Mobile, Tensaw, Apalachee, and Blakeley Rivers. It is estimated by the U.S. Army Corps of Engineers that the total flow entering Mobile Bay is distributed approximately as follows: Mobile River—25%; Tensaw River—28%; Apalachee River— 22%; and Blakeley River—25% (Alabama Water Improvement Commission 1976).

Stream channels are characteristically wide and shallow in cross-section and the channel slopes are relatively flat, resulting in low streamflow velocities. Time-of-travel for the Mobile River from near Mt. Vernon, Alabama to the mouth of the river at the head of Mobile Bay is estimated to be about two days for average flow conditions (Alabama Water Improvement Commission 1976). Average flows occur when most of the flow is neither storm runoff or ground-water discharge.

The drainage area of the entire Mobile River basin is 113,000 km^2 (43,629 mi^2) and includes areas in Alabama, Georgia, Mississippi, and Tennessee (Figure 23). The mean annual discharge of the river system is

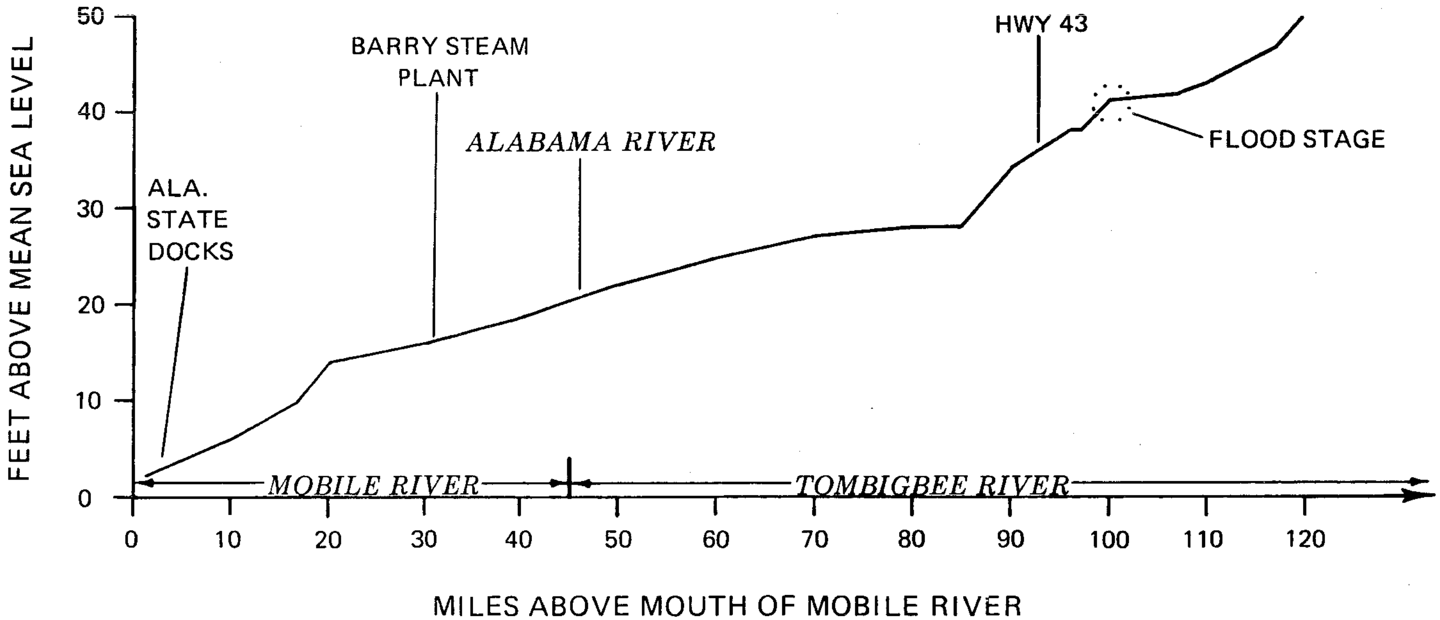


Figure 21. Flood profile of Mobile and Tombigbee Rivers for the flood of February-March 1961.

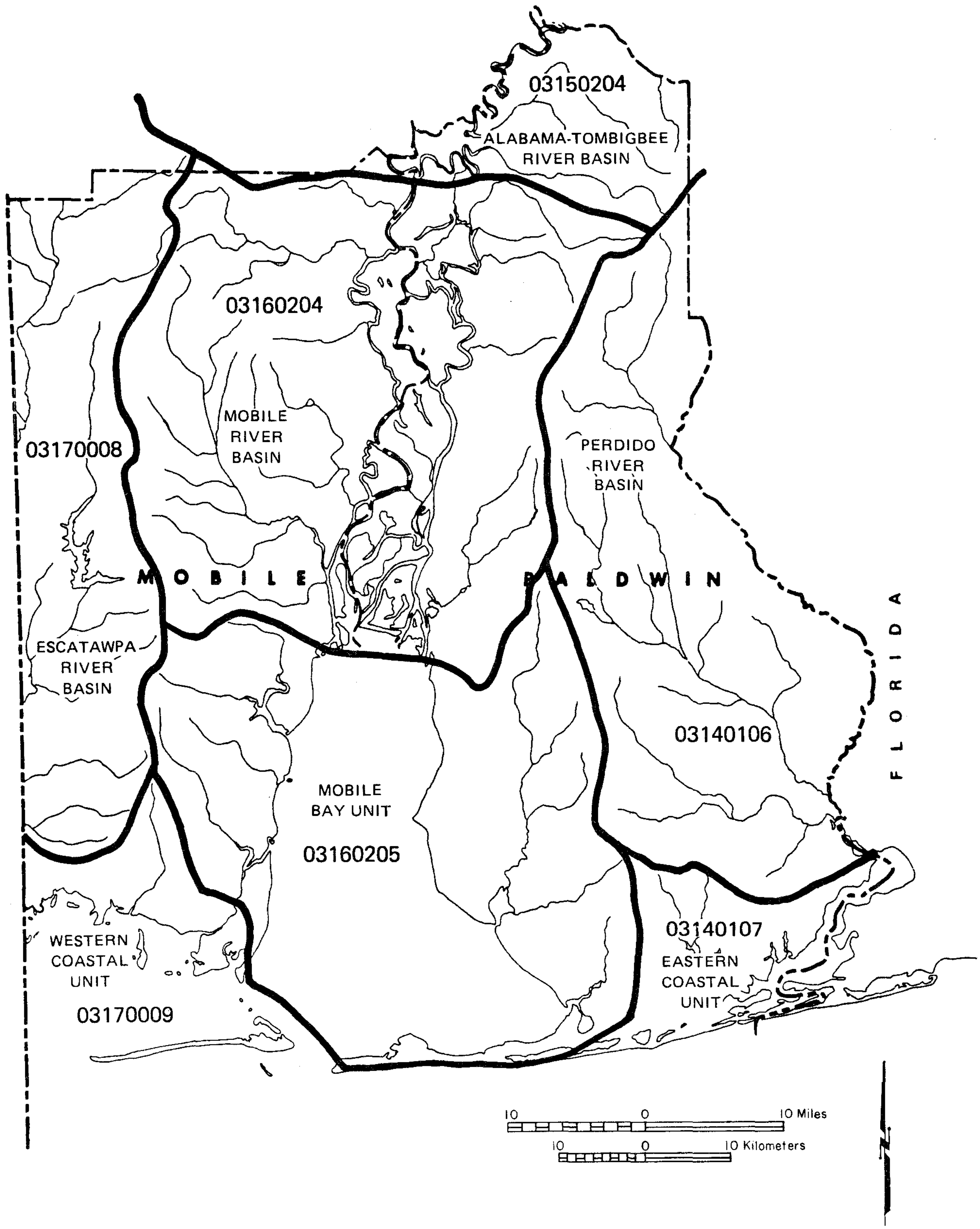


Figure 22. Hydrologic units in Mobile and Baldwin Counties (modified from U.S. Geological Survey 1974).

Table 6. Major basin characteristics, Mobile and Baldwin Counties.

Basin and hydrologic number unit	Area (mi^2)	Elevation (ft above MSL) High	Elevation (ft above MSL) Low	Physiography	Major surface waters
Escatawpa (03170008)	460	300	4	Pine Meadows Southern Pine Hills	Escatawpa River Big Creek Puppy Creek Jackson Creek Miller Creek
Mobile (03160204)	2,060	300	sea level	Pine Meadows Southern Pine Hills	Mobile River Tensaw River Dog River Fowl River Fish River Three Mile Creek Chickasaw Creek Blakeley River Magnolia River Halls Mill Creek
Perdido (03140106)	810	300	sea level	Southern Pine Hills Western Highlands Coastal Lowlands	Perdido River Styx River Blackwater River Hollinger Creek Negro Creek Bellefontaine Creek

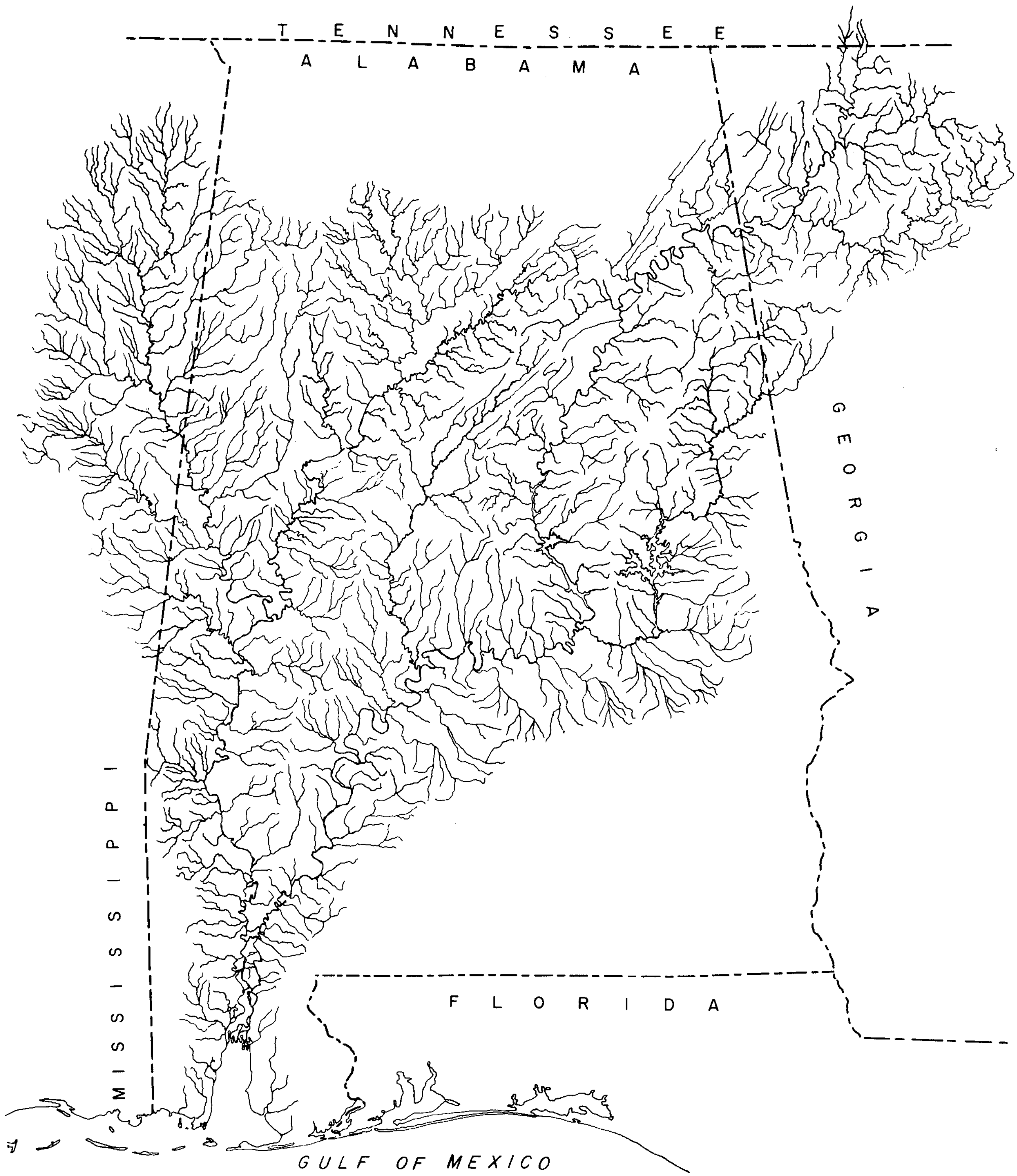


Figure 23. Mobile River drainage basin.

1,764,789 l/s (62,316.8 ft^3/s). The 7-day average low flow of the Mobile River near Mt. Vernon, Alabama is 222,880 l/s (7,870 ft^3/s) (Hayes 1978). Table 7 lists monthly mean discharges of selected streams in the Mobile River basin. This large river receives water from thousands of tributaries with diverse qualities of water. Small towns and large cities, each one affecting the quality and quantity of the streamflow, depend on the rivers of this basin for drinking water, industrial water, wastewater disposal, navigation, and recreation.

There are no U.S. Geological Survey continuous-record discharge stations for the Mobile River. Discharges are often calculated by adding the discharges computed at the Claiborne Lock and Dam on the Alabama River and Jackson Lock and Dam on the Tombigbee River and multiplying the discharge by a factor of 1.09 to correct for drainage areas. Some flow data has been gathered near Mt. Vernon but it has been collected intermittently.

The Tennessee-Tombigbee Waterway project, soon to be completed, will allow a significant increase in barge traffic on the Mobile River. Hydrologic modifications, such as channel dredging, could change salinity gradients, water quality, and natural flow patterns in the river.

The average and low-flow conditions in the Mobile River system will be altered upon completion of the Tennessee-Tombigbee Waterway. Present projections by the Mobile District Office of the U.S. Army Corps of Engineers (written comm. 1976) indicate that in the first year of operation the average flow in the Mobile River system can be expected to increase by 24,070 l/s (850 ft^3/s). In subsequent years, with full development of the waterway, the average flow could be increased by as much as 44,180 l/s (1,560 ft^3/s). It is also projected that low flow in the Mobile River system will be increased by 7,080 l/s (250 ft^3/s) upon completion of the project because the low flow of the Tombigbee River will be increased by that amount.

PERDIDO RIVER BASIN

The Perdido River basin drains portions of Alabama and Florida. In Alabama, the Perdido River basin drains the eastern half of Baldwin County and a small part of Escambia County, encompassing approximately 2,098 km^2 (810 mi^2). The major streams of this basin are the Perdido River, Blackwater River, and Styx River. The Florida portion of the basin drains 619 km^2 (238 mi^2).

There is large variability of flow in the Perdido River with comparatively stable flows during medium and low flow periods (May to November) and high, more erratic flows during floods (January to April). Monthly mean discharges of streams flowing into Perdido Bay are given in Table 8. Streamflow of the Perdido River is variable, ranging from flood flows of over 110,448 l/s (39,000 ft^3/s) to flows as low as 5,324 l/s (188 ft^3/s) at Barrineau Park, Florida.

Throughout its length the Perdido River channel contains sand bars and deep holes, and the streambed is composed principally of sand and gravel. Considerable water quality and streamflow data have been collected at the U.S. Geological Survey gaging station at Barrineau Park.

ESCATAWPA RIVER BASIN

The Escatawpa River basin, which is part of the Pascagoula River basin, covers approximately 1,196 km^2 (460 mi^2) in the western part of Mobile County.
The major tributaries of this basin are the Escatawpa River, Big Creek, Miller Creek, Jackson Creek, and Puppy Creek.

A reservoir on Big Creek is the source of drinking water for the city of Mobile. This reservoir, impounded in 1952 by the construction of a 1.6 km (1 mi) long dam with spillway, covers 14.6 km^2 (5.6 mi^2) and is capable of delivering 100 to 120 Mgal/d to the city.

Streamflow of the Escatawpa River is variable, ranging from flood flows of over

Table 7. Monthly mean discharges (ft^3/s) of streams in the Mobile River basin (Crance 1971).

Month	Alabama River[a]	Tombigbee River[b]	East Bassett Creek[c]	Chickasaw Creek[d]	Montlimer Creek[e]
January	36,772	38,854	344	342	23
February	54,267	54,422	531	370	23
March	65,267	67,908	521	389	18
April	60,547	62,353	449	452	22
May	32,241	26,048	208	199	16
June	18,620	9,111	184	231	15
July	16,992	9,028	185	234	18
August	13,192	3,852	94	254	16
September	13,051	4,023	120	194	12
October	14,251	5,142	118	179	15
November	16,646	9,741	208	217	13
December	31,234	22,074	326	238	17

[a]Alabama River at Claiborne, Alabama (Station Number: 02429500; Period of Record: 1955-1969).
[b]Tombigbee River near Leroy, Alabama (Station Number: 02470000; Period of Record: 1951-1960).
[c]East Bassett Creek at Walker Springs, Alabama (Station Number: 02470100; Period of Record: 1956-1969).
[d]Chickasaw Creek near Whistler, Alabama (Station Number: 02471000; Period of Record: 1955-1969).
[e]Montlimer Creek at U.S. Highway 90 at Mobile, Alabama (Station Number: 02471065; Period of Record: 1962-1967).

Table 8. Monthly mean discharges (ft^3/s) of streams draining into Perdido Bay (Crance 1971).

Month	Perdido River[a]	Jacks Branch[b]	Styx River[c]
January	755	20	218
February	897	45	254
March	785	37	209
April	1,075	50	229
May	566	10	129
June	631	32	154
July	615	21	169
August	558	14	212
September	551	32	176
October	516	25	136
November	483	11	110
December	674	21	141

[a]Perdido River at Barrineau Park, Florida (Station Number: 02376500; Period of Record: 1954-1968).
[b]Jacks Branch near Muscogee, Florida (Station Number: 02376700; Period of Record: 1958-1962).
[c]Styx River near Loxley, Alabama (Station Number: 02377500; Period of Record: 1958-1969).

311,520 l/s (11,000 ft^3/s) to flows as low as 3,965 l/s (140 ft^3/s) near Wilmer, Alabama. The reaches of the Escatawpa River near Deer Park and Citronelle have disproportionally low flows, probably due to a form of watershed leakage induced by topographic features and favored by structural attitudes of aquifers feeding the stream (Peirce 1966).

MOBILE BAY UNIT

Numerous small streams and rivers comprise a drainage basin of 1,554 km^2 (600 mi^2). The major streams are the Fish River, Dog River, Bon Secour River, Magnolia River, and Fowl River. Except for Fish River, little information on streamflow is available for these streams.

COASTAL UNITS

East and west of Mobile Bay are two small hydrologic units (Figure 22) that represent areas of coastal marshes, sand dunes, and beaches of quartz sand.

The major streams within the Western Coastal hydrologic unit are the Little River, Hammar Creek, and other streams near Bayou La Batre. Peirce (1966) determined that larger streams originating in south Mobile County have well-sustained low flows; however, smaller streams in upland areas have not cut their channels deeply enough into the sandy soil to intercept the water table when it is low during the summer and fall months. Thus, these streams flow only intermittently when the rate of precipitation exceeds the infiltration capacity of the soil, as during intense rain or when the water table is high enough to provide water to the stream channels by seepage (Table 9).

During periods of flood tide highly mineralized water moves into streams in the southern and eastern parts of Mobile County. The extent of tidal flood movement inland depends on such factors as stream discharge, tidal variation, and shape and configuration of the stream channel (Reed and McCain 1971).

The major streams within the Eastern Coastal hydrologic unit are Wolf Creek, Graham Creek, Palmetto Creek, Soldier Creek, and the Intracoastal Waterway. The Intracoastal Waterway is 28.8 km (17.9 mi) long and has a channel 3.7 m (12 ft) deep and 38.1 m (125 ft) wide. The waterway extends from the Ono Island area into Bon Secour Bay terminating near the mouth of Mobile Bay. Another waterway constructed by the U.S. Army Corps of Engineers is the small Perdido Pass Channel. It is 3.06 km (1.9 mi) long and 30.48 m (100 ft) wide. The many small tidewater creeks and some of the rivers in this area are subject to inundation during high tides and storm events.

Table 9. Streamflow of selected streams in Western Coastal hydrologic unit (Peirce 1966).

Stream	Quadrant	Mean annual 7-day low flow[a]	Average flow[a]
Jackson Creek	SW¼SW¼ Sec. 17, T. 6 S., R. 4 W.	-	3.29 (75)
Franklin Creek	SE¼NW¼ Sec. 4, T. 7 S., R. 4 W.	0.037 (8.4)	1.00 (23)
Manor Creek	SW¼NE¼ Sec. 26, T. 7 S., R. 3 W.	-	0.88 (20)
Fowl River	NE¼NW¼ Sec. 28, T. 7 S., R. 2 W.	0.66 (15)	3.50 (80)
Rabbit Creek	NE¼NE¼ Sec. 24, T. 5 S., R. 2 W.	-	0.88 (20)

[a]In m^3/s (Mgal/d)

ALABAMA-TOMBIGBEE RIVER BASIN

A small portion of forested land consisting of less than 52 km^2 (20 mi^2) in northern Mobile County is contained in the Lower Tombigbee basin. About 259 km^2 (100 mi^2) of the northernmost tip of Baldwin County is in the Alabama River basin. The major tributaries of this basin are Holley Creek, Turkey Creek, and Little River.

WATER TEMPERATURE

In Mobile and Baldwin Counties surface-water temperatures are directly related to air temperatures. Stream temperatures in coastal Alabama vary from a minimum of 3°C (38°F) to 7°C (44°F) during the months of January and February to a high of 27°C (80°F) to 33°C (92°F) during the months of July and August (Avrett and Carroon 1964).

The large withdrawals and discharges of cooling water by power plants, and waste-water discharges into streams of Mobile and Baldwin Counties often modify seasonal water temperatures. The upper reaches of the Mobile River and Chickasaw Creek are two such streams subject to thermal modification. The modification of stream temperature affects to some extent the stream ecosystem because the physical, chemical, and biological properties of water are often closely related to its temperature.

ESTUARIES AND EMBAYMENTS

A complex estuarine system is partially separated from the Gulf of Mexico by Fort Morgan Peninsula, and Dauphin and Petit Bois Islands. Its main components are Mississippi Sound, Mobile Bay, Mobile Delta, Little Lagoon, and Perdido Bay. These estuaries are mixing zones affected by both fresh and salt waters and each has unique hydrologic characteristics. Collectively, these estuaries and embayments have a surface area of 159,792 ha (394,712 acres) of open water and 679 km (433 mi) of shoreline (Table 10).

SALINITY

One of the major hydrographical and ecological aspects of coastal Alabama is the presence of saline waters. The average salinity of the world's oceans is 35 parts of salt per 1,000 parts of water (Goldberg 1963). Seawater salinity often changes but the proportion of salts to each other remains relatively constant. Coastal Alabama is under a slightly lower salinity regime than the other areas of the world because the waters of the Mississippi River tend to lower the salinity of the Gulf of Mexico and thus reduce salt concentrations for Alabama's estuaries (Parker et al. 1974). In Mobile Bay, the most important factor influencing salinity is the discharge of fresh water from the Mobile River basin.

Salinities of inland coastal waters can change rapidly from ocean concentrations during periods of low fresh-water discharge to less than 0.5 ppt during floods. Estuarine waters can also become stratified, or more saline on the bottom and fresher at the surface. Stratified water often occurs in Mobile Bay due to the slight difference in densities of bay water and river water.

Normally, Mobile Bay would be classified as a partially mixed estuary because of its relatively shallow bathymetry. The Mobile Ship Channel, however, has a pronounced effect upon salinity of the bay. Spoil banks that parallel the ship channel partition the bay and possibly inhibit mixing of the water resulting in the formation of a salt-water wedge within the channel. Penetration of the wedge north into Mobile Bay is dependent upon river discharge. For discharges of less than 283,000 l/s (10,000 ft^3/s), the wedge has been observed 36.8 km (23 mi) upstream from Mobile in the Mobile River (Figure 24).

Bault (1972) showed that a similar pattern of stratification occurred in Perdido

Table 10. Dimensions of Alabama's bays and estuaries (Crance 1971).

Dimensions of Mississippi Sound estuary at mean high water.

Subarea	Surface area of open water (acres)	Average depth (feet)	Volume of open water (acre-feet)
Mississippi Sound	72,162	11.72	845,739
Portersville Bay (East)	7,688	4.54	34,904
Fowl River Bay	845	3.26	2,755
West Fowl River	180	4.0	720
Bayou Coden	12	6.0	72
Grand Bay	6,154	5.14	31,632
Bayou La Fourche	430	1.90	817
Sandy Bay	222	3.07	682
Bull Bay Bayou	75	2.00	150
Grand Bayou	9	2.5	23
Portersville Bay (West)	1,718	4.69	8,057
Little Bay	98	2.00	196
Bayou La Batre	101	10.0	1,010
Little River	44	4.0	176
Heron Bay	1,914	2.52	4,823
Heron Bayou	292	2.40	701
Dauphin Island Bay	758	4.26	3,229
Total estuary	92,702	10.09	935,686

Dimensions of Mobile Bay estuary at mean high water.

Mobile Bay, south of battleship Parkway, west of ship channel	78,985	9.42	753,459
Pelican Bay	7,485	13.49	100,973
Dog River	1,426	4.5	6,417
Halls Mill Creek	94	4.0	376
Rabbit Creek	78	3.5	273
Alligator Bayou	47	4.0	188
Perch Creek	25	4.0	100
Robinson Bayou	22	3.0	66
Rattlesnake Bayou	13	4.0	52
Moore Creek	8	3.5	28
East Fowl River	629	6.70	4,214
Deer River, Middle and North Fork	40	11.0	440
Deer River, South Fork	7	3.5	25
Subtotal	88,859		866,611

Table 10. Continued

Dimensions of Mobile Bay estuary at mean high water.

Subarea	Surface area of open water (acres)	Average depth (feet)	Volume of open water (acre-feet)
Mobile Bay, south of battleship Parkway, east of ship channel	170,358	9.93	1,691,655
Weeks Bay	1,718	4.76	8,178
Bay John-Ducker Bay	929	3.91	3,632
Oyster Bay	724	3.18	2,302
Bon Secour River	594	5.30	3,148
Fish River	386	7.50	2,895
Blakeley River	265	12.94	3,429
D'Olive Bay	254	2.60	660
Magnolia River	203	7.50	1,523
Apalachee River	131	9.63	1,262
D'Olive Creek	41	2.50	103
Fly Creek	8	6.0	48
Subtotal	175,611		1,718,835
Total estuary	264,470	9.74	2,585,446

Dimensions of Mobile delta estuary at mean high water.

Subarea	Surface area of open water (acres)	Average depth (feet)	Volume of open water (acre-feet)
Grand Bay	1,963	3.62	7,106
Chacaloochee Bay	1,919	2.72	5,220
Polecat Bay	1,693	2.22	3,758
Chuckfee Bay	598	3.54	2,117
Delvan Bay	531	2.85	1,513
Bay Minette	403	5.02	2,023
Big Bateau Bay	288	2.50	720
Bay Minette Basin	194	3.97	770
Justin Bay	158	2.50	395
Little Bateau Bay	74	2.50	185
Tensaw River	3,473	20.70	17,891
Mobile River	2,216	21.40	47,422
Apalachee River	1,085	14.27	15,483
Spanish River	1,060	15.80	16,748
Raft River	673	14.80	9,960
Bayou Canot	477	18.30	8,729
Blakeley River	471	11.19	5,270
Briar Creek	372	13.30	4,948
Chickasaw Creek	310	11.30	3,503
Bayou Sara	304	12.90	3,922
Bay Minette Creek	190	10.30	1,957
Three Mile Creek	74	11.10	821
Industrial Canal	39	16.24	633
Other	1,758	3.00	5,274
Total estuary	20,323	10.84	166,368

Table 10. Concluded.

Dimensions of Perdido Bay estuary at mean high water.

Subarea	Surface area of open water (acres)	Average depth (feet)	Volume of open water (acre-feet)
Perdido Bay	10,174	8.37	85,156
Wolf Bay	3,330	5.48	18,248
Bay La Launch	1,059	8.55	9,054
Terry Cove and Cotton Bayou	1,009	5.67	5,721
Arnica Bay	792	8.38	6,637
Perdido River north to Blackwater River	478	15.10	7,218
Soldier Creek	270	6.13	1,655
Intracoastal Waterway	159	12.50	1,988
Total estuary	17,217	7.86	135,677

Bay. However, the wedge that develops in Perdido Bay apparently does not extend as far upstream into the Perdido River as does the wedge in Mobile Bay. Figure 25 shows the average monthly surface salinity at Perdido Pass and in Perdido Bay. Stratification in Perdido Pass is limited because of mixing of the waters during tidal exchanges.

Figures 26 and 27 are bimonthly surface and bottom isohaline maps of Mobile Bay and Mississippi Sound. The surface isohaline maps show progressively higher concentrations of salt during periods of low river discharge. Isohaline maps of the bay bottom reveal the salt-water wedge that has developed due to channelization.

Figure 28 shows the difference in stratification in the Mobile Ship Channel between periods of ebb and flood tide. During ebb tides the stratification is much more pronounced because more fresh water is allowed to flow out of the Mobile River basin.

Figure 25 shows that the salinity in Little Lagoon is highest in the summer and lowest in the winter and spring. The low salinities are probably due to increased precipitation while the high salinities are due to increased evaporation and low rainfall.

TIDES

Along coastal Alabama the tidal cycle is a diurnal type with one high and one low tide occurring in a day. The interval between succeeding high (or low) stages is about 24.8 hours but it may vary. Accurate tidal forecasts are published annually by the U.S. Department of Commerce in "Tide Tables—East Coast of North and South America."

In Mobile Bay, the mean tidal range is about 0.46 m (1.5 ft) in the upper end, 0.49 m (1.6 ft) in Bon Secour Bay, and 0.37 m (1.2 ft) at the mouth of the bay. In Mississippi Sound, the mean diurnal tide range is 0.34 m (1.1 ft) in Dauphin Island Bay and 0.46 m (1.5 ft) in Bayou La Batre. In Perdido Pass, the mean tidal range is about 0.18 m (0.6 ft).

Tides are extremely important to the existence and maintenance of Alabama's estuaries. They affect currents and circulation patterns in bays, sounds, and inlets, and their vertical range determines in part, the extent of tidal marshes and mud flats. In addition, they are a determining factor in the areal distribution of many organisms occurring within the area.

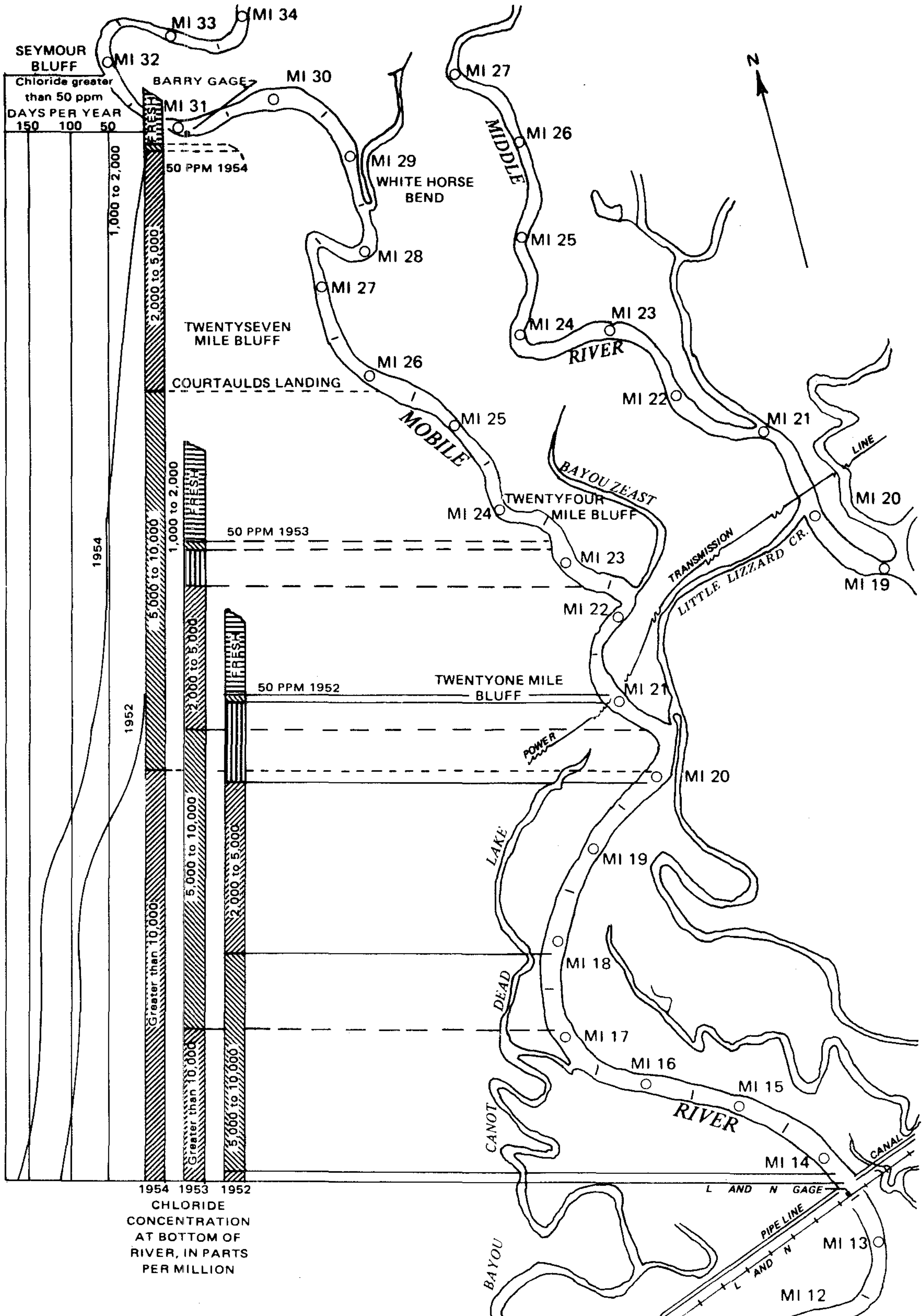


Figure 24. Chloride concentration in the Mobile River between river miles 13.6 and 31.0, 1952, 1953, 1954 (Robinson et al. 1956).

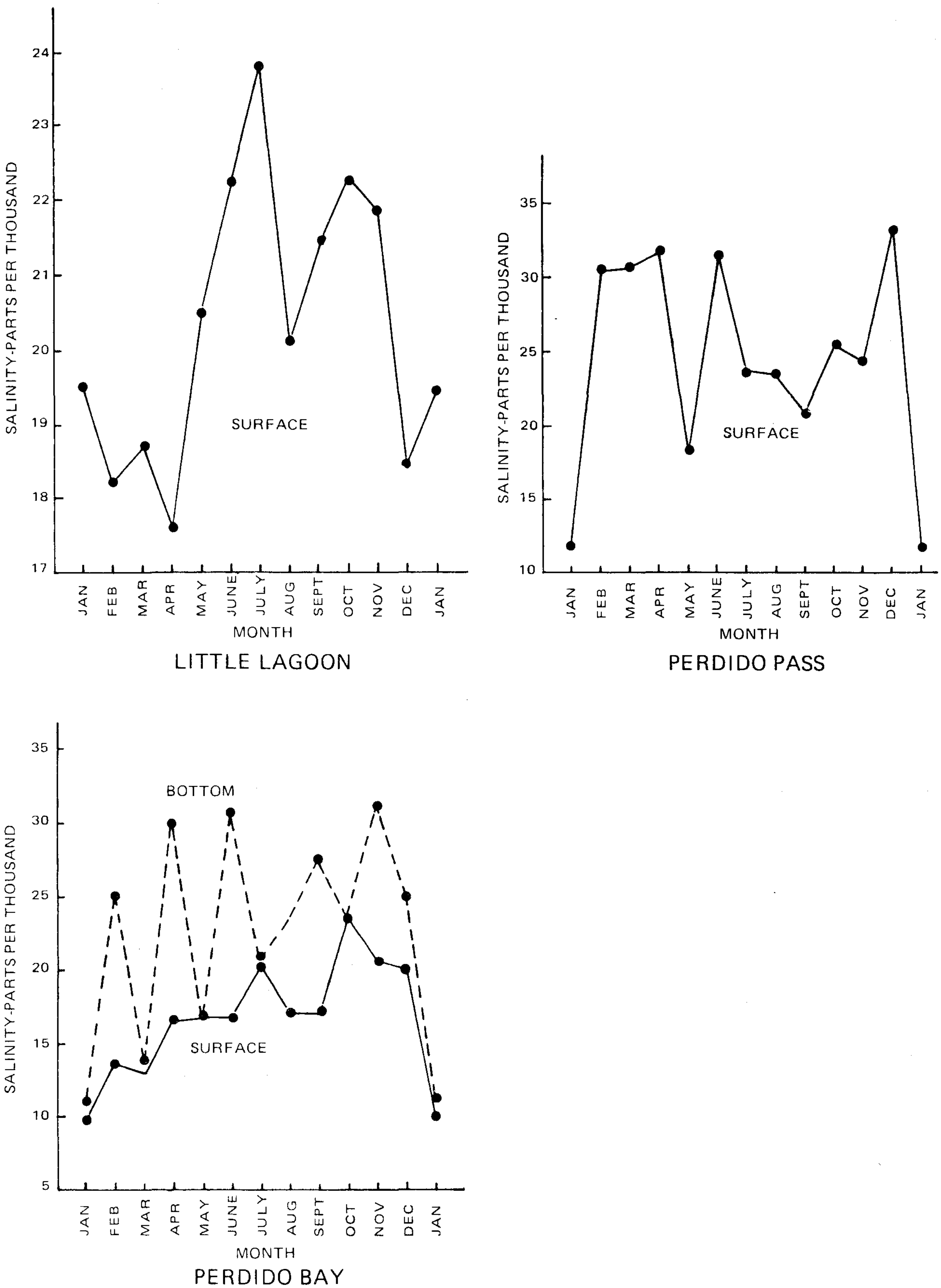


Figure 25. Salinity of Little Lagoon, Perdido Pass, and Perdido Bay (modified from Bault 1972).

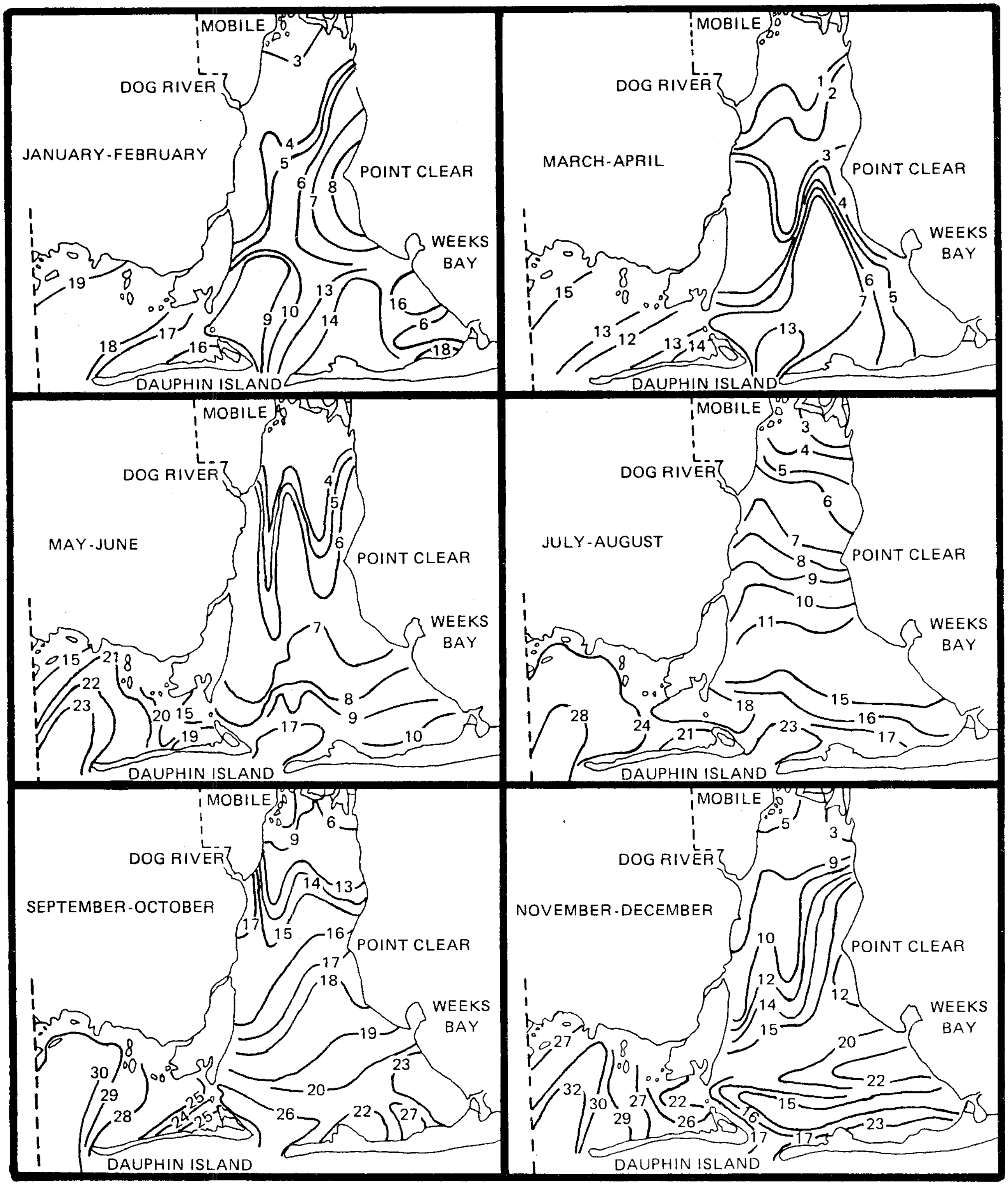


Figure 26. Bimonthly surface isohaline maps (ppt) of Mobile Bay and Mississippi Sound (Bault 1972).

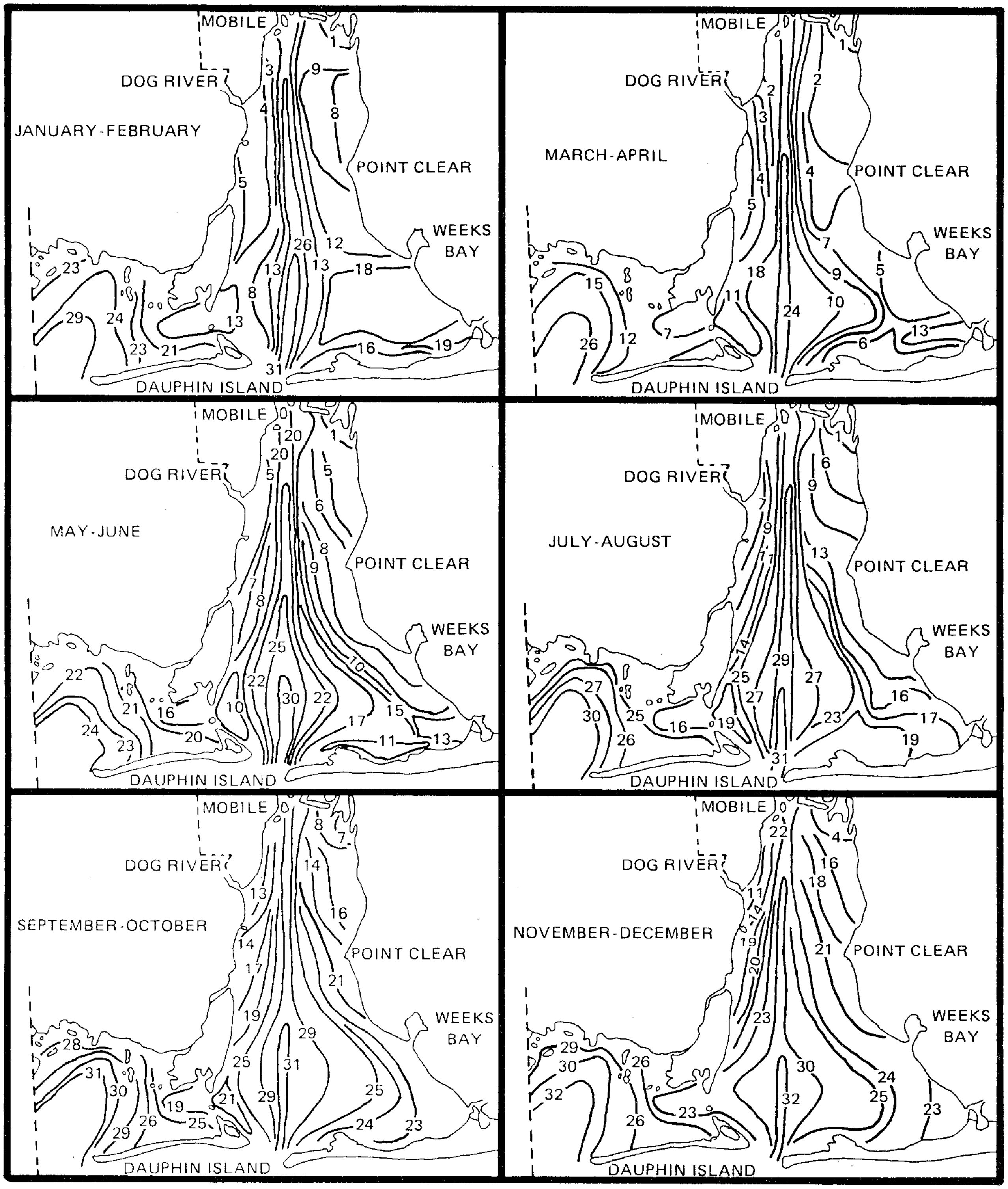


Figure 27. Bimonthly bottom isohaline maps (ppt) of Mobile Bay and Mississippi Sound (Bault 1972).

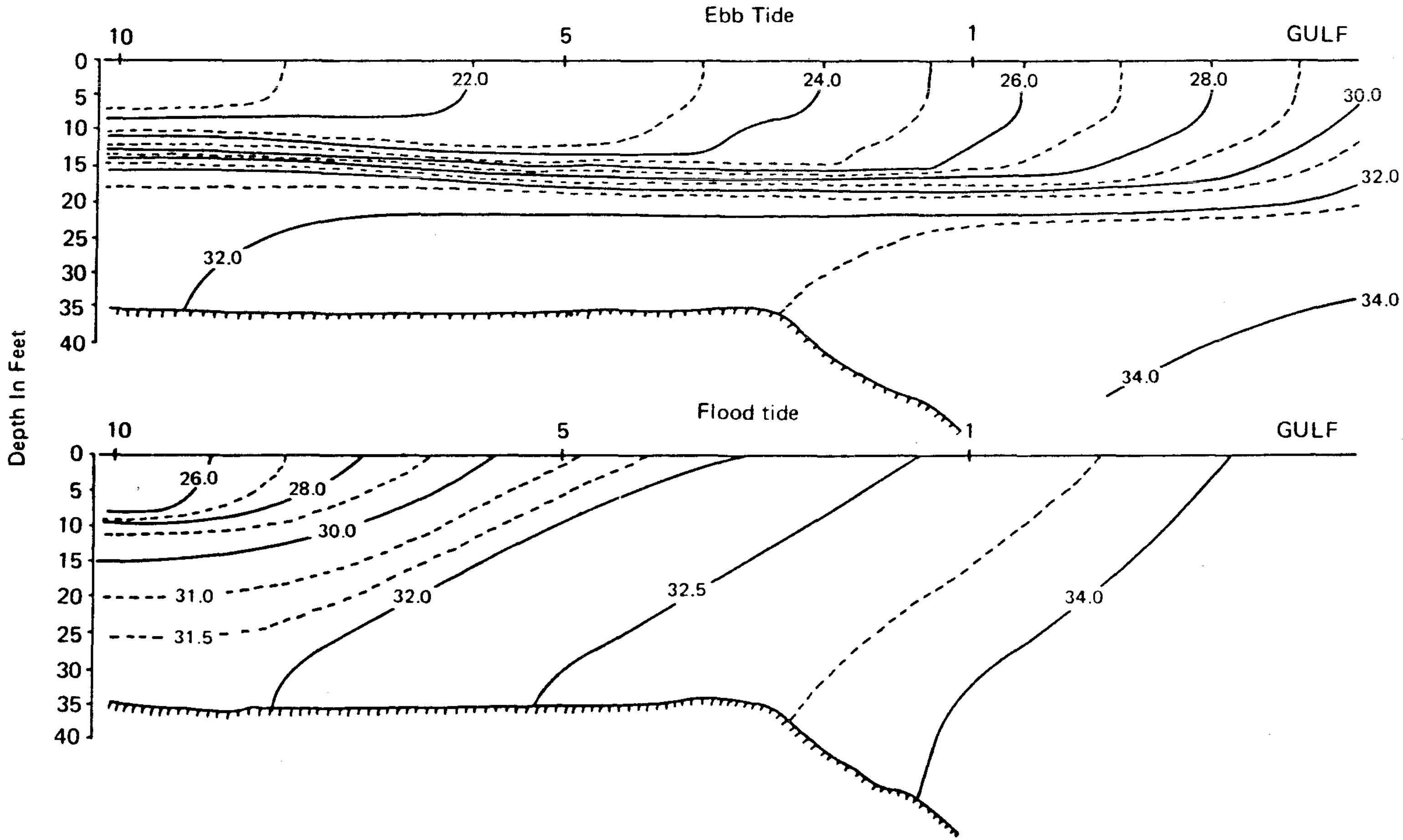


Figure 28. Salinity (ppt)-depth section, lower Mobile Ship Channel (Austin 1954).

Tides are governed by many factors, the most important of which is the moon and its gravitational pull. The largest tidal variations are due to differences in the moon's angle of declination with respect to the equator. Equatorial tides have the least range between high and low tides and occur when the moon is nearest the equator and has the least declination. Tropic tides, on the other hand, have the largest range and occur when the moon is farthest from the equator and has the largest declination. The cycle is called a tropical month and is completed every 27.2 days.

Astronomical tides are principally daily with an average range of <0.5 m. During the tropic tides, the range can reach 0.8 m, while during the equatorial tides, the range can be <0.1 m. Periods of semi-daily tides usually occur twice a month for one to three days at a time (Schroeder 1979a). Additional information on tides can be found in Marmer (1954) and McPhearson (1970).

Another type of lunar month that also affects tides is the synodic month (new moon to new moon), and takes 29.53 days per cycle. When the moon, sun, and earth are in or approaching syzygy (a straight line of three or more celestial bodies), spring tides occur. Spring tides occur during the new and full moon and have the largest range of the synodic tides. When the moon, sun and earth form an angle at or near 90°, neap tides occur. Neap tides occur during the first and third quarters, and have the least range of the synodic tides. Mean tidal range is the term that is most commonly used when speaking of tidal variation, and is defined as the range between the average high tide and the average low tide.

Factors other than the position of the sun, moon, and earth that affect tidal variation are winds, fresh-water discharge, and storms. Of these factors storms, although occurring infrequently, are by far the most important. Storm tides are normally considerably higher than the highest equatorial tides and can be destructive. Storm tides associated with hurricanes can be 3 m (10 ft) or more above mean tide levels.

Winds, other than those associated with storms, affect tidal range most frequently. South winds tend to concentrate water in northern Mobile Bay and inhibit ebb tides by retarding streamflow whereas north winds tend to push salt water out of the bays and inhibit flood tides.

Fresh-water discharge also affects tidal variation. During periods of high river discharge tides are higher than normal because of extra water in the bays. However, the significance of flooding is not nearly as great as one might expect. Even the largest floods will raise the level of Mobile Bay an average of less than 0.6 m (2 ft), which is considerably less than storm tides.

CURRENTS, CIRCULATION, SEDIMENTATION, AND EROSION

Many factors contribute to the circulation patterns of Alabama's coastal waters. These include tides, fresh-water discharges, shoreline configuration, winds, longshore currents, and the Coriolis force.

Tidal currents are of the reversing or rectilinear type. Flood currents flow into estuaries for about 6 hours and ebb currents flow seaward for about 6 hours. The change from flood to ebb and back to flood tide gives rise to periods during which there is no current. Longshore currents in the Gulf of Mexico flow parallel to the shore in a net westerly direction.

Stream and river discharges affect circulation patterns and currents in that they tend to increase ebb current velocities and decrease flood current velocities. During periods of high discharge fresh water moves with such force that it can alter, at least for short periods, normal circulation patterns within estuaries.

Shoreline configuration also plays a significant role in estuarine circulation patterns. A point, spit, or island will deflect surface water and thus alter current direction and circulation pattern.

Coriolis forces are produced by rotation of the earth on its axis, and in the northern hemisphere, tend to deflect all moving objects to the right. It is most influential in wider estuaries where current flows are unrestricted by shorelines.

Sediment includes solid materials weathered from rocks, chemical and biochemical precipitates, and decomposed organic material. The quantity, characteristics, and causes of sediment occurrence in streams are influenced by factors such as degree of slope, length of slope, soil characteristics, land use, and quantity and intensity of precipitation.

Sedimentation of coastal embayments occurs by both natural and man-made processes. Sediments within coastal waters range from clean sands to relatively pure clays, with various mixtures of sand, silt and clay covering much of the area. The distribution of these sediments is an indication of the average pattern of circulation, and may provide valuable information about circulation changes through time.

Modern methods of studying sediment dispersal rely heavily upon remote sensing. This tool has not been thoroughly utilized in the study of sediments in Mobile Bay (Lamb 1979).

PERDIDO BAY

In 1964 the U.S. Army Corps of Engineers measured tidal currents in Perdido Pass over a 24-hour period and reported that the mean flood tide velocity was 0.8 m/s (2.5 ft/s) with a maximum velocity of 1.2 m/s (4.0 ft/s). The mean ebb tide velocity was 0.6 m/s (2.0 ft/s) with a maximum of 0.7 m/s (2.3 ft/s). Figure 29 shows both the surface and bottom currents during flood tide and Figure 30 shows those currents during ebb tides. During flood tide, surface currents moved consistently toward the mouth of Perdido Bay. The bottom currents, however, showed a more complex pattern. Waters from the Perdido River and Eleven Mile Creek flowed outward for a short distance and then were deflected in a counterclockwise direction by the bottom currents flowing into the bay from the Gulf of Mexico.

During the ebb tide the general current patterns were much more consistent. Both the surface currents and the bottom currents were directed toward the Gulf of Mexico.

The shores of Perdido Bay are well drained because elevations rise abruptly 9.1 to 21.3 m (30 to 70 ft) on the west side of the bay and 1.5 to 4.6 m (5 to 15 ft) along the remaining shore (Parker 1968).

Perdido Bay has experienced little measurable shoreline change along the Alabama portions of the bay, but significant changes have occurred as the result of excavations by local residents, hurricanes, and westward littoral drift (Hardin et al. 1976). Jetties have been constructed to arrest the westward drift of the shoreline that tends to close Perdido Pass.

Sediments in Perdido and Wolf Bays consist of estuarine clayey silt and silty clay in the central part and clean, well-sorted, bay-margin quartz sand around the periphery (Figure 31). The northern part of Perdido Bay is floored by delta-front silty sand, silt, and sand. Bayou St. John, Old River, and Big Lagoon are floored mainly by sand with some silty sand and clayey silt (Parker 1968). Sedimentation rates for the Perdido Bay system are not known.

MISSISSIPPI SOUND

The northern shoreline of Mississippi Sound consists primarily of low-lying salt marshes with numerous tidal creeks. The southern shoreline is comprised of a series of sandy barrier islands that protect the northern marshy coast from the full impacts of gulf wave action.

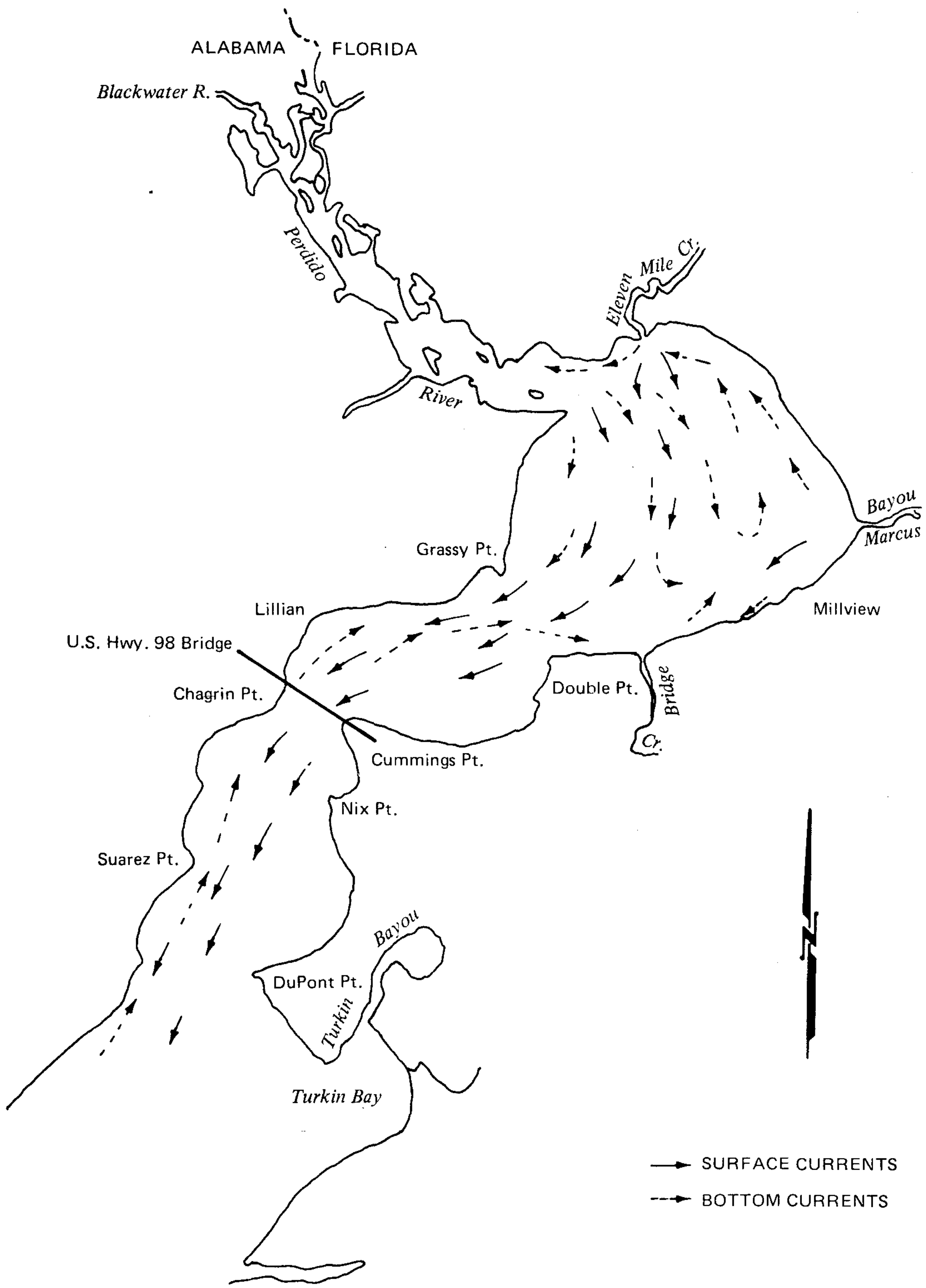


Figure 29. Flood-tide current patterns in Perdido Bay (Federal Water Pollution Control Administration 1970a).

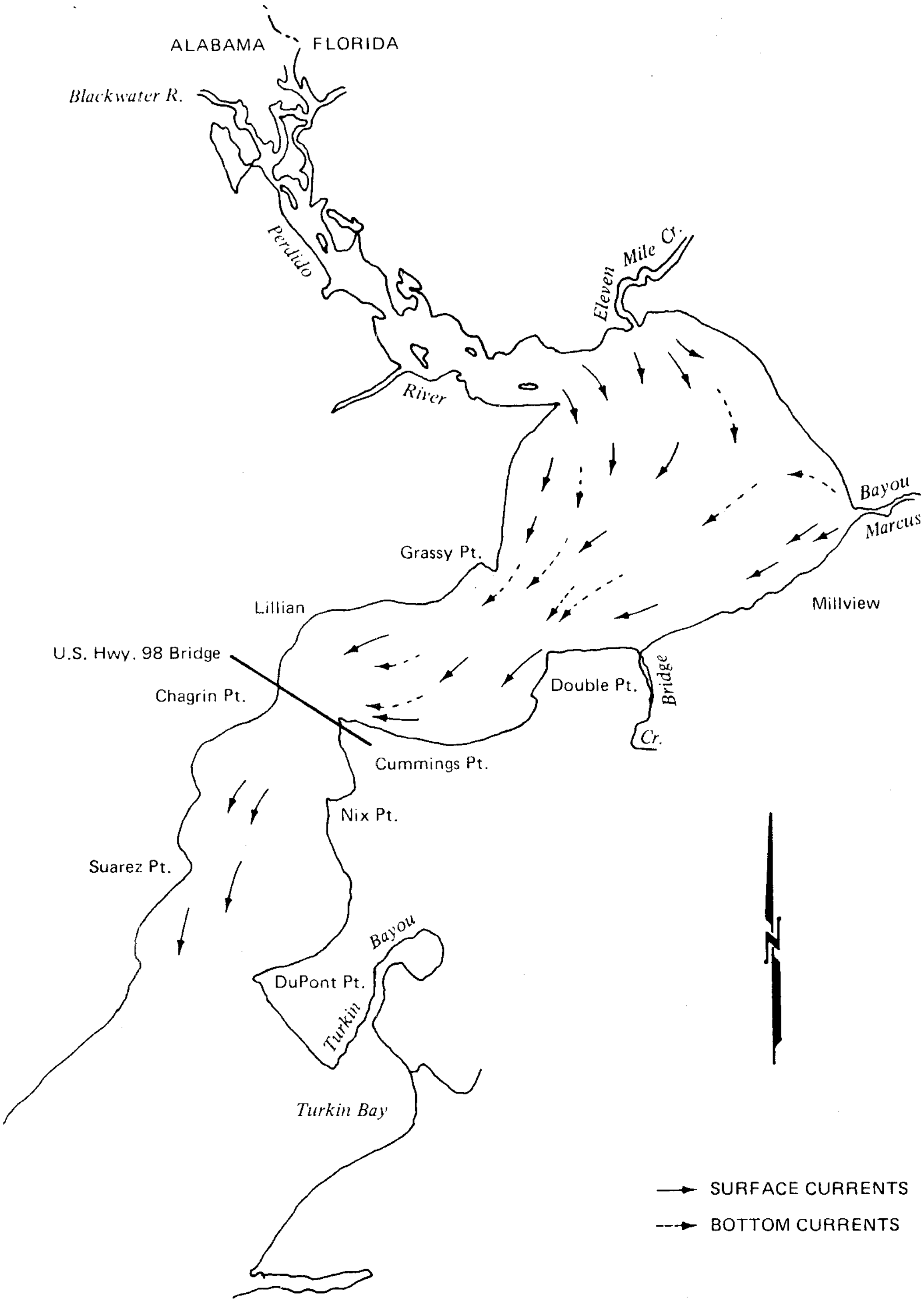


Figure 30. Ebb tide current patterns in Perdido Bay (Federal Water Pollution Control Administration 1970a).

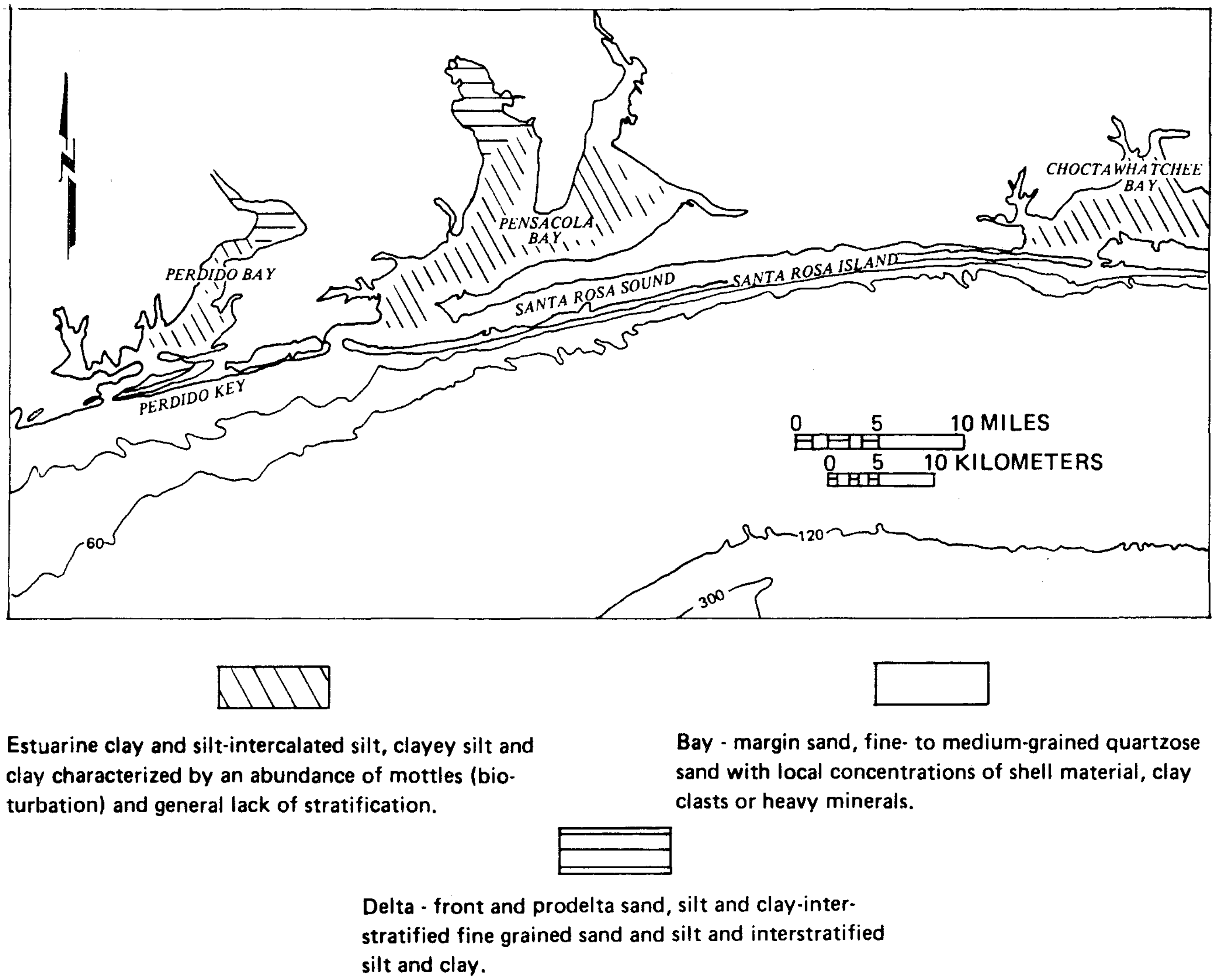
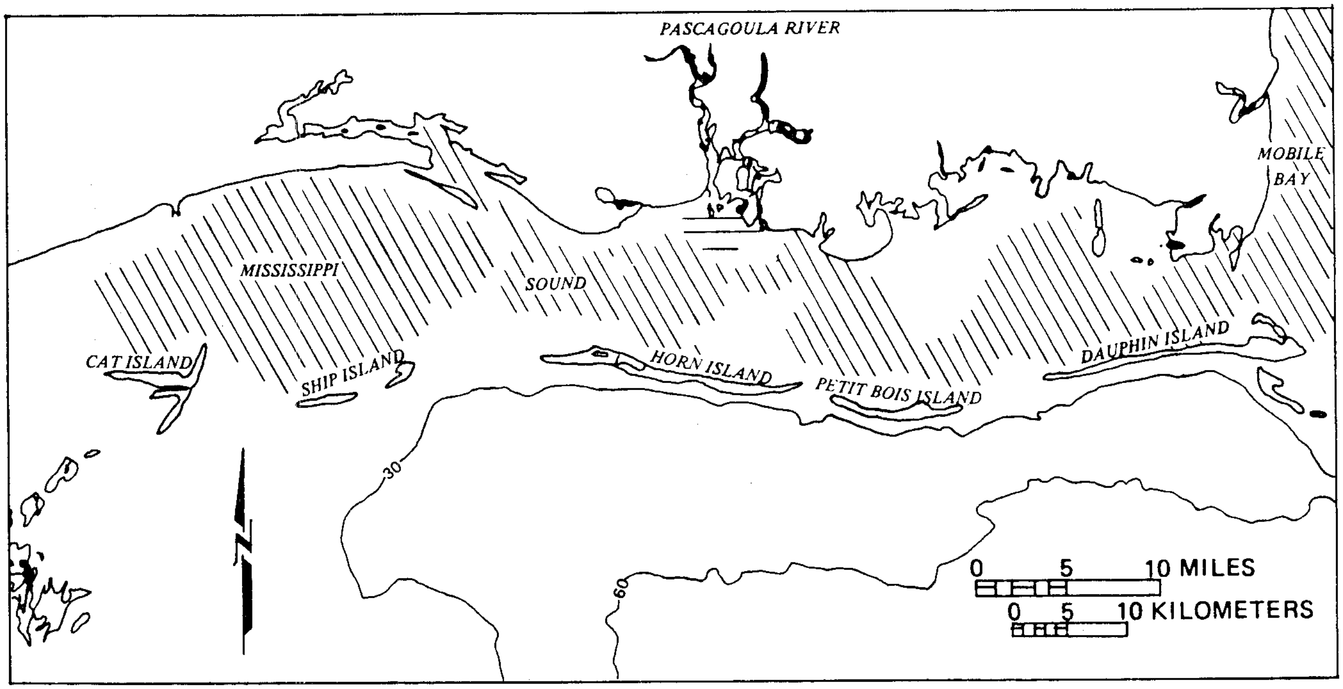


Figure 31. Sediment distribution in Perdido Bay (Boone 1973).

The configuration of the barrier islands is constantly changing, and such changes probably alter circulation patterns in Mississippi Sound. Foxworth et al. (1962) indicated that during flood tides longshore currents of the Gulf of Mexico move through the passes between the barrier islands. On early ebb tide, currents are reversed at the surface but deeper currents remain unchanged until the late ebb tide when all currents are passing back into the gulf. The interchange of water between the sound and Mobile Bay further complicates the circulation patterns.

Longshore currents in the Gulf of Mexico move east to west at rates of 0.5 to 1.3 m/s (1.5 to 4.4 ft/s), and on the incoming tides flow increases to 1.3 to 2.7 m/s (4.4 to 8.8 ft/s) (Chermock 1974). Wave action intensity on the Alabama-Mississippi Shelf is low to moderate with wave periods from 3 to 8 seconds and wave heights rarely over 1 m (0.9 ft) except during storms or high winds.

The Alabama portion of Mississippi Sound does not receive water directly from a large river such as the Perdido or Mobile River, but portions of Mobile Bay discharge



Estuarine clay and silt-intercalated silt, clayey silt and clay characterized by an abundance of mottles (bioturbation) and general lack of stratification.

Bay - margin sand, fine- to medium-grained quartzose sand with local concentrations of shell material, clay clasts or heavy minerals.

Delta - front and prodelta sand, silt and clay-interstratified fine grained sand and silt and interstratified silt and clay.

Figure 32. Sediment distribution in Mississippi Sound (Boone 1973).

enter Mississippi Sound. The northern shoreline of Mississippi Sound has experienced net shoreline erosion of at least 1.2 m (3.8 ft) per year for the last 100 years (Hardin et al. 1976).

Sediments are brought into the sound from various sources, and from different directions. Some sediments are brought in from Mobile Bay, some from the Gulf of Mexico on the south, and some from the northern, mainland, shore. Once in the sound, these sediments are distributed by a complex current system (Isphording and Lamb 1980b).

Sediments in Mississippi Sound (Figure 32) consist of estuarine silt and clay in much of the central part and bay-margin sands around the periphery (Upshaw et al. 1966). The estuarine sediment facies are characterized by variable lithology, general lack of stratification, abundance of mottles (bioturbation), and irregular pods of differing lithology (Curray and Moore 1963; Rainwater 1964). Bay-margin sands are quartzose with 1 to 2% heavy minerals (Foxworth et al. 1962). Medium and coarse sand generally occurs along the mainland beaches west of Pascagoula; whereas, fine sand, silt, and clay occurs east of Pascagoula (Upshaw et al. 1966). Medium to coarse sand occurs along barrier-island beaches facing the sound (Upshaw et al. 1966; Weidie 1968). Holocene sediments range in thickness from about 1.5 m (5 ft) in the northern part of the sound to 12 to 18 m (40 to 60 ft) at the barrier island (Ludwick 1964). Sedimentation rates have been estimated at 0.25 mm (0.8 ft) per 1,000 years (Ludwick 1964) to 1.2 m (4 ft) per 1,000 years (Rainwater 1964). Upshaw et al. (1966) indicated the higher rate is more probable, but ". . . the question about the rate of deposition in Mississippi Sound is not resolved."

MOBILE BAY

Average current velocities associated with flood and ebb tides for several locations in Mobile Bay vary between 0.15 and 0.76 m/s (0.5 and 2.5 ft/s).

Austin (1954) investigated circulation during periods of unusually low river flow and developed tidal flushing rates for Mobile Bay. Ryan (1969) identified flow circulation as first coming from the Mobile Bay tidal pass then being deflected to the east, and then northward in a counterclockwise direction.

A more recent concept of circulation patterns within Mobile Bay has been suggested by Schroeder (1974). His concept of flood tide circulation differs considerably from that of Austin (1954). Schroeder described the flood tide flow as spreading evenly from both the Gulf of Mexico and Mississippi Sound and the ebb tide circulation as a rapid movement directly out of the bay. Models of the bay have been developed by April et al. (1976), Pitts and Farmer (1976), and Gaume et al. (1978). The major irregularities between these studies are in the Dauphin Island area where flow is deflected by the pile-up of water along Dauphin Island and Little Dauphin Island. Taking into consideration a zero wind velocity, inflow and outflow circulation profiles are shown in Figures 33 and 34. These profiles were derived by a hydrodynamic model by April et al. (1976).

An annual average of 4.7 million tons of suspended sediment and an unknown quantity of bed load are currently transported into Mobile Bay (Ryan 1969). As the sediments encounter increasing salinity and decreasing water velocity of the bay, many suspended particles flocculate and settle. As shown in Figure 35, the bay bottom is composed mostly of silty clays and clays; while coarser inorganic sands encircle the bay near its shores. Annually about 1.4 million tons of sediment pass through the estuary, some of which are deposited to the south and west of the tidal inlet.

According to Chermock (1974), sediments in northern Mobile Bay are prodeltaic silts, clayey silts and delta front sands and silty sands. In the southern part of the bay, sediments are estuarine silty clay and clay. Toward the periphery of the bay are bay-margin sands and clayey sands. Oyster shell accumulations occur locally, forming oyster shell bottoms and reefs. Holocene sediments are from 5 to 6 m (15 to 20 ft) thick in the western parts of the bay.

Ryan (1969) summarized results of 310 "grab" samples of the upper 5 to 8 cm (2 to 3 inches) of sediments within the bay. The U.S. Army Corps of Engineers collected sediment samples from the harbor portion of the bay in 1971 and 1974. In the 1974 study sediment core samples were collected along the alignment of the Mobile and proposed Theodore Ship Channel. Analyses included physical, chemical, heavy metals, bacteriological, and pesticides by the bulk analyses technique, and elutriate analyses for chemical and heavy metals constituents. Results of the elutriate analyses for the sandy upper bay sediments indicated that the nutrient-related constituents, such as ammonia nitrogen and total Kjeldahl nitrogen, displayed the greatest potential to be released to the water column. Analyses of heavy metals in the dike construc-

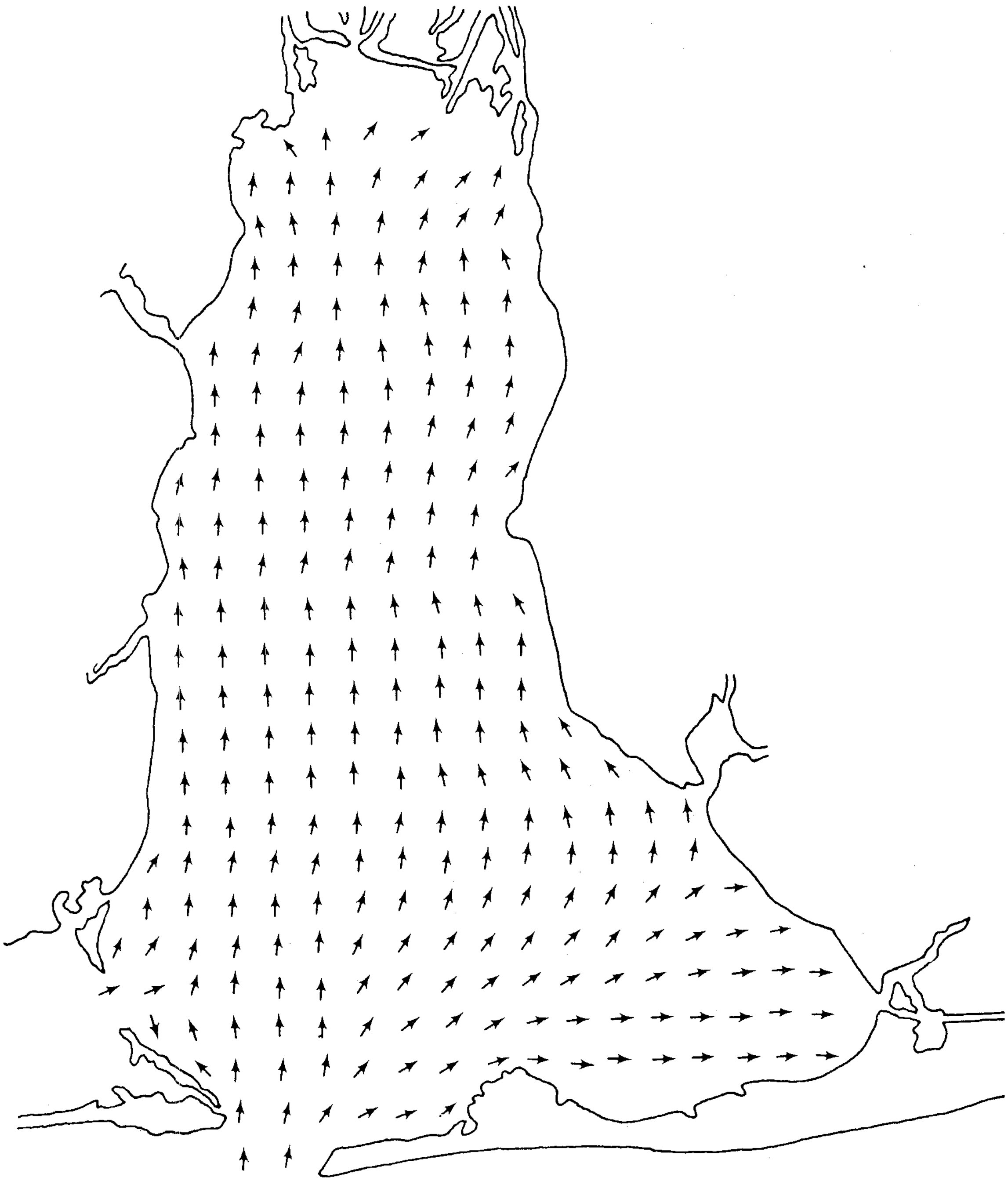


Figure 33. Velocity directions for flood-tide flow predicted by a hydrodynamic model (April et al. 1976).

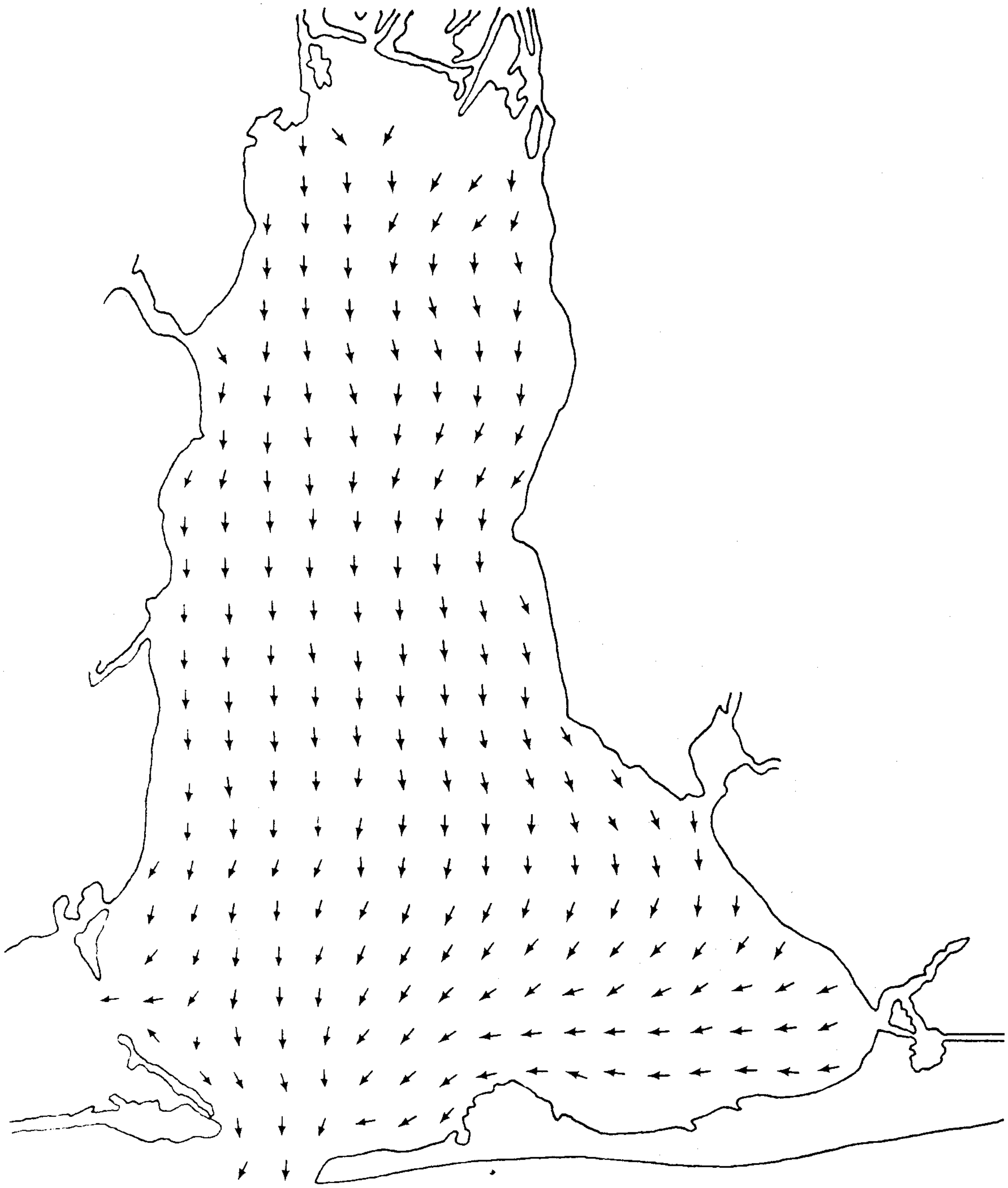


Figure 34. Velocity directions for ebb-tide flow predicted by a hydrodynamic model (April et al. 1976).

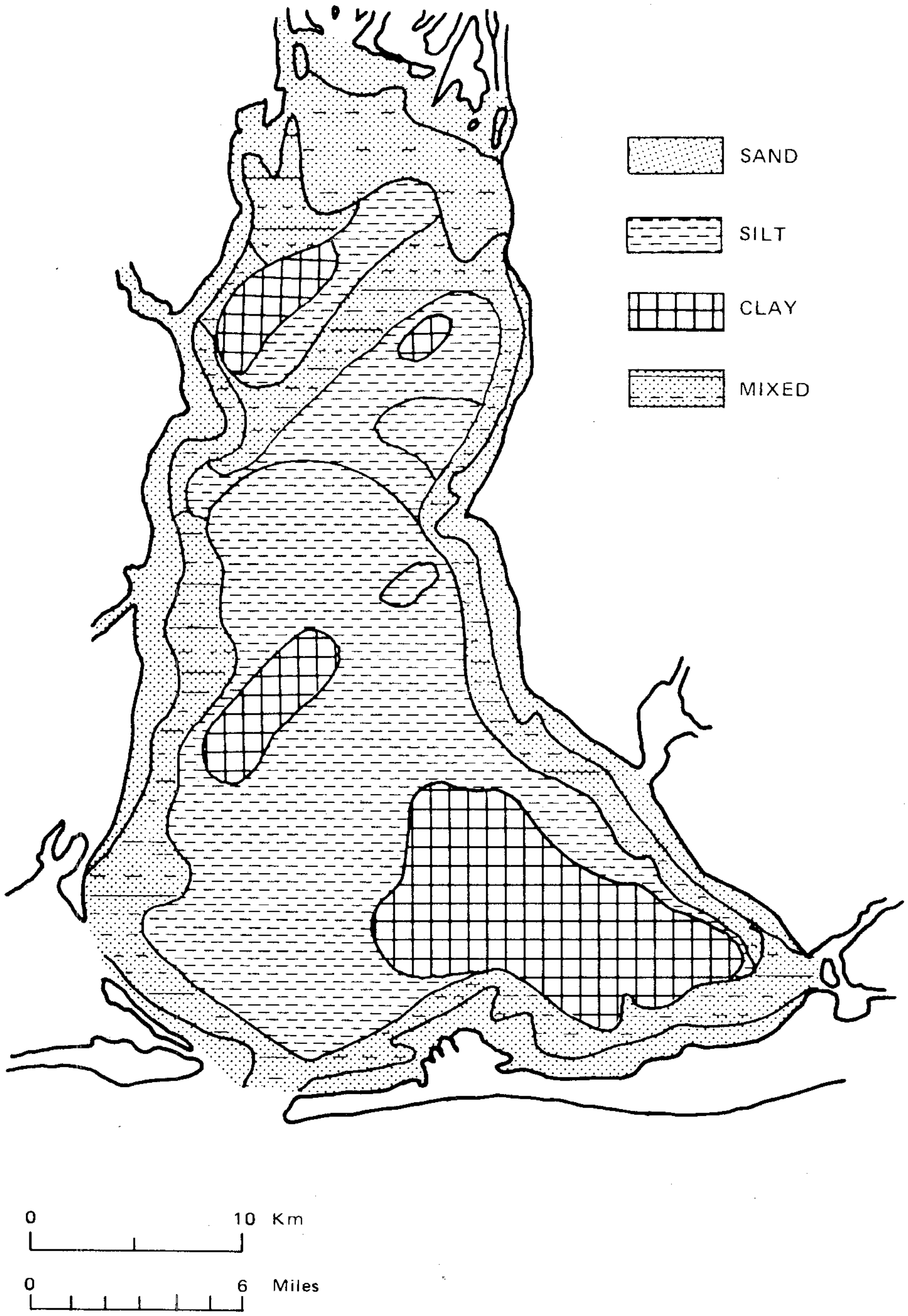


Figure 35. Sediment distribution in Mobile Bay (modified from Ryan 1969).

tion material, however, indicated only nickel and zinc would be released to the water column. The study of the bottom sediments of Mobile Bay and the harbor channels has been fairly well documented in recent years (Technical Committee for Analysis of Mobile Bay Dredging 1972; Chermock 1974; U.S. Army Corps of Engineers 1980). The Technical Committee for Analysis of Mobile Bay Dredging (1972) collected sediment samples from 33 stations in the Mobile Bay area, including 17 stations located in the bay proper. The sediment samples were analyzed for volatile solids, COD, TKN, phosphorous, chromium, zinc, lead, copper, and mercury. Results of the study indicated that:

a. The concentrations for all parameters analyzed were generally higher in the clay, silty clays, and clayey silts, rather than the sand and silty sand bottom;
b. The concentrations of the materials generally appear to increase with distance from the Highway 90 causeway (Ryan 1969);
c. The relationship of concentration with depth varied from station to station with no discernible pattern. However, most often no change was exhibited with depth.

The Alabama Highway Department conducted extensive subsurface investigations in connection with the bridge crossing of Interstate Highway 10 at the delta front. As a result of the analyses, it was found that the trace metals in the sediments are stratified and increased with depth. Surface lead, zinc, and mercury west of the Tensaw River nearer the city of Mobile were higher than to the east.

Isphording and Lamb (1980a) conducted a study to determine the mineralogy and spatial variation of clay species within Mobile Bay. Data on textural distribution of bay sediments collected during the study were used in selecting 60 sampling stations for a study of the chemical quality of bottom sediments in Mobile Bay (Malatino 1980). The chemical quality of bottom sediments in the bay is summarized in Table 11. Sediments were found to consist primarily of calcium, magnesium, iron, and manganese compounds. Concentrations of the metals cobalt, copper, zinc, arsenic, selenium, silver, cadmium, mercury, and lead were low. These metals were distributed uniformly throughout Mobile Bay. These analyses were for total sample (sand, silt, and clay fractions).

Ryan (1969) and Hardin et al. (1976) agree on sedimentation rates of 1.2 m (4 ft) per 110 years in the delta area and 0.6 to 1.0 m (2 to 3 ft) per 110 years in Bon Secour Bay. Hardin et al. report that the rate of filling appears to be decreasing in the upper bay and increasing in the lower bay. As a result of filling, Mobile Bay will shrink in size and the delta will prograde southward (Hardin et al. 1976).

Tanner et al. (1969) identified four processes by which man has modified the natural sedimentation rate in Mobile Bay. These are (1) change in sediment influx into the estuary by water conservation and agricultural processes, (2) modification of circulation within the estuary by construction of landfill causeways, landfill residential sites, and creation of spoil banks adjacent to navigation channels, (3) resuspension of sediment by dredging navigation channels and oyster shell, and (4) introduction of solid wastes from municipal and industrial plants.

Ryan (1969) reported that construction of the Mobile Ship Channel resulted in modification of natural circulation patterns within the bay causing above-average rates of sediment accumulation in the southwestern part of the bay.

The effects of dredging in Mobile Bay were studied by May (1973a). It was concluded that the resuspension of sediments by dredging activity does not have serious detrimental effects on the estuarine environment.

Table 11. Chemical quality of Mobile Bay sediments (modified from Malatino 1980).

Parameter	Concentration range [a]
Aluminum (Al)	10 - 50
Arsenic (As)	1 - 14
Barium (Ba)	10 - 640
Cadmium (Cd)	<10 - 10
Calcium (Ca)	nondetectable to 67,000
Cobalt (Co)	5 - 30
Iron (Fe)	2,000 - 42,000
Lead (Pb)	nondetectable to <10
Mercury (Hg)	<0.2 - 1.1
Manganese (Mn)	12 - 1,600
Magnesium (Mg)	80 - 7,200
Selenium (Se)	<1 - 1.0
Silicon (Si)	1 - 10
Silver (Ag)	all <10
Titanium (Ti)	all <10
Strontium (Sr)	10 - 390
Zinc (Zn)	40 - 1,200
Copper (Cu)	5 - 120
Chromium (Cr)	nondetectable to 90
Nitrogen (N)	0.0000 - 0.019%
Volatile solids	0.1 - 9.1%
Organic carbon	0.01 - 0.12
Phosphorus (P)	0.0000 - 0.0019%

[a]All parameters in micrograms per gram (μg/g) except where indicated.

Historical events have had a profound effect on bay sedimentation. The first of these was the introduction of extensive agriculture. As forests were cleared and lands plowed, a marked increase in runoff and erosion rates occurred, and consequently the amount of sediment being supplied to the bay increased. In the present century there has been a trend toward less extensive farming, with more land acreage being devoted to forests and pasture throughout drainage basins. Although there are insufficient data to prove a reduction in the rate of sedimentation, it is probable that such a reduction has taken place. Construction of dams along all of the major rivers throughout the Mobile basin has caused a reduction in the amount of river-borne sediment. There are now over 20 dams on these rivers with more planned.

Other human activities, such as dredging and filling within the bay, have tended to rearrange sediment distribution and drastically affect some local areas of the bay, but the overall sediment budget has not greatly changed (Lamb 1979). The greatest deposition of sediments in and near Mobile Bay occurs in four areas: (1) east of Mobile, (2) east of Dauphin Island, (3) south of Dauphin Island, and (4) north of Point Clear.

Three areas where shoreline has been eroded by 1.5 to 3.0 m (5 to 10 ft) in the last 100 years are (1) off Mobile, (2) in the tidal pass, and (3) along the Gulf of Mexico bordering Mobile Point.

WATER TEMPERATURE

Water temperatures of Alabama estuaries vary seasonally reflecting changes in air temperature (Figure 36). Vertical variation from surface to bottom is relatively slight because of the constant mixing caused by tidal action, currents, river discharge and winds. In general, from January to April bottom temperatures are slightly higher, whereas during the remainder of the year surface temperatures are higher (McPhearson 1970). The average annual temperature tends to be fairly constant throughout the estuaries with bottom temperatures normally being slightly less than those at the surface (Table 12).

From November to April, there is a north-south gradient in Mobile Bay characterized by an increase in surface temperature that continues into Mississippi Sound. This gradient is less pronounced during the warmer months. Bottom temperatures also show this gradient from September through April. Figures 37 and 38 show surface and bottom isothermal maps, respectively.

Most animals and plants found within estuaries and offshore waters of Alabama are poikilothermic, their body temperatures varying with that of the environment. Since metabolic activity is influenced by temperature, their rates of growth, activity and reproduction are usually closely associated with water temperatures.

WATER QUALITY

The chemical quality of water is characterized by concentrations of dissolved ions and suspended solids. Most major constituents are reported in milligrams per liter (mg/l), which is equivalent to parts per million (ppm), though some minor elements are reported in micrograms per liter (μg/l), which is equivalent to parts per billion (ppb). Biologists, chemists and engineers have learned from past experience and research, the quantities of many of these ions that can be tolerated by humans, plants, and industrial processes. These quantities are referred to as "criteria" for use and are often very different for each use.

The chemical quality of streams in Mobile and Baldwin County is often categorized by the degree of mineral content. The total minerals in the water is often referred to as the total dissolved solids (TDS). Most fresh-water streams in coastal Alabama have a TDS of 100 mg/l or less. The total dissolved solids of seawater is much higher than the fresh water of the streams in coastal Alabama.

Table 13 is a comparison of the average chemical composition of water from the gulf, Mobile, Perdido, and Escatawpa Rivers. The chemical analysis of water from the Mobile River at Creola reflects a "mixed" water sample from both the Mobile River and Mobile Bay waters.

PERDIDO RIVER BASIN

Streams in the Perdido River basin are usually low in mineral content. Most of the streams in this basin have sodium chloride type water. The Perdido River near Barrineau Park, Florida has a TDS ranging from 17 to 52 mg/l, with silica often being the prominent mineral. Locally, the water is acidic and may be objectionable for some uses. A major tributary of the Perdido River, the Styx River, near Loxley has a sodium chloride type water and trends toward a sodium bicarbonate type at low flow (Peirce 1966). Hollinger Creek receives large volumes of wastewater from a sewage treatment plant near Bay Minette. This results in water-quality problems at low flow even though the mineral content is not significantly elevated. The problems of wastewater discharge will be discussed in following sections.

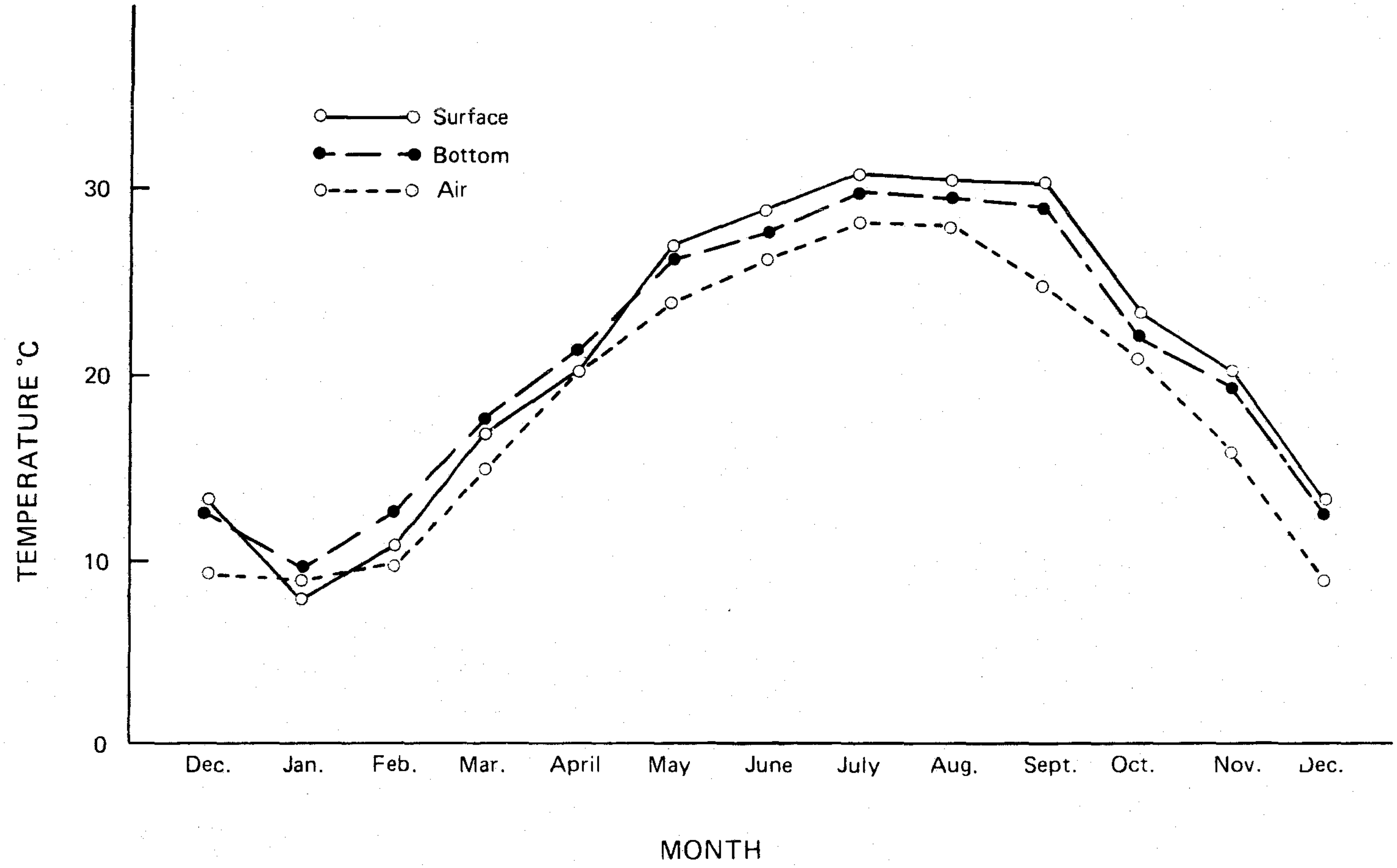


Figure 36. Monthly average temperatures for Mobile Bay and Mississippi Sound, 1963-1964 and 1965-1966 (McPhearson 1970).

Table 12. Average annual surface and bottom temperatures (°C) in Alabama estuaries (Chermock 1974).

Location	Surface	Bottom
Upper Mobile Bay	22.4	21.9
Middle Mobile Bay	22.9	22.4
Lower Mobile Bay	23.5	23.3
Bon Secour Bay	23.4	21.5
Entrance to Mobile Bay	23.5	23.1
Northern Mississippi Sound	23.7	23.3
Southern Mississippi Sound	23.0	22.5
Little Lagoon	22.7	-
Perdido Pass	20.8	20.1
Wolf Bay	20.9	20.9
Perdido Bay	20.4	20.9
Oyster Bay	20.7	20.3
Pass aux Herons	20.2	19.6

ESCATAWPA RIVER BASIN

Water-quality data for the Escatawpa River basin has been published by the U.S. Geological Survey for the gaging stations near Agricola, Mississippi and near Wilmer, Alabama. Data collected at these stations indicate that the river contains water of very good quality. The water is normally low in mineral content, but the iron concentration may be above drinking water limits (0.3 mg/l, U.S. Public Health Department 1962) at certain times of the year. The chemical composition indicates that the water is a sodium chloride type at high flows and a calcium chloride type at low flows. This change in water quality type is unusual because no other streams adjacent to this river basin nor below the confluence of the Tombigbee and Alabama Rivers have similar changes.

A reservoir on Big Creek is a source of good quality water for the city of Mobile. Puppy Creek and Beaver Pond Branch, in the northern portion of the Escatawpa River basin, have experienced water-quality problems due to salt-water spills from oil field activities in the Citronelle area (Hinkle 1981).

MOBILE RIVER BASIN

The quality of water in the Mobile River is largely dependent on the water quality of its major tributary rivers, the Alabama and Tombigbee Rivers.

Water in the Mobile River is a calcium-magnesium bicarbonate type. Peirce (1966) reported that at higher flows the Mobile River may have water quality more like the Tombigbee River. Many smaller tributary streams in this basin, such as Majors and Chickasaw Creeks, have a sodium chloride or sodium bicarbonate water type.

The most complicating factor in determining water quality in coastal areas is the affects of the tides. The introduction of salt water far upstream from the bays (especially during low flows) has limited the use of many inland freshwater streams. The saline water moves upstream as a wedge usually on the bottom of the stream due to the difference in density and temperatures. These two separate bodies of water move independently. This salinity line in the Mobile River has been determined by the U.S. Army Corps of Engineers and other agencies since 1944. At

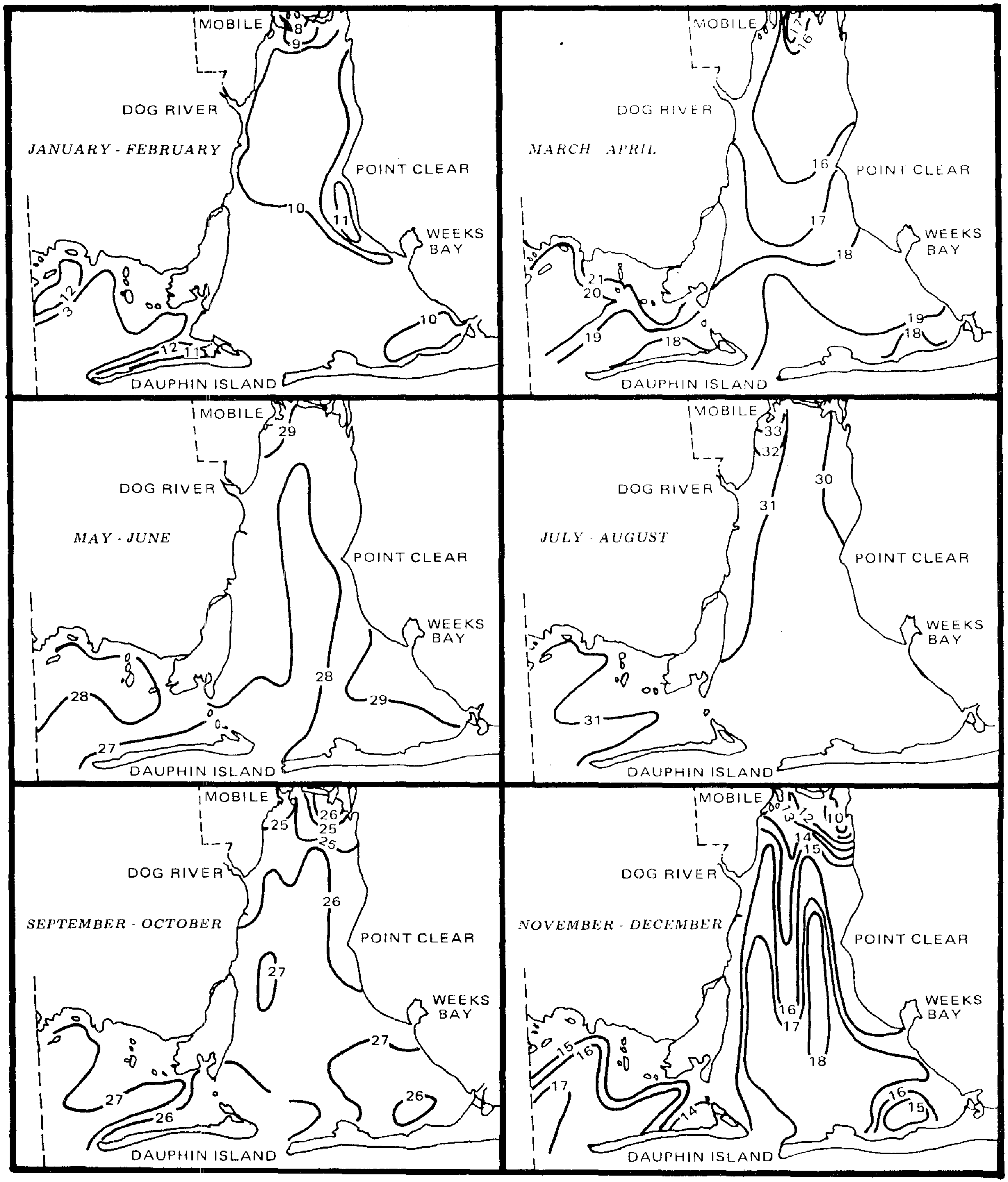


Figure 37. Bimonthly surface isothermal (°C) maps of Mobile Bay and Mississippi Sound (Bault 1972).

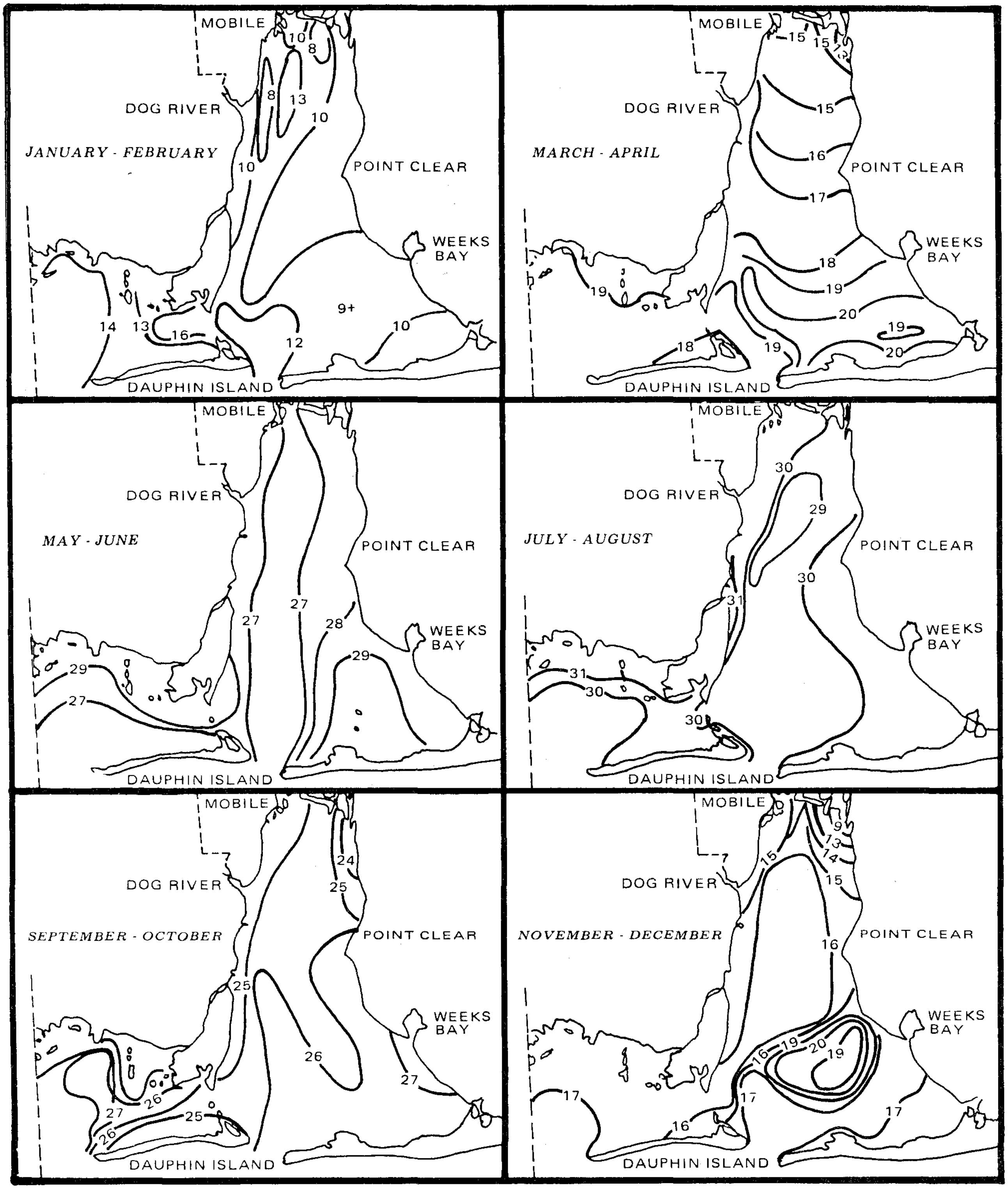


Figure 38. Bimonthly bottom isothermal (°C) maps of Mobile Bay and Mississippi Sound (Bault 1972).

Table 13. The chemical composition of surface water in coastal Alabama.

Parameter[a]	Seawater[b]	Escatawpa River[c]	Perdido River[d]	Mobile River		Mobile River[g] near Creola
Chloride(Cl)	19,000	4.3	3.6	3.5[e]	9.0[f]	620
Sodium(Na)	10,500	2.3	2.2	3.8	8.3	370
Sulfate(SO_4)	2,700	2.5	1.7	10	7.8	120
Magnesium(Mg)	1,350	0.6	0.4	1.4	3.8	46
Calcium(Ca)	400	0.9	0.8	9.7	12	27
Potassium(K)	380	0.5	0.5	1.5	1.5	14
Bicarbonate(HCO_3)	142	2	6	29	56	53
Bromide(Br)	65	no data	no data	no data	no data	-
Strontium(Sr)	8	0.060(1)	0.030(1)	no data	no data	0.390
Silica(SiO_2)	6.4	7.1	7.0	7.4	9.8	4.8
Boron(B)	4.6	no data	no data	no data	no data	-
Fluoride(F)	1.3	0.0	0.0	0.1	0.1	0.1
Nitrogen(N)	0.5	2.5 (NO_3)	0.43	1.1(NO_3)	0.5(NO_3)	0.15 (NO_3+NO_2 as N)
Phosphorus(P)	0.07	0.02	0.04	no data	no data	-
Iron(Fe)	0.01	0.25	0.146	0.070	0.08	0.001

[a]All parameters in mg/l unless otherwise indicated.
[b]Goldberg (1963).
[c]U.S. Geological Survey 1977 (an average of water-quality data for 1977 water year).
[d]U.S. Geological Survey 1979 (an average of water-quality data for 1979 water year).
[e]Peirce et al. (1966) (date of analysis: February 10, 1954, high flow).
[f]Peirce et al. (1966) (date of analysis: August 10, 1954, low flow).
[g]U.S. Geological Survey 1979.

higher flows of the Mobile River, salt water does not move inward but is actually forced out of the river and during the largest floods causes Mobile Bay's water quality to be river-like. The latest salinity determinations by the U.S. Geological Survey have attempted to correlate tides, flow, and rainfall with salinity of the four rivers at the causeway. Data accumulated in these studies indicates the navigation channels in the Mobile and Tensaw Rivers cause salinities to be much higher than those of the Apalachee and Blakeley Rivers.

Wastewater from Mobile has significantly changed the water quality of Chickasaw and Three Mile Creeks. These streams are impacted by wastes of sewage treatment plants and other industries. Consequently, flow from these tributaries has caused the lower Mobile River to have water-quality problems in its ability to assimilate and naturally decompose these wastes. Most sources seem to agree that the Mobile River is of good quality above Chickasaw Creek.

MOBILE BAY UNIT

Streams entering Mobile Bay are influenced by tides and often have periods during which highly mineralized water from the bay moves inland. These streams are generally a sodium chloride or sodium bicarbonate type.

Because Mobile Bay and Mobile River are large, sources of pollution in Mobile Bay have little affect on the overall water quality except in highly- localized areas. Nonetheless, wastewater discharged into the Bon Secour, Deer, Fish, and Fowl Rivers may subject Mobile Bay to slow degradation in water quality. Although these streams are not sources of drinking water, contamination may affect fishing, swimming, and shellfish harvesting.

In estuarine areas seawater can become significantly diluted. During major floods, Mobile Bay often contains fresh water, but in times of low flow highly saline water may extend far upstream above Mobile Bay.

WESTERN AND EASTERN COASTAL UNITS

Streams in south Mobile and Baldwin Counties, except those in areas affected by salt-water intrusion, generally contain water of suitable chemical quality for most uses. The water generally is soft and has a dissolved-solids content of less than 100 mg/l. Locally, the water is acidic and may be objectionable for some uses.

ALABAMA-TOMBIGBEE RIVER BASIN

The Alabama-Tombigbee River basin comprises a very small portion of the study area. The streams in this basin are of good quality and are low in total dissolved solids.

WATER-QUALITY MONITORING

Chemical quality of surface water at many locations throughout coastal Alabama has been periodically studied by the U.S. Geological Survey, Alabama Water Improvement Commission, the U.S. Environmental Protection Agency, Alabama Power Company, South Alabama Regional Planning Commission, and the U.S. Army Corps of Engineers, as well as the Geological Survey of Alabama and several academic institutions. Much of the data generated are available and reflect a good data base for Alabama's coastal zones. Table 14 lists 59 monitoring stations identified by the South Alabama Regional Planning Commission for which water-quality information is available and Figure 39 shows the locations of these stations. Also, the U.S. Geological Survey has streamflow and water-quality data available from several gaging stations in the Mobile-Baldwin County area. Table 15 lists data collection sites and Figure 40 shows their locations. Details about period of operation and type of data as well as the actual data are available from computer storage through National Water Data Exchange (NAWDEX) and in annual U.S. Geological Survey reports "Water Resources Data for Alabama."

Table 14. Water quality monitoring stations (modified from South Alabama Planning Commission 1979).

1.	Mobile River opposite David Lake (RM[a] 42)
2.	Mouth of Mobile River at Choctaw Point
3.	Mouth of Spanish River and Delvan Bay
4.	Mouth of Tensaw River
5.	Mouth of Apalachee River at Causeway
6.	Mouth of Blakely River (west of D'Olive Bay)
7.	Dauphin Island Bridge (Grant's Pass)
8.	Mouth of Mobile Bay, between Ft. Gaines and Ft. Morgan
9.	Mobile Bay approximately 1.5 miles east of Dog River
10.	Mobile Bay approximately 2 miles northwest of Montrose
11.	Mobile Bay approximately 1.5 miles east of Fowl River
12.	Mobile Bay approximately 5 miles east of Fowl River
13.	Mobile Bay approximately 3 miles southwest of Point Clear
14.	Mouth of Three Mile Creek
15.	Three Mile Creek at St. Stephens Road
16.	Mobile River at Pinto Pass (RM 5)
17.	Intersection of Mobile and Spanish Rivers (RM 6.0)
18.	Mouth of Eight Mile Creek
19.	Eight Mile Creek at Highway 45
20.	Mouth of Dog River
21.	Mouth of Theodore Ship Channel (Deer River)
22.	Mouth of Fowl River
23.	Mouth of Intracoastal Waterway
24.	Mouth of Bon Secour
25.	Mouth of Weeks Bay (Fish River Point)
26.	Magnolia River at Highway 49
27.	Mouth of Polecat Creek
28.	Corn Branch near Camp Loxley
29.	Mouth of Styx River
30.	Styx River at Hollinger's Creek
31.	Tensaw River at Big Lizard Creek (north of Gravine Island)
32.	Tensaw River at Middle Creek
33.	Bayou Sara at Norton Creek
34.	Mobile River near Grog Hill Creek (RM 35.3)
35.	Mobile River below Shell Chemical (RM 24)
36.	Mouth of Chickasaw Creek
37.	Mobile River above Chickasaw Creek (RM 3.5)
38.	Mobile River below Three Mile Creek (RM 0.5)
39.	Mobile Bay approximately 3 miles east of Dog River at Mobile Ship Channel
40.	Mobile Bay approximately 8 miles east of Dog River
41.	Gulf of Mexico approximately 1 mile south of Sand Island
42.	Dog River at Luscher Park
43.	Mobile River at I-65
44.	Mobile River at L & N Railroad Bridge
45.	Mobile River at Alabama State Docks
46.	Bayou La Batre at Alabama Highway 188
47.	Three Mile Creek between U.S. 43 and Southern RR
48.	Chickasaw Creek at Highway 43
49.	Chickasaw Creek at L & N RR Bridge
50.	Escatawpa River at Highway 98
51.	Hollinger Creek southeast of Bay Minette
52.	Wolf Creek at County Road 12
53.	Wolf Creek 0.25 mile upstream of County Road 12 Bridge
54.	Bon Secour River near Bon Secour, Alabama
55.	Intracoastal Canal east of Gulf Shores
56.	Tensaw River at L & N RR Bridge
57.	Tensaw River just below Gravine Island
58.	Chickasaw Creek near Kushla
59.	Perdido River

[a]RM--River Mile.

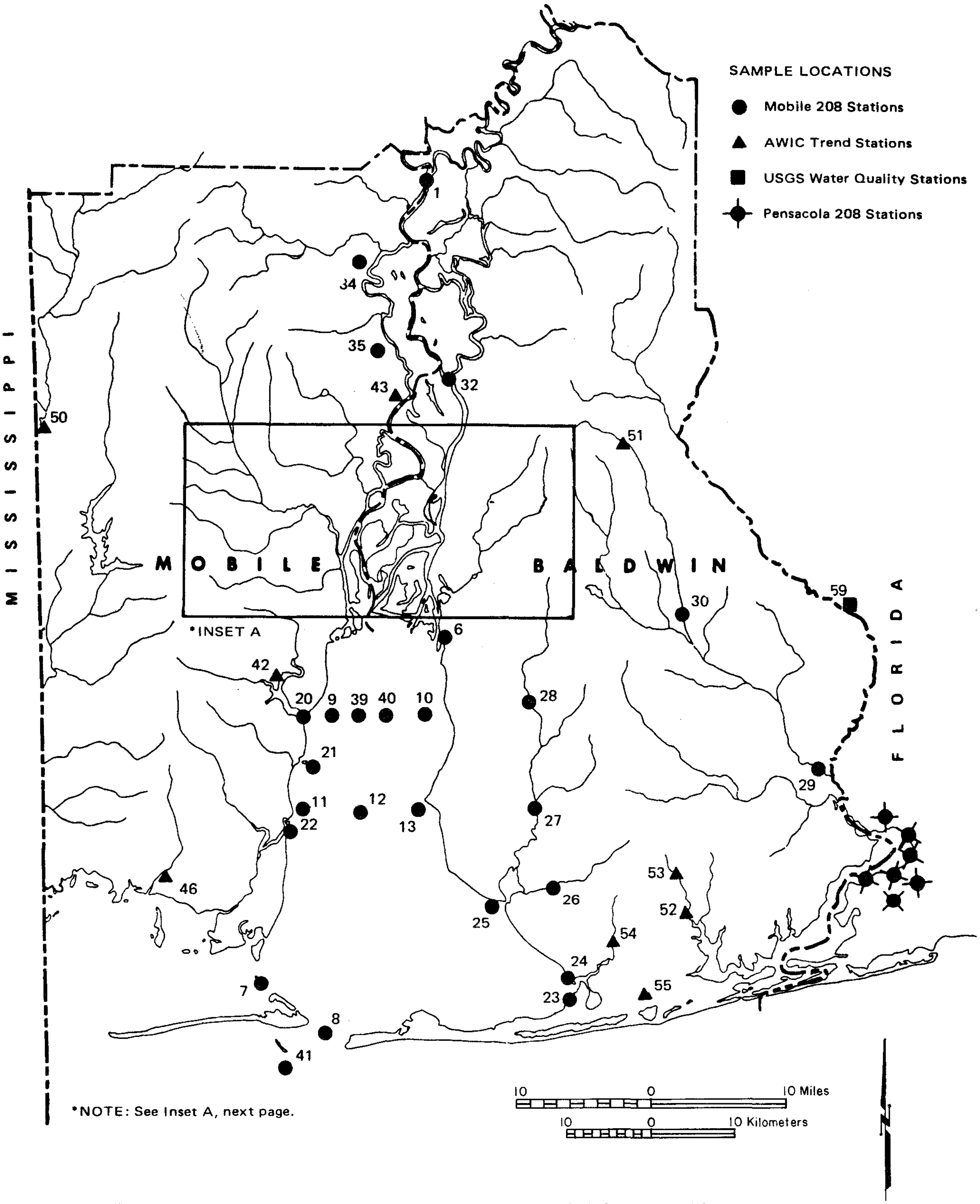


Figure 39. Location of water quality stations in Mobile and Baldwin Counties (South Alabama Regional Planning Commission 1979).

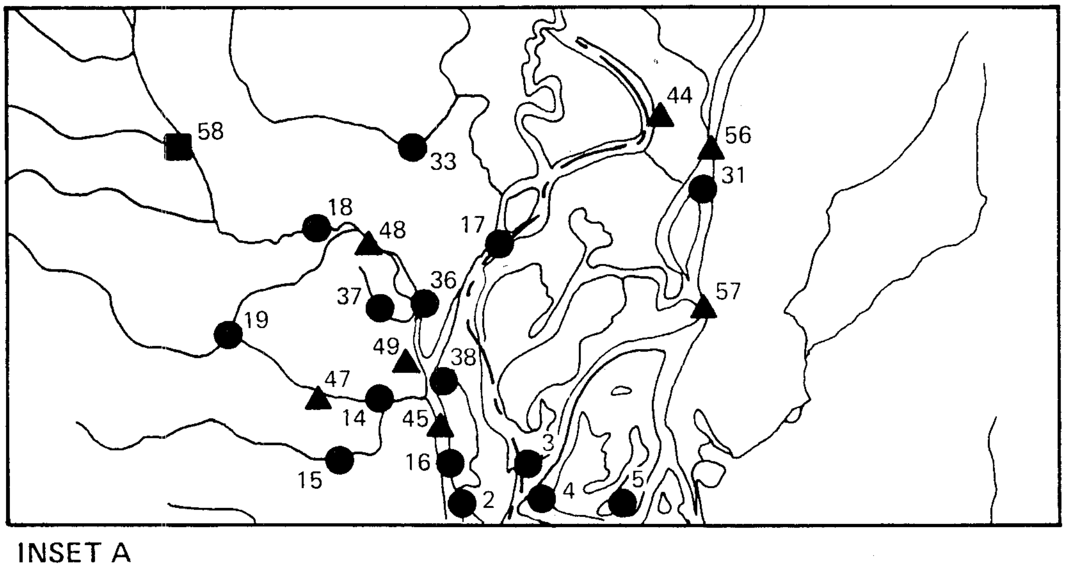


Figure 39. Concluded.

Table 15. U.S. Geological Survey surface-water gaging stations.

Site number	U.S. Geological Survey identification number	Station name[a]	Drainage area (mi^2)
1	02479500	Escatawpa River near Wilmer	506
2	02479468	Puppy Creek near Georgetown	-
3	02479450	Escatawpa River at county road 96	-
4	02471065	Montlimar Creek at U.S. Hwy. 90 at Mobile	-
5	02471018	Mobile River at Bankhead Tunnel at Mobile	-
6	02471000	Chickasaw Creek near Whistler	123
7	02470800	Bayou Sara near Saraland	-
8	02470805	Bayou Sara at Saraland	23.4
9	02470925	Chickasaw Creek at Chunchula	45.4
10	02470910	Chickasaw Creek at county road near Gulfcrest	-
11	02470560	Little Creek at Citronelle	-
12	02470530	Cedar Creek at county road 36	-
13	02470607	Bull Branch Creek near Citronelle	-
14	02470610	Cedar Creek at Cedar Creek Falls	-
15	02470675	Mobile River near Creola	-
16	02470480	Borrow Creek near Mt. Vernon	-
17	02470500	Mobile River near Mt. Vernon	43,000
18	02471025	Halls Creek near Chrysler	-
19	02471021	Farris Creek near Chrysler	-
20	02429650	Majors Creek near Tensaw	44.7
21	02429635	Pine Log Creek near Chrysler	-
22	02429625	Holley Creek near Chrysler	-
23	02429628	Turkey Creek near Blacksher	-
24	02471036	Whitehouse Creek near Bromley	-
25	02471033	Bay Minette Creek near Stapleton	-
26	02376240	Dyas Creek near Dyas	57.3
27	02378410	Fish River near Daphne	30.7
28	02378500	Fish River near Silver Hill	55.1
29	02378550	Fish River near Yupon	-
30	02377550	Hollinger Creek near Gateswood	-
31	02377500	Styx River near Loxley	93.2
32	02378300	Magnolia River near Foley	-
33	02377975	Blackwater River above Seminole	115
34	02376500	Perdido River at Barrineau Park, Florida	394
35	02480000	Big Creek near Mobile	84

[a]All stations in Alabama, except as otherwise indicated.

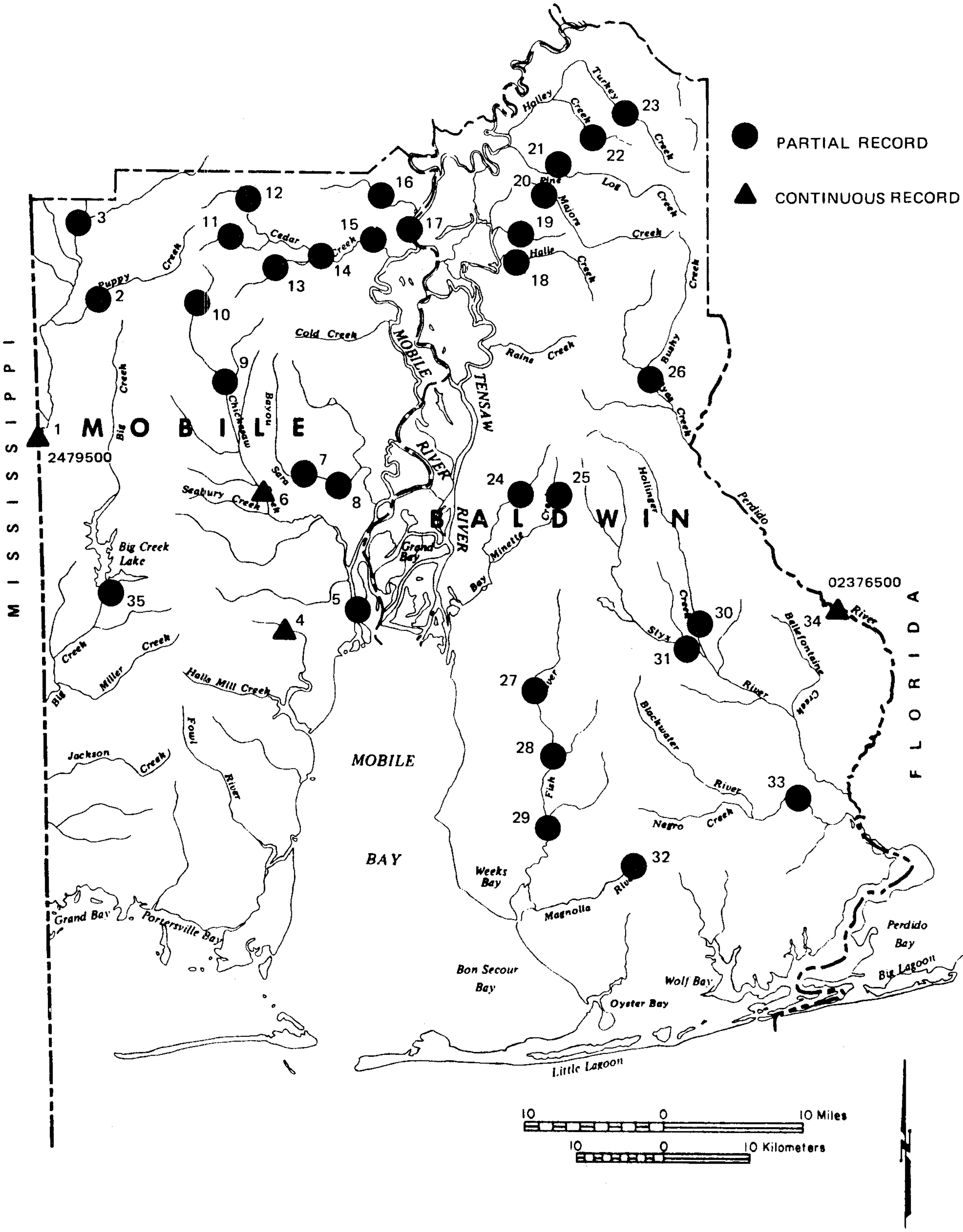


Figure 40. Location of U.S. Geological Survey surface-water gaging stations.

STREAM CLASSIFICATION

The Alabama Water Improvement Commission has established water-quality standards for interstate coastal and intrastate waters. Water-quality standards in coastal Alabama were established by classifying bodies of water for different water uses such as public-water supply, shellfish harvesting, and swimming. The establishment of water-quality standards was first required in 1965 by the Water Quality Act which amended the Federal Water Pollution Control Act. Appendix A gives the water-use classifications of stream segments and coastal waters in the Mobile River-Mobile Bay basin and Figure 41 shows the locations of the use classifications.

WASTEWATER IN COASTAL ALABAMA

The major point sources of wastewater in Mobile and Baldwin Counties are the 19 municipal wastewater treatment plants (Table 16 and Figure 42). In addition there are 49 semi-public and private dischargers of cooling water, miscellaneous sanitary wastes, and other permitted wastes. There are 38 industrial process wastewater discharges with NPDES (National Pollutant Discharge Elimination System) permits (Brady 1979) (Table 17 and Figure 43). The large volume of daily waste has created water-quality problems of bacterial pollution, oxygen depletion, and toxic compound buildup. Although many forms of bacteria are found in water, most of them are nonpathogenic to humans. Coliform bacteria normally inhabit intestinal tracts of humans and other animals and are excreted in feces. Coliform bacteria, therefore, are useful as "indicators" of contamination since their presence in water indicates contact with soils or plants, or indicates that water has been contaminated by sewage so recently that the bacteria have not died or have not been removed by artificial treatment. Coliform bacteria can be detected by routine laboratory tests, thereby indirectly testing for pathogens which are much more difficult to routinely investigate.

One major concern related to Mobile Bay is fecal coliform concentrations in oysters. Sanitary water-quality standards for shellfish harvesting in Mobile Bay require a fecal coliform median concentration of less than 14 MPN/100 milliliters before harvesting is allowed. This standard is most frequently exceeded during the late winter and spring months when the Mobile River has high flows. The Alabama Department of Public Health closed north Mobile Bay to oyster harvesting and a smaller zone in extreme northern Mobile Bay to shrimping.

Much organic waste in streams is effluent from municipal and industrial discharges. These wastes are primarily carbohydrates, protein, and miscellaneous fats and oils. When bacteria come in contact with this organic material, they utilize it as a food source. The amount of oxygen used in this process is called the biochemical oxygen demand (BOD) and is considered to be an indirect measurement of the organic content of the material.

DISSOLVED OXYGEN

The depletion of oxygen caused by bacteria can reduce the dissolved oxygen concentration to low levels and cause fish kills. Dissolved oxygen depletion has occurred near metropolitan Mobile, Bayou La Batre, Bayou Coden, Rattlesnake Bayou, Deer River, Bon Secour River, Dauphin Island Bay, the Intracoastal Waterway, and the northern part of Perdido Bay.

Data sources pertaining to the dissolved oxygen system in Alabama's coastal water bodies include the 208 Wastewater Management Plan study (South Alabama Regional Planning Commission 1979), the Physical Environmental Atlas of Coastal Alabama (Schroeder 1976; 1977), the U.S. Army Corps of Engineers sponsored Theodore Ship Channel project (U.S. Army Corps of Engineers 1979), the Pensacola 208 Wastewater Management Plan, U.S. Geological Survey annual reports, "Water Resources Data for Alabama," and the Symposium on the Natural Resources of the Mobile Estuary, Alabama (Schroeder 1979b).

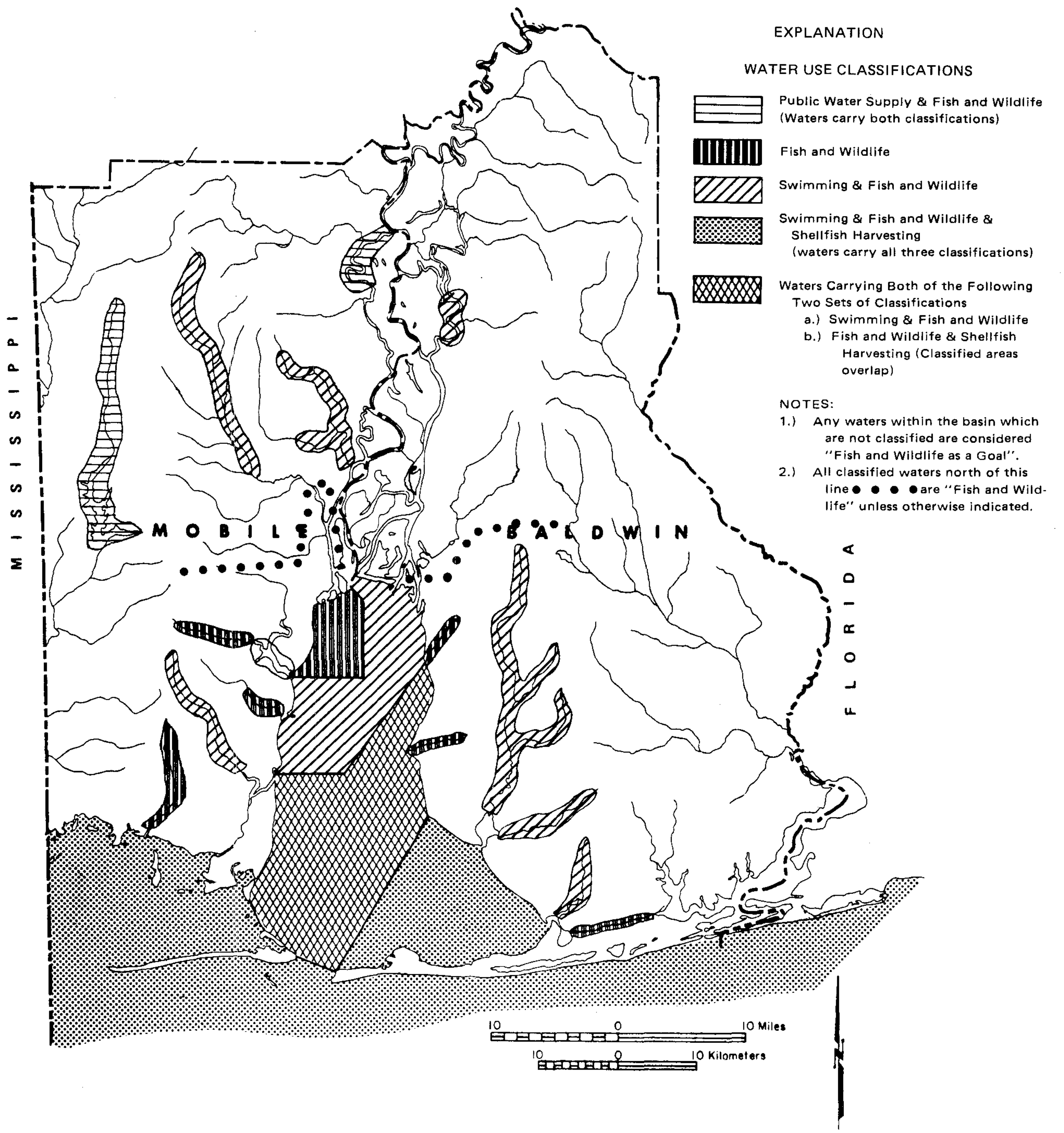


Figure 41. Water use classification in Mobile and Baldwin Counties (South Alabama Regional Planning Commission 1979).

Table 16. Existing municipal sewage plants, 31 December, 1977 (Brady 1979).

Number	Plant	Treatment description	Design flow (Mgal/d)	Receiving water
	MOBILE COUNTY			
1	McDuffie Island/Mobile[a]	High rate activated sludge	16.00	Mobile Bay
2	Halls Mill Creek/Mobile[b]	High rate trickling filter	1.50	Halls Mill Creek
3	Three Mile Creek/Mobile	High rate trickling filter	10.00	Spring Branch
4	Hog Bayou/Mobile	Package plant	0.35	Hog Bayou
5	Bill Ziebach/Mobile	High rate trickling filter	2.00	Mobile Bay
6	Grover Street/Prichard	2 stage trickling filter	4.00	Three Mile Creek
7	Eight Mile/Prichard	High rate trickling filter	1.50	Eight Mile Creek
8	Chickasaw lagoon	2 single stage lagoons	1.50	Chickasaw Creek
9	Saraland	Conventional activated sludge	0.59	Norton Creek
10	Dauphin Island	Standard rate trickling	0.25	Aloe Bay
11	Bayou La Batre	Conventional activated sludge	1.00	Portersville Bay
12	Citronelle	Single stage lagoon	0.22	Puppy Creek
	BALDWIN COUNTY			
13	Gulf Shores	3 stage lagoon	0.33	Intracoastal Waterway
14	Robertsdale	Extended aeration activated sludge	0.25	Rock Creek
15	Bay Minette	Primary clarification	1.00	Hollingers Creek
16	Westside lagoon/Bay Minette	2 stage lagoon	0.225	Martin Branch
17	Loxley lagoon	3 stage lagoon	0.16	Corn Branch
18	Foley lagoon	Single stage lagoon	0.27	Wolf Creek
19	Fairhope	Step aeration activated sludge	2.00	Mobile Bay

[a]Currently being converted to a 28 Mgal/d pure oxygen A.S. process.

[b]Will be closed in 1978.

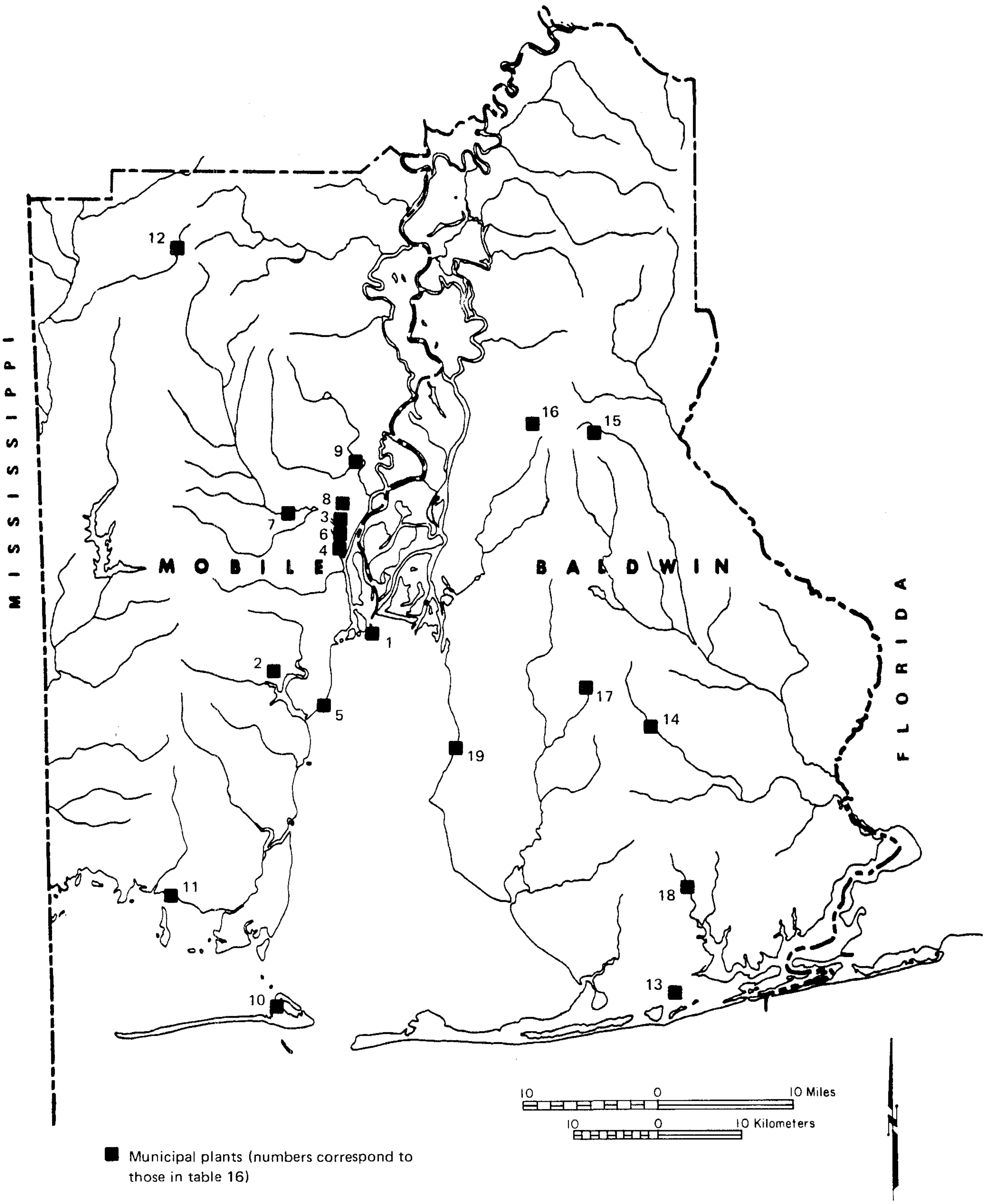


Figure 42. Location of municipal wastewater treatment plants.

Table 17.--Flow summary of industrial process wastewater discharges, 13 December 1979 (Brady 1979).

Number	Company	M gal/d
1	Barber Pure Milk	0.05
2	SARS	0.02
3	Aquila Seafood	0.001
4	Plashes Seafood	0.003
5	Grass Seafood	0.001
6	Gulf Shrimp	0.010
7	Mallon Seafood	0.0005
8	Oyster Bay Seafood	0.001
9	Star Fish & Oyster	0.288
10	Patronas Seafood	0.001
11	Causeway Seafood	0.001
12	Gulf Coast Knight Seafood	0.013
13	Bon Secour Fisheries	0.014
14	Crown Zellerbach	0.010
15	International Paper	33.2
16	Scott Paper	42.43
17	Stone Container	0.02
18	Stauffer Chemical-LaMoyne	1.10
19	Diamond Shamrock	0.06
20	Union Carbide-Chickasaw	3.634
21	Halby	0.0025
22	American Cyanamid	0.0600
23	ALCOA	0.8000
24	Virginia Chemical	0.2000
25	Eagle Chemical	0.2250
26	Courtaulds of North America	8.80
27	Reichhold Chemical	0.1900
28	Degussa	0.3710
29	Shell Chemical	1.044
30	Stauffer Chemical Cold Creek	0.400
31	Marion Refinery	0.0453
32	Louisiana Land & Exploration	0.110
33	Chevron Asphalt	0.350
34	Airco Alloys	0.354
35	Frisco Railroad	0.000325
36	I.C.G. Railroad	0.0115
37	Alabama Power-Barry Steam Plant	40.0
38	Thompson-Hayward	0.0041

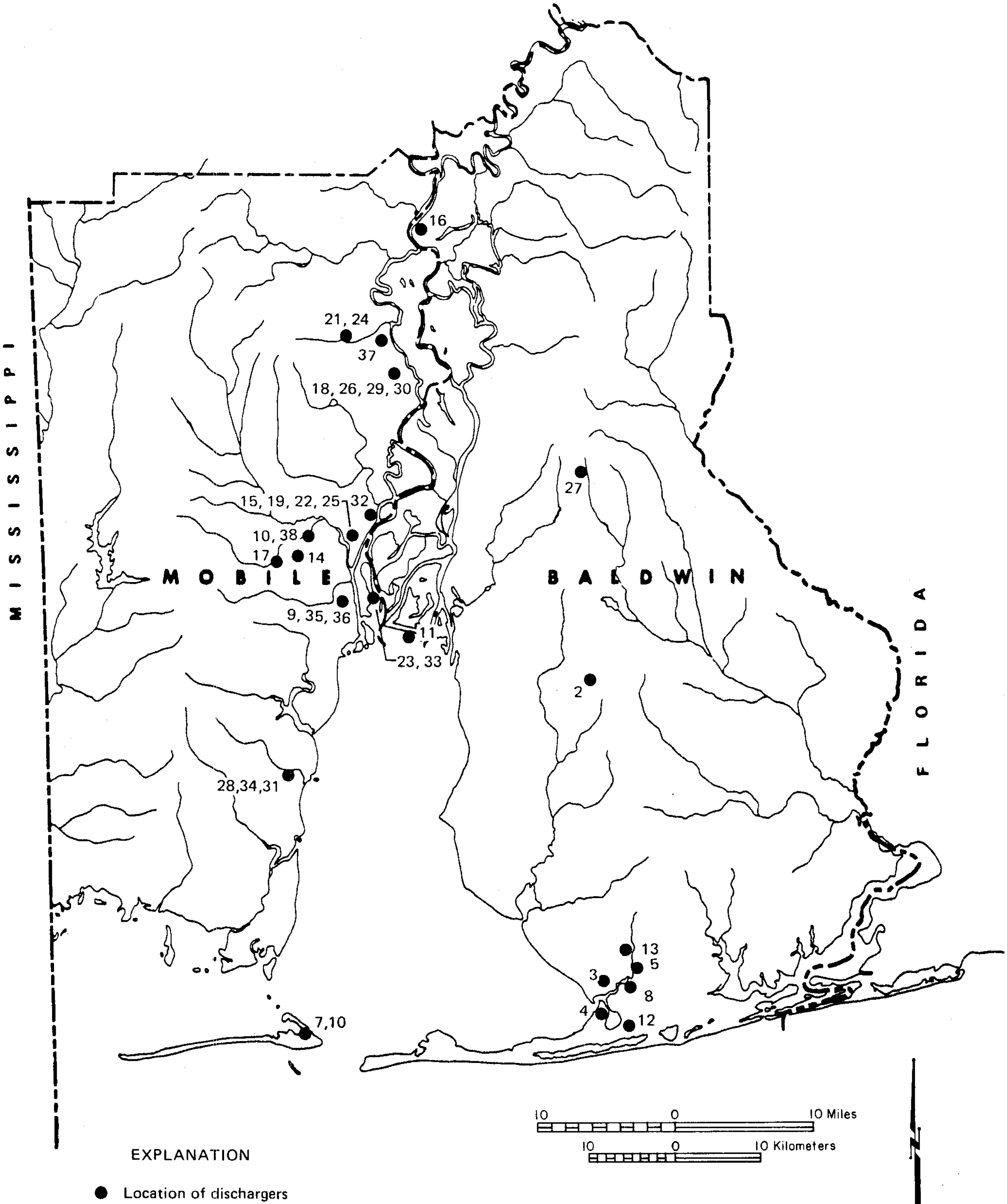


Figure 43. Location of industrial discharge points in Mobile and Baldwin Counties (Brady 1979).

Historical data on dissolved oxygen (Loesch 1960; Bault 1972) were collected so randomly, either spatially or temporally, that they are of minimal value. Results presented by May (1973b) consisted of one figure generalizing the distribution pattern of the lowest dissolved oxygen observations made during the period June through September 1971. Unfortunately, no field data were presented in May's paper nor was there any reference made to where the data may be archived.

Dissolved oxygen concentrations are often stressed by the discharge of more than 32 Mgal/d of treated wastewater from 19 municipal treatment plants and 130 Mgal/d from industrial discharges (Loyacano and Busch 1979). These wastes, as they are biologically and chemically degraded, often reduce the concentrations of dissolved oxygen.

The oxygen content of surface water is a highly transient property. Streams with large loads of organic material may have oxygen-consuming organic and inorganic reactions that deplete oxygen to levels that are less than saturation. During the 1979 water year (October 1978 to September 1979) dissolved oxygen concentrations in the Perdido River near Barrineau, Florida ranged from 5.1 to 9.8 mg/l. The Escatawpa River near Wilmer had concentrations ranging from 5.5 to 9.6 mg/l. The Tombigbee River below Coffeeville Lock and Dam had concentrations ranging from 5.9 to 12 mg/l and the Alabama River at Claiborne had concentrations ranging from 7.0 to 11.3 mg/l (U.S. Geological Survey 1979). The upper Mobile River most likely has dissolved oxygen concentrations similar to the Tombigbee and Alabama Rivers. During periods of high flows, many streams experience their highest concentrations of dissolved oxygen. During low-flow periods in the warmer months, dissolved oxygen concentrations are generally low.

The dissolved oxygen concentrations in Mobile Bay are generally 6 to 8 mg/l. Low dissolved oxygen periods (0 to 5 mg/l) are known to occur especially during warmer months.

Chickasaw Creek frequently has extremely low dissolved oxygen concentrations. At the mouth of Chickasaw Creek concentrations range from 0 to 3.2 mg/l (South Alabama Regional Planning Commission 1979). Low dissolved oxygen is often found throughout Three Mile Creek from Spring Branch to its mouth.

Dog River experiences low dissolved oxygen due to sewage treatment plant discharges and stormwater runoff. Eleven fish kills have occurred in Eslava Creek and other tributaries of Dog River since 1968; one fish kill resulted in the death of over 3,240,000 menhaden on May 27, 1970 (South Alabama Regional Planning Commission 1979).

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Hollinger Creek receives the bulk of Bay Minnette's treated wastes. The 7-day 10-year low flow at Hollinger Creek's junction with the Styx River is only 1.0 ft^3/s. The waste discharges may total 4.6 ft^3/s and probably often constitute over 90% of the flow of Hollinger Creek.

During periods of low dissolved oxygen, phenomena known as "Jubilee's" occur in Mobile Bay. Aquatic fauna (particularly fishes, crabs and shrimps) move into shallow waters seeking oxygen. By using the occurrence of the "Jubilee" phenomenon as a signature for oxygen depletion periods it is then possible to go back through newspaper records for historical documentation purposes. The earliest report of a "Jubilee" and therefore an implied low dissolved oxygen period was in 1821, according to newspapers in files of the Fairhope Single Tax

Corporation. From that date, to the present, numerous accounts of "Jubilee" have been published in newspapers throughout the area. Historical reviews of "Jubilee" occurrence were presented by Loesch (1960) and May (1973b).

The important implication of "Jubilee's" is that low dissolved oxygen periods have occurred in the bay for over 150 years and, therefore, prior to major man-made alterations to the bay bottom or municipal-industrial waste stresses. With this in mind a concerted effort must be made, during the designing of future studies, to consider both natural as well as man-made consequences with respect to the dissolved oxygen system.

TOXIC MATERIALS

A wide variety of toxic metals, pesticides, and other chemicals harmful to man and to the estuarine system have been found in varying amounts in coastal Alabama. Sources of these compounds usually originate from industrial discharges, agricultural applications, silvicultural spraying, urban runoff, or subsurface disposal of wastes. These materials may have a short, significant impact or they may have a more subtle, long-term interference with growth and reproduction of organisms. Although concentrations of these toxic materials in water may be well below levels hazardous to humans, they may be concentrated in the tissues of aquatic organisms at levels that could be harmful to humans who ingest them.

Metals with concentrations of less than 1 ppm are generally termed trace metals. Many of the trace metals are also heavy metals. The more common heavy trace metals that are of environmental concern include arsenic, cadmium, chromium, copper, lead, mercury, nickle, silver, and zinc. These metals may enter the estuarine environment through natural weathering of rocks or by waste discharges.

Little monitoring of heavy metal concentrations in Alabama's coastal waters has been done. Crance (1971) reported that some fish in the Mobile delta area contained levels of mercury as high as 2.5 mg/l, which is unsafe for human consumption. May (1973a) recorded concentrations of selected heavy metals in water and sediment samples from Mobile Bay. Relatively high levels of heavy metals in some sediment samples indicate the need for further investigation.

The pesticide group is of particular concern in the estuarine environment because the biological accumulation capability of estuarine organisms significantly increases the hazard and destructive potential of pesticides derived from agricultural runoff.

The presence of selected pesticides in Mobile Bay was studied by Casper et al. (1969). Dieldrin, endrin, aldrin, chlordane, DDT, DDD, DDE, BHC-lindane, and heptachlor-epoxide were detected in oyster, water, and sediment samples. With the exception of DDT and its metabolites, all pesticides were present at very low levels. The median measure of total DDT (DDT, DDD, and DDE) was 0.33 mg/l in oyster samples and 0.001 mg/l in water samples. May (1971a, 1973a) also reported concentrations of DDT, DDE, DDD, and dieldrin in oyster samples and sediment cores from Mobile Bay. Any concentration of pesticide residues in living tissue reflects a movement of that compound into the food chain.

WATER-QUALITY PROBLEMS ASSOCIATED WITH OIL FIELD OPERATIONS

The production of oil and gas in coastal Alabama is a potential source of water-quality problems. The principal indicator of stream contamination from brines and oil-field related waters is abnormal chloride concentraion (Hinkle 1981). In 1961, the U.S. Geological Survey and the Alabama State Oil and Gas Board initiated a planned program for studying and monitoring water-oriented problems of oil and gas fields in Alabama.

In Mobile County 26 oil field monitoring stations are sampled monthly for chloride concentrations. In Baldwin County there are four monitoring stations. Samples collected at these stations are analyzed for specific conductance, pH, and chloride concentrations.

The present water-resources monitoring network of the State Oil and Gas Board within oil and gas fields has been sufficient in scope to detect significant changes in chloride concentrations. Investigations by the State Oil and Gas Board traced many such changes to breaks in pipelines, salt-water spills, and leakage from disposal pits. Prompt analysis and interpretation of data have on numerous occasions helped minimize or prevented adverse affects on the environment. Results of the monitoring program have also indicated that improvements in water quality have occurred following the discontinuance of brine disposal in surface pits. The network has also been effective as a data base for decision making by the State Oil and Gas Board in their task of regulating development of oil fields. The future success of the monitoring network is dependent on the expansion of the network to new fields as they develop and continued analyses of data on a timely basis.

WATER QUALITY ASSESSMENT

As part of their 208 Study the South Alabama Regional Planning Commission (1979) assessed water-quality problems of Mobile and Baldwin Counties. The results of this study highlighted areas of poor water quality and potential problems. Information concerning the water quality was derived from numerous sources. The results of the 208 Study indicated that:

1. The upper reaches of the Mobile River exhibit good water quality with two significant exceptions, temperature and fecal coliform. Temperatures are elevated as a result of large volumes of cooling water discharged into the river and fecal coliform concentrations from sources along the river.
2. Chickasaw Creek is heavily impacted by point-source discharges from both industrial and municipal origins. The water quality of this stream is additionally degraded by heated discharge from the Chickasaw Steam Plant. Water quality is poor and degraded by a heavy biochemical oxygen demand and the intrusion of a salt-water wedge. Storm-water runoff has little or no impact on the in-stream water quality.
3. Three Mile Creek has poor water quality largely due to the discharge from two municipal sewage treatment plants and poor reaeration of the stream due to strong tidal influences. Nonpoint sources also impact the stream.
4. The lower segment of the Mobile River has poor water quality as a result of point-source discharges contributed from Three Mile and Chickasaw Creeks and the tidal influence of the bay.
5. Deer River has poor hydraulic flushing because of dredging and, as a result, is expected to be heavily impacted by storm-water runoff. This also limits its assimilative capacity for direct discharges.
6. Mobile Bay experiences water-quality problems on its western shores due to poor circulation and heavy bacterial contamination from fresh-water inflows. Bacterial contamination has resulted in the permanent closing by the Alabama Department of Public Health of several areas of shellfish harvesting.
7. Bayou Coden and Bayou La Batre have poor water quality as a result of waste disposal from seafood industries operating in these areas.
8. Poor water quality in Norton Creek is the result of discharges from the overloaded Saraland sewage treatment plant, particularly during periods of low flows.

9. Hollinger Creek has poor water quality resulting from the discharge of primary effluent from the Bay Minette sewage treatment plant.
10. Nonpoint sources, primarily urban runoff, may heavily impact the water quality of Three Mile Creek and Dog River.
11. Other nonpoint sources, primarily improperly operating or improperly installed septic drainfields, deteriorate water quality in local resort areas such as Dauphin Island and Gulf Shores and in some streams discharging directly into the bay, such as Fish River, Fowl River, etc.
12. Continued growth without immediate remedial action and some accomodation in the way of pollution control planning and action will cause further water quality deterioration not only in these areas but in other areas and streams.

GROUND WATER

Large quantities of water are available from permeable sands throughout Mobile and Baldwin Counties. Geologic units containing permeable sands that yield water to wells range in age from Eocene to Holocene, although the vast majority of wells are completed in the Miocene-Pliocene Series undifferentiated. Wells generally will yield supplies adequate for domestic use within 46 m (150 ft) of the land surface, and in the southern half of the area (from the mouth of the Mobile River southward) many yield supplies at depths of less than 30.5 m (100 ft). The thickness, lithology, and yield of the units underlying Mobile and Baldwin Counties are summarized in Tables 18 and 19, respectively. The locations of some of the wells tapping the units are shown in Figure 44 and records and water-quality data for the wells are tabulated in Tables 20 and 21.

MIOCENE-PLIOCENE AQUIFERS

The primary source of ground water in Mobile and Baldwin Counties is the Miocene-Pliocene Series undifferentiated. The entire Miocene Series is undifferentiated in Alabama while the Pliocene Series is composed solely of the Citronelle Formation. Because the geologic contact between these units is difficult to determine and because the units are often hydraulically connected, the Miocene Series and the Citronelle Formation are normally grouped together as one aquifer system. Such will be the case in this report.

The lithologic descriptions of this and other aquifer systems are presented in another section of this report, and will not be discussed at this time. It will suffice to state that the primary water-bearing zones are the sand beds within the aquifer system and that these sand beds are interbedded with relatively impermeable limestones and clays. Large fluctuations in bed thickness are not unusual in many areas, primarily because of the lenticular nature of the clays and sands.

The individual sand beds in the Miocene-Pliocene aquifer system are typically 15.2 to 30.5 m (50 to 100 ft) thick, but in the central parts of Mobile and Baldwin Counties they attain thicknesses of about 61 m (200 ft). The sand beds will yield as much as 2,650 l/min (700 gal/min) to properly constructed wells but may yield significantly more water in some areas. The wells tapping the Miocene-Pliocene aquifer range in depth from about 30.5 to 244 m (100 to 800 ft) with specific capacities ranging up to 35 gal/min per foot of drawdown (Hinkle and Dark 1981).

The quality of the water in the Miocene-Pliocene aquifer system generally is good. Except for some areas near the Mobile River, wells from this aquifer yield water that generally is soft and has a dissolved solids concentration of less than 250 mg/l. Locally, however, there are objectionable amounts of iron and chloride.

Table 18. Summary of geologic units, lithology, and availability and quality of ground water in Mobile County (Reed and McCain 1972).

System	Series	Geologic unit	Thickness in feet (meters)	Lithology	Availability of water	Quality of water
Quaternary	Holocene and Pleistocene	Alluvium, low-terrace, and coastal deposits	0-150 (0-46)	Sand, white, gray, orange and red, very fine- to coarse-grained, contains gravel in places; gray and orange sandy clay.	Will yield 10 gal/min (38 l/min) where saturated sands are of sufficient thickness. Potential source of 350 to 700 gal/min (1,325 to 2,650 l/min) per well in the Mobile River basin.	Water generally suitable for most uses but commonly contains iron in excess of 0.3 mg/l and may be sufficiently acidic to be corrosive. Locally, in areas close to Mobile Bay and Mississippi Sound, water is very hard, has high chloride and dissolved-solids contents, and contains iron in excess of 0.3 mg/l
		High-terrace deposits	0-40 (0-12)		Will yield 10 gal/min (38 l/min) or more where saturated sands are of sufficient thickness.	Probably soft and low in dissolved solids. May contain iron in excess of 0.3 mg/l.
Tertiary	Pliocene	Citronelle Formation	0-200 (0-61)	Sand, brown, red, and orange, fine- to coarse-grained, gravelly in places, contains clay balls and partings; gray, orange, and brown lenticular sandy clay, ferruginous cemented sandstone.	Will yield 700 gal/min (2,650 l/min) or more per well.	Water generally is soft and low in dissolved solids but may contain iron in excess of 0.3 mg/l and may be sufficiently acidic to be corrosive. In areas adjacent to Mobile River, Mobile Bay, and Mississippi Sound, water may have a dissolved-solids content that exceeds 1,000 mg/l, a sulfurous odor, and a chloride content that exceeds 500 mg/l.
	Miocene	Miocene Series undifferentiated	400-3,400 (120-1,030)	Sandy, gray, orange, and red, very fine to coarse-grained, contains gravel in places; gray thin-bedded to massive sandy silty clay; gray thin-bedded limestone in subsurface.		

Table 19. Summary of geologic units, lithology, and availability and quality of ground water in Baldwin County (Reed and McCain 1971).

System	Series	Geologic unit	Thickness in feet (meters)	Lithology	Availability of water	Quality of water
Quaternary	Holocene and Pleistocene	Alluvium, low-terrace, and coastal deposits	0-150 (0-46)	Sand, white, gray, orange, and brown, very fine- to coarse-grained, contains gravel in places; gray and orange sandy clay.	Will yield 10 gal/min (38 l/min) or more where saturated sands are of sufficient thickness. Potential source of 350 to 700 gal/min (1,325 to 2,650 l/min) per well in the Mobile basin.	Probably of good chemical quality in north half of county but locally may have a dissolved content that exceeds 1,000 mg/l and may contain objectionable amounts of iron. In south half of county adjacent to major waterways, water commonly contains objectionable amounts of iron, is very hard, and has a sulfurous odor. Locally, in areas adjacent to the coastline, the water is highly mineralized.
		High terrace deposits	0-30 (0-9)		Will yield 10 gal/min (38 l/min) where saturated sands are of sufficient thickness.	Water probably is of good chemical quality; locally it may contain objectionable amounts of iron.
Tertiary	Pliocene	Citronelle Formation	0-130 (0-40)	Sand, dark-reddish-brown, fine- to coarse-grained, gravelly in places, contains clay balls and partings; light-gray, orange, and brown sandy clay; ferruginous cemented sandstone.	Will yield 700 gal/min (2,650 l/min) or more per well.	Water generally is of good quality being soft and low in dissolved solids. Locally, the water contains objectionable amounts of iron and generally is acidic. In some areas adjacent to the coastline and in the Mobile River basin, the water has a dissolved-solids content that exceeds 1,000 mg/l, a chloride content that exceeds 500 mg/l, and a sulfurous odor.
	Miocene	Miocene Series undifferentiated	100-3,000 (30-900)	Sand, light-gray, yellowish-gray, yellow, white, fine- to coarse-grained, thin-bedded to massive; gray sandy clay; gray thin-bedded limestone.		
	Oligocene	Eocene and Oligocene Series	100-500 (30-152)	Limestone, grayish-yellow and gray, glauconitic, fossiliferous; gray and green clay that is glauconitic and carbonaceous in places.	Potential source of 350 gal/min (1,325 l/min) per well.	Water may be of good chemical quality in northernmost part of the county near Little River. Dissolved-solids content exceeds 1,000 mg/l in all other parts of the county.
	Eocene		400-700 (120-210)	Limestone-light-brown and light-gray, sandy, fossiliferous; light-gray fine- to coarse-grained sand; gray calcareous sandy fossiliferous clay.		

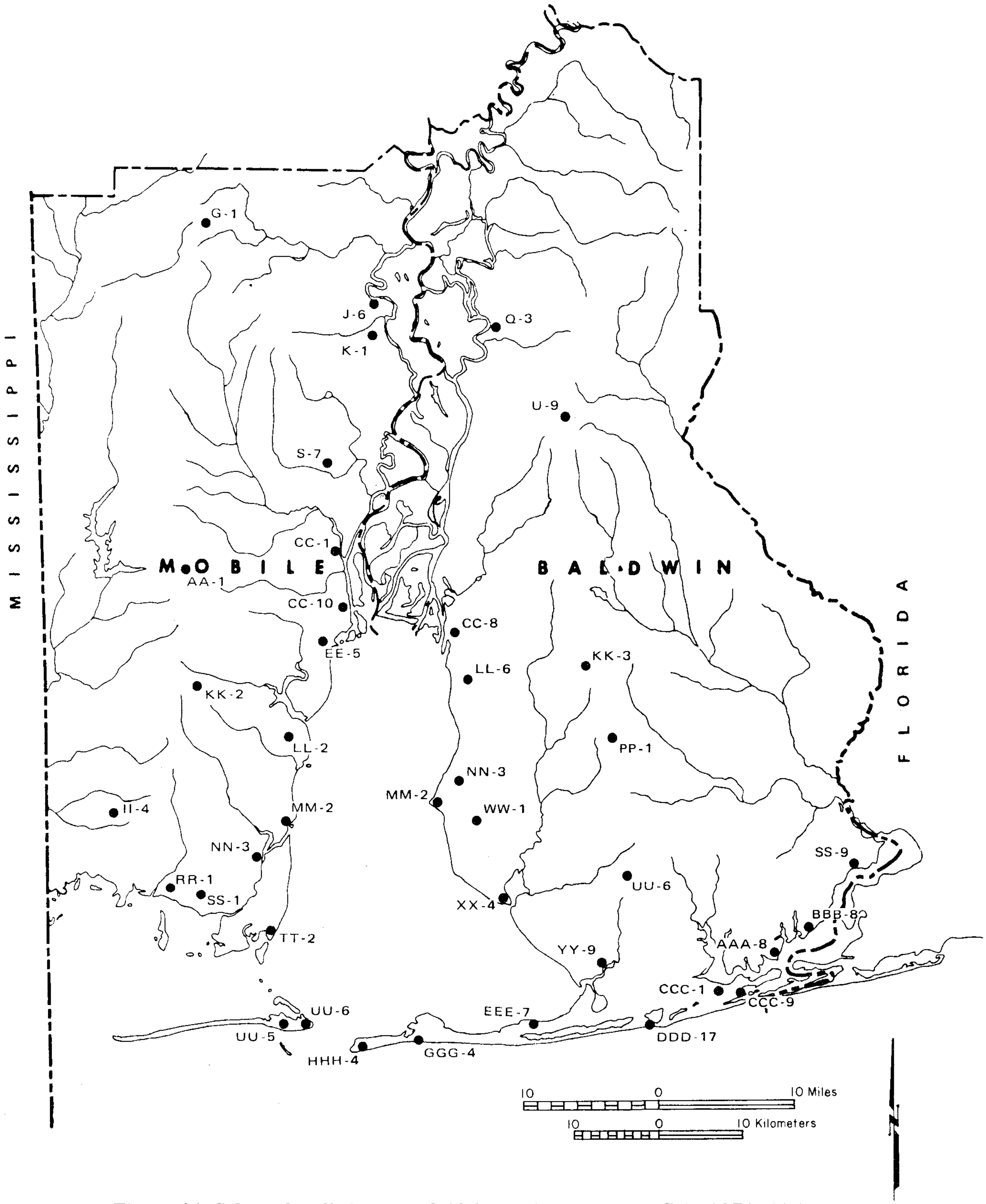


Figure 44. Selected wells in coastal Alabama (Reed and McCain 1971, 1972). Note: Well numbers correspond to those in Tables 20 and 21.

Table 20. Chemical analyses of water from selected wells in Mobile County (modified from Reed and McCain 1971).

Number [a]	Well owner	Date of collection	Water-bearing unit[b]	Well depth (ft)	Iron (Fe) (mg/l)	Bicar-bonate (HCO_3) (mg/l)	Carbonate (CO_3) (mg/l)	Chloride (Cl) (mg/l)	Hardness as $CaCO_3$: Calcium, magnesium (mg/l)	Hardness as $CaCO_3$: Noncar-bonate (mg/l)	Specific conductance (µmhos at 25°C)	pH
G-1	Water and Sewer Board, Citronelle	6-27-67	Tpm	805	.49	135	0	12	2	0	255	8.2
J-6	Alabama Power Co., Barry Steam Plant	8-11-67	Qal	135	.24	26	0	6.8	2	0	59	6.6
K-1	Stauffer Chemical Co. (LaMoyne Plant)	8-16-67	Qal	128	.08	-	-	2.4	5	0	27	6.5
S-7	Town of Saraland	7-26-67	Qal	98	.27	15	0	7.0	8	0	52	6.1
AA-1	U.S. Coast Guard	7-23-67	Tpm	198	.16	6	0	2.6	4	0	18	6.0
CC-1	Scott Paper Co.	9-13-67	Qal	90	1.9	22	0	926	390	372	3,100	6.2
CC-10	U.S. Post Office	7-18-66	Tpm	739	.52	460	0	1,560	85	0	5,290	8.2
EE-5	U.S. Government, Brookley Air Force Base	8-15-67	Qal	113	8.3	40	0	28	29	0	159	6.6
II-4	Grand Bay Water Works Bd.	6-21-67	Tpm	155	.24	6	0	4.4	4	0	28	5.7
KK-2	Mobile Co. Water and Fire Protection Authority	6-26-67	Tpm	476	.30	156	11	51	12	0	479	8.8
LL-2	McWane Cast Steel Pipe Co.	7-11-66	Tpm	120	.68	8	0	8.2	8	1	52	5.9
MM-2	Bayley's Ranch Club	8-14-67	Qal	90	.12	16	0	6.2	11	0	69	6.8
NN-3	Bellingrath Gardens	7-28-67	Tpm	308	.56	56	0	9.2	8	0	138	7.2
RR-1	Roman Catholic Church, Brothers of the Sacred Heart	9-06-67	Tpm	566	1.6	96	0	80	15	0	375	7.2
SS-1	J. L. Regan, Jr.	8-30-67	Tpm	109	.36	92	0	16	1	0	196	7.3
TT-2	C. B. Sprinkle	7-28-67	Tpm	400	.16	144	0	80	5	0	467	8.0
UU-5	Isle Dauphin Country Club	6-28-67	Qal	38	2.0	92	0	110	113	38	536	8.1
UU-6	Dauphin Island Property Owners Association	6-28-67	Tpm	563	1.3	128	0	650	123	18	2,320	7.1

[a]Well numbers correspond to those in Figure 44.

[b]Water bearing unit: Qal, alluvium, low-terrace, and coastal deposits; Tpm, Pliocene-Miocene Series undifferentiated.

Table 21. Chemical analyses of water from selected wells in Baldwin County (modified from Reed and McCain 1971).

									Hardness as $CaCO_3$			
Number[a]	Well owner	Date of collection	Water-bearing unit[b]	Well depth (ft)	Iron (Fe) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Carbonate (CO_3) (mg/l)	Chloride (Cl) (mg/l)	Calcium, magnesium (mg/l)	Noncarbonate (mg/l)	Specific conductance (μmhos at 25°C)	pH
Q-3	Bacon McMillian Veneer Co.	7-29-66	Tpm	90	1.3	68	0	4.4	22	0	123	7.5
U-9	Town of Bay Minette	4-27-66	Tpm	204	.05	6	0	4.4	12	7	25	5.4
CC-8	Spanish Fort Utility	4-27-66	Tpm	341	2.2	34	0	6.0	15	0	90	6.6
KK-3	Town of Loxley	3-08-66	Tpm	184	.07	6	0	4.0	10	5	21	5.6
LL-6	Town of Daphne	3-08-66	Tpm	430	.10	13	0	5.2	15	4	46	6.4
MM-2	Grand Bay Development Corp.	5-12-66	Tpm	338	.26	88	0	3.0	30	0	155	7.5
NN-3	Town of Fairhope	3-15-66	Tpm	510	.96	46	0	4.2	32	0	98	6.8
PP-1	Town of Robertsdale	3-11-66	Tpm	203	.06	3	0	8.6	15	13	42	5.5
SS-9	Baldwin Co. Bd. of Educ.	6-16-66	Tpm	80	.78	6	0	5.4	15	10	44	6.1
UU-6	Riviera Utilities	3-14-66	Tpm	157	.10	0	0	15	28	28	103	4.5
WW-1	Fairhope Hatchery	6-24-66	Tpm	70	.27	4	0	8.4	20	17	53	6.6
XX-4	H. B. Bentley	6-24-66	Tpm	155	1.1	10	0	6.6	8	0	35	6.8
YY-9	Bon Secour Fisheries	8-05-66	Tpm	220	-	4	0	4.8	8	5	38	5.4
AAA-8	S. A. Braham	7-13-66	Tpm	22	.33	4	0	6.0	5	2	37	5.3
BBB-8	C. W. Bear	6-16-66	Tpm	197	.66	6	0	4.6	15	10	36	5.6
CCC-1	Gulf Telephone Co.	7-12-66	Tpm	40	1.3	6	0	14	8	3	63	5.8
CCC-9	W. G. and P. Gilcrist	7-11-66	Tpm	750	.17	618	0	2,500	160	0	8,190	7.8
EEE-7	B. Terry	6-29-66	Tpm	17	.34	2	0	9.8	12	10	54	5.6
GGG-4	W. M. Apple	6-29-66	Qal	15	.08	136	0	320	188	76	1,260	7.3
HHH-4	U.S. Coast Guard	7-28-66	Qal	31	.26	228	0	27	202	15	432	7.8

[a]Well numbers correspond to those in Figure 44.

[b]Water-bearing unit: Tpm, Pliocene-Miocene Series undifferentiated; Qal, alluvium, low-terrace, and coastal deposits.

Iron concentrations range from less than 10 $\mu g/l$ to as high as 29,000 $\mu g/l$. The highest concentrations tend to be most prevalent in shallow wells near major streams and to a lesser degree in very deep wells in the upland areas. High iron concentrations in water are not known to be toxic to humans, but levels in excess of public drinking-water standards (300 $\mu g/l$) can stain fixtures and limit uses of the water (Hinkle and Dark 1981).

High chloride concentrations occur in some places in the Miocene-Pliocene aquifer because of saltwater encroachment from Mobile Bay and the Mobile River and because of saltwater intrusion from deep formations. Encroachment from the river and bay occurs during dry periods when flow of the Mobile River is too low to prevent the more saline water in the bay from moving up the river as a saltwater wedge along the bottom of the river. This salt water can then enter the permeable sands of the river bed and eventually contaminate nearby aquifers. The movement of salt water into shallow aquifers is enhanced when wells drilled near the river are excessively pumped. Saltwater intrusion from deeper formations also occurs when wells are over-pumped.

OTHER AQUIFERS

Other formations that yield significant amounts of water to wells in Mobile and Baldwin Counties are the Oligocene Series undifferentiated and the alluvial and low terrace deposits. The Oligocene units are utilized as an aquifer in the northern portions of the study area while the alluvial and low terrace deposits are used as sources of ground water in the Mobile River basin and in other places where they attain sufficient thicknesses.

The Oligocene Series consists of a series of limestones that generally attain a thickness of about 30.5 m (100 ft) of potentially water-bearing strata. These limestones can yield as much as 1,330 l/min (350 gal/min) to wells that penetrate solution cavities (Reed and McCain 1971).

The quality of the water produced from the Oligocene deposits is generally only fair. Most of the water has a dissolved solids content in excess of 1,000 mg/l.

The alluvial and low terrace deposits are primarily interbedded gravel, sand, and clay. These deposits are as much as 45.7 m (150 ft) thick and reportedly yield as much as about 3,230 l/min (850 gal/min). Specific capacities of wells completed in this aquifer range up to 73 gal/min per 1 ft of drawdown.

The quality of water from alluvial and low terrace deposits is good. The water is generally soft and has a dissolved solids content of less than 100 mg/l, but may contain iron in excess of 0.3 mg/l. In areas near Mobile Bay, Mississippi Sound, and the Gulf of Mexico, water often contains iron in excess of 0.3 mg/l, chlorides in excess of 250 mg/l, and dissolved solids in excess of 1,000 mg/l.

WATER LEVELS

Fluctuations of water levels in shallow wells in coastal Alabama are cyclic and are related directly to rainfall. The average monthly precipitation is greatest in March, April, July and August. The period of high water-table elevations generally occurs in March and April because of continuous and large amounts of recharge from precipitation and the parallel low evapotranspiration rates. The water table is generally low in October and November when precipitation is least. This phenomenon is illustrated in Figure 45 in which the water level in the U.S. Geological Survey observation well MOB-1 (K-2) is shown in relation to the average yearly rainfall for the years 1954 through 1970 at Bates Field Weather Station.

Ground-water level data are published for two sites by the U.S. Geological Survey (Figure 46). Well MOB-2 taps the alluvial deposits of Quaternary age and well BAL-1 is completed in sand and gravel of the Miocene aquifer.

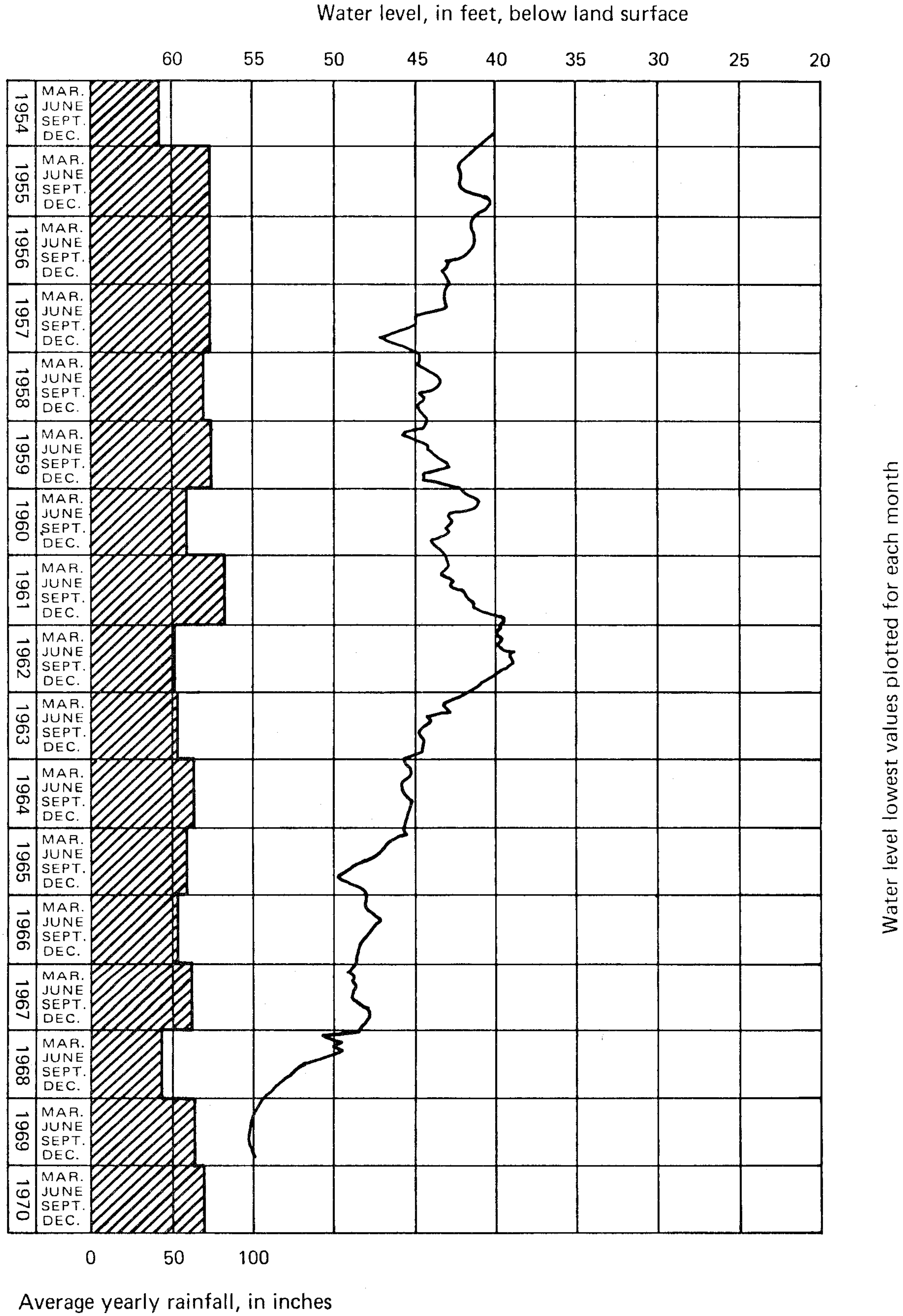


Figure 45. Hydrograph showing water levels in observation well MOB-1 (K-2 Mobile County) and average yearly precipitation (Riccio et al. 1973).

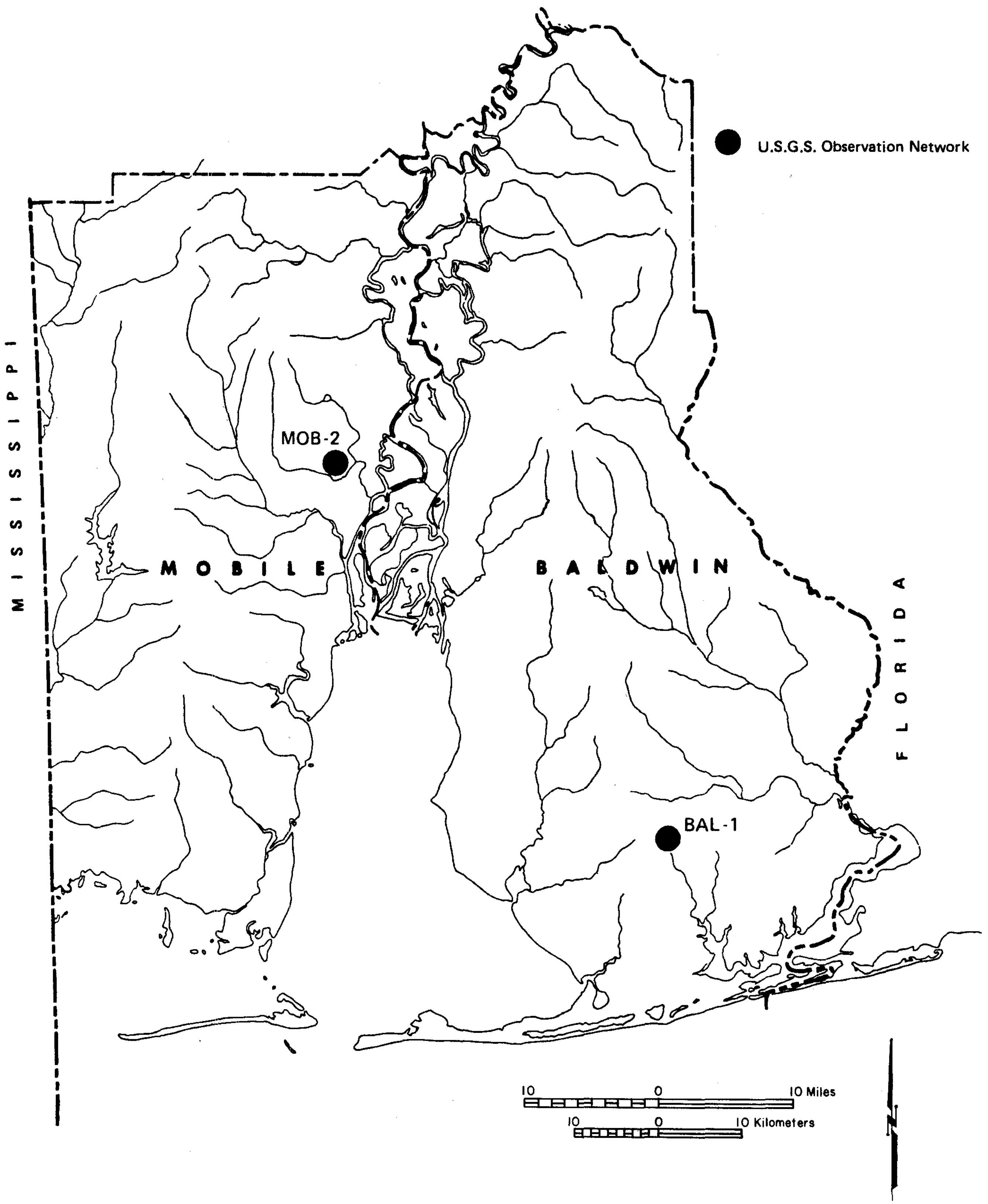


Figure 46. U.S. Geological Survey ground water observation network.

PHREATOPHYTES

Phreatophytes are plants which depend upon shallow water-table conditions. Sycamore, cottonwood, and willow occur in coastal Alabama. These trees are phreatophytes in dry regions and thus we assume they retain those ground water affinities in this area.

Available data indicate that declines in water levels have not been significant except in areas of high pumpages or areas of artesian flow. Continuous discharge has caused many artesian wells to cease flowing. Lowering of the water table could change the habitat of these phreatophytes by limiting the areas of suitable ground-water levels.

SALT-WATER ENCROACHMENT

Salt-water encroachment has occurred in Mobile, on Dauphin Island, in the Mobile River delta, and possibly at Gulf Shores. Much of the time encroachment occurs because of over-pumpage of wells near the coast. Excessive withdrawal of fresh water causes a change in the relationship between fresh water and the underlying salt water. The following discussion of that relationship is taken directly from Walter and Kidd (1979).

The occurrence of salt water in coastal fresh-water aquifers is governed by the density contrast between the two waters, the elevation of the water table or piezometric surface in the fresh-water aquifer, and the flow rate within the fresh-water aquifer. Under natural conditions when the aquifer is relatively unaffected by pumpage, a net flow of fresh water to the sea will be present. In this case salt water will occupy a wedge-shaped volume at the seaward end of the aquifer (Figure 47). Exploitation of the aquifer often results in a decline in the water table or piezometric surface with a resulting landward migration of the salt-water zone.

The boundary between salt water and fresh water is referred to as the interface. Many descriptions of salt-water encroachment treat the interface as a sharp contact between salt water and fresh water. In reality, mixing between the waters results in a gradual transition from fresh water to salt water. This zone of mixing is referred to as the "dispersion zone." The dispersion zone may range from a few meters to a few hundred meters in thickness.

The results of the studies of Walter and Kidd (1979) indicate that in the Gulf Shores area, only in the shallow sand aquifer, can cases of salt-water contamination be unequivocably attributed to sea-water encroachment. Based on the results of numerical modeling and interpretation of the water chemistry, the cases of contamination in the Gulf Shores aquifer may be due to leakage of saline water around well bores, leakage from confining beds and movement of pockets of relic salt water within the aquifer rather than lateral seawater encroachment.

USE OF WATER

In 1980, an average of 1,264 Mgal/d was withdrawn from the surface and underground sources in Mobile and Baldwin Counties. Water use for thermoelectric power generation was approximately 1,004 Mgal/d or 79% of the total use in the two counties. Table 22 lists the quantities for each use. This data collection is part of a continuing effort by the Geological Survey of Alabama in cooperation with the U.S. Geological Survey to compile water-use information in Alabama.

CLIMATE

By Steven C. Harris

The climate of coastal Alabama is primarily subtropical, being influenced by a high-pressure belt extending over or near the Gulf of Mexico throughout the year. Long-term climatological summaries are available for Mobile from the National Climatic Center in Asheville, North Carolina. Weather reporting stations in Mobile and Baldwin Counties

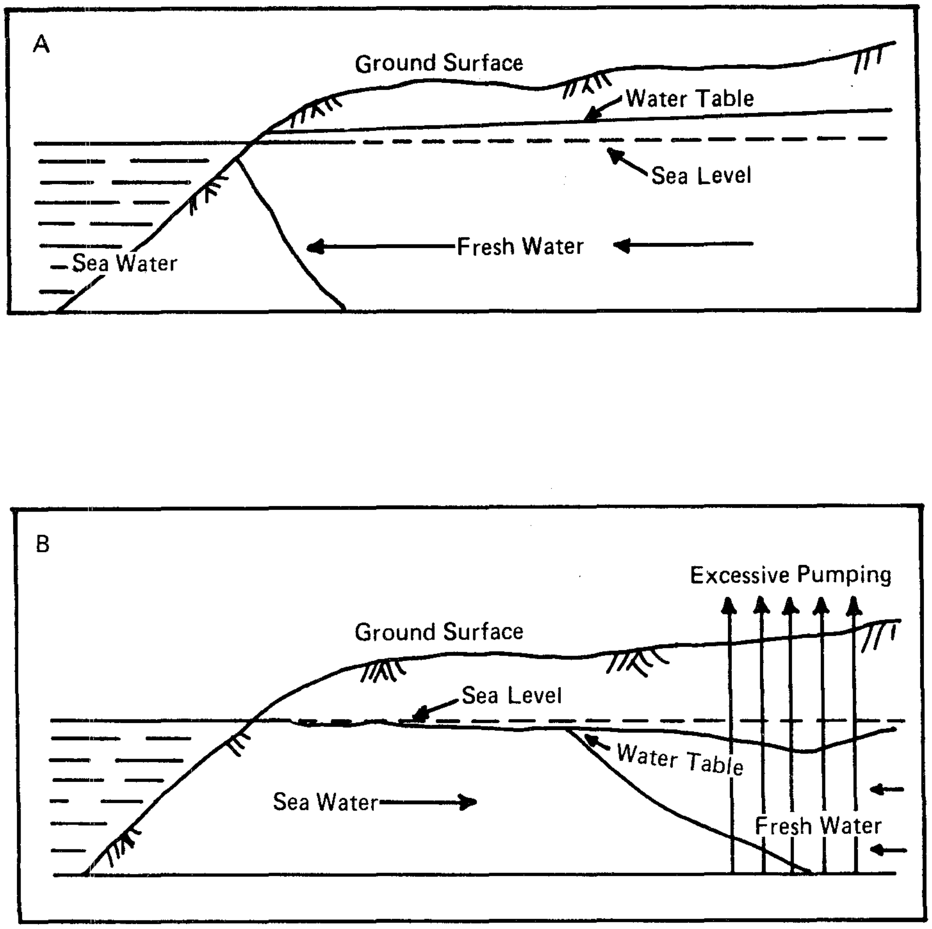


Figure 47. Schematic of hydrologic conditions in an unconfined water system (A) not subject to salt-water intrusion and (B) subject to salt-water intrusion (Walter and Kidd 1979).

Table 22. Withdrawal use of water (Mgal/d) in Mobile and Baldwin Counties, 1980, by source and principal use.

Water uses	Mobile County		Baldwin County	
	Ground water	Surface water	Ground water	Surface water
Public water supply	5.04	130.06	6.48	0
Rural use				
Domestic	4.107	0	2.19	0
Livestock	0.175	0.247	0.243	0.354
Irrigation	0.700	0.256	3.656	0.429
Catfish farming	0.07	0.64	0.02	0.16
Self-supplied industries	25.95[a]	79.58[a]	0.494	0.0288
Thermoelectric	0.0561	1,003.5	0	0
TOTALS	36.098	1,214.283	13.08	0.97

[a] Indicates a use of saline water.

are located in Citronelle, Bay Minette, Fairhope, Robertsdale, Coden, and Dauphin Island.

TEMPERATURE

The air temperature of coastal Alabama is relatively mild, being markedly influenced by the Gulf of Mexico, with an average annual temperature of 20℃ (68℉) in Mobile. Summer temperatures are influenced by the Bermuda High, a semipermanent high-pressure cell that extends over portions of the Gulf of Mexico near 30° latitude (Figure 48). During the summer, southerly winds generated by this high-pressure cell have a high moisture content which tends to keep coastal temperatures lower than those of inland areas. Summer temperatures range between 21° and 32℃ (70° and 90℉) (Figure 49). In the winter, winds are northerly and move in cold, continental air masses. Temperatures remain relatively mild, however, ranging from lows in the 40's to highs in the 60's (Figure 49).

The lowest mean monthly temperature, near 10℃ (50℉) occurs in January; the highest mean monthly temperature near 28℃ (82℉) occurs in July (Table 23). An average of 22 days a year are below freezing and an average of 81 days reach temperatures above 32.5℃ (90℉). The lowest recorded temperature in Mobile was -14℃ (7℉) in January 1962 (National Climatic Center 1980; Chermock 1974). In Citronelle, 55 km (35 mi) inland, a low of -19℃ (-2℉) has been recorded. Such cold readings are very unusual. Winter temperatures usually have the lowest readings in the upper 20's. The highest temperature recorded in Mobile was 40℃ (104℉) during July 1952 (National Climatic Center 1980). The daily fluctuation in temperature readings is about 20 degrees (Table 23). The average number of heating degree days for the Mobile area is 1,650; the average number of cooling degree days is 2,759 (Table 23).

Mobile and Baldwin Counties have a growing season ranging from 230 days in the northern sector to 300 days in areas near the coast (Figure 50). The first killing frost occurs in early November in the northern parts of the counties and in early December near the coast (Figure 50); the last killing frost occurs in mid-March in the north and in mid-February near the coast (Figure 50).

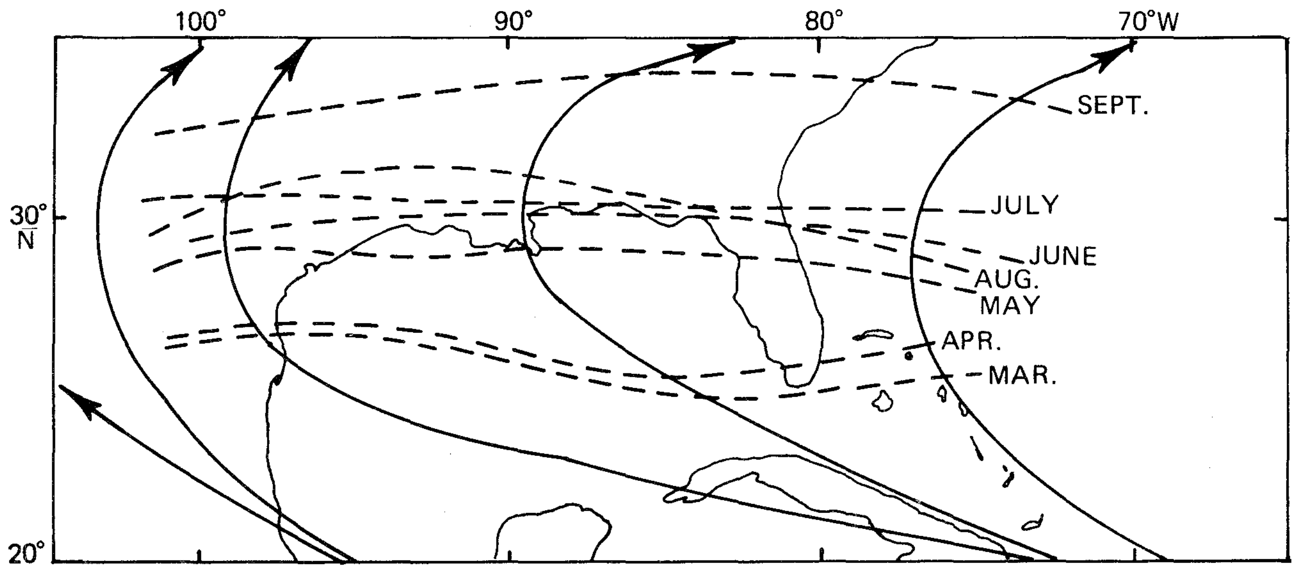


Figure 48. Mean streamlines of the low-level flow (solid) for the month of May. The dashed lines show the mean monthly position of the ridgeline, or the point of turning of the wind, from southeasterly to southwesterly (Jordan 1973).

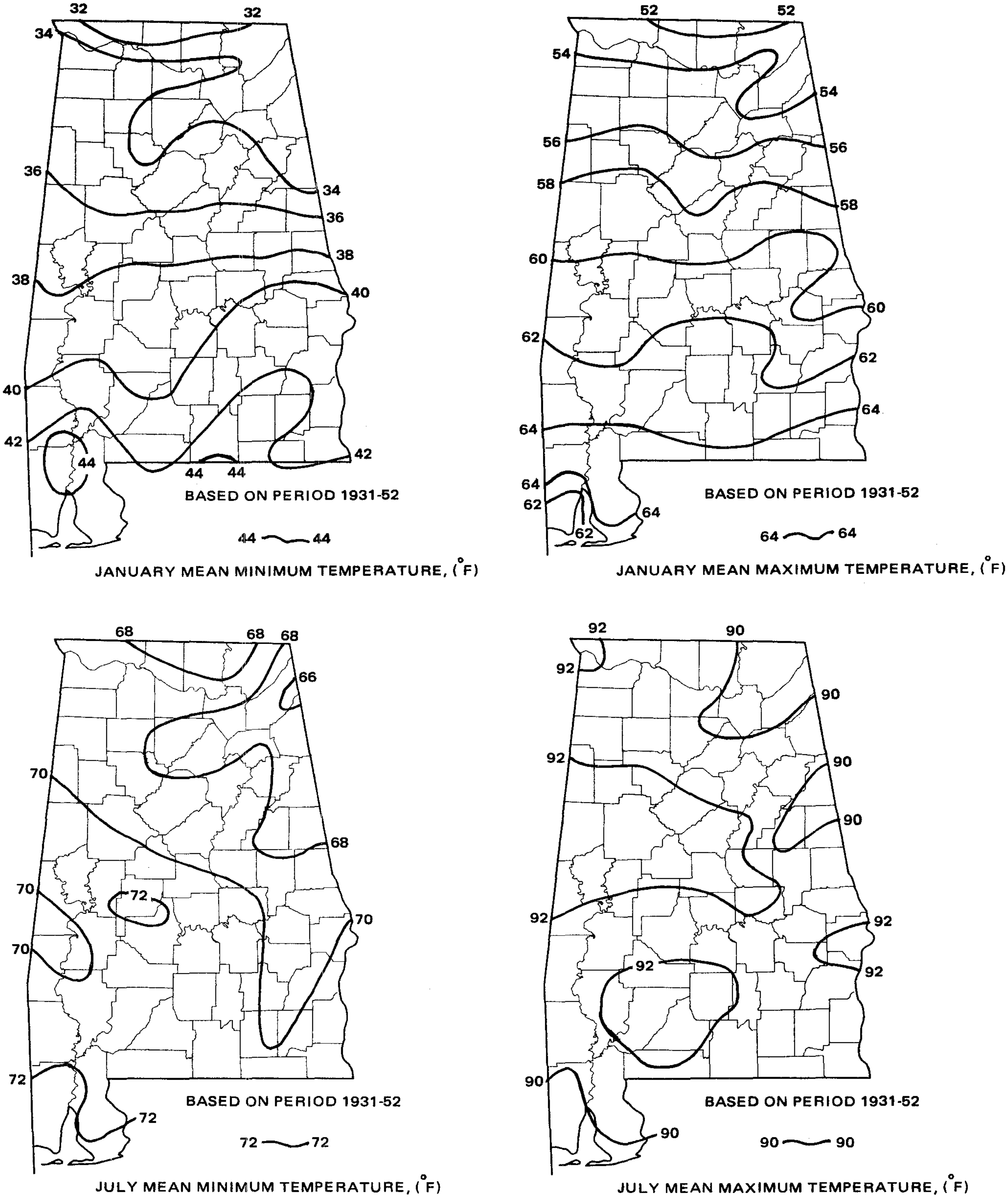


Figure 49. Temperature isoclines for Alabama (Long 1978).

Table 23. Summary of temperature and rainfall data for Mobile, Alabama (National Climatic Center 1980).

Month	Temperature (°F) Mean	Avg. Max.	Avg. Min.	Degree days[a] (mean) Heating	Cooling	Precipitation (inches) (mean)
Jan	51.7	60.4	42.9	486	15	4.73
Feb	54.3	63.2	45.3	366	12	4.98
Mar	60.2	69.0	51.3	186	48	6.63
Apr	67.2	76.1	58.2	37	137	5.13
May	74.3	83.2	65.3	2	307	4.71
Jun	80.3	88.8	71.7	0	484	5.49
Jul	81.8	90.0	73.6	0	559	7.57
Aug	81.6	89.8	73.3	0	538	6.62
Sep	78.1	86.4	69.8	2	427	5.62
Oct	68.8	78.4	59.2	44	168	3.20
Nov	58.9	68.5	49.3	216	40	3.73
Dec	53.0	61.9	44.1	401	22	5.15
Annual	67.5	76.3	58.7	1650	2759	63.36

[a]One heating or cooling degree-day is assigned for each degree that the daily mean temperature is below 65° F or above 75° F, respectively.

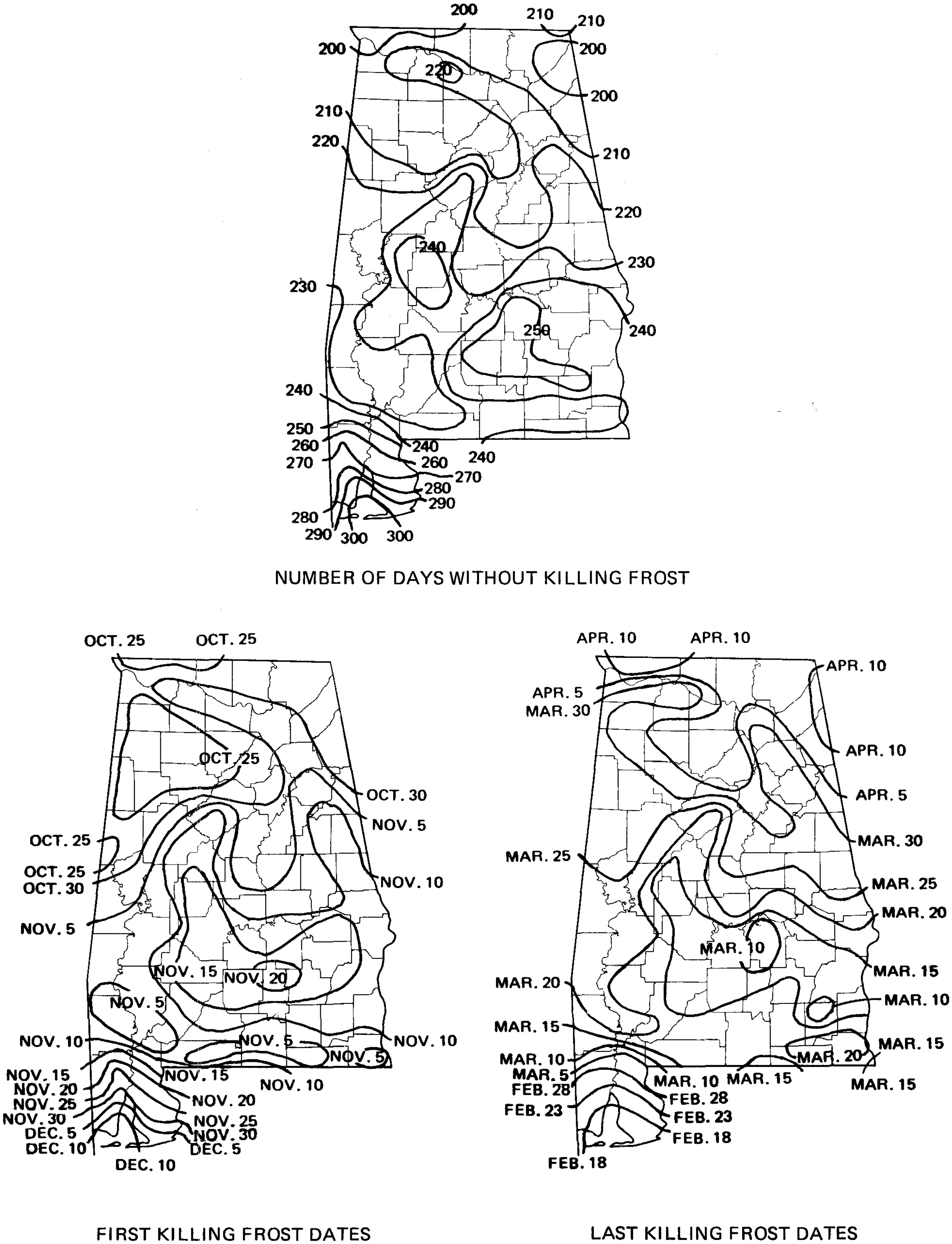


Figure 50. Occurrence of frost in Alabama (U.S. Department of Agriculture 1941).

PRECIPITATION

The normal annual rainfall in coastal Alabama is the highest in the State and among the highest in the United States (Figure 51). Rainfall amounts tend to average about 162.5 cm (64 inches) per year around the bay, decreasing to about 140 cm (55 inches) per year along the Morgan Peninsula of Baldwin County (Table 24). In coastal Alabama rainfall is fairly evenly distributed over the year being greatest during the thunderstorm season in July, averaging 19.3 cm (7.6 inches), and least in October and November, averaging 9 cm (3.5 inches) (Table 24). The greatest amount of monthly rain ever recorded in the Mobile area was 49 cm (19.3 inches) in July 1949. The least amount of rain recorded in a month was a trace in October 1978. The greatest daily maximum of rain in Mobile was 34 cm (13.4 inches) recorded in April 1955 (Table 25). Rainfall of more than 0.02 cm (0.01 inch) occurs on the averge of 124 days a year in Mobile. This same region has an average of 80 days with thunderstorms each year. These are most frequent in the summer (June through August) with 55% of the thunderstorms occurring during this time. Thunderstorm frequency in this area is one of the highest in the United States (Figure 52). Thunderstorms are rare in the fall and winter (September through February) with only 12% of the storms during this period. This percentage is the highest of any reporting station along the northeastern Gulf of Mexico and is related to the greater frequency of extratropical cyclones or fronts in the area (U.S. Army Corps of Engineers 1973). Thunderstorms in the coastal area are seldom violent and hail is rarely produced (Table 26). Snowfall is likewise a rare occurrence in coastal Alabama (Table 26).

Relative humidity is fairly constant through both the day and the year (Table 27). In Mobile, relative humidity varies an average of 28% throughout the day. Humidity is usually highest between 2400 and 0600 hours (83%) and lowest between 1200 and 2000 hours (62%).

A close interaction exists between temperature and moisture in terrestrial environments; and the two determine, to a large extent, the climate of a region and the distribution of vegetation. Climographs relating these two factors throughout Alabama are presented in Figures 53 and 54.

VISIBILITY, FOG, CLOUD COVER, AND SMOG

Cloud cover over the Mobile area has an annual value of about 6/10, a slight tendency for cloudiness in the area (Table 28). Cloudiness tends to be highest in the winter and summer with lower values in the spring and fall. Such a cloudiness pattern is typical of recording stations from around the Gulf of Mexico (Jordan 1973). Much of the summer cloudiness consists of convective cumulus or high, thin clouds. Winter cloudiness is generally associated with movement of extratropical cyclones and their associated frontal systems (Chermock 1974). Overall cloudiness in the Mobile area is relatively even, in part accounting for the evenness of precipitation and rarity of long periods of continuous rain (Chermock 1974).

In the Mobile area, periods of low visibility (0.4 km [0.25 mi] or less) from November through May correspond with heavy fog periods (Table 28). Winter fogs are fairly frequent along the gulf coast (Figure 55) as the larger rivers and tributaries empty cold water into the warmer gulf waters (Petterssen 1969). Heavy rains during the summer are probably responsible for occasional low visibility. Fog, the primary visibility inhibitor, reduces visibility to less than 0.4 km (0.25 mi) an average of 39 days a year (Table 28).

Air pollution may be widely defined as particulate materials and gases present in the atmosphere which have a direct or indirect adverse effect on the welfare of man. Air

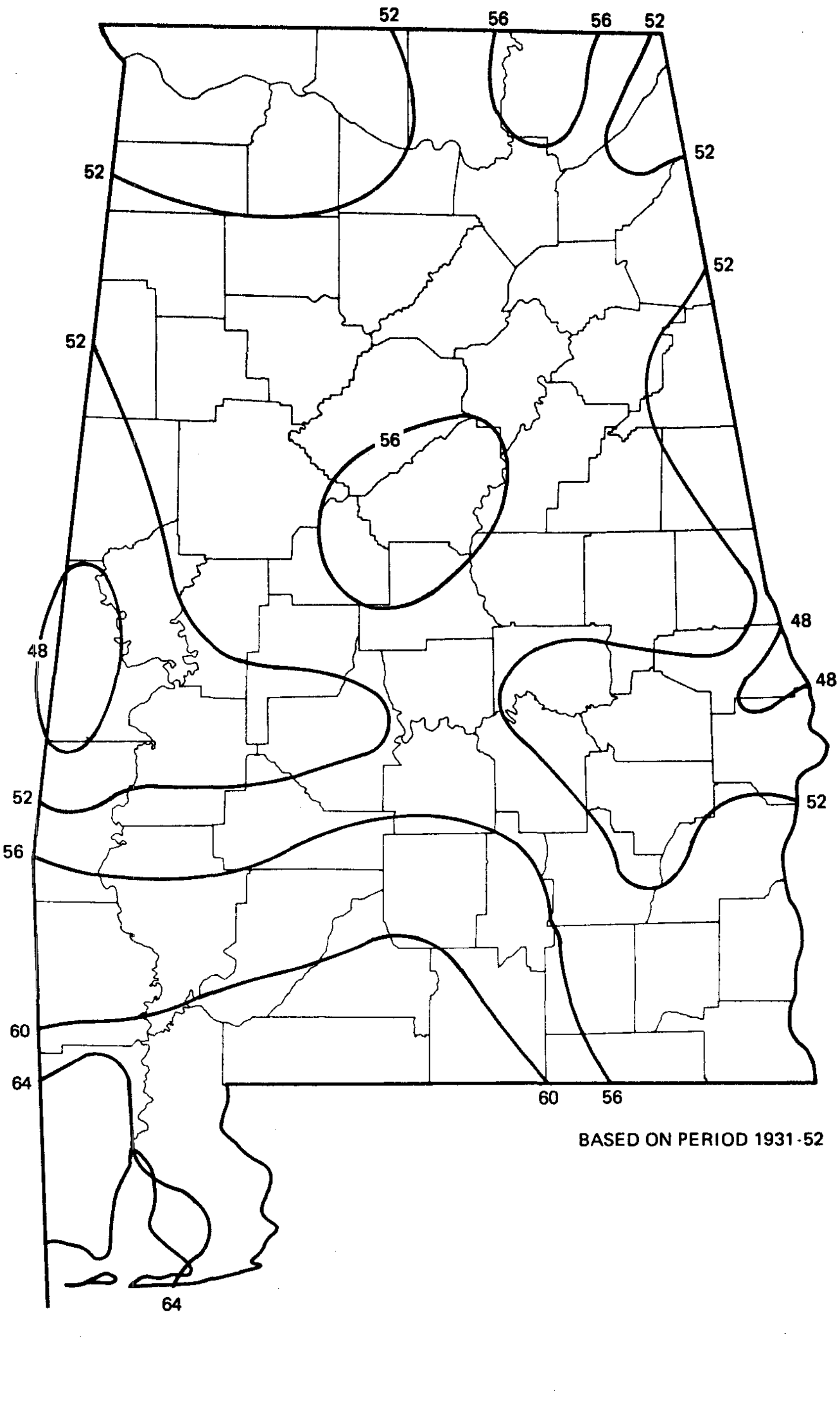


Figure 51. Mean annual precipitation (inches) for Alabama (Long 1978).

Table 24. Rainfall (inches) in coastal Alabama, 1955 - 69 (Crance 1971).

Month	Mean precipitation					
	Mobile	Bay Minette	Fairhope	Robertsdale	Gulf Shores	Fort Morgan
Jan	5.17	5.01	4.68	5.04	4.41	3.71
Feb	5.30	5.58	5.14	5.45	5.65	4.16
Mar	5.45	5.60	4.82	4.76	4.46	4.10
Apr	5.36	5.52	4.71	4.73	4.63	3.90
May	4.69	5.62	4.29	4.50	3.12	2.41
Jun	5.56	5.81	6.42	6.61	4.59	4.57
Jul	7.91	7.65	7.92	8.03	6.20	5.55
Aug	6.88	6.82	6.59	7.38	6.62	5.28
Sep	6.24	5.63	6.79	7.36	8.79	8.14
Oct	2.75	3.59	3.78	3.91	3.51	3.57
Nov	2.53	2.35	2.88	2.81	2.85	2.77
Dec	5.51	5.14	4.59	4.27	3.95	3.97
Annual	63.35	65.33	62.61	64.84	58.79	51.32

pollution and its severity depend, to a great extent, on climatological factors, including wind direction and speed, precipitation, and temperature variations. Wind direction and speed determine the movement of pollutants from the source to the receptor. In the Mobile area the wind direction is primarily northerly and southerly with an average speed of approximately 14.5 km/h (9 mi/h) (National Climatic Center 1980).

The dominant mechanism for dispersing air pollution is mixing of the lower, polluted atmospheric levels with higher relatively unpolluted layers. During an inversion this mechanism is blocked. The dilution of pollutants is diminished and they build up in the lower atmosphere. Typically, air closest to the earth is warmer than air in the upper atmosphere. Pollutants emitted near ground level are carried upward by thermal convection and diluted by cooler, cleaner, upper air masses. An inversion represents the opposite condition with temperature increasing rather than decreasing with elevation. Pollutants released in the cool, dense air near the earth tend to accumulate rather than be dispersed.

The major periods of short-duration inversions in coastal Alabama occur between 2200 and 0800 hours (Mobile County Board of Health 1970) due to the earth's radiational cooling at night. During these inversions, pollutants decrease visibility, sometimes to less than 2 km (1.2 mi). The increase in wind and temperature during the day will ordinarily break low-level inversions, dispersing the pollutants.

Table 25. Climate extremes for Mobile, Alabama (modified from National Climatic Center 1980).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Highest recorded temperature (°F)	84 (1949)	82 (1944)	90 (1946)	92 (1943)	100 (1953)	102 (1952)	104 (1952)	102 (1968)	99 (1980)	93 (1963)	87 (1971)	81 (1974)
Lowest recorded temperature (°F)	7 (1962)	11 (1951)	21 (1943)	36 (1973)	43 (1960)	56 (1966)	60 (1947)	59 (1956)	42 (1967)	32 (1957)	22 (1950)	10 (1962)
Max. monthly rainfall (inches)	10.40 (1978)	9.14 (1979)	15.58 (1946)	17.69 (1955)	15.08 (1980)	13.07 (1961)	19.29 (1949)	12.05 (1969)	13.61 (1957)	6.72 (1975)	13.65 (1948)	11.38 (1953)
Min. monthly rainfall (inches)	0.98 (1968)	1.31 (1948)	0.59 (1967)	0.48 (1954)	0.45 (1962)	1.19 (1966)	2.16 (1972)	2.35 (1972)	0.58 (1963)	[a]T (1978)	0.25 (1960)	1.29 (1980)
Max rainfall in 24 hrs (inches)	8.34 (1965)	5.00 (1952)	6.52 (1951)	13.36 (1955)	7.53 (1980)	7.38 (1961)	5.34 (1975)	6.62 (1969)	8.55 (1979)	4.30 (1967)	7.02 (1975)	5.50 (1968)
Max. monthly snow or hail (inches)	3.5 (1955)	3.6 (1973)	1.6 (1954)	0	0	0	0	0	0	0	T (1966)	3.0 (1963)
Max. snow or hail in 24 hrs (inches)	3.5 (1955)	3.6 (1973)	1.6 (1954)	0	0	0	0	0	0	0	T (1966)	3.0 (1963)
Max. recorded wind speed and direction (mi/h)	44N (1959)	46N (1960)	40N (1962)	44N (1964)	51NE (1963)	44N (1959)	46N (1960)	63N (1969)	163N (1979)	46NE (1964)	37NE (1959)	38NE (1959)

[a] Trace.

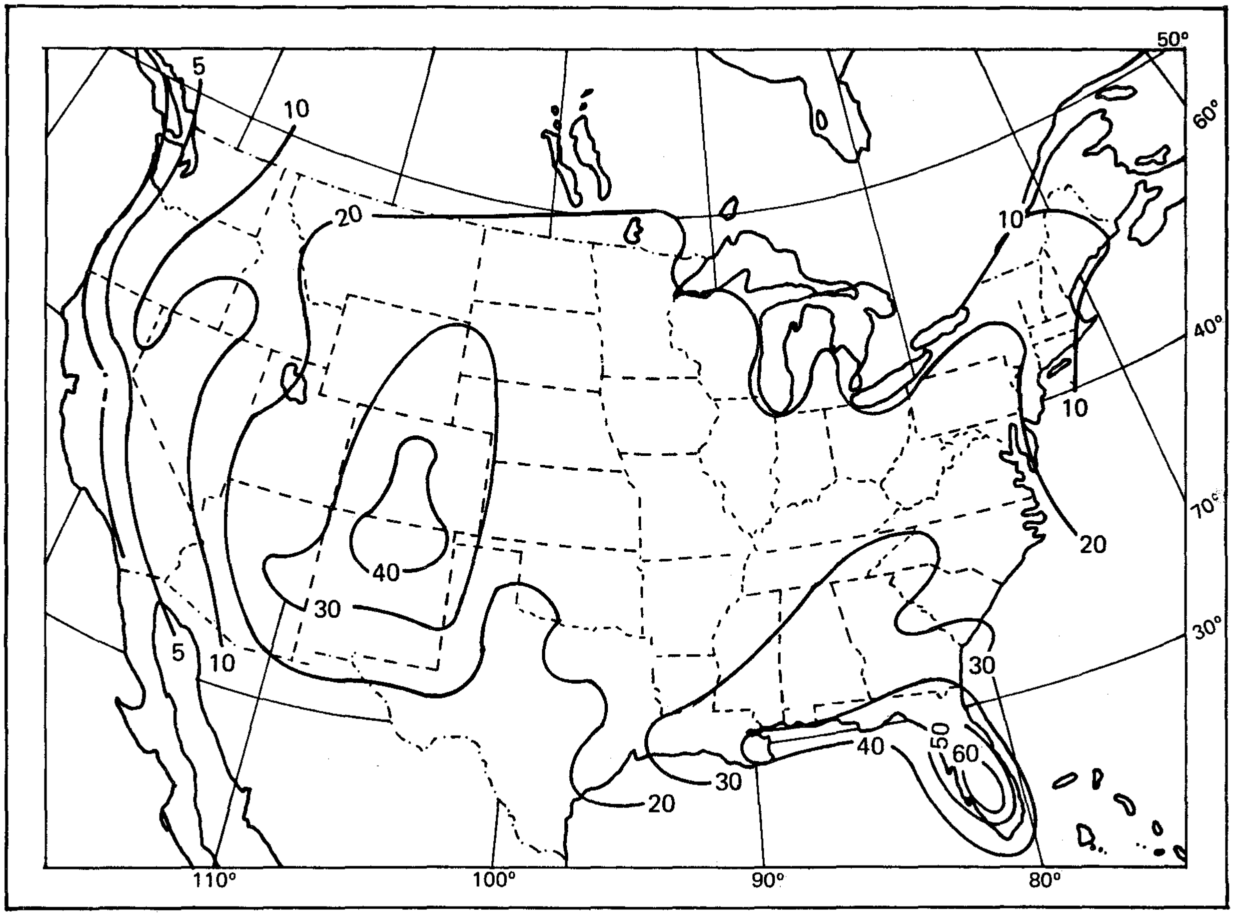


Figure 52. Number of days with one or more thunderstorms in June, July, and August (Petterssen 1969).

Table 26. Miscellaneous climate data for Mobile, Alabama (modified from National Climatic Center 1980).

Month	Average number of days					Average	
	Thunderstorms[a]	Rainfall[a] (≥0.01 inches)	Hail[a]	Temperature[a] (≥90° F)	Temperature[b] (≤32° F)	Wind speed and direction[c] (mph)	Snowfall[d] (inches)
Jan	2	11	<1	0	8	10.6N	0.1
Feb	2	10	<1	0	6	10.8N	0.2
Mar	5	11	<1	0	1	11.1N	[e]T
Apr	5	7	0	<1	0	10.4S	0
May	7	8	0	5	0	8.9S	0
Jun	12	11	0	19	0	7.7S	0
Jul	18	17	0	23	0	6.9S	0
Aug	14	14	0	21	0	6.8NE	0
Sep	8	11	0	11	0	8.0NE	0
Oct	2	6	0	1	0	8.2N	0
Nov	2	8	0	0	1	9.3N	T
Dec	2	10	<1	0	6	10.0N	0.1
Annual	80	124	<1	81	22	9.1N	

[a]Data for the period 1940-1980.
[b]Data for the period 1962-1980.
[c]Data for the period 1948-1980.
[d]Data for the period 1970-1980.
[e]Trace.

Table 27. Average relative humidity (%) in Mobile, Alabama, for 1962 - 80 (modified from National Climatic Center 1980).

Month	Time of day				Monthly average
	2400	0600	1200	1800	
Jan	78	81	62	69	72
Feb	76	80	55	61	68
Mar	80	83	56	63	70
Apr	83	87	54	63	72
May	84	86	54	62	72
Jun	84	87	54	65	72
Jul	87	89	61	71	77
Aug	87	90	61	73	78
Sep	85	88	60	72	76
Oct	82	85	51	66	71
Nov	82	85	56	70	73
Dec	80	83	61	71	74
Yearly average	82	85	57	67	73

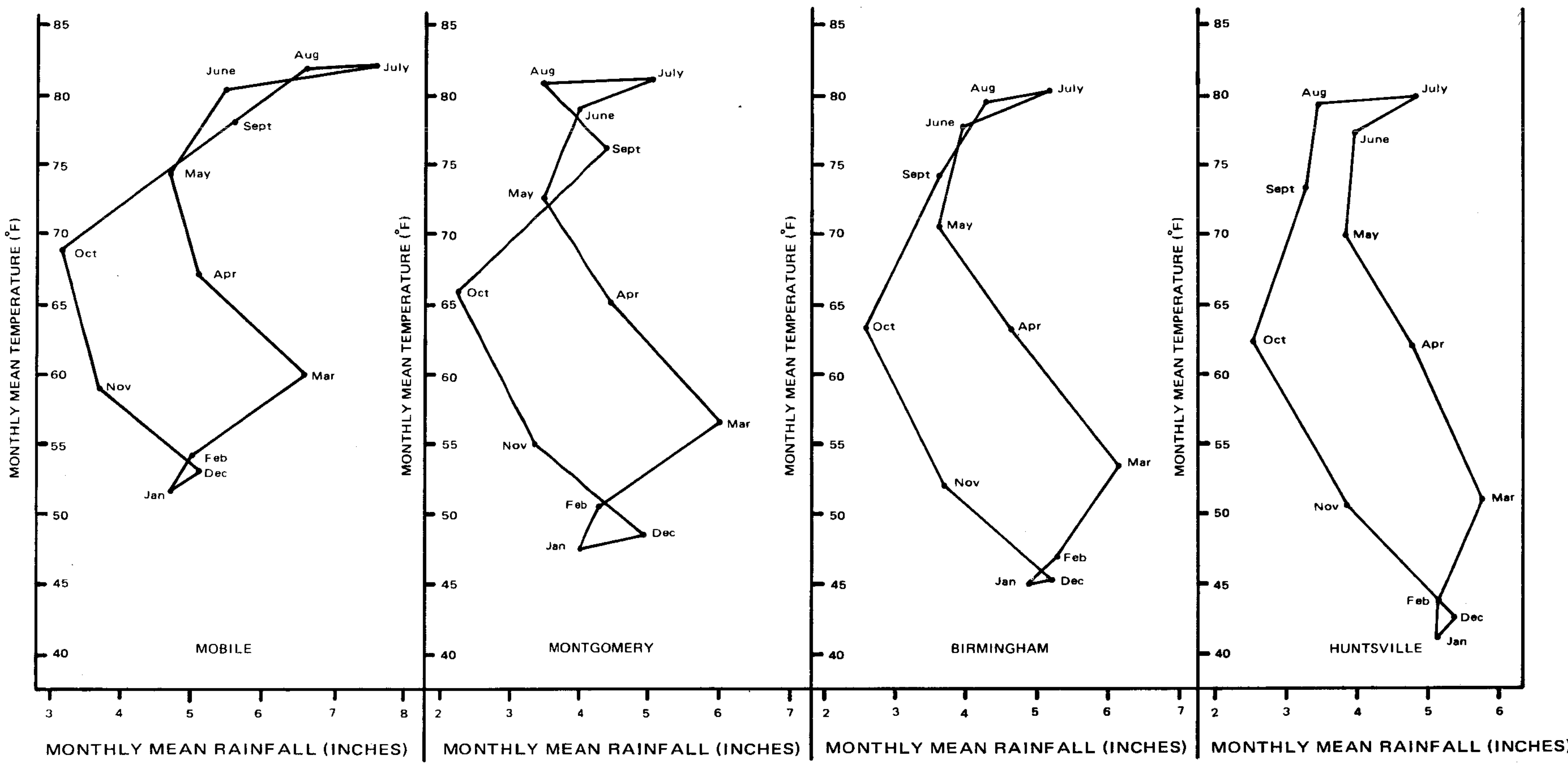


Figure 53. Rainfall climographs for major cities in Alabama.

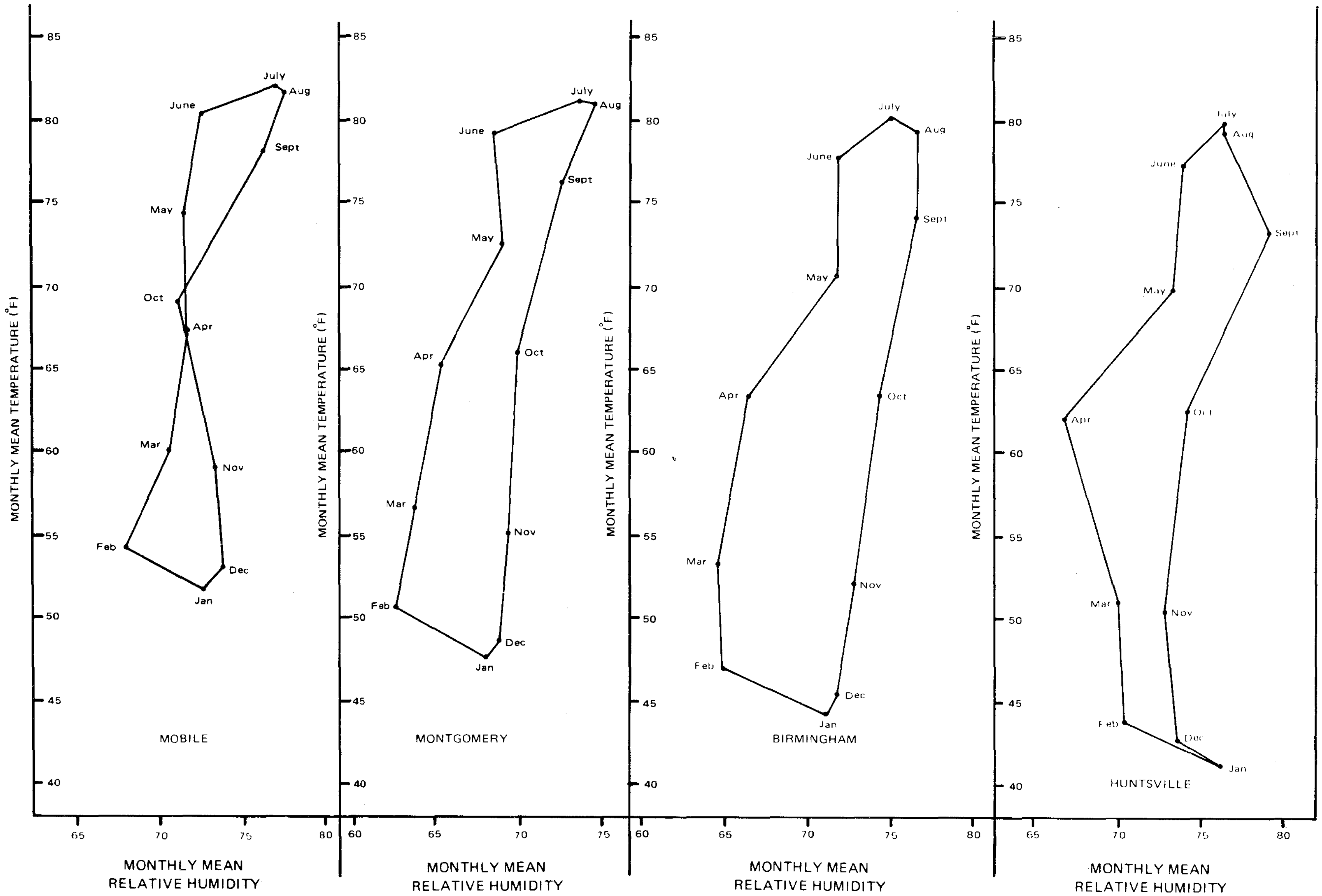


Figure 54. Relative humidity climographs for major cities in Alabama.

Table 28. Sky conditions (mean number of days) in Mobile, Alabama, 1948 - 80 (modified from National Climatic Center 1980).

Month	Clear	Partly Cloudy	Cloudy	Mean sky cover[a]	Heavy fog[b]
Jan	7	7	17	6.7	6
Feb	8	7	13	6.1	5
Mar	8	8	15	6.2	5
Apr	9	9	12	5.8	5
May	9	11	11	5.8	3
Jun	7	15	8	5.7	1
Jul	3	15	13	6.7	1
Aug	6	15	10	6.0	1
Sep	8	10	12	5.9	2
Oct	15	8	8	4.2	2
Nov	11	7	12	5.3	4
Dec	9	7	15	6.2	5
Annual total	100	119	146		39
Annual average				5.9	

[a]Tenths of total sky area, sunrise to sunset.
[b]Visibility 0.25 mile or less.

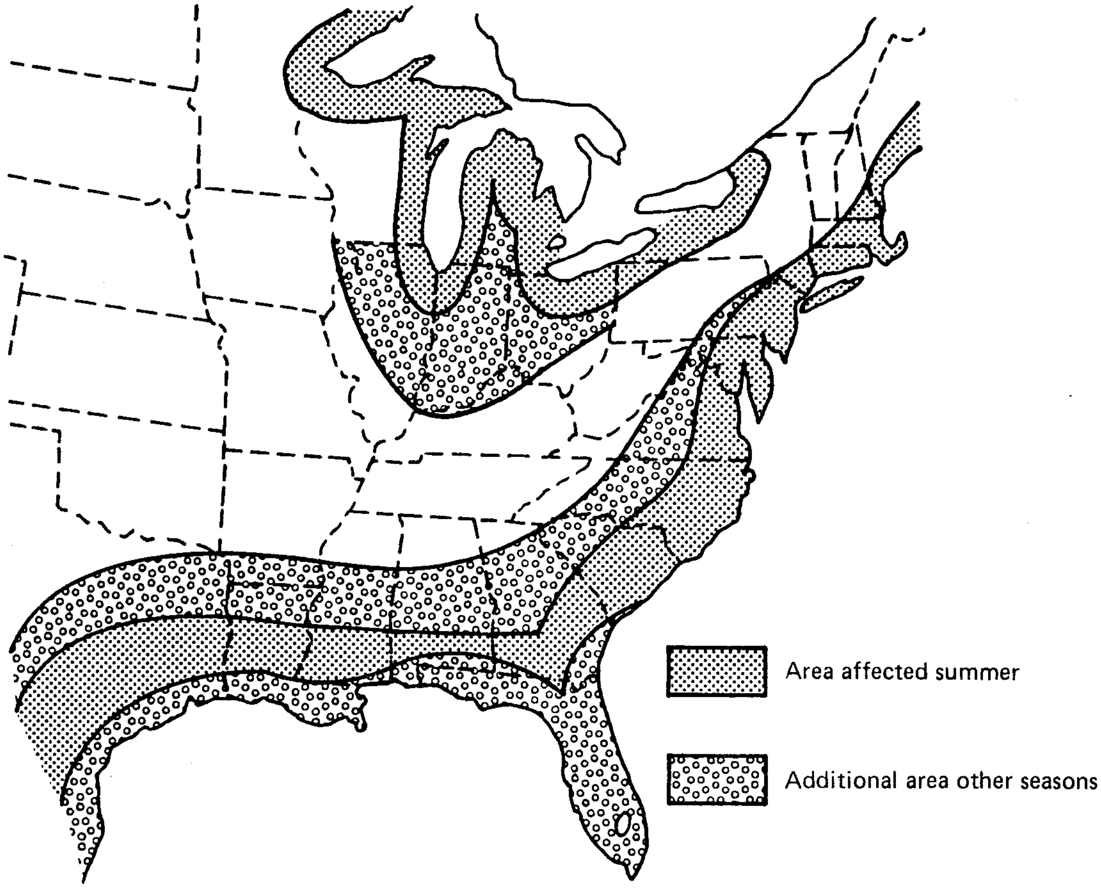


Figure 55. Regions of the Eastern United States where fogs often occur as a result of advection followed by radiative cooling during the night (Petterssen 1969).

When high-pressure systems persist for several days, air pollution stagnation occurs. From 1936 to 1965, 42 stagnation periods of four or more days duration for a total of 240 stagnation days occurred in the coastal Alabama region (Mobile County Board of Health 1970) (Figure 56). Low-level inversions (152 m [500 ft] or lower) have been estimated to exist in coastal Alabama between 30 and 35% of total hours (Mobile County Board of Health 1970).

Particulate pollutants in the atmosphere consist of a variety of suspended solids and liquids including sulfate salts, sulfuric acid, lead salts, carbon particles, liquid hydrocarbons, iron oxide, and silica. Particulate pollution can have direct and indirect impacts on living conditions. Visibility is directly affected by particulate levels in the atmosphere. As visibility declines, so does light availability for plant photosynthesis. Particulate pollution can also adversely affect human respiratory tracts (Stern et al. 1973). The south Alabama regional air pollution study (Mobile County Board of Health 1970) separated atmospheric particulate matter into two categories: settleable and suspended. Settleable particles are heavy enough to fall from the atmosphere near their point of origin. The distribution of settleable particles in coastal Alabama shows a concentration in industrial areas primarily in Mobile County (Figure 57). Suspended materials are light enough to remain in suspension in the atmosphere over long distances. In coastal Alabama, the distribution pattern of suspended material is similar to that of settleable material (Figure 58).

In the 1970's, air quality in coastal Alabama, particularly in Mobile, was monitored by the Alabama Air Pollution Control Commission (Figure 59) according to Federal and State ambient air-quality standards. Particulate matter in the atmosphere has exceeded the primary standard (level for health protection) on 10 occasions since 1972 (Table 29). The secondary standard (level for adverse effects, other than human health) has been exceeded 140 times since 1972 (Table 29).

Gaseous pollutants are vapors and gases in the atmosphere such as carbon monoxide, nitrogen oxide, sulfur dioxide, and photochemical oxidants.

Sulfur oxides are common atmospheric pollutants that originate primarily as a result of fossil fuel combustion. Sulfur dioxide has corrosive properties with detrimental effects on metals and building stone. This corrosive effect is accelerated by particulate matter. Sulfur dioxide at a level near 5 ppm can irritate the mucous lining of the respiratory tract (Stern et al. 1973). Chronic and acute injury to vegetation has been recorded in areas with high levels of sulfur oxides in the atmosphere (Mobile County Board of Health 1970). Sulfur dioxide levels in Mobile since 1976 have exceeded air-quality standards only on one occasion (Table 30).

Nitrogen oxides are also byproducts of the combustion process. Like sulfur oxides, high concentrations can have adverse effects on vegetation and the respiratory system of man. The 1970 study of air quality in south Alabama reported nitrogen dioxide levels ranging from 0.002 to 0.069 ppm (Table 31). Levels were much higher in Mobile than in surrounding cities (Mobile County Board of Health 1970).

In the atmosphere, sulfur and nitrogen oxides are transformed into sulfates and nitrates, which then react with moisture in the air forming acids. These acids in the atmosphere and in rainfall can have numerous effects. Sulfuric acid is irritating to respiratory tracts in concentrations of a few parts per million. The lowering of pH in streams and lakes as a result of acid rain can kill or severely impair fishes and other aquatic organisms. Photosynthetic efficiency and growth of vegetation is decreased. Acid rain can significantly increase the deterioration and weathering of various structures. Direct as well as long-term effects of acid rain on

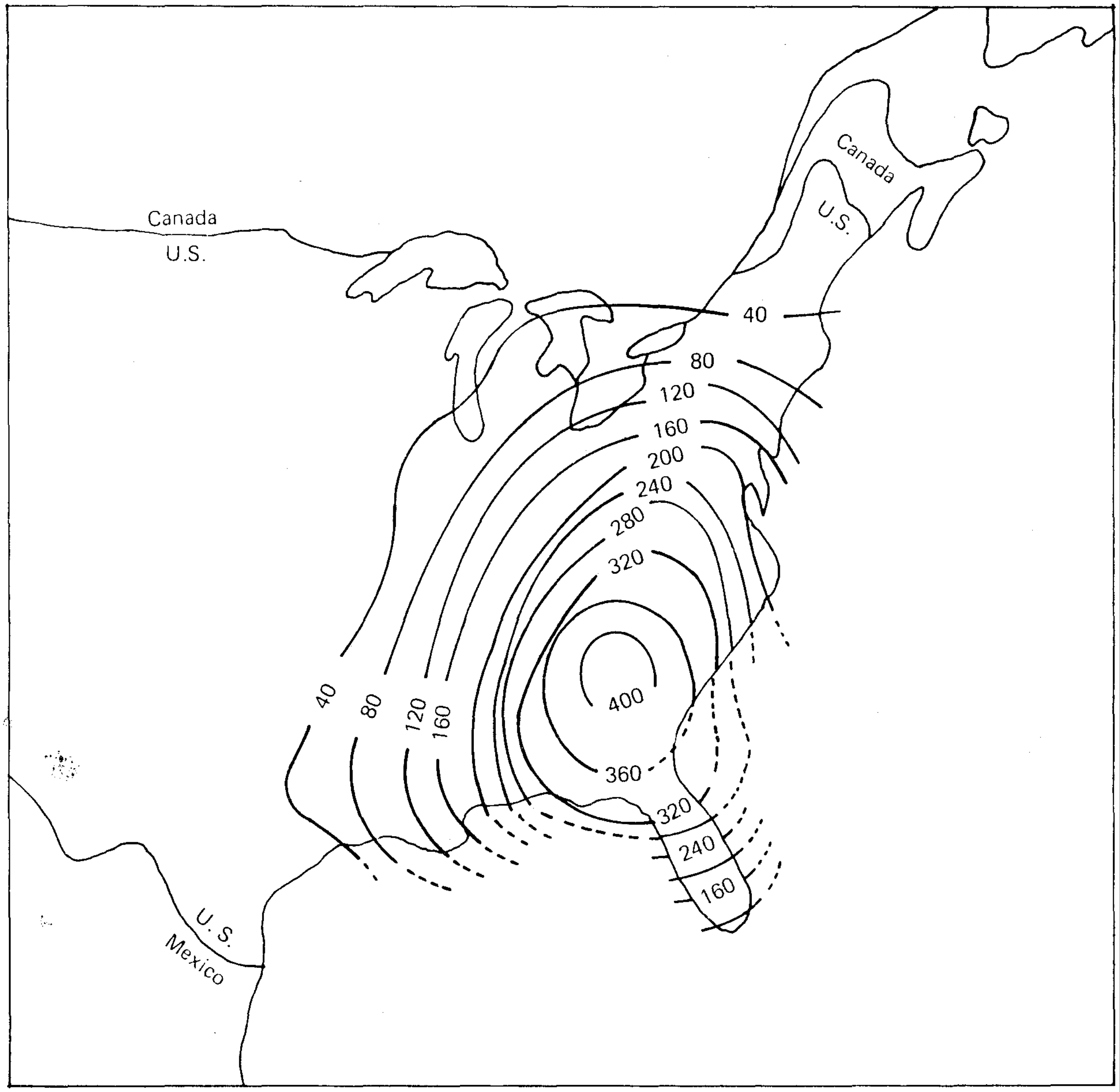


Figure 56. Total number of air stagnation days during 1936-65 east of the Rocky Mountains (Stern et al. 1973).

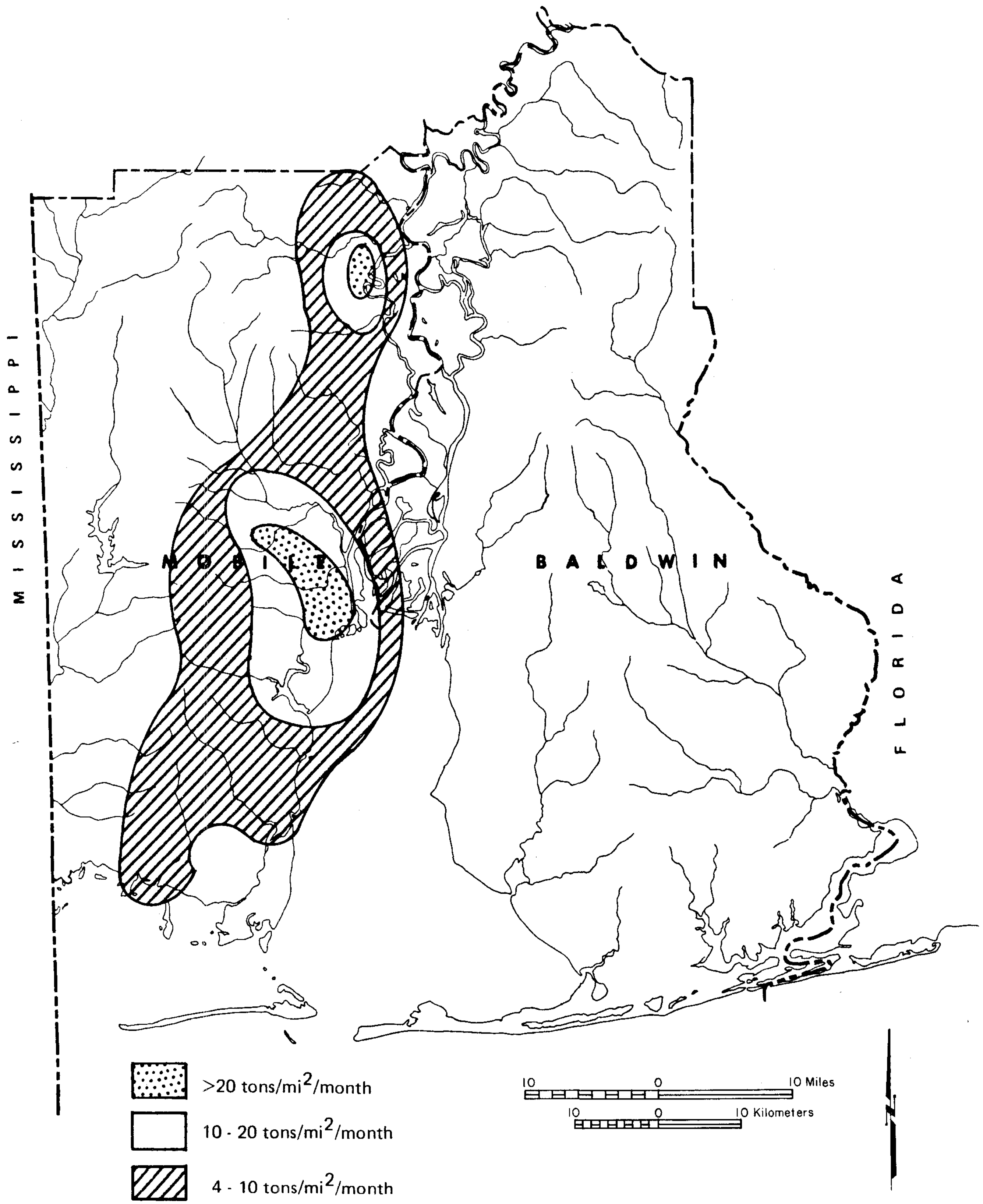


Figure 57. Probable dust fall pattern, 1969 (Mobile County Board of Health 1970).

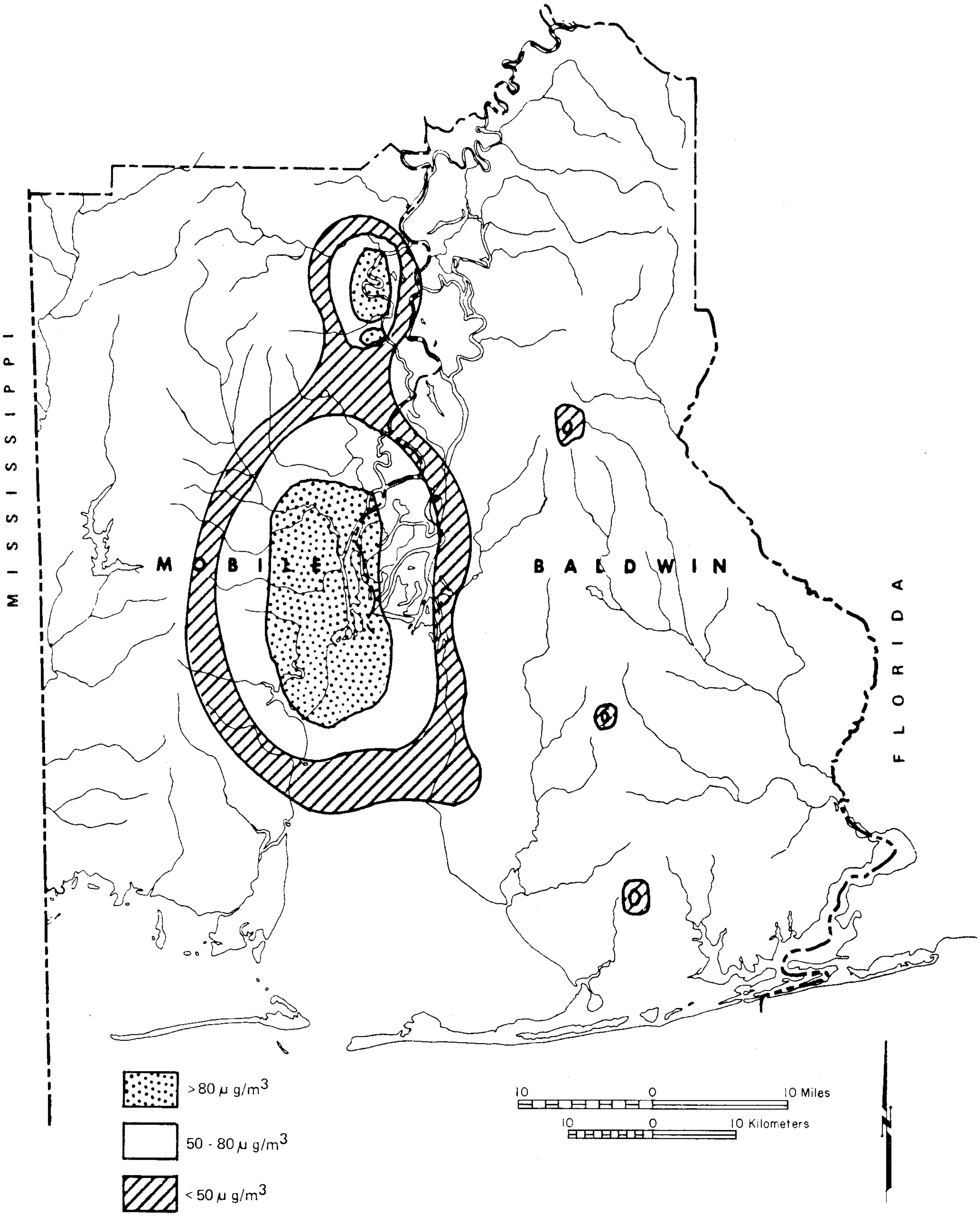


Figure 58. Probable average suspended particulate values, 24-hour average (Mobile County Board of Health 1970).

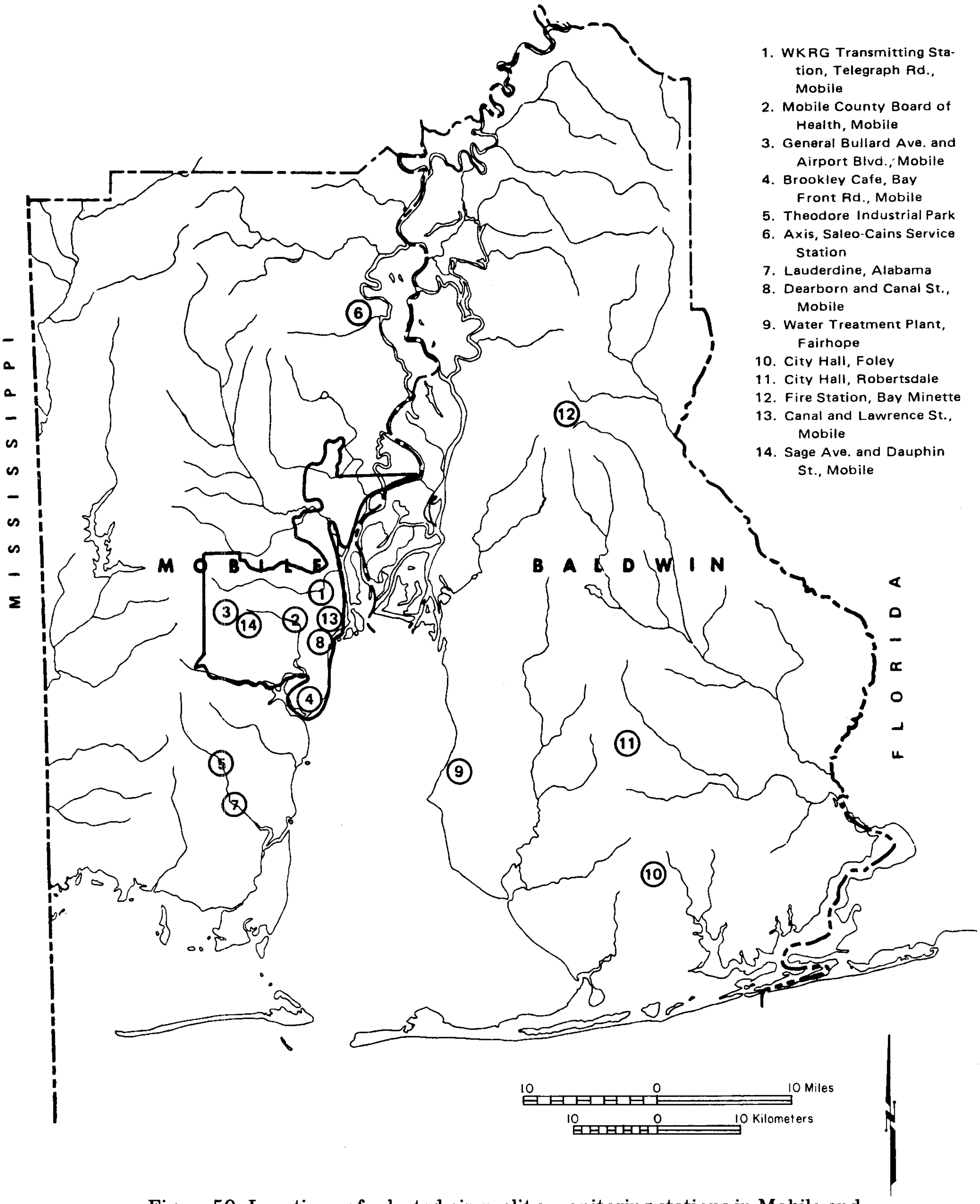


Figure 59. Locations of selected air-quality monitoring stations in Mobile and Baldwin Counties (modified from Alabama Air Pollution Control Commission 1981 and Mobile County Board of Health 1970).

Table 29. Particulate matter concentrations ($\mu g/m^3$) in atmosphere of Mobile, Alabama, and surrounding areas (modified from Alabama Air Pollution Control Commission 1981).

Sampling[a] location	Year	Number of samples	24-hr reading Max.	24-hr reading 2nd Max.	Number of samples exceeding standard Primary[b]	Number of samples exceeding standard Secondary[c]
1	1972	54	579	480	--	--
	1973	53	436	435	--	--
	1974	55	324	320	--	--
	1975	58	319	252	1	20
	1976	108	344	213	1	10
	1977	326	350	253	1	30
	1978	332	295	289	2	32
	1979	257	292	272	2	23
	1980	75	230	206	0	7
2	1972	60	267	256	1	--
	1973	49	380	270	--	--
	1974	43	322	204	1	--
	1975	47	193	174	0	3
	1976	48	169	116	0	1
	1977	227	188	165	0	2
	1978	237	149	136	0	0
	1979	218	117	115	0	0
	1980	139	128	125	0	0
3	1972	27	151	126	0	1
	1973	54	138	113	0	0
	1974	45	148	122	0	0
4	1972	31	219	171	0	--
	1973	53	204	198	0	--
	1974	47	194	144	0	1
	1975	53	136	131	0	0
	1976	53	116	100	0	0
	1977	51	132	99	0	0
	1978	46	108	103	0	0
	1979	20	97	92	0	0
	1980	6	73	56	0	0
5	1972	52	379	197	1	--
	1973	46	206	140	0	1
	1974	52	167	136	0	1
	1975	55	127	125	0	0
	1976	57	156	148	0	0
	1977	55	161	90	0	1
	1978	58	98	85	0	0
	1979	35	119	110	0	0
	1980	51	104	95	0	0

Table 29. Concluded.

Sampling[a] location	Year	Number of samples	24-hr reading Max.	24-hr reading 2nd Max.	Number of samples exceeding standard Primary[b]	Number of samples exceeding standard Secondary[c]
6	1974	32	405	199	--	--
	1975	56	205	183	0	2
	1976	57	241	156	0	5
	1977	55	138	129	0	0
	1978	54	90	87	0	0
	1979	14	53	49	0	0
7	1978	30	71	40	0	0
	1979	27	44	42	0	0

[a]See Figure 59 for sampling locations.
[b]Primary standard -- >260 $\mu g/m^3$.
[c]Secondary standard -- >150 $\mu g/m^3$.

Table 30. Sulfur dioxide concentrations (ppm) in atmosphere of Mobile, Alabama, and surrounding areas (modified from Alabama Air Pollution Control Commission 1981).

Sampling[a] location	Year	Number of observations	3-hr reading[b] (average) Max.	3-hr reading[b] (average) 2nd Max.	24-hr reading[c] (average) Max.	24-hr reading[c] (average) 2nd Max.
1	1976	7126	0.33	0.25	0.14	0.07
	1977	7395	0.10	0.10	0.04	0.04
	1978	7347	0.07	0.07	0.04	0.03
	1979	6022	0.09	0.07	0.04	0.03
	1980	1317	0.08	0.06	0.03	0.03
5	1976	5470	0.04	0.04	0.02	0.02
	1977	6847	0.09	0.08	0.04	--
	1978	6547	0.05	0.05	0.02	0.02
	1979	1386	0.04	0.03	0.02	0.02
	1980	1585	0.05	0.05	0.02	0.02
6	1976	1143	0.17	0.16	0.06	0.05
	1977	1599	0.23	0.23	0.08	0.06
	1978	7350	[d]0.51	--	0.09	0.09
	1979	5155	0.21	0.15	0.07	0.06
	1980	1992	0.17	0.12	0.07	0.00

[a]See Figure 59 for sampling locations.
[b]3-hr standard--0.5 ppm.
[c]24-hr standard--0.14 ppm.
[d]Exceeded 3-hr standard.

Table 31. Nitrogen dioxide concentrations (ppm) in the atmosphere of Mobile, Alabama, and surrounding areas (modified from Alabama Air Pollution Control Commission 1981).

Sampling[a] location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2	0.0480	0.0345	0.0100	0.0335	0.0290	0.0185	[b]--	--	--	0.0415	0.0690	0.0560
6	--	--	--	--	--	--	--	--	--	0.0565	0.0076	0.0550
8	--	--	--	--	--	--	--	--	--	0.0045	0.0612	0.0470
9	--	--	--	--	--	--	--	0.0030	--	--	--	--
10	--	--	--	--	--	--	0.0040	0.0019	0.0060	0.0110	0.0140	0.0190
11	--	--	--	--	--	--	--	0.0050	--	--	--	--
12	--	--	--	--	--	--	0.0040	0.0100	0.0050	0.1300	0.0120	0.0150

[a]See Figure 59 for sampling locations.

[b]Not measured.

humans are yet to be established, but the potential definitely exists.

Carbon monoxide affects humans by restricting the ability of the blood to transport oxygen. Readings in central Mobile during 1978 and 1979 exceeded standards on one occasion (Table 32).

Ozone is a component of the total oxidant mixture, which is used as an index of photochemical smog. Ozone at high concentrations will deteriorate rubber products and damage field crops. In the Mobile region, ozone standards were exceeded on four occasions in 1976-79 (Table 33).

WIND

Although wind direction over the coastal area tends to be variable throughout the year (Figure 60), the overall circulation pattern is northerly winds from September through February and southerly winds the remainder of the year (Table 34). Wind speed also has a seasonal pattern, being stronger from November through April than in summer months. Wind charts for Mobile, Alabama, and Biloxi, Mississippi, indicate that the strongest winds, in excess of 40 km/h (25 mi/h), in the coastal area occur less than five days during the year and originate from both the north and south. The highest wind speed recorded in the Mobile area was 233 km/h (145 mi/h) during Hurricane Frederic in September 1979 on Dauphin Island (U.S. Army Corps of Engineers 1981).

HURRICANES AND TROPICAL STORMS

A hurricane is a tropical cyclone with wind velocities of 119 km/h (74 mi/h) or greater. Most hurricanes form in zones between 8° and 15° latitude from the equator, where the sea surface temperature is high and the Coriolis force strong enough to cause the spinning of winds around low-pressure centers (Petterssen 1969). Hurricanes pose a definite threat to the Alabama coast from June through October, being most frequent in Alabama during September (Figure 61). These late summer hurricanes tend to originate in the eastern North Atlantic near the Cape Verde Islands and are often severe. Those hurricanes arising in June and July usually originate in the western Atlantic or Caribbean and tend to be weak (U.S. Army Corps of Engineers 1981).

A total of 57 hurricanes have affected the Gulf of Mexico coastline since 1711 (Table 35), an average of one hurricane every five years. Even though the landfall of the center of a hurricane may not occur along the Alabama coast, those which move inland from Louisiana to the Florida panhandle can have significant effects in Alabama. During the 1900's, nine of these hurricanes were classified as severe, with the Saffir/Simpson system. The high winds typically generated by hurricanes are ordinarily not as destructive as the marked rise in water level, referred to as hurricane surge. Hurricane Frederic, the last hurricane to hit the Alabama coast (12-13 September 1979), had record wind speeds of 233 km/h (145 mi/h) recorded at Dauphin Island. At Mobile, wind speeds were recorded at a record 164 km/h (101 mi/h). Heavy rains associated with hurricanes may lead to increased river discharge, affecting coastal areas for several days. Rainfall associated with Hurricane Frederic amounted to 21.7 cm (8.6 inches) in Mobile and 21.5 cm (8.5 inches) on Dauphin Island on 12-13 September 1979. The highest recorded total was reported at Merrill, Mississippi, as 23 cm (9 inches) fell in a 24-hour period. The intense rainfall associated with Hurricane Frederic followed a period of relatively dry weather and flooding was less than might be expected in or near the hurricane path (U.S. Army Corps of Engineers 1981). Only a slight drop in air temperature (2° to 4°C [4° to 7°F]) was reported during the hurricane activity (U.S. Army Corps of Engineers 1981). Hurricanes are also capable of bringing cold water to the ocean surface. Hurricane Hilda in 1964 lowered surface-water temperature in the gulf 5°C (9°F).

Table 32. Carbon monoxide concentrations (ppm) in atmosphere of Mobile, Alabama (modified from Alabama Air Pollution Control Commission 1981).

			Hourly reading		8-hr average[b]	
Sampling[a] location	Year	Number of observations	Max.	2nd Max.	Max.	2nd Max.
14	1978	6224	15.1	13.1	[c]9.5	8.8
	1979	5937	12.7	10.7	8.1	6.5

[a]See Figure 59 for sampling locations.

[b]8-hr standard--9.0 ppm.

[c]Exceeded 8-hr standard.

Table 33. Ozone concentrations (ppm) in atmosphere of Mobile, Alabama, and surrounding areas (modified from Alabama Air Pollution Control Commission 1981).

			1-hr reading[b]	
Sampling[a] location	Year	Number of observations	Max.	2nd Max.
1	1976	8157	0.12	0.12
	1977	2691	0.09	0.09
5	1977	1196	0.09	0.09
	1978	5505	[c]0.15	[c]0.15
	1979	4791	0.10	0.10
6	1977	5601	0.15	0.14
	1978	7359	0.12	0.11
	1979	3235	0.10	0.10
13	1975	2453	0.10	0.09

[a]See Figure 59 for sampling location.

[b]1-hr standard--0.12 ppm.

[c]Exceeded 1-hr standard.

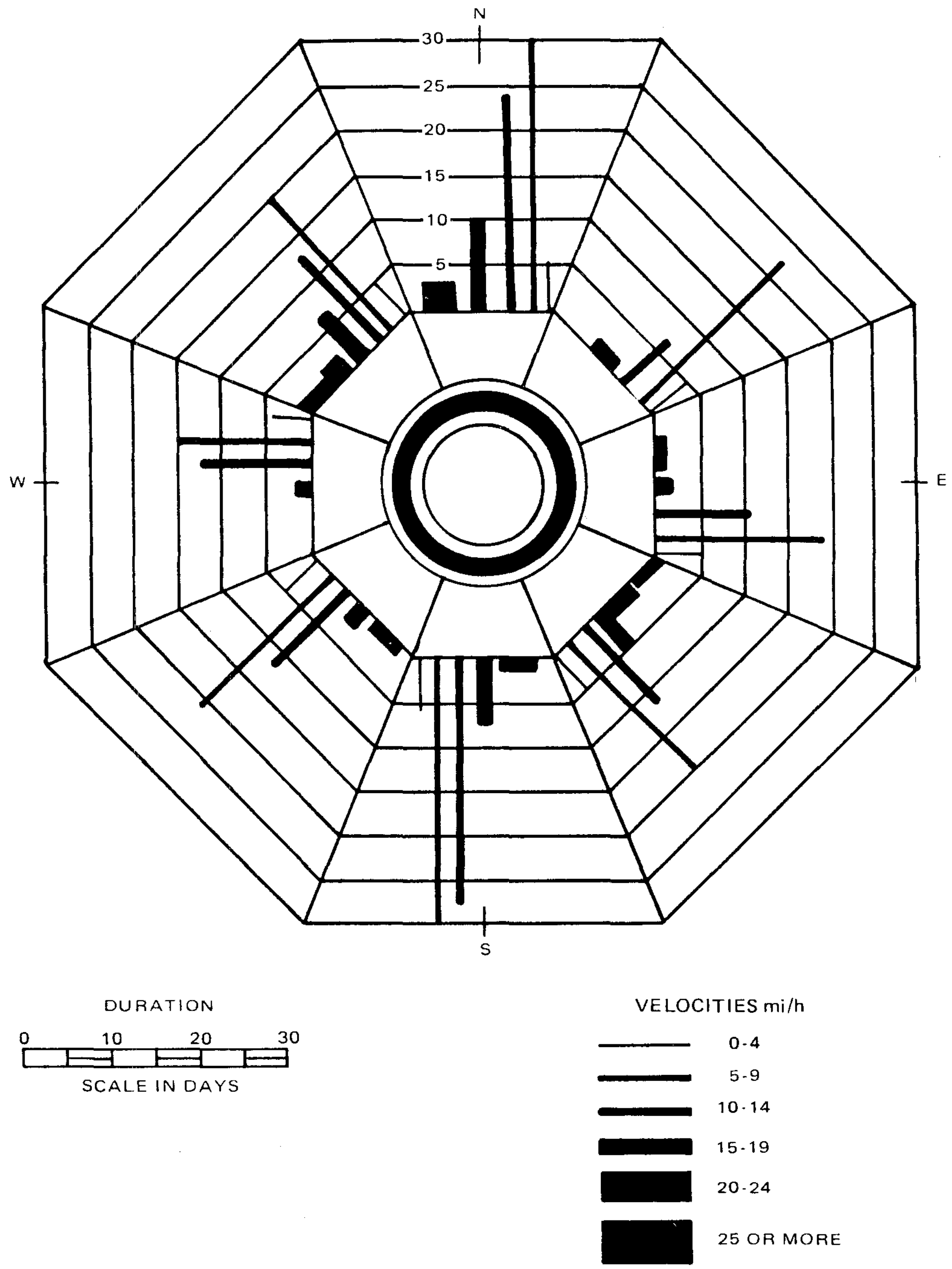


Figure 60. Wind chart for Mobile, Alabama (U.S. Army Corps of Engineers 1953).

Table 34. A summary of wind data from selected U.S. Weather Bureau stations in Alabama, 1872 - 1930 (Crance 1971).

Station	Number of years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
							Prevailing wind direction							
Citronelle	38	NW	NW	S	S	S	S	S	S	SE	N	NW	NW	S
Daphne	25	NW	NW	SW	SW	SW	SW	SW	SW	NE	NW	NW	NW	SW
Mobile	59	N	N	S	S	S	S	SW	SW	N	N	N	N	N
Robertsdale	19	NE	SW	SW	SW	SW	SW	SW	SW	NE	NE	N	NE	SW
							Average hourly wind velocity (mi/h)							
Mobile	58	8.8	9.1	9.3	9.2	8.6	7.7	7.2	7.1	7.6	8.1	8.4	8.7	8.3

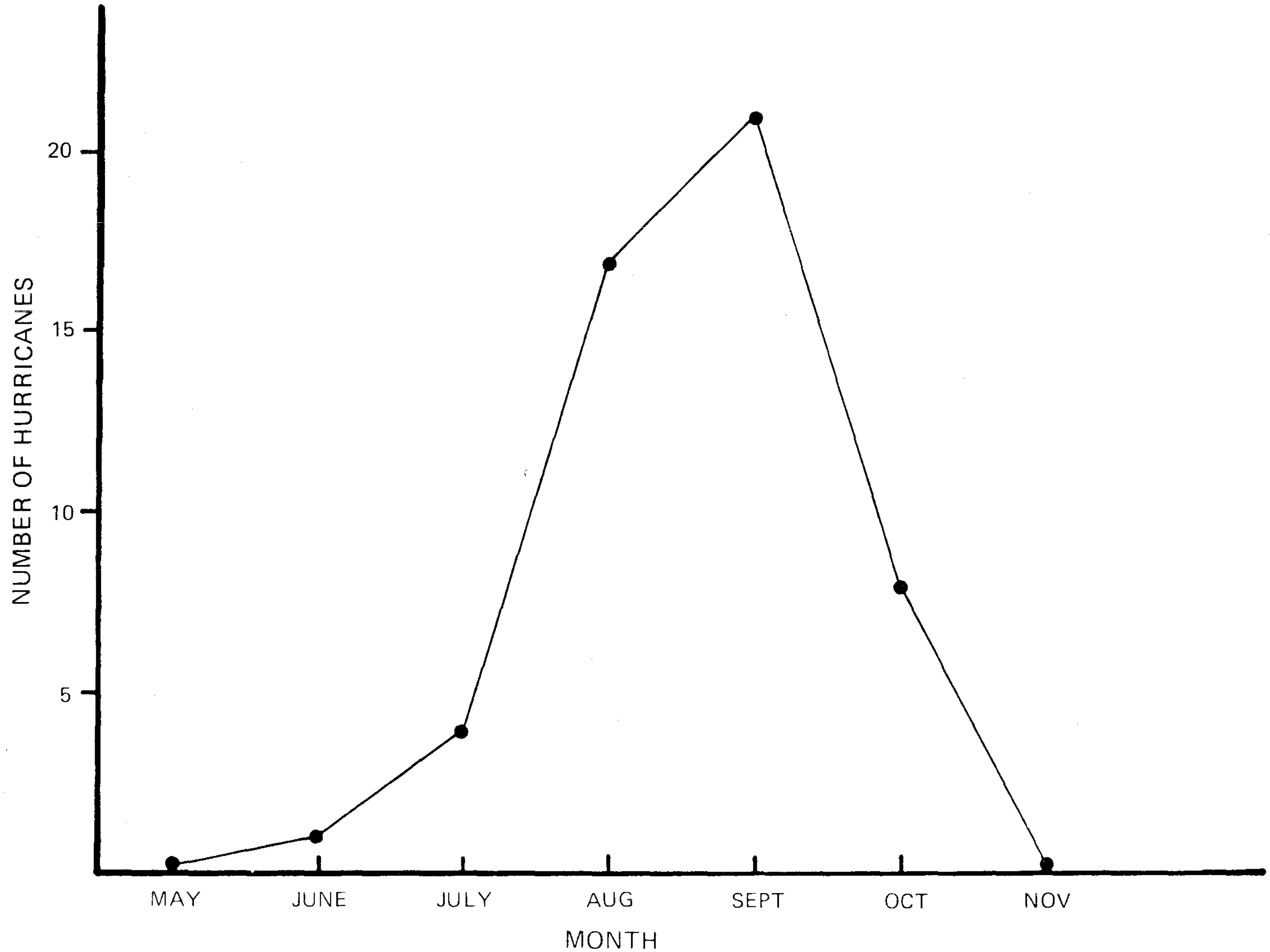


Figure 61. Monthly frequency of hurricanes affecting Alabama since 1711 (modified from Chermock 1974).

Table 35. Hurricanes affecting Alabama, 1711 - 1972 (modified from U.S. Army Corps of Engineers 1971).

Date	Landfall	Origin	Principal gulf area affected
Sep 11-13, 1711	[a]*	*	New Orleans, LA
Sep 12-13, 1722	*	*	New Orleans, LA
1732	*	*	Mobile, AL
1736	*	*	Pensacola, FL
Sep 12, 1740	*	*	Pensacola, FL
Sep 1759	*	*	Gulf coast
Oct 22, 1766	*	*	Pensacola, FL
Sep 04, 1772	*	*	Louisiana
Jul 10, 1776	*	*	New Orleans, LA
Aug 18, 1779	*	*	New Orleans, LA
Oct 07-10, 1779	*	*	New Orleans, LA
Aug 24, 1780	*	*	New Orleans, LA
Aug 23, 1781	*	*	New Orleans, LA
Aug 1800	*	*	New Orleans, LA
1811	*	*	New Orleans, LA
Aug 19, 1812	*	*	New Orleans, LA
Aug 19, 1813	*	*	Gulf coast
Aug 25-28, 1819	*	*	Bay St. Louis, MS
1821	*	*	New Orleans, LA
Jul 11, 1822	*	*	Mobile, AL
Aug 16, 1831	*	Atlantic	Mouth of Miss. River
Oct 07, 1837	New Orleans, LA	Caribbean	New Orleans, LA
Sep 18-22, 1842	*	*	Gulf coast
Oct 12, 1846	*	*	New Orleans, LA
Aug 23, 1852	*	*	Mobile, AL
Aug 12, 1856	*	*	Louisiana
Aug 30, 1856	Mobile, AL	*	Mobile, AL
Aug 11, 1860	*	*	Mobile, AL
Sep 15, 1860	*	*	Mobile, AL
Jul 30, 1870	*	*	Mobile, AL
Sep 21, 1877	*	*	Gulf coast
Aug 26-30, 1880	Mobile, AL	Atlantic	Mobile, AL
Sep 10, 1882	Mobile, AL	*	Mobile, AL
Oct 19, 1887	Grand Isle, LA	Atlantic	Mississippi coast
Aug 19, 1888	Lake Charles, LA	Atlantic	Louisiana to Mobile, AL
Sep 23, 1889	Burrwood, LA	Atlantic	Louisiana to Pensacola, FL
Oct 02, 1893	Pascagoula, MS	Caribbean	Louisiana
Aug 15, 1901	Grand Isle, LA	Atlantic	Louisiana
Sep 27, 1906	Pascagoula, MS	Caribbean	Mobile, AL
Sep 20, 1909	Grand Isle, LA	Caribbean	New Orleans, LA
Sep 14, 1912	Mobile, AL	Gulf	Mobile, AL
Sep 29, 1915	Grand Isle, LA	Atlantic	New Orleans, LA
Jul 05, 1916	Gulfport, MS	Caribbean	Mobile, AL

Table 35. Concluded.

Date		Landfall	Origin	Principal gulf area affected
Oct 18,	1916	Pensacola, FL	Caribbean	Pensacola, FL
Sep 28,	1917	Pensacola, FL	Atlantic	Pensacola, FL
Sep 20,	1926	Perdido Beach, AL	Atlantic	Pensacola, FL
Sep 01,	1932	Mobile, AL	Atlantic	Mobile, AL
Sep 19,	1947	New Orleans, LA	Atlantic	Mississippi coast
Sep 04,	1948	Grand Isle, LA	Gulf	Louisiana
Aug 30,	1950	Mobile, AL	Atlantic	Gulf Shores, AL
Sep 24,	1956	Fort Walton Beach, FL	Caribbean	Alabama and northwest Florida
Sep 15,	1960	Pascagoula, MS	Gulf	Mississippi coast
Oct 03,	1964	Franklin, LA	Caribbean	Louisiana
Aug 17,	1969	Waveland, MS	Caribbean	Mississippi and Louisiana coast
Jun 19,	1972	Panama City, FL	Caribbean	Florida Panhandle
Sep 23,	1975	Panama City, FL	Caribbean	Alabama and northeast Florida
Sep 22,	1979	Dauphin Island, AL	Caribbean	Mobile, AL

[a] Not available.

As Hurricane Frederic reached landfall, the storm surge reached heights of 3 to over 4 m (10 and 16 ft) above mean sea level along the Alabama coastline with a high reading of 5.2 m (17 ft) recorded about 4.8 km (3 mi) west of Perdido Bay (U.S. Army Corps of Engineers 1981). The eastern shore of Mobile Bay had high-water elevations of 2.4 to 3 m (8 to 10 ft). Readings near 1.6 m (5.5 ft) were recorded on the Tensaw and Mobile Rivers. The western shore of Mobile Bay had high-water readings ranging from 2.1 to 3.6 m (7 to 12 ft).

In terms of damage to life and property, Hurricane Frederic was one of the most physically destructive storms ever to strike the Alabama coast (Table 36), although not as destructive as Hurricane Camille in 1972. Flooding in Mobile and Baldwin Counties covered 34,800 ha (87,000 acres). Throughout the gulf coast, some 49,200 ha (123,000 acres) were inundated by Hurricane Frederic, in comparison to the flooding of 173,200 ha (433,000 acres) as a result of Hurricane Camille (U.S. Army Corps of Engineers 1981). Only 13 deaths were attributed to Hurricane Frederic, in comparison to 256 deaths as a result of Hurricane Camille. In Alabama, Hurricane Frederic resulted in economic losses of near 1.5 billion dollars. This is similar to the entire loss attributed to Hurricane Camille (U.S. Army Corps of Engineers 1981).

A tropical storm is a cyclone with maximum sustained surface wind between 63 and 117 km/h (39 and 73 mi/h). In a 178-year period, 17 tropical storms affected the Alabama coastal region (Table 37). The Alabama coast has been particularly subject to destructive hurricanes and tropical storms (Figure 62). The probability of a tropical storm or hurricane affecting the 80-km (50-mi) area between Biloxi, Mississippi, and Mobile Bay has been calculated as 13% for a tropical storm, 6% for a hurricane, and 1% for a severe hurricane each year (Simpson and Lawrence 1971). For the eastern gulf coast, the probability of hurricane or tropical storm influence increases to 50% each year (Hope and Neumann 1971).

Table 36. Costliest hurricanes in the Gulf of Mexico 1900 - 80 (U.S. Army Corps of Engineers 1981).

Hurricane	Location	Year	Category (Saffir/Simpson scale)	Damage (billions of dollars)	Deaths
Frederic	AL,MS,FL	1979	4	2.22	13
Camille	MS,LA	1969	5	1.42	256
Betsey	FL,LA	1965	3	1.42	75
Celia	TX	1970	3	0.46	--
Carla	TX	1961	4	0.45	--
Beulah	TX	1967	3	0.20	--
Audrey	LA,TX	1957	4	0.15	390
Carmen	LA	1974	3	0.15	--
Hilda	LA	1964	3	0.12	--
(a)	FL,LA,MS	1947	4	0.11	51
(a)	TX	1900	4	[b]--	6,000
(a)	FL,TX	1928	4	--	600
					900
(a)	LA	1909	4	--	350
(a)	LA,TX	1915	4	--	275
(a)	MS,AL,FL	1906	3	--	134

[a]No name.

[b]Not available.

Table 37. Tropical storms affecting Alabama, 1886 - 1964 (U.S. Army Corps of Engineers 1967a and b).

Date	Landfall	Origin
12 Sep 1892	Port Eads, LA	Gulf
07 Aug 1894	Pensacola, FL	Gulf
16 Aug 1895	Bayou La Batre, AL	Gulf
12 Sep 1900	Port Eads, LA	Caribbean
14 Jun 1901	Mobile, AL	Caribbean
10 Oct 1902	Mobile, AL	Gulf
02 Nov 1904	Port Eads, LA	Caribbean
21 Sep 1907	Gulfport, MS	Caribbean
04 Jul 1919	Pensacola, FL	Gulf
17 Oct 1922	Pensacola, FL	Caribbean
17 Oct 1923	Biloxi, MS	Gulf
06 Oct 1934	Mobile, AL	Caribbean
16 Jun 1939	Mobile, AL	Caribbean
10 Sep 1944	Biloxi, MS	Gulf
08 Sep 1947	Pascagoula, MS	Gulf
18 Sep 1957	Grand Isle, LA	Gulf
08 Oct 1959	Pensacola, FL	Gulf

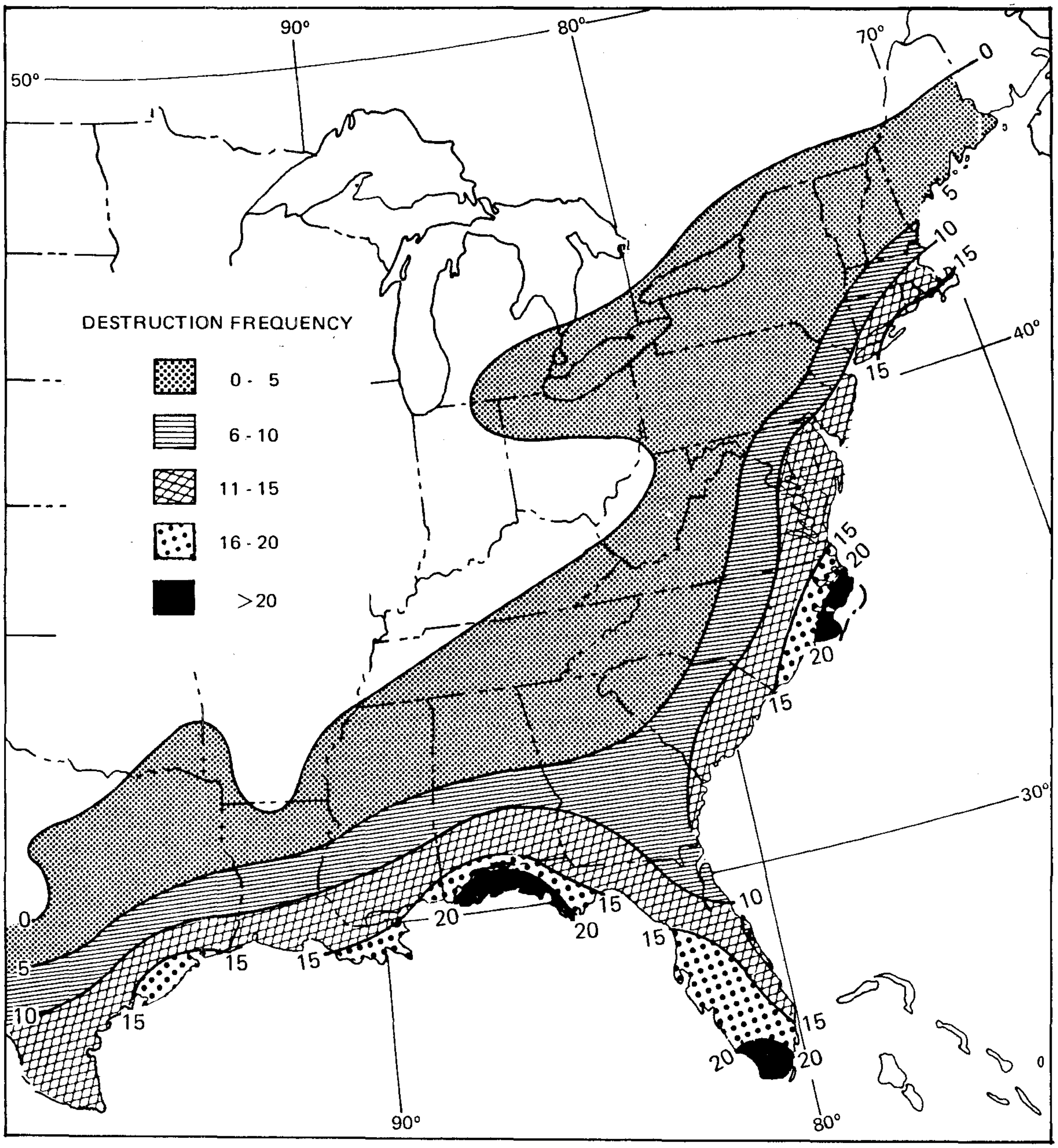


Figure 62. Number of times destruction was caused by tropical storms, 1901-55 (Long 1978).

TORNADOES

Tornadoes are local storms consisting of winds rotating at very high speeds around a central cavity in which the centrifugal force produces a partial vacuum. Air surrounding the vortex picks up dust, debris, or water as it moves forward forming the characteristic funnel. Most tornadoes have wind speeds of 161 to 322 km/h (100 to 200 mi/h), but speeds of violent ones have been estimated at near 805 km/h (500 mi/h). Much of the damage resulting from a tornado is the result of pressure differentials causing buildings to explode outward rather than being blown over. Wind pressure may be as great as 33.7 kg/m^2 (800 lbs/ft^2) (Petterssen 1969).

Alabama is a tornado-prone state; and, on the basis of data accumulated from 1953 to 1969, it ranks fourteenth among the states in order of frequency per unit area (NOAA 1974). Tornadoes are most frequent in the state in March and April. Between 1953 and 1964, there were an average of 18 tornadoes per year (Chermock 1974). They occur at all hours but tend to be more numerous between 1400 and 1900 hours. In coastal Alabama, tornadoes are often associated with thunderstorms and may be associated with hurricanes (Chermock 1974).

PLANT LIFE

By Steven C. Harris
and Patrick E. O'Neil

Sunlight irradiates the earth at the estimated rate of 2 $gcal/cm^2/min$ (Odum 1971). Only about half of this solar energy ever reaches the earth's surface and of this amount only about 5% is utilized by green plants in photosynthesis. This process converts solar energy into the chemical energy of organic products, which is then available to all other living organisms. Only a few major groups of organisms—the green plants, algae, and some bacteria—have chlorophyll, which is necessary for photosynthesis. These chlorophyll-bearing organisms are the foundation and bases for all life.

ALGAE

Algae are a diverse group of single and multicellular plants characterized by the common presence of unicellular reproductive structures. In the aquatic environment, they can be grouped into two broad categories: planktonic and benthic. Planktonic algae are suspended in the water column while benthic algae are attached to the substrate or bottom-dwelling organisms. Algae occur in many habitats and are well represented in coastal Alabama environments.

PLANKTONIC ALGAE

The two major groups of planktonic algae in the Gulf of Mexico are the unicellular diatoms (Chrysophyta) and dinoflagellates (Pyrrophyta). Although studies dealing specifically with phytoplankton diversity and seasonal abundance for coastal Alabama waters are lacking, a probable species assemblage can be compiled from several northern gulf surveys (Table B-1, Appendix B). In more complete compilations of the Gulf of Mexico Gulf surveys (Table B-1, Appendix B). In more complete compilations of the Gulf of Mexico phytoplankton, over 890 species of dinoflagellates (Steidinger 1972), and over 380 species of diatoms (Conger et al. 1972) have been reported.
Mexico, there are at least four species (*Gonyaulax monilata*, *G. polyedra*, *G. tamarensis* var. *excavata*, and *Gymnodinium breve*) known to produce neurotoxins capable of killing fishes and invertebrates, but only two of these species have been associated with mass mortalities (Steidinger 1973). *Gonyaulax monilata* has been reported as the causative agent for numerous fish kills in the northern Gulf from Texas to Florida (Williams and Ingle 1972). During August of

1979, a bloom of *Gonyaulax monilata* created reddish discolored water in scattered northern Gulf coastal waters, including Mississippi Sound, lower Mobile Bay, and Pensacola Bay. No mortality was associated with the bloom in Mississippi, but small fish kills were reported in both Alabama and Florida (Perry et al. 1979). *Gymnodinium breve* is essentially coastal in distribution and the cause of extensive mortalities in fishes and shellfish. Blooms are primarily restricted to the west coast of Florida but have been reported from the northwest coast of Florida, the east coast of Texas, and off the coast of Mexico. The species has been collected in Mississippi Sound (Housley 1976) and is likely to occur off the Alabama coast.

The blue green alga, *Oscillatoria erythraea*, is also a cause of "red tides" during blooms. The species is widely distributed in the northern Gulf of Mexico, but widespread blooms are rare. In August 1974, an extensive bloom of *O. erythraea* occurred in Mississippi Sound, extending in a thin band from north of Cat Island to near Dauphin Island, off the Alabama coast (Eleuterius et al. 1981). Qasin (1970) reported the blooms may be harmful to certain plants and animals, but no fish mortalities were reported following the 1974 Mississippi bloom. Most fishes and larger invertebrates simply avoided the area of the blooms (Eleuterius et al. 1981).

Planktonic primary production (the amount of radiant energy stored by photosynthetic activity) in Gulf waters is highest in the estuaries, decreasing from the head to the mouth. This reduction of primary production continues seaward so that estuaries and bays are the most fertile, followed by continental shelf waters, and finally open Gulf waters. Inshore chlorophyll *a* values in surface and integrated water samples (average 0.23 mg/m^3 and 16.59 mg/m^2, respectively) are slightly less than twice the offshore values (average 0.13 mg/m^3 and 10.94 mg/m^2) (El-Sayed 1972). These values do not take into account the contribution to production made by benthic and epiphytic algae and seagrasses. Several investigators, including Pomeroy (1960), Schelske and Odum (1961), and Teal (1962), have reported that in shallow estuaries phytoplankton is of secondary importance in comparison to marsh grasses, seagrasses, and benthic flora. Taylor and Saloman (1968) suggested that in Boca Ciega Bay, Florida, planktonic algae accounted for only one-sixth of the total primary production. In a study of phytoplankton production in Mississippi Sound, Mulkana and Abbott (1972) determined net plankton standing crop was greatest during the spring and summer, declining in the fall with decreasing gulf temperature. Nannoplankton biomass was estimated to be considerably higher than that of the net plankton, with population peaks showing no seasonal trend. The importance of phytoplankton to primary production is reversed in open gulf waters. The diversity of phytoplankton also increases in a seaward direction as holoplanktonic ("permanent plankton") forms replace meroplanktonic ("temporary plankton") forms (Thomas and Simmons 1960).

Davis (1954) stated that the greatest immediate need in the field of phytoplankton research in the Gulf of Mexico was a thorough, quantitative study of the diversity and seasonal distribution of the entire gulf flora. Since the 1950's numerous phytoplankton studies, primarily net plankton, have been conducted in the Gulf of Mexico, but as yet thorough studies of the coastal waters off Alabama are lacking. However, the Alabama Coastal Area Board is currently undertaking an intensive study of the phytoplankton of Mobile Bay.

BENTHIC ALGAE

Several studies dealing with benthic algae have been conducted off the Alabama coast (Table B-2) and in the northern Gulf of Mexico (Table B-3), although the species lists are far from complete. Benthic algae in coastal Alabama waters are limited in abundance and diversity because of a scarcity of suitable substrates. In many areas, populations of benthic algae are concentrated on manmade structures such as jetties and seawalls or such natural structures as oyster reefs, clam shells, or seagrass leaves. Light penetration, which tends to be low, is also a limiting factor in benthic algae abundance in the northern gulf. Other factors likely affecting benthic algae, as well as planktonic algae, include salinity, nutrients, and temperature. Although diatoms comprise the greatest portion of the benthic algae reported from coastal Alabama (Table B-2), the red, brown, and green algae are more conspicuous.

Benthic algae occur in greatest abundance and diversity in the late winter and early spring in coastal Alabama waters. *Dasya pedicellata*, *Ecotocarpus confervoides*, *Polysiphonia* spp., *Gracilaria* spp. and *Enteromorpha* spp. are commonly present at this time. In late spring, *Champia parvula* and *Spyridia filamentosa* are abundant. During the summer, sargassum weed and the epiphytic red algae *Jania* sp. and *Ceramium fastigiatum*, are especially abundant off the Alabama coast. In late summer, the red algae, *Hypnea musciformis*, *Gelidium crinale*, *Chondria leptacremon*, *Goniotrichum alsidii*, *Erythrotrichia carnea*, and *Acrochaetium seriatum*, and brown algae, *Dictyota dichotoma* and *Sphacelaria tribuloides*, are common in coastal Alabama waters. The blue-green algae are fairly abundant year round (Morrill 1959).

In addition to their role as primary producers, algae also generate oxygen through photosynthesis. The larger benthic algae provide a refuge for small animals, including juveniles of many seafood species, and often provide a substrate for the attachment of epiphytic organisms.

Man utilizes algae in numerous ways. More than 70 species of marine algae (mostly red and brown algae) have been used as a food source, primarily in oriental countries. Cell wall polysaccharides of several red algae, agar, carrageenan, and algin, are used in food processing and microbiology. Algae are also increasingly being used as animal fodder and crop fertilizers.

SUBMERGED MARINE AND ESTUARINE PLANTS

In addition to benthic algae, several spermatophytes occur off the Alabama coast. Unlike benthic algae, which ordinarily require a solid, hard substrate for attachment, these spermatophytes grow on substrates of partially consolidated sand or sandy clay.

SEAGRASSES

Seagrass is a general term used to describe the beds of submerged flowering plants growing off the coastline in undiluted seawater down to depths of 23 m (75 ft). These plants are monocots of the family Hydrocharitaceae and are classified into four genera: *Thalassia*, *Cymodocea*, *Halophila*, and *Halodule* (Humm 1973). The two most common species in the eastern Gulf of Mexico are turtle-grass (*Thalassia testudinum*), which comprises over 60% of the seagrasses, and manatee-grass (*Cymodocea filiformis*) (Humm 1973). In the northern gulf, seagrasses cover approximately 9,200 ha (22,800 acres), with 88% of this acreage in Mississippi Sound (Eleuterius 1973a; Stout and Lelong 1981). The most abundant species in the northern gulf is shoal grass (*Halodule wrightii*). Species which are regarded as rare throughout the gulf but are occasionally locally abundant include *Halophila baillonis* and *H. engelmannii*. Widgeon-grass (*Ruppia maritima*), although not a true seagrass, being primarily brackish in occurrence, is another common gulf monocot (Borom 1979). It is abundant along the shoreline in eastern and northern estuarine gulf waters.

Along coastal Alabama, the high turbidity of estuarine waters limits seagrass beds to waters less than 2 m (6 ft) deep with most occurring at depths of 50 cm (20 inches) or less (Stout and Lelong 1981). Alabama's seagrass beds are comprised of three species. Shoal-grass, which covers 266 ha (656 acres), and widgeon-grass, which covers 123 ha (305 acres), are the most common (Stout and Lelong 1981). Turtle grass beds are limited to Old River east of the mouth of Perdido Bay. Small patches of turtle grass are also found among the extensive beds of shoal-grass (Stout and Lelong 1981).

OTHER SUBMERGED AQUATIC VEGETATION

In 1957, Baldwin estimated that submerged aquatic vegetation covered 2,024 ha (5,000 acres) in Mobile Bay and 3,036 ha (7,500 acres) in the lower delta. Dominant vegetation included the common water nymph (*Najas quadalupensis*), muskgrass (*Nitella* sp.), which is a green algae, tape grass (*Vallisneria americana*), and horned pondweed (*Zannichellia palustris*). Lueth (1963), in a study of the lower Mobile Delta, reported pondweeds (*Potomogeton* spp.), tape grass, and the common water nymph as abundant. Widgeon-grass was rare while fanwort (*Cabomba caroliniana*) and marestail (*Myriophyllum* spp.) were locally abundant. Since the 1950's and early 1960's, tape grass, which was abundant throughout the bays of the delta and along the eastern shore, has been gradually replaced by Eurasian water-milfoil (*Myriophyllum spicatum*) (Figure 63). Tape grass populations are now reduced to isolated but fairly extensive patches primarily in the upper portions of Mobile Bay, while Eurasian water-milfoil is widespread. Tape grass now accounts for about 27% (297 ha [741 acres]) of all submerged vegetation off Alabama's coastline, while Eurasian water-milfoil accounts for 35% (383 ha [958 acres]). The total amount of submerged vegetation, including seagrasses, is estimated to be 1,119 ha (2,763 acres) (Stout and Lelong 1981).

Since the inventory by Baldwin in 1957, numerous changes have occurred in areal coverage and species composition of submerged vegetation off Alabama's coast. Areal coverage of beds have decreased with dredging and filling operations in the Bay and with increased turbidity resulting from shoreline development (Stout and Lelong 1981). Accompanying the decline in submerged vegetation have been reported declines in sport and commercial fisheries and invertebrates associated with the vegetation (Stout and Lelong 1981). The actual extent of these losses is difficult to quantify, however, since early inventories were accomplished without benefit of aerial photography. A comparative list of submerged aquatic plants reported as occurring in Mobile Bay by Baldwin (1957), Lueth (1963), and Stout and Lelong (1981) is seen in Table 38.

Community diversity and species composition of the submerged vegetation has declined, with single species beds now fairly common (Stout and Lelong 1981). Widgeon-grass beds, once extensive, have declined to a few isolated patches (Borom 1975). Widgeon-grass now accounts for 11% of all submerged vegetation and covers approximately 121 ha (300 acres), most in pure stands (Stout and Lelong 1981). The extent of shoal-grass has also declined, particularly along the shores of Mobile Bay and in lower Perdido Bay (Stout and Lelong 1981). The most obvious change, however, has been the invasion of Eurasian water milfoil, which was not noted in the inventories of Baldwin (1957) and Lueth (1963). Water milfoil has become the predominant species in Alabama's coastal waters with populations likely to increase in the future. The species is considered a nuisance by waterfowl managers and boaters, and a chemical eradication plan is being considered by the U.S. Army Corps of Engineers (Stout and Lelong 1981). Water milfoil beds also appear to provide suitable habitat for mosquitoes and their decomposition creates

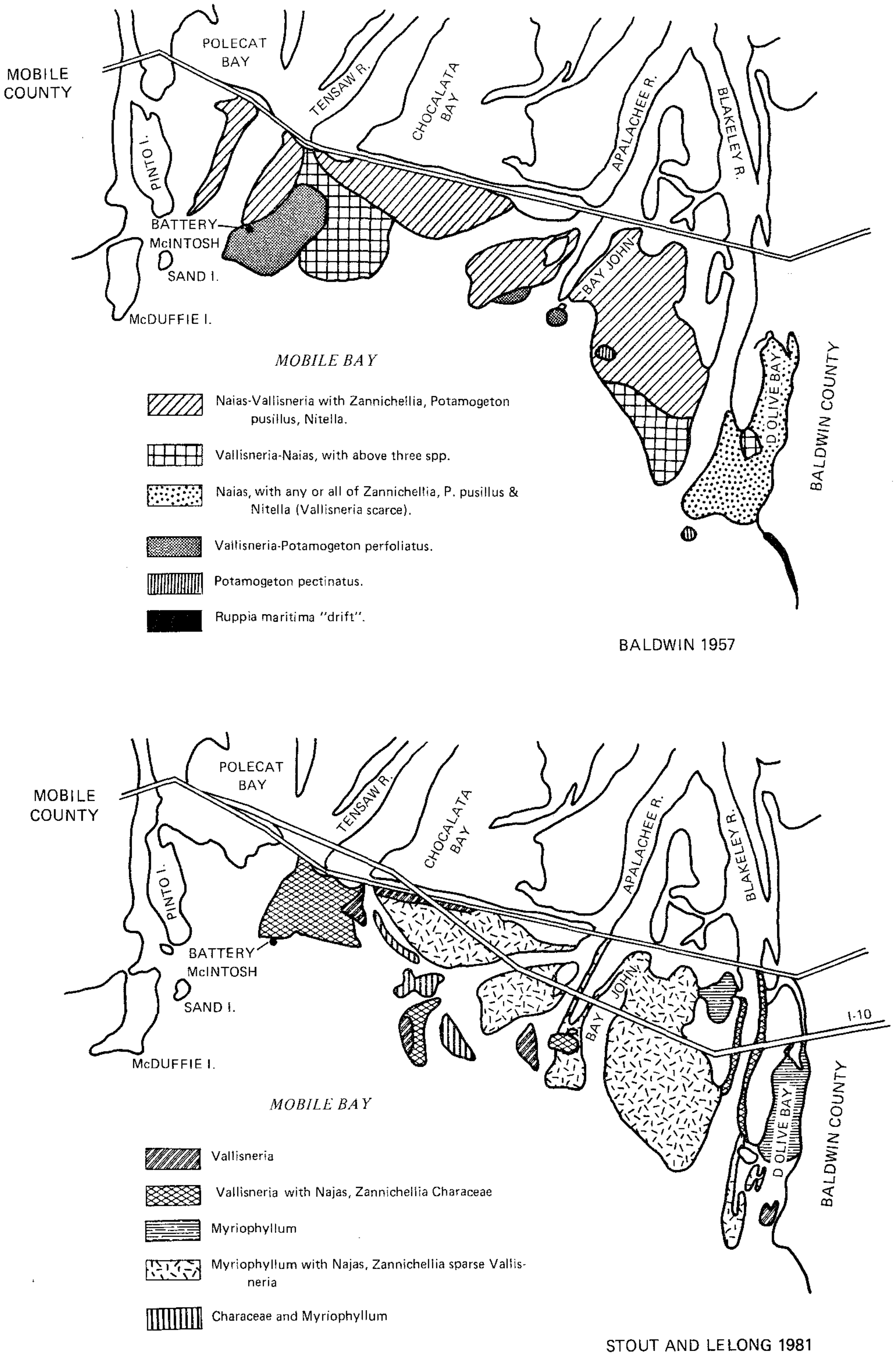


Figure 63. Comparison of submerged aquatic vegetation along lower Mobile Delta from 1957 to 1981 (modified from Stout and LeLong 1981).

Table 38. Submerged and floating aquatic plants occurring in the coastal waters of Alabama.

Scientific name	Common name	Baldwin (1957)	Lueth (1963)	Stout & Lelong (1981)
Submerged Vegetation				
Bacopa caroliniana	Lemon bacopa			X
Cambomba caroliniana	Fanwort	X	X	X
Callitriche heterophylla	Water starwort			X
Ceratophyllum demersum	Coontail	X		X
Chara sp.	Stonewort			X
Egeria densa	Waterweed			X
Elodea canadensis	Waterweed		X	
Halodule wrightii	Shoal grass			X
Heterantheria dubia	Water star-grass	X	X	
Hydrochloa caroliniensis	Watergrass			X
Isoetes sp.	Quillwort		X	
Mayaca aubletii	Bogmoss		X	
Mayaca fluviatilis	Bogmoss			X
Myriophyllum heterophyllum	Variable watermilfoil			X
Myriophyllum sp.	Watermilfoil	X	X	
Myriophyllum spicatum	Eurasian watermilfoil			X
Najas quadelupensis	Common water nymph	X	X	X
Nitella sp.	Muskgrass	X	X	X
Potamogeton crispus	Curly pondweed			X
Potamogeton diversifolius	Snailseed pondweed			X
Potamogeton epihydrus	Ribbon-leaf pondweed	X	X	
Potamogeton foliosus	Gray-duck moss	X	X	
Potamogeton gramineus	Variable pondweed		X	
Potamogeton nodosus	Longleaf pondweed	X	X	
Potamogeton pectinatus	Sago pondweed	X	X	
Potamogeton perfoliatus	Clasping leaf pondweed	X	X	
Potamogeton pulcher	Pondweed		X	
Potamogeton pusillus	Slender pondweed			X
Ruppia maritima	Widgeon grass	X	X	X
Thalassia testudinum	Turtle-grass			X
Tolypella sp.	Stonewort			X
Vallisneria americana	Eel-grass	X	X	X
Zannichellia palustris	Horned pondweed	X	X	X
Floating Vegetation				
Azolla caroliniana	Mosquito fern		X	
Eichhornia crassipes	Water hyacinth		X	
Lemna perpusilla	Duckweed		X	
Limnobium spongia	Frogbit		X	
Nelumbo lutea	Lotus		X	
Nuphar luteum	Cowlily		X	X
Nymphaea odorata	White waterlily		X	X
Nymphoides aquatica	Floating heart		X	X
Utricularia biflora	Bladderwort		X	X

objectionable odors along the shore (Borom 1975). Borom (1975) suggests that floral changes in Alabama's coastal waterways are the result of several factors, including increased input of fertilizers and herbicides, increased inputs of municipal and industrial effluents, petrochemical spills, and natural changes in salinity, turbidity, and water movements.

Submerged aquatic vegetation has several important functions in the Gulf of Mexico. It is a primary producer and, in total production, probably exceeds the benthic algae (Humm 1973). Submerged aquatic vegetation provides the principal food source for waterfowl, numerous fishes, and other aquatic animals. The extravagant growth of milfoil has caused some concern among waterfowl enthusiasts as to milfoil's acceptability as a food source. Florschutz (1969) indicated water milfoil was a low-quality waterfowl food. With the invasion of water milfoil, and subsequent decline in eel-grass, winter waterfowl counts have decreased in the Mobile Bay area (Borom 1979). A similar water milfoil invasion in Chesapeake Bay resulted in an 80% decrease in winter waterfowl counts (Bayley et al. 1968).

FLOATING VEGETATION

Several floating aquatic plants occur in the Mobile Delta (Table 38), but they tend to be rare and localized in freshwater environments. Wind action is reported as the probable limiting factor, restricting most floating vegetation to protected ponds and ditches (Chermock 1974). Water hyacinth (*Eichhornia crassipes*), at one time reached nuisance abundance blocking streams and ditches and forming shoreline bands as much as 15 m (50 ft) wide (Lueth 1963). However, in recent years, it has not been observed in any abundance throughout the lower delta (J. P. Stout, personal communication).

TIDAL MARSHES

The tidal marshes of coastal Alabama, which are associated with the estuaries, are most extensive in the Mobile Delta and the northern shore of Mississippi Sound (Figure 64; Table 39). These wetlands are small in area, comprising less than 1% of the State's total land area. Based on the estimates of Vittor and Stout (1975), approximately 6,879 ha (16,992 acres), or 60% are saline and brackish marsh and 4,547 ha (11,232 acres), or 40%, are freshwater marsh.

Total marsh acreage is low in part because of the extremely limited tidal range. This range varies from 0.5 m (1.6 ft) at the Bon Secour River to 0.4 m (1.2 ft) at Mobile Point. The periodic tide in Perdido Bay is even lower—less than 0.2 m (0.5 ft). A low tidal range will only flood a small amount of land surface, thereby yielding limited tidal marsh area. Another reason for low marsh acreage is the steep relief of the eastern shore, which effectively circumvents any regular tidal flooding.

Marshes, whether saline or fresh, have several important functions in coastal Alabama. They chiefly function as primary producers for the detritus-based food chain, but they also provide food and habitat for young and juvenile organisms, especially commercially important species. Other seafood species utilize the marshes as breeding and spawning areas. Marshes are also important in removing nutrients and toxic materials from the water and in controlling erosion by sediment binding.

Stout (1979) categorized Alabama's marshes into four types: saline marsh, brackish I marsh, brackish II marsh (sometimes known as intermediate marsh), and freshwater marsh. Vegetational features of each marsh type are unique and exhibit zonational patterns of occurrence from the mean low-tide line to the upper reaches of the marsh (Figure 65). Demarcation between marsh

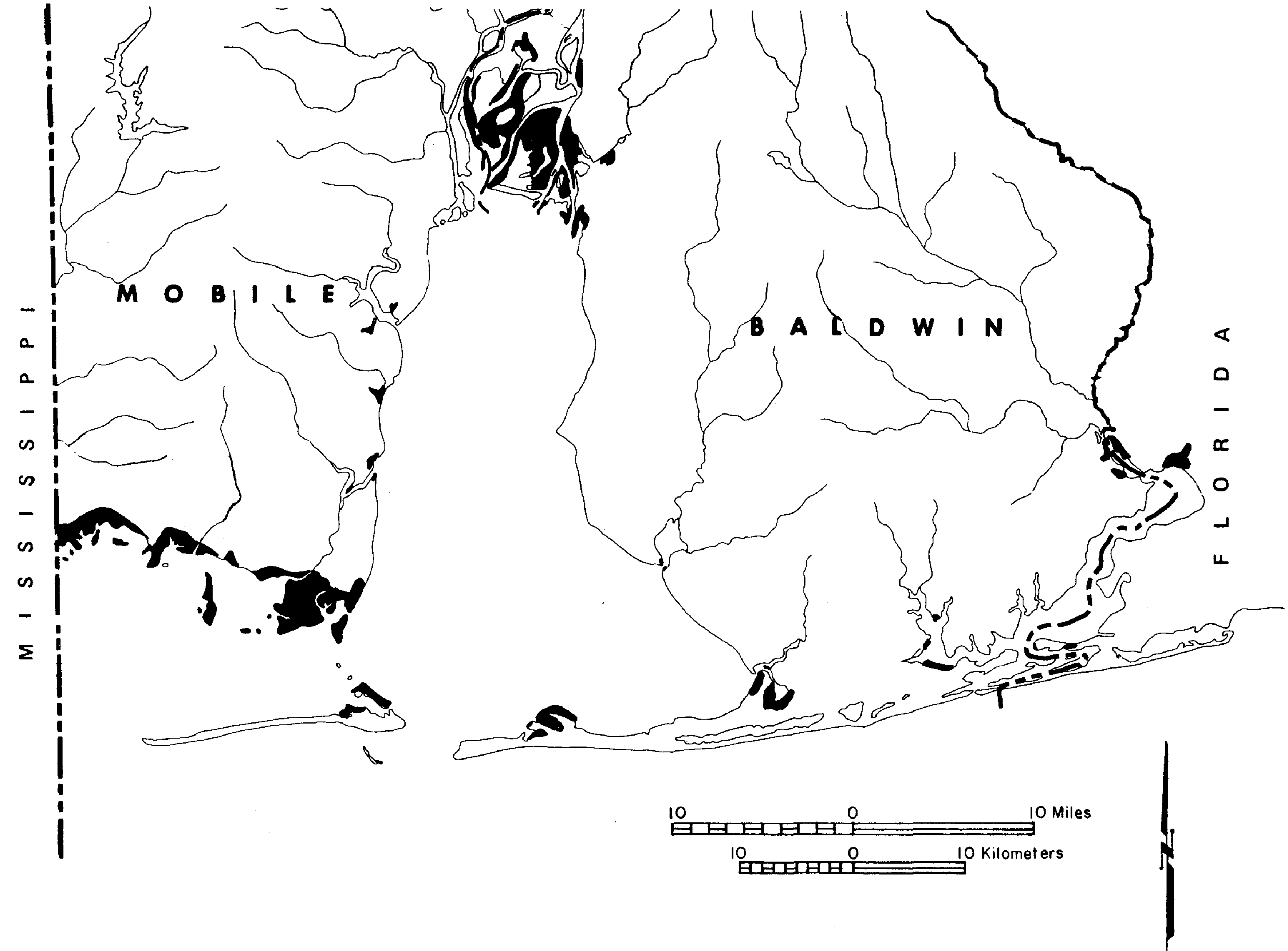


Figure 64. Distribution of tidal marshes in coastal Alabama (Chermock 1974).

Table 39. Area (acres) of tidal marsh within coastal Alabama.

Region	Source		
	Crance 1971	Chermock 1974	Vittor and Stout 1975
Mississippi Sound	11,762	11,366	10,889
Mobile Bay	6,224	2,862	3,505
Mobile Delta[a]	15,257	15,155	10,450
Perdido Bay west to Little Lagoon	1,371	829	3,380
Total	34,614	30,217	28,224

[a]Northern limit of delta tidal marsh was established around latitude 30° 52' 30".

types is usually not distinct but rather a gradation from one type to another throughout the estuary (Figure 66). Plant species abundance, associations, and salinity of flooding waters are major factors used to delineate marsh types. While many plant species occur throughout tidal marshes, some are restricted to specific marsh conditions (Table 40).

SALINE MARSHES

Of the total marshland of Alabama, as estimated from data presented in Vittor and Stout (1975), only about 8%, 943 ha (2,329 acres), can be considered true salt marsh. These marshes are found in Isle Aux Herbes, Grand Bay, Heron Bay, Little Dauphin Island, and Weeks Bay.

Two species of plants dominate saline marshes in coastal Alabama. Stands of needle rush (*Juncus roemerianus*) normally comprise the majority of the marsh, growing in what seems to be almost pure stands. However, intermixed with these may be giant cordgrass (*Spartina cynosuroides*), saltmeadow cordgrass (*Spartina patens*), and three square (*Scirpus olneyi*). Occasionally, sea lavendar (*Limonium nashii*) and salt marsh aster (*Aster tenuifolius*) are also found in this zone (Table 41). As the salinity of the marsh decreases, needle rush tends to grow taller. Seaward, in the more saline waters, smooth cordgrass (*Spartina alterniflora*) grows in pure stands and forms a distinct peripheral zone. With increased salinity, the plants are taller, more robust, and dense. The line of demarcation between the zone of smooth cordgrass and needle rush is usually distinct because of differences in plant height.

Further zonation may occur inland from that of needle rush (Figure 66). A zone of three square may be present, usually occurring in areas where there is drainage of fresh water from upland areas (Eleuterius 1973b). Beyond this, on slightly higher ground, is often a pure zone of saltmeadow cordgrass. This species forms dense turfs that may prevent the growth of other species.

Saline marshes are bordered by a sharp rise of terrain inhabited by shrubs and other plants, including groundsel tree (*Baccharis halmifolia*), sea ox-eye (*Borrichia frutescens*), *Eryngium integrifolium*, marsh elder (*Iva frutescens*), wax-myrtle (*Myrica cerifera*), and goldenrod (*Solidago sempervirens*). Beyond the shrubs are trees—mostly oaks (*Quercus* spp.) and pines (*Pinus* spp.).

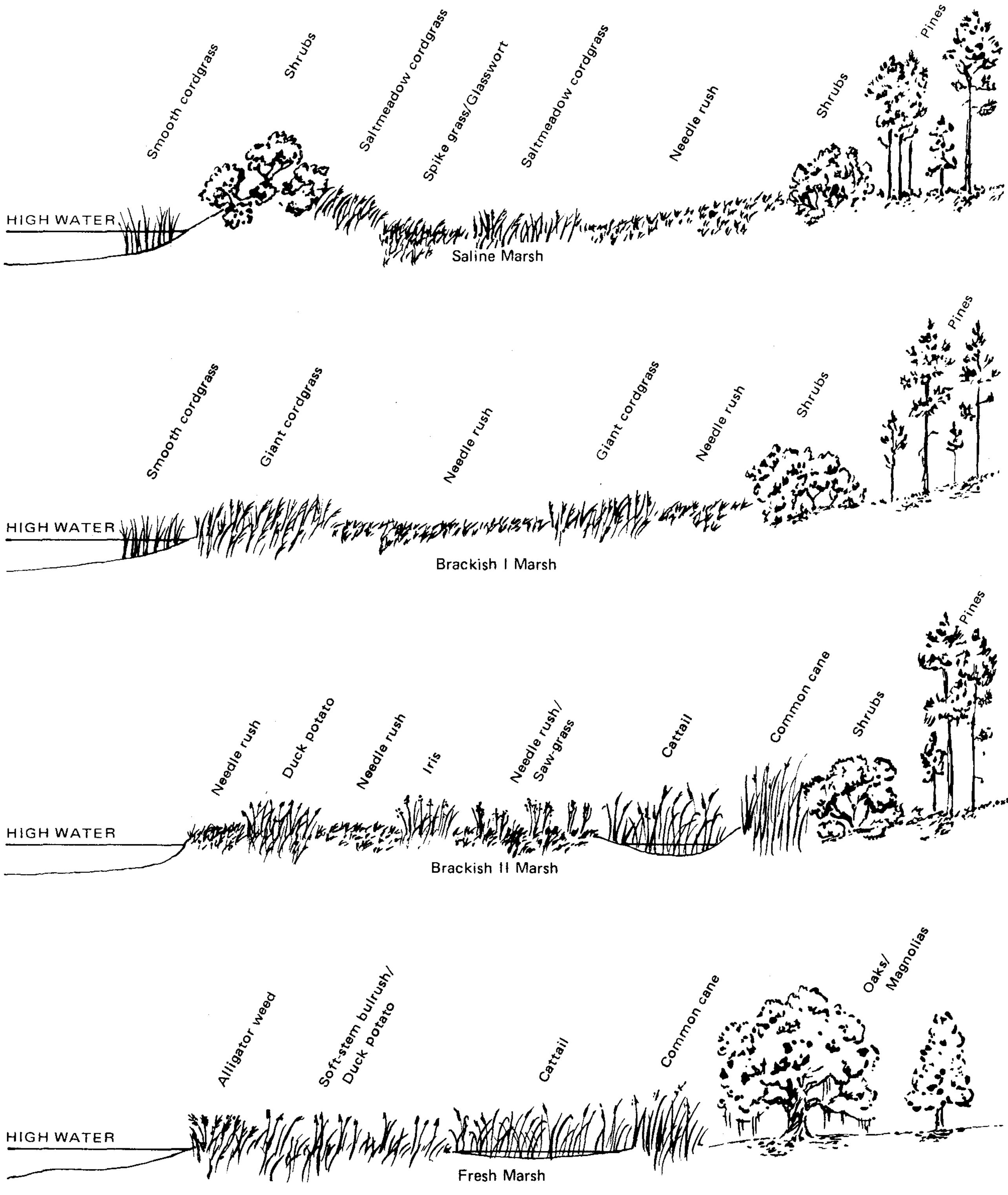


Figure 65. Vegetational zonation for marsh types in coastal Alabama (modified from Sapp et al. 1976).

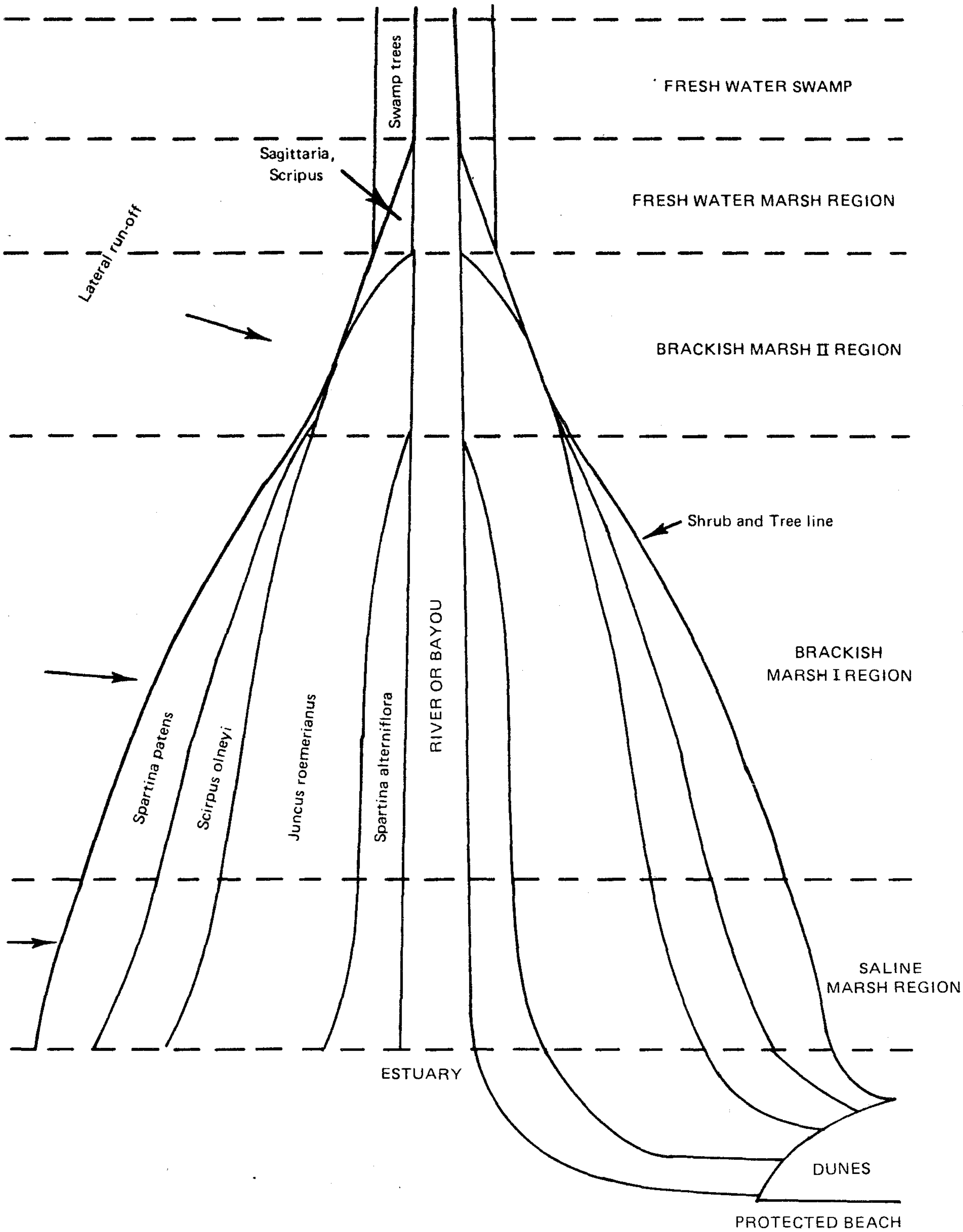


Figure 66. Marsh zonation within coastal Alabama (modified from Chermock et al. 1975).

Table 40. Common tidal marsh plant species found in coastal Alabama (Sapp et al. 1976).

Scientific name	Common name	Occurrence	Salinity tolerance (ppt)
Alternanthera philoxeroides	Alligator weed	Low trailing species forming mats in water and as understory ground cover to taller species.	Less than 2.
Andropogon spp.	Broom sedge	Mixed disjunctly in patches with *Spartina patens* and *Juncus roemerianus* in high marsh and frequent on hummocks and higher elevations. Extends into uplands as common understory grass.	No flooding. 0-5.
Borrichia frutescens	Sea ox-eye	In salt and brackish marshes usually mixed with *Spartina patens*. Frequently on shell rim of marsh margins just above MHW.	8-12. Only incidental flooding tolerated.
Cladium jamaicense	Saw-grass	High marsh species. Large, pure stands.	Less than 2.
Distichlis spicata	Spike grass	In pure stands usually only along margins of salt pans or covering depressions with standing tidal water. Frequently mixed with *Spartina alterniflora* (eastern shore Point aux Pins) and *Juncus roemerianus*. Located above normal tidal activity but may often be found in standing water of higher salinity than adjacent tidal water.	12-25. *Distichlis spicata* is found only in salt and brackish marshes.
Fimbristylis spadicea	No common name--a sedge.	In salt and brackish marshes, mixed with *Spartina patens* in high salt marsh. Common with *Juncus roemerianus* in drier areas of brackish marshes. Usually inconspicuous as a sub-dominant of community.	No flooding tolerated. 0-10.

Ilex vomitoria	Yaupon	Typical of maritime forest. Replaces or occurs with salt shrubs on higher elevations of sand beach and island marshes.	Salt spray aerosols only.
Juncus roemerianus	Needle rush	From water's edge (may be flooded at high tide) to tree line, usually in pure stands but may be mixed, as follows: (1) in salt marshes, (a) low marsh, with *Spartina alterniflora* and *Distichlis spicata*; (b) high marsh, with *Spartina patens*; (2) in brackish marshes, with *Spartina cynosuroides* or *Cladium jamaiscense*. Dense stands of *Juncus roemerianus* occur around Oyster Bay (Baldwin Co.), Heron Bay and Mississippi Sound (Mobile Co.).	2-25. Probably the greatest range of all salt marsh species. *Juncus roemerianus* is also found in fresh marshes.
Peltandra virginica	Arrow arum	As an emergent in fresh marshes often forming islands or large clumps along water's edge. Frequently mixed with *Sagittaria falcata* and *Alternanthera philoxeroides*.	Less than 2.
Phragmites communis	Common cane	High marsh species. Small clumps to broad bands of pure *Phragmites*, especially on higher knobs and ridges.	Less than 2.
Pontederia cordata	Pickerelweed	Low understory. Only very small pure stands, most frequently mixed with other species.	Less than 2.

Table 40. Concluded.

Scientific name	Common name	Occurrence	Salinity tolerance (ppt)
Sagittaria falcata	Duck potato	Wide range; occurring in intertidal of protected brackish marshes and as an emergent in truly fresh marshes. In brackish marshes typically mixed with *Juncus roemerianus* and *Spartina cynosuroides*. In fresh water may occur as pure mats or islands or mixed with *Alternanthera philoxeroides*, *Peltandra virginica* and other emergent species.	Less than 2.
Scirpus olneyi	Three-square	Same general distribution as *Scirpus robustus* though less frequent. Often as higher zone of marsh above area with *Scirpus robustus*.	5-7.
Scirpus robustus	Salt-marsh bulrush	In brackish marshes above MHW. Usually mixed with *Spartina patens* and/or *Distichlis spicata* though it may form pure stands.	5-9.
Scirpus validus	Soft-stem bulrush	Scattered individuals in large stands (south of causeway) or may be dense small clusters on marsh edge. Taller canopy in fresh marsh.	Less than 2.
Spartina alterniflora	Smooth cordgrass	Infrequently in pure stands, but largest pure stands observed at Isle aux Herbes, Dauphin Island airport, Point aux Pines. Usually occurs as a marginal fringe in intertidal zone. May extend up river (e.g., Fish River) to almost fresh water. Frequently found at higher elevations mixed with *Distichlis spicata* and/or *Juncus roemerianus*.	Commonly 2-35 and not in fresh water.

Spartina cynosuroides	Giant cordgrass	Not observed in Alabama in pure stands more extensive than 100 m^2 (1,100 ft^2). Usually found along margins of brackish marshes and creeks or as small clumps mixed with *Juncus* in brackish marshes (e.g., Heron Bay), and *Cladium* and *Juncus* in near-fresh marshes (e.g., Fish River and Fowl River).	2-20. Brackish to near fresh.
Spartina patens	Saltmeadow cordgrass	Above high water level to tree line. May appear as a band just before tree line, either pure or mixed with *Juncus*, *Scirpus* sp., *Fimbristylis* or a combination. May form meadows within larger marsh areas, mixed with *Distichlis spicata* (Isle aux Herbes) or pure (southeast Mon Louis Island).	10-35. Frequent submergence not tolerated.
Typha angustifolia	Narrow-leaf cat-tail	Broader distribution than *Typha latifolia*, from creek margins to moist higher elevations. Frequently in disturbed areas.	Less than 2.
Typha latifolia	Common cat-tail	Usually as an emergent along edges of larger water courses. Frequently mixed with *Scirpus validus* and may occur with *Typha angustifolia* in disturbed areas but less abundant than *Typha angustifolia*.	Less than 2.
Zizania aquatica	Wildrice	Individual clumps scattered in water's edge. Taller canopy in fresh marsh.	Less than 2.

Table 41. Plants occurring in saline and brackish marshes (Stout and Lelong 1981).

Scientific name	Common name
Herbaceous Plants	
Acnida cuspidata	Water hemp
Agalinis maritima	Marsh gerardia
Alternanthera philoxeroides	Alligator weed
Aster tenuifolius	Salt marsh aster
Bacopa monnieri	Coastal water-hyssop
Boltonia asteroides	
Cynanchum palustre	
Hibiscus moscheutos	Marsh mallow
Ipomoea sagittata	Marsh morning glory
Kosteletzkya virginica	Salt marsh mallow
Lilaeopsis chinensis	
Limonium nashii	Sea lavender
Lythrum lineare	Salt marsh loosestrife
Pluchea camphorata	Marsh fleabane
Pluchea purpurascens	Marsh fleabane
Sabatia stellaris	Rose-gentian
Sagittaria falcata	Arrow head
Salicornia bigelovii	Glasswort
Salicornia virginica	Glasswort
Sesuvium maritimum	Marsh purslane
Solidago sempervirens	Seaside goldenrod
Suaeda linearis	Sea-bite
Typha domingensis	Cattail
Typha latifolia	Cattail
Vigna luteola	Cow pea
Grasses, Sedges and Rushes	
Cladium jamaicense	Saw grass
Cyperus odoratus	Umbrella sedge
Cyperus virens	Umbrella sedge
Distichlis spicata	Salt grass
Echinochloa walteri	
Eleocharis cellulosa	Spike rush
Elocharis parvula	Spike rush
Fibristylis castanea	Saltmarsh fimbristylis
Fuirena scirpoidea	Umbrella grass
Juncus roemerianus	Needle rush
Panicum repens	Torpedo grass
Panicum virgatum	Switch grass
Paspalum distichum	Knotgrass
Phagmites australis	Common cane
Scirpus americanus	American bulrush
Scirpus californicus	Giant bulrush
Scirpus olneyi	Olney bulrush
Scirpus robustus	Saltmarsh bulrush
Scirpus validus	Soft stem bulrush
Setaria geniculata	Foxtail grass
Spartina alterniflora	Smooth cordgrass
Spartina cynosuroides	Big cordgrass
Spartina patens	Salt-meadow cordgrass
Spartina spartinae	Gulf cordgrass

BRACKISH I MARSHES

Brackish I marshes are usually found inland along the margins of rivers, streams, and bayous where salinity decreases to levels lower than the estuaries (Figure 66). The primary floral difference between the brackish and saline marshes is a reduction in the abundance of smooth cordgrass and needle rush. Dispersed and intermixed throughout the needle rush zone are a variety of brackish and freshwater species (Eleuterius 1973b) (Table 41).

Bordering the needle rush zone is a zone composed of giant cordgrass. However, small isolated patches of three-square may be present on higher ground where freshwater runoff occurs. This marsh type is bordered peripherally by shrubs and trees as are the saline marshes (Figure 65).

BRACKISH II MARSHES

Brackish II marshes occur inland to brackish I marshes along water courses and represent the limit of tidal influence (Figure 66). Characteristic of this marsh type is a variable salinity which ranges between fresh and brackish. The extent of these intermittent marshes is small and their limits poorly defined. Brackish II marshes mark the upper limit of needle rush. Numerous freshwater species are intermixed with needle rush, such as saw-grass (*Cladium jamaicense*), arrowhead, spike-rush (*Eleocharis cellulosa*), sword-grass (*Scirpus americanus*), pickerelweed (*Pontederia cordata*), swamp-lily (*Crinum americanum*), and southern blue flag (*Iris virginica*). In higher areas of the marsh, pure stands of common cane (*Phragmites australis*) may be present; in deeper waters soft-stem bulrush (*Scirpus validus*) may occur. Cattails (*Typha* spp.) are usually present in small wet depressions.

FRESHWATER MARSHES

Freshwater marshes are found beyond the influence of normal tidal movements, although they may be temporarily brackish as a result of abnormal tides. They occur in discontinuous patches along water courses and differ from freshwater swamps in that they consist primarily of herbaceous plants and lack an overhead canopy of trees or shrubs (Table 42).

FRESHWATER SWAMPS

Freshwater swamps are not included in the tallies of total marsh acreage, but they do have an important function in estuarine dynamics. These swamps are found along alluvial flood plains of larger water courses, the most extensive areas occurring from the junction of the Alabama and Tombigbee Rivers south to Saraland. The frequent inundation of these swamps results in the flushing of nutrients and detritus into the estuaries.

The vegetation of these swamps varies to a large extent on the amount and duration of flooding (Stout and Lelong 1981). In extensively flooded areas, pond cypress (*Taxodium distichum* var. *nutans*) and swamp tupelo (*Nyssa sylvatica* var. *biflora*) often dominate the flora. With moderate flooding, the dominant trees are often sweet bay (*Magnolia virginiana*), red maple (*Acer rubrum*), swamp bay (*Persea palustris*), tulip tree (*Liriodendron tulipifera*), and swamp tupelo (Table 43).

These trees create a dense canopy and the understory is sparse. Virginia willow (*Itea virginica*), star anise (*Illicium floridanum*), and fetterbush (*Leucothoe axillaris*) often comprise part of this understory. Netted chain fern (*Woodwardia areolata*) and cinnamon fern (*Osmunda cinnamomea*) are among the few shade-tolerant herbs in the understory (Table 43).

Table 42. Plants of freshwater marshes (Stout and Lelong 1981).

Scientific name	Common name
Woody Plants	
Baccharis halimifolia	Groundsel tree
Cephalanthus occidentalis	Buttonbush
Hibiscus moscheutos	Marsh mallow
Ilex vomitoria	Yaupon
Myrica cerifera	Wax-myrtle
Phragmites australis	Reed
Salix nigra	Black willow
Sambucus canadensis	Elderberry
Sesbania exaltata	Coffee weed
Sesbania punicea	Rattlebox
Sesbania vesicaria	Bladder pod
Herbaceous Plants	
Alternanthera philoxeroides	Alligator weed
Aster dumosus	Aster
Aster umbellatus	Aster
Bidens mitis	Beggars-tick
Bidens laevis	Beggars-tick
Boehmeria cylindrica	False nettle
Centella asiatica	Centella
Colocasia esculenta	Elephants' ear
Crinum americanum	Swamp-lily
Eupatorium capillifolium	Dog fennel
Eupatorium coelestinum	Mist flower
Eupatorium fistulosum	Joe Pye weed
Eupatorium serotinum	Fall thoroughwort
Galium tinctorium	Bedstraw
Helianthus angustifolius	Narrow-leaf sunflower
Hydrocotyle bonariensis	Pennywort
Hydrocotyle umbellata	Pennywort
Hymenocallis occidentalis	Spider lily
Hypericum mutilum	St. John's wort
Hypericum virginicum	St. John's wort
Iris virginica	Blue flag
Ludwigia alterniflora	False loose strife
Ludwigia leptocarpa	False loose strife
Ludwigia palustris	False loose strife
Lycopus rubellus	Bugleweed
Mikania scandens	Climbing hempweed
Orontium aquaticum	Golden club
Oxypolis filiformis	Cowbane
Peltandra virginica	Arrow arum
Pluchea camphorata	Camphor weed
Polygonum hydropiperoides	Smartweed
Polygonum punctatum	Smartweed

Table 42. Concluded.

Scientific name	Common name
Pontederia cordata	Pickerel weed
Ptilimnium capillaceum	Bishop weed
Sagittaria falcata	Arrow head
Sagittaria latifolia	Arrow head
Saururus cernuus	Lizard's tail
Typha latifolia	Cattail
Xyris iridifolia	Yellow-eyed grass
Grasses and Grass-like Plants	
Andropogon glomeratus	Bushy beardgrass
Carex glaucescens	Sedge
Carex lurida	Sedge
Cladium jamaicense	Saw grass
Cyperus erythrorhizos	Umbrella sedge
Cyperus haspan	Umbrella sedge
Cyperus strigosus	
Cyperus virens	
Eleocharis flavescens	Spike rush
Eleocharis microcarpa	Spike rush
Eleocharis obtusa	Spike rush
Eleocharis tuberculosa	Spike rush
Fimbristylis autumnalis	
Fimbristylis miliacea	
Fuirena scirpoidea	Umbrella grass
Fuirena squarrosa	Umbrella grass
Juncus biflorus	Rush
Juncus effusus	Rush
Juncus elliottii	Rush
Juncus scirpoides	Rush
Leersia oryzoides	Rice cutgrass
Panicum repens	Torpedo grass
Panicum rigidulum	Panic grass
Panicum scoparium	Panic grass
Panicum virgatum	Switch grass
Rhynchospora corniculata	Beak rush
Rhynchospora macrostachya	Beak rush
Sacciolepis striata	
Scirpus americanus	Three-square bulrush
Scirpus californicus	Giant bulrush
Scirpus cyperinus	Marsh bulrush
Scirpus validus	Great bulrush
Spartina cynosuroides	Big cordgrass
Zizania aquatica	Wildrice
Zizaniopsis miliacea	Southern wildrice

Table 43. Plants of freshwater swamps (Chermock et al. 1975; Stout and Lelong 1981).

Scientific name	Common name
Trees	
Acer rubrum	Red maple
Chamaecyparis thyoides	White cedar
Fraxinus tomentosa	Water ash
Gordonia lasianthus	Loblolly bay
Liquidambar styraciflua	Sweet gum
Liriodendron tulipifera	Tulip tree
Magnolia glauca	White bay
Magnolia grandiflora	Southern magnolia
Magnolia virginiana	Sweet bay
Nyssa aquatica	Tupelo
Nyssa sylvatica var. *biflora*	Swamp tupelo
Osmanthus americana	Devilwood
Persea palustris	Swamp bay
Persea pubescens	Red bay
Pinus elliottii	Slash pine
Quercus hemisphaerica	Laurel oak
Quercus nigra	Water oak
Salix nigra	Black willow
Taxodium distichum var. *nutans*	Pond cypress
Shrubs and Vines	
Alnus serrulata	Hazel alder
Arundinaria gigantea	Cane
Clethra alnifolia	Pepper bush
Cliftonia monophlylla	Black titi
Coreopsis nudata	Pink coreopsis
Cyrilla racemiflora	Swamp cyrilla
Decumaria barbara	Climbing hydrangea
Dendropogon usneoides	Spanish moss
Ilex coriacea	Large gallberry
Ilex vomitoria	Yaupon
Illicium floridanum	Star anise
Iris virginica	Blue flag
Itea virginica	Virginia willow
Leucothoe axillaris	Fetterbush
Ludwigia peploides	Water primrose
Lyonia lucida	Fetterbush
Myrica cerifera	Wax-myrtle
Smilax glauca	Green briar
Smilax laurifolia	Green briar
Viburnum nudum	Possum-haw viburnum
Vitis rotundifolia	Muscadine

Table 43. Concluded.

Scientific name	Common name
Herbaceous Plants	
Carex glaucescens	Sedge
Eleocharis flavescens	Spike rush
Gratiola virginiana	Hedge hyssop
Hypericum mutilum	St. John's wort
Hypericum virginicum	St. John's wort
Juncus debilis	Rush
Juncus diffusissimus	Rush
Leersia virginica	Rice cutgrass
Lindernia dubia	False pimpernel
Lycopus rubellus	Water horehound
Orontium aquaticum	Golden club
Osmunda cinnamomea	Cinnamon fern
Osmunda regalis	Royal fern
Peltandra sagittifolia	Spoon flower
Peltandra virginica	Arrow-arum
Polygonum punctatum	Smartweed
Rhynchospora miliacea	Beak rush
Saururus cernuus	Lizard's tail
Thelypteris normalis	Widespread maiden fern
Typha angustifolia	Narrowleaf cattail
Woodwardia areolata	Netrein chain fern
Xyris iridifolia	Yellow-eyed grass

The more open borders of the swamps may be covered by dense thickets of swamp cyrilla (*Cyrilla racemiflora*), black titi (*Cliftonia monophylla*), and large gallberry (*Ilex coriacea*). Wax-myrtle and yaupon (*Ilex vomitoria*) also occur in this habitat, particularly in more brackish areas (Stout and Lelong 1981). In the better drained transition zone between the swampy areas and the upland pine-oak forests are found water oak (*Quercus nigra*), laurel oak (*Quercus laurifolia*), sweet gum (*Liquidambar styraciflua*), southern magnolia (*Magnolia grandiflora*), and devil-wood (*Osmanthus americana*) (Stout and Lelong 1981).

FLORA OF DAUPHIN ISLAND

Mississippi Sound and the Gulf of Mexico are separated by a chain of barrier islands, the easternmost being Dauphin Island, which lies at the mouth of Mobile Bay. From 1964 to 1967, Deramus (1970) surveyed the flora of Dauphin Island, and reported 584 species of vascular plants (Table 44).

Dauphin Island is characterized on its eastern portion by a variety of plant associations, mainly pine forests, interspersed with freshwater swamps, tidal marshes, and dune complexes (Figure 67). The western end of Dauphin Island is dominated by a sand plain and a narrow tidal marsh.

A beach-dune association (Figure 68) extends along the south shore of Dauphin Island. The flora of this region is sparse because it is subjected to winds, salt spray, and wave action, which is most intense at the waters' edge. Among the plants of the lower beach region are beach-morning glory (*Ipomoea stolonifera*), pennywort (*Hydrocotyle bonariensis*) and camphor plant (*Heterotheca subaxillaris*). Species less tolerant of salt spray

Table 44. Flora of Dauphin Island (Deramus 1970).

Taxon	Families	Genera	Species
Pteridophyta	7	7	9
Spermatophyta			
Gymnospermae	3	3	6
Angiospermae			
Monocotyledoneae	15	71	156
Dicotyledoneae	87	256	413
Total	112	337	584

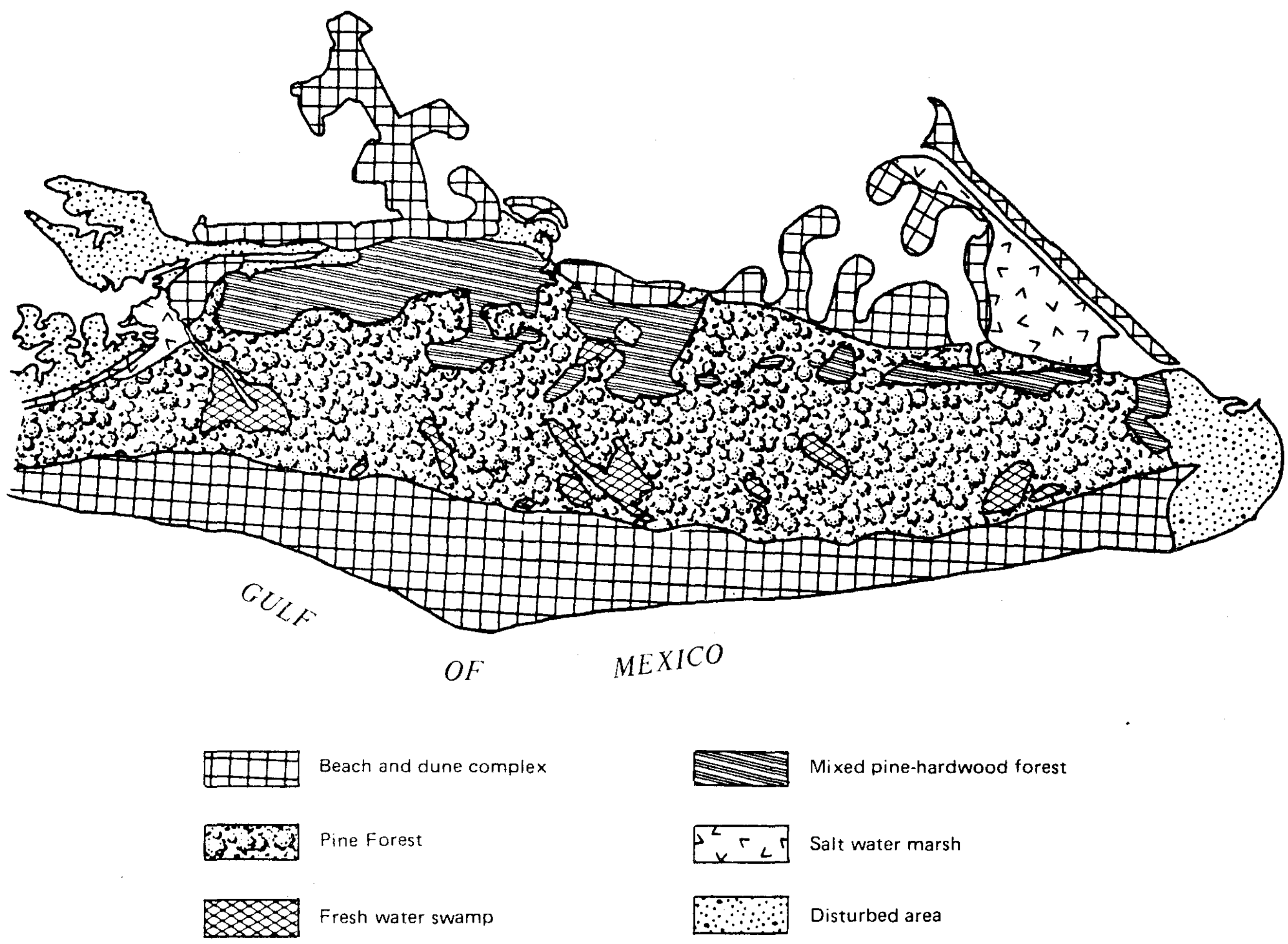


Figure 67. Plant associations of eastern Dauphin Island (modified from Deramus 1970).

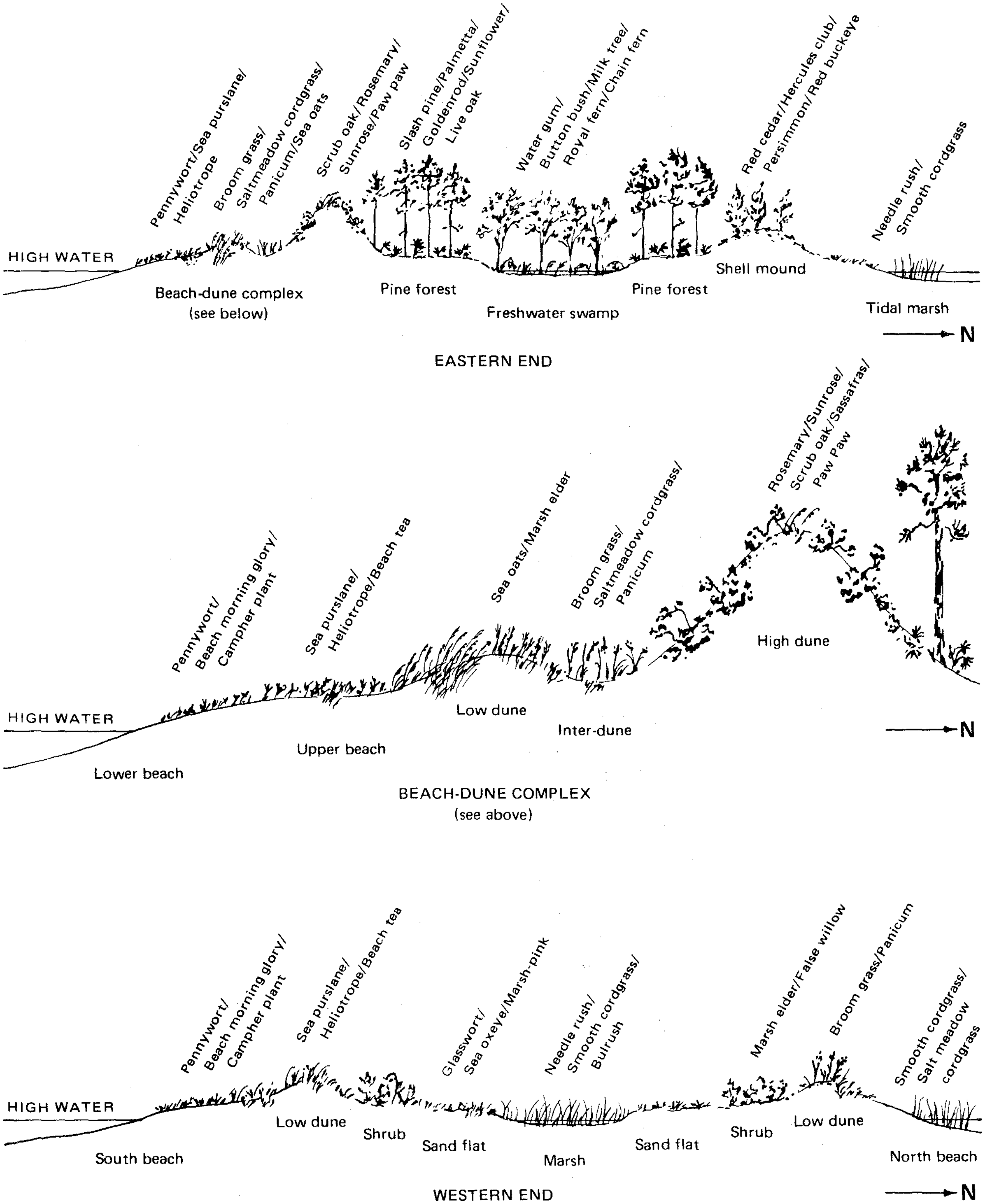


Figure 68. Vegetational zones of Dauphin Island.

occurring on the upper beach include sea purslane (*Sesuvium portulascastrum*), seaside heliotrope (*Heliotropium cuvassavicum*), and seaside evening primrose (*Oenothera humifusa*). Also common on the beach are several species of *Panicum* grasses and sea oats (*Uniola paniculata*) (Deramus 1970).

The beach is bordered by an area of dunes, normally a low, seaward dune paralleled by a high inland dune (Figure 68). The low dunes are characterized by soil binders, namely sea oats and marsh elder (*Iva frutescens* and *Iva imbricata*). On the older, more inland dunes are found such shrubs as goldenrod (*Solidago pauciflosculosa*) and rosemary (*Ceratiola ericoides*). Herbaceous plants common on these dunes include spurge nettle (*Cnidoscolus stimulosus*), prickly pear (*Opuntia compressa*) and sun rose (*Helianthemum arenicola*). The more stable portions of the dunes protected from the wind support scrub oak (*Quercus virginiana* var *maritima*), southern magnolia (*Magnolia grandiflora*), sassafras (*Sassafras albidum*), and dwarf pawpaw (*Asimina parviflora*). Between the low, seaward and high, inland dunes is an interdune region characterized by a sparse grass cover of several species, including beach broomgrass (*Andropogon maritimus*), Bermuda grass (*Cynodon dactylon*), cordgrass (*Spartina patens*), and several species of *Panicum* grasses (Deramus 1970).

North of the dunes, the eastern end of the island is characterized by a slash pine (*Pinus elliottii*) forest with several small freshwater swamps (Figure 68). The southeast portion of the forest is fairly dry and the understory is comprised of woody plants, including live oak (*Quercus virginiana*), palmetto (*Serenoa repens*), and several species of huckleberry (*Vaccinium* spp.) and herbs, including false hoarhound (*Eupatorium rotundifolium*), goldenrod (*Solidago microcephala*), Queen-of-the-meadow (*Vernonia angustifolia*), sunflower (*Helianthus radula*), several species of candyweed (*Polygala* spp.) and meadow beauty (*Rhexia* spp.). The western and northern portions of the forest are more moist. The understory here is dominated by sweet gum (*Liquidambar styraciflua*) and the shrubs dwarf sumac (*Rhus copallina*), waxmyrtle (*Myrica cerifera*), and several species of holly (*Ilex* spp.) (Deramus 1970).

Interspersed through the pine forest, primarily on the southern side, are small freshwater swamps. These are shallow bodies of water which frequently are dry in the summer. The swamps support a small number of plant species, the dominant being swamp tupelo. At the margin are found the shrubs buttonbush (*Cephalanthus occidentalis*) and milk tree (*Sapium sebiferum*); herbs including sedge (*Carex glaucescens*), lizard's tail (*Saururus cernuus*), and bladderwort (*Utricularia inflata*); and several species of ferns (*Osmunda* spp. and *Woodwardia* spp.) and *Panicum* grasses (Deramus 1970).

A unique area of Indian-built mounds of oyster shells is located on the northern side of the island between the pine forest and bay. Associated with the mounds is a unique flora of calciphilic plants including southern red cedar (*Juniperus silicicola*), hackberry (*Celtis laevigata*), Hercules' club (*Zanthoxylum clava-herculis*), possum grape (*Cissus incisa*), and spidervine (*Boerhaavia erecta*) (Deramus 1970).

The western end of Dauphin Island is narrow and about 18 km (11 mi) long, with unforested sand plains and marsh areas (Figure 68). Along the south shore is a beach and low dune area which is essentially an extension of the eastern portion of the island, with a similar associated flora. Inland from the tidal marsh along the north shore is a narrow zone of back-beach or low dunes. The flora of this zone is composed of saltmeadow cordgrass, salt grass, panic grass (*Panicum repens*), and broomgrass (Deramus 1970; Chermock et al. 1975).

Between the beach-dune complexes of the north and south shores are marshes inhabited by needle rush, smooth cordgrass, and several species of sedge and bulrush. On the elevated sandflats adjacent to the marsh are found glasswort (*Salicornia bigelovii*), seablite (*Suaeda linearis*), bulrush, marsh pink (*Sabatia stellaris*), sea ox-eye, *Cyperus lecontei*, and *Cynanchum palustre*. On higher ground occur shrub thickets of marsh elder, groundsel tree, and false willow (*Baccharis angustifolia*) (Deramus 1970; Chermock et al. 1975).

The greatest floral diversity on the island is in the disturbed areas and drainage ditches along highways. Over 70% of the species collected by Deramus (1970) were from this habitat. Alligator Lake and surrounding regions are also rich in plant species. The flora of the beach and dune region is probably the most fragile on the island, owing to the adverse environmental conditions. It is this same flora which is most encroached upon by recreational enthusiasts. Dune plants are important because their roots bind the sand and help stabilize the dunes. Loss of the dune flora could reverse the dune formation and stablization process (Chermock et al. 1975).

PINE WOODLANDS

The pine woodlands extend from northern Florida across Alabama into Mississippi. The vegetation of this region can be subdivided on the basis of soil moisture and elevation. In the areas of low relief and poor drainage, slash pine (*Pinus elliottii*) is common. Longleaf pine (*Pinus palustris*) is also often found in these moist pinelands. The understory consists largely of gallberry (*Ilex glabra*), wax-myrtle, saw palmetto (*Serenoa repens*), and St. John's wort (*Hypericum fasciculatum*). Occasionally, such trees as sweet bay, swamp bay, and swamp tupelo occur in this region (Table 45) (Stout and Lelong 1981).

The pine savannah region is similar to that of the moist pinelands. The dominant overstory is slash or longleaf pine; however, the canopy is much more open and the understory is more herbaceous than shrubby (Table 45) (Stout and Lelong 1981). Scattered throughout the pine savannah are ponds and numerous shallow bogs which support a unique flora, including pitcher plants (*Sarracenia* spp.), sundews (*Drosera* spp.), butterworts (*Pinguicula* spp.), milkworts (*Polygala* spp.), and several species of orchids (*Spiranthes* spp., *Habenaria* spp., *Pogonia ophioglossoides*, and *Cleistes divaricata*). Trees and shrubs characteristic of the ponds and bogs include pond cypress, which are often covered with Spanish moss (*Dendropogon usneoides*), mayhaw (*Crataegus aestivalis*), yaupon, and black titi (*Cliftonia monophylla*).

An upland pine-oak forest covers much of the remaining pine woodlands of Mobile and Baldwin Counties. It is usually found above the 10-foot contour but occasionally extends below this line intergrading with moist pinelands along streams and ponds (Stout and Lelong 1981). Longleaf pine is the dominant species in this forest with southern red oak (*Quercus falcata*), laurel oak (*Quercus hemisphaerica*), turkey oak (*Quercus laevis*), sandpost oak (*Quercus margaretta*), flowering dogwood (*Cornus florida*), and persimmon (*Diospyros virginiana*) also common (Table 46).

A diverse understory occurs in the upland pine forests. Common shrub species include winged sumac (*Rhus copallina*), sparkleberry (*Vaccinium arboreum*), and blueberries (*Vaccinium elliottii*, *Vaccinium myrsinites*), and huckleberry (*Gaylussacia dumosa*). Conspicuous herbs include several species in the sunflower family, aster, and blazing star. Other common herbs are whitish basil (*Pycnanthemum incanum*), scarlet (*Calamintha coccinea*), blue sage (*Salvia azurea*), and flowering spurge (*Euphorbia corollata*). Dominant grasses include broomsedges (*Andropogon* spp.), love grasses (*Eragrostis* spp.), and three awn grasses (*Aristida* spp.) (Table 46).

Along the coast, the upland pine-oak forest consists of those plants better adapted to a sand substrate and gulf spray (Stout and Lelong 1981). Longleaf pine is replaced by slash pine and sand pine (*Pinus clausa*). The most common oaks are scrubby live oaks (*Quercus virginiana* var. *maritima*) and myrtle oak (*Quercus myrtifolia*). Shrubs include rosemary (*Ceratiola ericoides*), seaside balm (*Conradina canescens*), and seaside goldenrod (*Solidago pauciflosculosa*). Typical herbaceous plants include sand milkweed (*Asclepias humistrata*), golden aster (*Heterotheca subaxillaris*), rock rose (*Helianthemum arenicola*), dune evening primrose (*Oenothera humifusa*), and slender jointweed (*Polygonella gracilis*) (Stout and Lelong 1981).

Along the northern shores of Mississippi Sound, Bayou La Batre, Bayou Coden, and West Fowl River are numerous Indian oyster shell middens. Many are small, but Andrew's Place Shell Midden in Coden covered 37,160 m^2 (400,000 ft^2) and was 3.0 to 3.7 m (10 to 12 ft) high (Chermock et al. 1975). In addition to their archaeological value, they support a distinctive, calciphilic flora, similar to that found on the Dauphin Island shell mounds.

Table 45. Plants of the pine woodlands, including savannahs and bogs (Chermock et al. 1975; Stout and Lelong 1981).

Scientific name	Common name
Woody Plants	
Aronia arbutifolia	Red chokeberry
Arundinaria gigantea	Cane
Clethra alnifolia	Pepperbush
Cliftonia monophylla	Black titi
Cyrilla racemiflora	Swamp cyrilla
Hypericum brachyphyllum	St. John's wort
Hypericum cistifolium	St. John's wort
Hypericum fasciculatum	Sand weed
Hypericum myrtifolia	
Ilex cassine	Dahoon
Ilex coriacea	Large gallberry
Ilex glabra	Gallberry
Ilex vomitoria	Yaupon
Lyonia lucida	Fetterbush
Magnolia virginiana	Sweet bay
Myrica cerifera	Wax-myrtle
Nyssa sylvatica var. *biflora*	Swamp tupelo
Persea palustris	Swamp bay
Pinus elliottii	Slash pine
Pinus palustris	Longleaf pine
Rhododendron viscosum var. *serrulatum*	Swamp azalea
Rhus vernix	Poison sumac
Smilax laurifolia	Green briar
Serenoa repens	Saw palmetto
Taxodium distichum var. *nutans*	Pond cypress
Vaccinium elliottii	Blueberry
Vaccinium fuscatum	Blueberry

Table 45. Continued.

Scientific name	Common name
Herbaceous Plants	
Aletris aurea	Colic root
Aletris farinosa	Colic root
Asclepias lanceolata	Milkweed
Asclepias longifolia	Milkweed
Balduina uniflora	
Calopogon pulchellus	Grass pink orchid
Chondrophora nudata	Rayless goldenrod
Cleistes divaricata	Rosebud orchid
Drosera brevifolia	Sundew
Drosera filiformis	Sundew
Eriocaulon decangulare	Pipewort
Eriogonum tomentosum	Wild buckwheat
Eupatorium rotundifolium	False hoarhound
Habenaria blephariglottis	White fringe orchid
Luhnistera pinnata	Summer farewell
Lachnanthes caroliniana	Red-root
Liatris tenuifolia	Blazing-star
Lilium catesbaei	Pine lily
Lobelia glandulosa	Lobelia
Lobelia puberula	Lobelia
Lophiola americana	Golden crest
Lycopodium alopecuroides	Clubmoss
Lycopodium carolinianum	Clubmoss
Modiola caroliniana	Cheeses
Phyla nodiflora	Cape-weed
Pinguicula lutea	Yellow butterwort
Pinguicula planifolia	Butterwort
Pinguicula pumila	Small butterwort
Pogonia ophioglossoides	Rose-crested orchid
Polygala brevifolia	Milkwort
Polygala cruciata	Milkwort
Polygala cymosa	Yellow milkwort
Polygala lutea	Yellow milkwort
Polygala ramosa	Yellow milkwort
Pteridium aquilinum	Bracken fern
Rhexia alifanus	Meadow beauty
Rhexia lutea	Meadow beauty
Sabatia brevifolia	Rose gentian
Sabatia macrophylla	Rose gentian
Sarracenia alata	Yellow pitcher plant
Sarracenia flava	Yellow pitcher plant
Sarracenia leucophylla	Purple pitcher plant
Sarracenia psittacina	Parrot pitcher plant
Sarracenia purpurea	Red pitcher plant
Sarracenia rubra	Red pitcher plant

Table 45. Concluded.

Scientific name	Common name
Scutellaria integrifolia	Rough skullcap
Spiranthes praecox	Ladies tresses orchid
Spiranthes vernalis	Ladies tresses orchid
Tofieldia racemosa	False asphodel
Utricularia cornuta	Bladderwort
Utricularia juncea	Bladderwort
Xyris caroliniana	Yellow eyed grass
Xyris difformis	Yellow eyed grass
Grasses and Grass-like Plants	
Andropogon virginicus	Broom sedge
Anthaenantia rufa	
Aristida affinis	Three-awn grass
Aristida virgata	Three-awn grass
Ctenium aromaticum	Toothache grass
Dichromena latifolia	White-top sedge
Eleocharis microcarpa	Spike rush
Eleocharis tuberculosa	Spike rush
Erianthus giganteus	Plume grass
Fuirena squarrosa	Umbrella grass
Fuirena scirpoidea	Umbrella grass
Muhlenbergia expansa	Muhly grass
Panicum consanguineum	Panic grass
Panicum ensifolium	Panic grass
Panicum scabriusculm	Panic grass
Panicum spretum	Panic grass
Rhynchospora chapmanii	Beak rush
Rhynchospora ciliaris	Beak rush
Rhynchospora glomerata	
Rhynchospora plumosa	
Rhynchospora pusilla	
Scleria ciliata	Nut rush
Scleria reticularis	Nut rush

Table 46. Plants of the upland pine-oak forest (from Chermock et al. 1975; Stout and Lelong 1981).

Scientific name	Common name
Woody Plants	
Carya tomentosa	Mockernut hickory
Castanea pumila	Chinkapin
Ceratiola ericoides	Rosemary
Conradina canescens	Seaside balm
Cornus florida	Flowering dogwood
Diospyros virginiana	Persimmon
Gaylussacia dumosa	Dwarf huckleberry
Gelsemium sempervirens	Yellow jessamine
Ilex vomitoria	Yaupon
Magnolia grandiflora	Southern magnolia
Pinus clausa	Sand pine
Pinus elliottii	Slash pine
Pinus palustris	Longleaf pine
Quercus falcata	Southern red oak
Quercus hemisphaerica	Laurel oak
Quercus incana	Blue-jack oak
Quercus laevis	Turkey oak
Quercus margaretta	Sand post oak
Quercus myrtifolia	Myrtle oak
Quercus virginiana	Live oak
Quercus virginiana var. *martima*	Dwarf live oak
Rhus copallina	Winged sumac
Sassafras albidum	Sassafras
Serenoa repens	Saw palmetto
Smilax auriculata	Green briar
Solidago pauciflosculosa	Seaside goldenrod
Taxodium distichum var. *nutans*	Pond cypress
Vaccinium arboreum	Sparkleberry
Vaccinium elliottii	Blueberry
Vaccinium myrsinites	Blueberry
Herbaceous Plants	
Agalinis purpurea	Purple foxglove
Agalinis setacea	Purple foxglove
Asclepias humistrata	Sand milkweed
Asclepias tuberosa	Butterfly weed
Aster adnatus	Aster
Aster linariifolius	Aster
Calamintha coccinea	Red basil
Centrosema virginianum	Butterfly pea
Clitoria mariana	Butterfly pea
Cnidoscolus stimulosus	Spurge nettle
Coreopsis major	
Crotalaria angulata	Rattlebox

Table 46. Concluded.

Scientific name	Common name
Crotalaria purshii	Rattlebox
Dendropogon usheoides	Spanish moss
Desmodium laevigatum	Beggar's ticks
Desmodium viridiflorum	Beggar's ticks
Euphorbia corollata	Flowering spurge
Gaillardia aestivalis	Gaillardia
Galactia erecta	Milk pea
Galactia yolubilis	Milk pea
Helianthemum arenicola	Rock rose
Heterotheca subaxillaris	Golden aster
Lespedeza stuevei	Lespedeza
Lespedeza virginica	Lespedeza
Liatris elegans	Blazing star
Liatris graminifolia	Blazing star
Lupinus diffusus	Sandhill lupine
Oenothera humifusa	Dune evening primrose
Penstemon australis	Beard tongue
Phlox pilosa	Phlox
Polygonella gracilis	Slender jointweed
Polygonella polygama	October-flower
Pycnanthemum incanum	Whitish basil
Salvia azurea	Blue sage
Schrankia microphylla	Sensitive briar
Siphonychia corymbosa	Whitlow-wort
Solidago odoro	Goldenrod
Stillingia sylvatica	Queen's delight
Tephrosia florida	Hoary pea
Tephrosia chrysophylla	Hoary pea
Tetragonotheca helianthoides	False sunflower
Trilissa odoratissima	Deer tongue
Vernonia angustifolia	Narrow-leaf ironweed
Grass and Grass-like Plants	
Andropogon tener	
Aristida lanosa	
Aristida purpurascens	Three-awn grass
Cyperus globulosus	Umbrella sedge
Cyperus retrorsus	Umbrella sedge
Danthonia sericea	Oat grass
Eragrostis refracta	Love grass
Eragrostis spectabilis	Love grass
Gymnopogon ambiguus	Windmill grass
Panicum aciculare	Panic grass
Panicum angustifolium	Panic grass
Rhynchospora megalocarpa	Beak rush
Scleria triglomerata	Nut rush
Sorghastrum elliottii	Indian grass
Sporobolus junceus	Dropseed grass

ANIMAL LIFE

By Patrick E. O'Neil

Alabama has a great diversity of animal species within its boundaries. This includes a majority of terrestrial and freshwater species characteristic of temperate, Eastern United States, along with subtropical species occurring in the lower coastal plain. In addition, there is a great variety of salt and brackish water animals found in the states' coastal waters.

For many years, the marine and estuarine faunas of Alabama were poorly known except for species of economic importance. This situation began to change in the 1950's when the Gulf Coast Research Laboratory at Ocean Springs, Mississippi, conducted studies in Alabama waters. With the development of the Marine Resources Laboratory of the Alabama Department of Conservation, the Marine Sciences Institute of the University of Alabama, and the Dauphin Island Sea Lab, active programs to study the State's marine and estuarine resources were developed. These organizations have added considerably to our knowledge of the area.

PROTOZOA

The first detailed studies of coastal Alabama Protozoa examined species of the order Foraminiferida. Phleger (1954) surveyed the foraminiferans of Mississippi Sound in Alabama and the Gulf of Mexico off the coast of Dauphin Island (Figure 69). In Mississippi Sound, the variety of species was very limited, with the genus *Ammobaculites* comprising from 80% to over 90% of the individuals within samples. However, at the exit of Petit Bois Pass, the fauna was more diverse with the species assemblage resembling that of the open gulf (Phleger 1954). Samples taken off the coast of Dauphin Island out to the 18-m (60-ft) contour contained a great variety of species. Among the more abundant were *Ammobaculites* sp., *Cibicidina strattoni*, *Discorbis* sp. cf. *columbiensis*, *Nonionella atlantaca*, and *Ammonia beccarii*.

Anderson (1968) conducted a survey of coastal Alabama Foraminiferida based on samples collected at 36 different stations at depths of 3 m (10 ft) or less (Figure 69). The greatest diversity of foraminiferan species was found in Mississippi Sound and the open gulf (Table 47). *Elphidium gunteri* and *Ammonia beccarii* tolerated conditions of fluctuating salinity with *Ammonia beccarii* apparently able to withstand somewhat lower salinities. *Ammobaculites salsus* and *Miliammina fusca* characterized low salinity waters. *Hanzawaia concentrica* was characteristic of more stable higher salinity waters.

Anderson's study, when compared with that of Phleger, shows that there was a significant change in the population of Foraminiferida in the eastern end of Mississippi Sound. Lamb (1972) in a study of the Foraminiferida of Mobile Bay from 33 samples stations (Figure 70) attributed this to changes in salinity possibly associated with manmade modifications of the environment. Where Phleger (1954) reported that *Ammobaculites* comprised more than 90% of the foraminiferan population in Mississippi Sound, Anderson (1968) found that *Elphidium gunteri* comprised 46% of the population and *Ammonia beccarii*, 41% (Table 47). The latter two species were usually associated with greater salinity. Lamb (1972) felt that construction of the bridge system from Cedar Point to Dauphin Island (finished 1955) reduced the flow of fresh water from Mobile Bay into the sound resulting in increased salinity. The increased abundance of the oyster drill (*Thais*), which prefers higher salinity water, in Portersville Bay and the accompanying decline of oysters further substantiates this conclusion. Another contributing factor to the increased salinity, which Lamb failed to consider is the widening of Petit Bois Pass due to the erosion of the eastern end of Petit Bois Island. As a result, more high-saline gulf waters enter the sound with incoming tides.

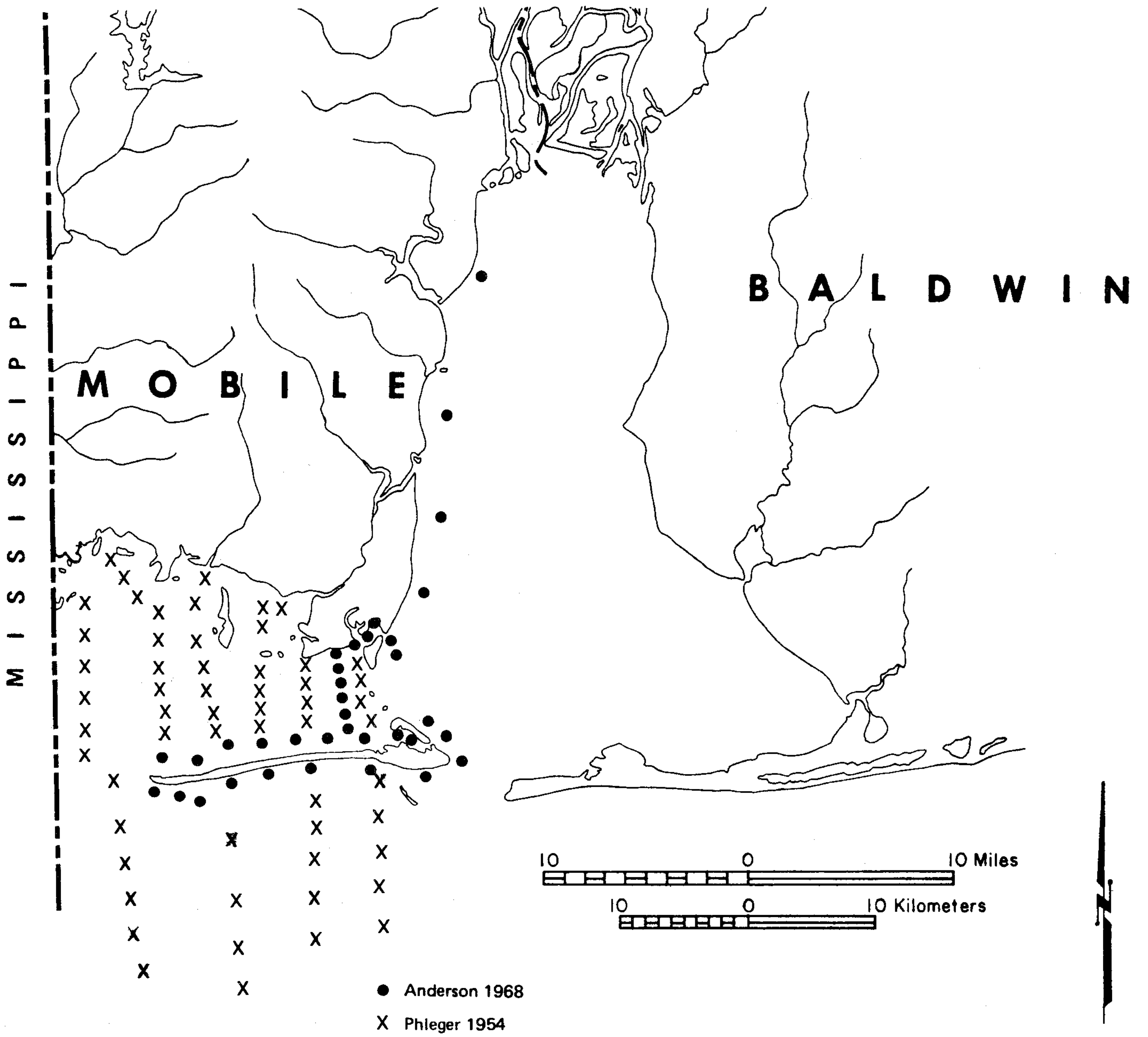


Figure 69. Foraminiferida collecting stations in Mississippi Sound, Mobile Bay, and the surrounding Gulf of Mexico, Alabama (modified from Phleger 1954 and Anderson 1968).

Table 47. Percent relative abundance of Foraminiferida in Alabama waters (modified from Anderson 1968 in Chermock 1974).

Species	Mississippi Sound	Gulf Beach Dauphin Island	Heron Bay	West Shore Mobile Bay
Elphidium gunteri	46	37	16	31
Elphidium poeyanum	1			
Elphidium incertum mexicanum	3	11	5	3
Elphidium discoidale	1			
Elphidium spp.	1			
Ammonia beccarii	41	25	33	41
Ammobaculites salsus	3		33	10
Miliammina fusca	1		13	15
Nonionella atlantica	1	2		
Nonionella opima	1			
Quinqueloculina poeyana	1			
Quinqueloculina semimulum		2		
Triloculina trigonula	1			
Triloculina sidebottomi		1		
Hanzawaia concentrica		13		
Cibicidina strattoni		5		
Discorbis concinnus		2		
Guttulina australis		2		

[a]A--Mississippi Sound, B--Gulf Beach Dauphin Island, C--Heron Bay, D--West Shore Mobile Bay.

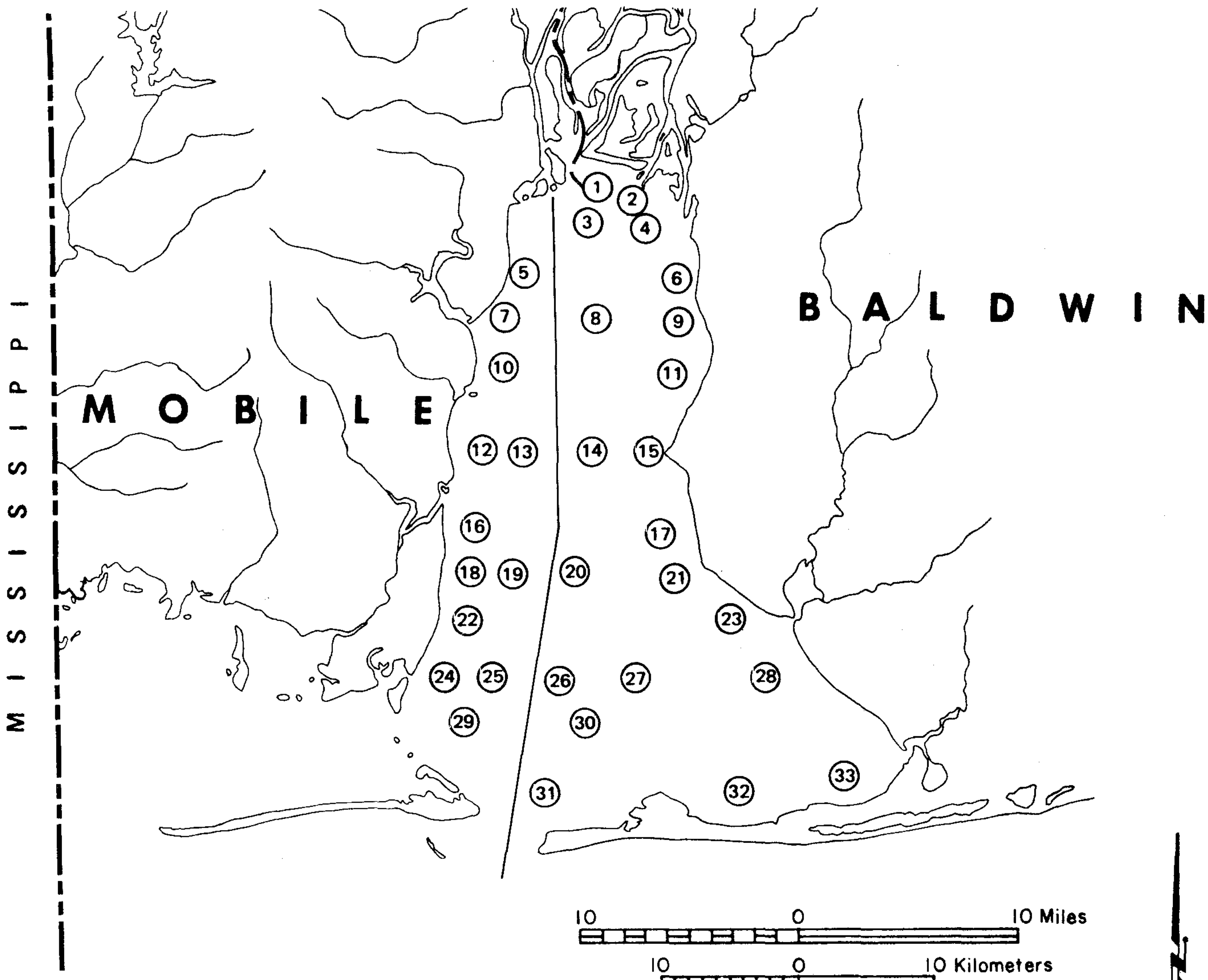


Figure 70. Foraminiferida sampling stations in Mobile Bay, Alabama (Lamb 1972).

Lamb (1972) found a correlation between salinity and foraminiferan species distribution within Mobile Bay (Figures 71 and 72; Table 48). *Elphidium gunteri* and *Ammonia beccarii* occurred in close association, were found with other calcareous species and were most abundant in the lower bay where salinities were greatest. Two areaceous species were restricted to the upper end of the bay with *Miliammina fusca* being most abundant in salinities of less than 10 ppt and *Ammobaculites salsus* being able to tolerate slightly higher concentrations.

In 1974, Jones published the results of his comprehensive Protozoa survey of Mobile Bay. Perforated plastic boxes holding 10 microscope slides each were suspended from 18 fixed channel markers along the shore and down the center of the bay (Figure 73). Specimens were collected from the traps once a month for 24 consecutive months. Bottom dredge samples were also collected at each trap site. Sand samples were collected from 20 stations along the bay shore throughout the two-year period. In addition, numerous plankton tows were made from docks.

Jones (1974) collected 258 species of Protozoa from Mobile Bay (Table C-1, Appendix C). Of this total, 162 species were ciliates, 57 species were Sarcodinans (ameboid-like protozoans), 32 species were phytomastigophorans (plant-like flagellates), and 7 species were zoomastigophorans (animal-like flagellates). Jones included a brief description of each species along with general distribution remarks. Protozoa within Mobile Bay are an important component of the ecosystem consuming bacteria, including harmful and pathogenic forms, and various species of unicellular algae. Protozoa in turn are consumed by larger animals, serving as a major food component for many species.

COELENTERATES

Burke (1975a) reported 61 species of Coelenterates as occurring in the Mississippi Sound and surrounding gulf areas in the northwestern Gulf of Mexico. Waters south of the Barrier Islands were more diverse than the Mississippi Sound. Twenty-six species of hydromedusae, 25 species of siphonophores, and 10 species of scyphomedusae were present in the samples. Species commonly collected included *Liriope tetraphylla*, *Nemopsis bachei*, *Bougainvillia carolinensis*, and *Persa incolorata*.

In the Mississippi Sound, hydromedusae were generally more numerous at higher temperatures, achieving maximum density during summer months. In the gulf, populations were more stable in terms of density and abundance. Three species were confined to inshore habitats, 22 were collected in both inshore and offshore habitats, and 36 species were exclusively marine. Although none of the stations sampled by Burke (1975a) were within Alabama's coastal waters, the results can probably be extrapolated to the area. In addition to trawl samples, plankton samples were regularly collected within bay areas and passes between Barrier Islands. Examination of 326 plankton samples revealed no larval stages of any coelenterate species. This evidence suggested to Burke that the coelenterate fauna of the Mississippi Sound is derived from offshore marine populations.

In another study by Burke (1975b), which included stations within coastal Alabama (Figure 74), seven species were reported as occurring near Barrier Islands, passes, and inland bays of the coast. The seven species collected in order of descending abundance were *Stomolophus meleagris*, *Crysaora quinquecirrha*, *Physalia physalis*, *Pelagia noctiluca*, *Aurelia aurita*, *Chiropsalmus quadrumanus*, and *Rhopilema verrillii*.

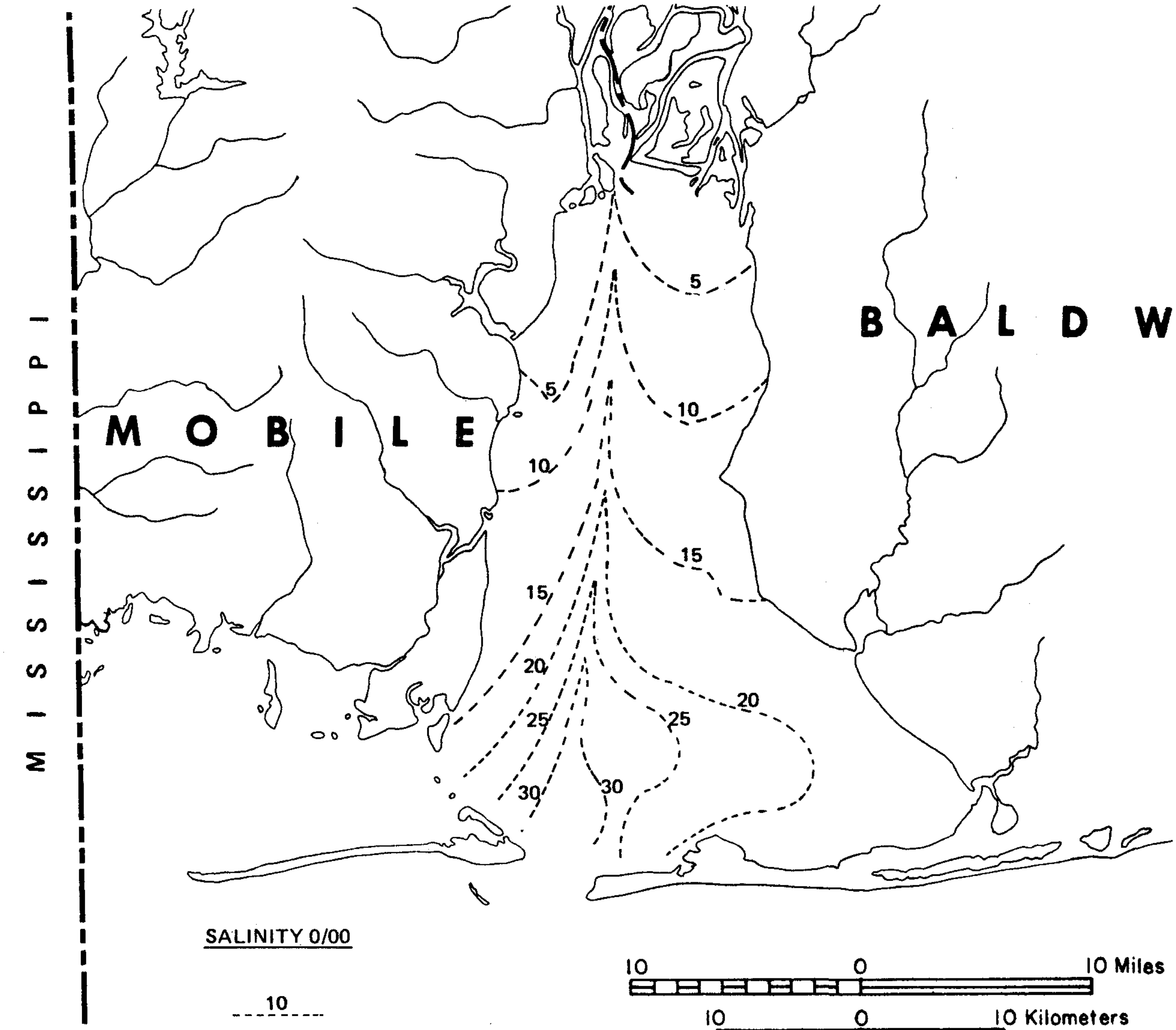


Figure 71. Average salinity isohalines from Mobile Bay sample stations over the period March through May 1969 (Lamb 1972).

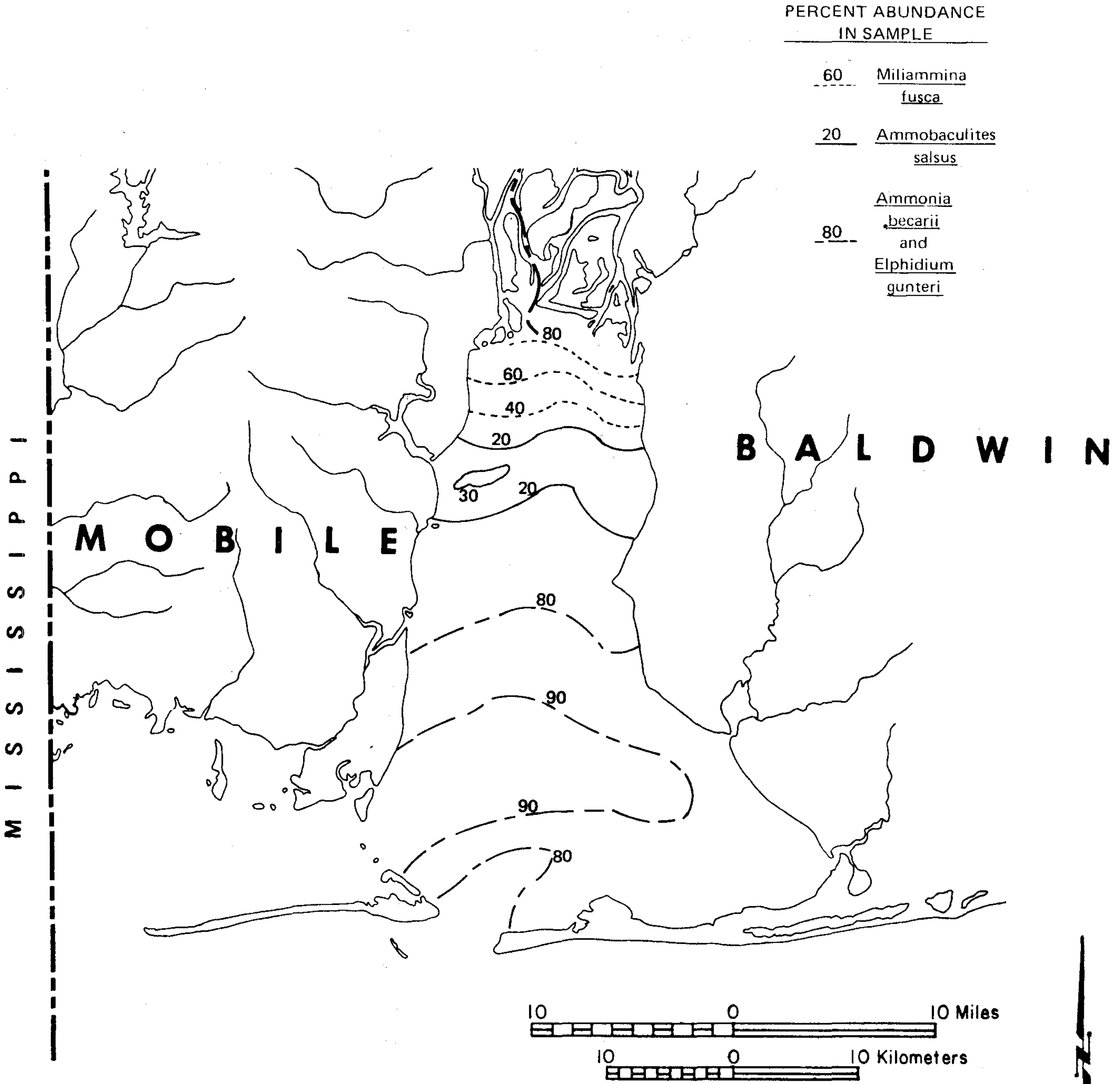


Figure 72. Distribution of representative species of Foraminiferida in Mobile Bay, Alabama (Lamb 1972).

Table 48. Percent relative abundance of significant species of Foraminiferida at stations in Mobile Bay (Lamb 1972).

Station[a]	*Miliammina fusca*	*Ammobaculites salsus*	*Elphidium gunteri*	*Ammonia beccarii*	Other calcareous forms
1	81	18	--	--	--
2	85	15	--	--	--
3	62	16	--	11	--
4	56	18	8	17	--
5	54	18	9	19	--
6	48	19	11	21	--
7	22	28	19	30	--
8	19	26	22	33	--
9	23	20	23	34	--
10	18	24	22	36	--
11	16	23	24	36	--
12	6	16	34	43	--
13	1	13	37	46	3
14	--	12	37	47	3
15	4	17	35	43	--
16	--	9	36	48	6
17	--	11	37	48	4
18	--	4	40	49	--
19	--	--	41	51	7
20	--	--	41	51	7
21	--	--	39	49	11
22	--	--	40	52	8
23	--	--	39	49	11
24	--	--	41	53	6
25	--	--	40	53	7
26	--	--	38	52	10
27	--	--	39	52	9
28	--	--	38	53	8
29	--	--	36	49	14
30	--	--	34	47	19
31	--	--	33	45	22
32	--	--	37	46	16
33	--	--	38	46	16

[a]See Figure 70.

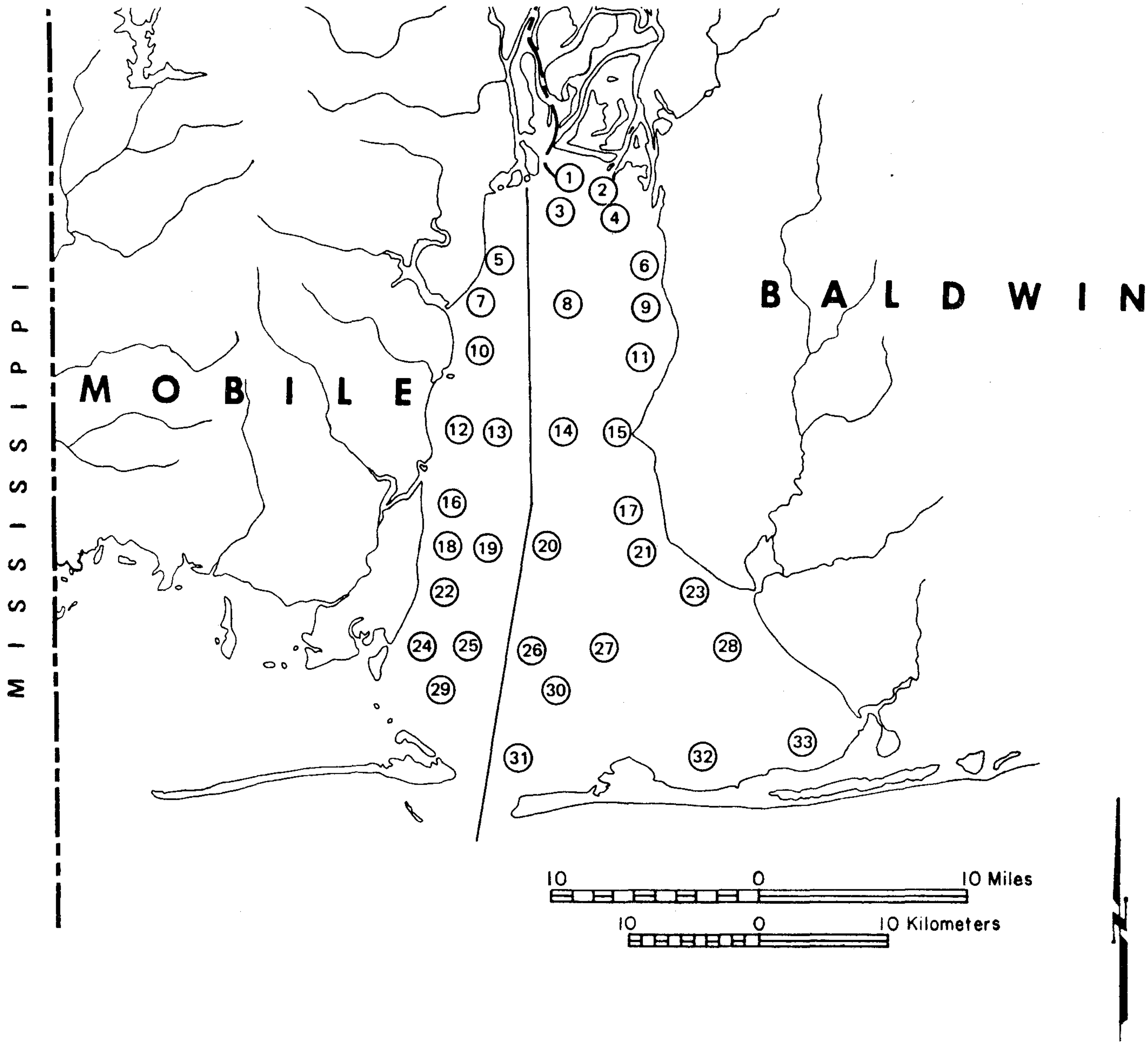


Figure 73. Protozoa collecting stations in Mobile Bay, Alabama (Jones 1974).

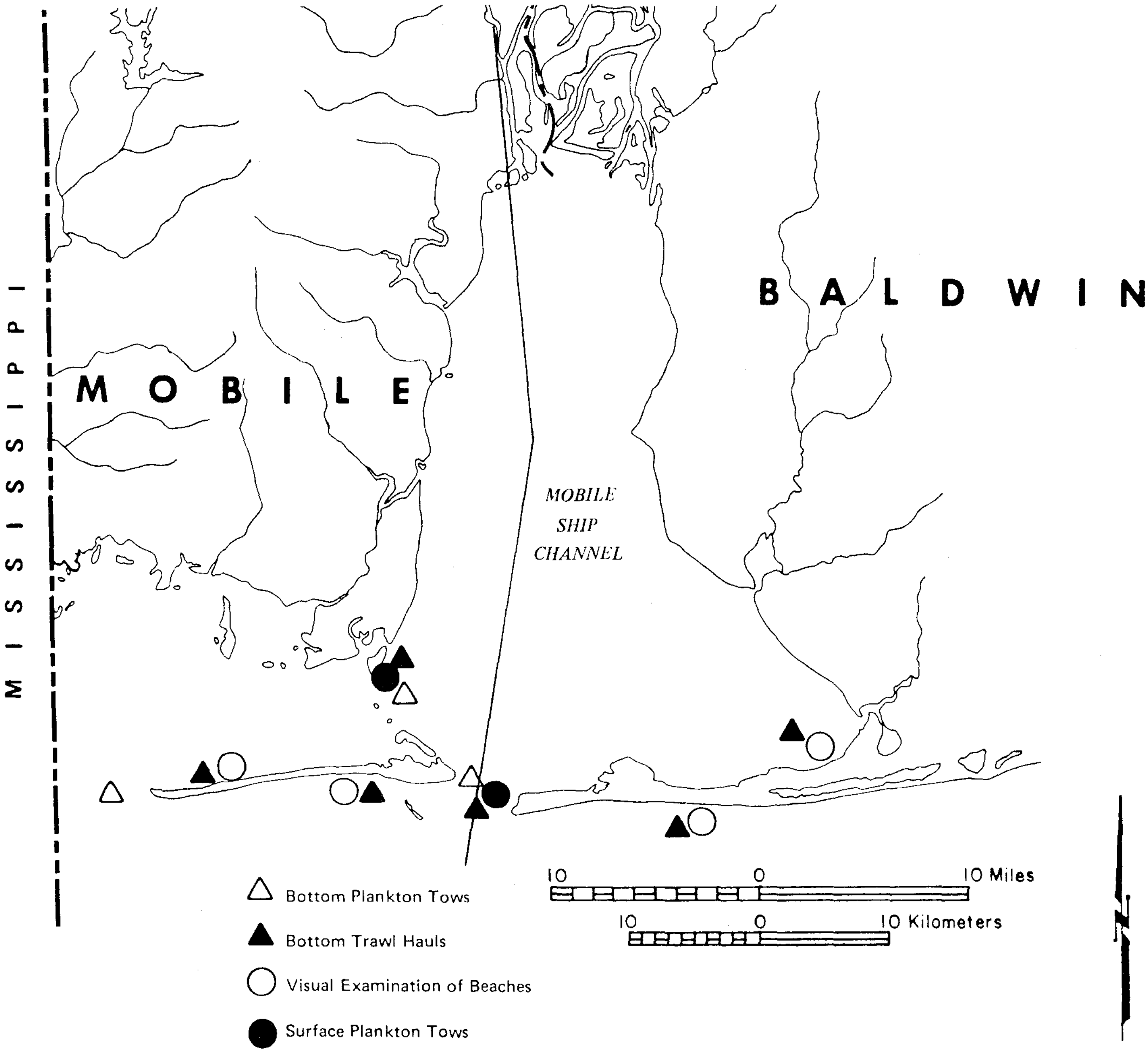


Figure 74. Coelenterate collecting stations in Mobile Bay and Mississippi Sound, Alabama (modified from Burke 1975b).

CRUSTACEA

One of the early studies of Crustacea in Alabama was that of Herrick (1887). He listed the following species of copepods from coastal waters: *Acartia gracilis*, *Amynome intermedia*, *Calanus americanus*, *Canthocamptus mobilensis*, *Harpacticus chelifer*, *Laophonte mississippiensis*, *Laophonte similis*, *Pseudo-diaptomus pelagicus*, *Temora affinis*, and *Temorella affinis*. Because of the date of his study, the taxonomy of these species, as given by Herrick, needs to be re-evaluated.

McIlwain (1968) conducted a monthly survey of copepods at a station located in Mississippi Sound north of the western end of Horn Island in Mississippi. Because of the short distance involved, the fauna would be expected to be similar to Alabama's part of the sound. McIlwain found that the copepod population was highest from June through August and less abundant during the colder months of the year (Figure 75). Of the 15 species collected, *Labidocera aestiva* was the most abundant (10,378 specimens), while *Acartia tonsa* occurred most commonly (Table 49). The greatest diversity of species occurred during the warmer months of the year.

Much of our early knowledge of decapod crustaceans in offshore and estuarine Alabama was from Brunson (1951), who recorded 62 species from Mobile Bay but provided little information on species abundance or habitat preferences. Shipp (1977) compared the distribution of larval decapod crustaceans occurring in a tidal marsh to environmental factors such as salinity and temperature. Freshwater crustaceans of coastal Alabama are even less well known. Hobbs (1974) listed 11 species of crayfishes as occurring in the area, primarily from streams and ditches (Table 50).

A list of marine and estuarine decapod crustaceans known from coastal Alabama can be found in Table C-1.

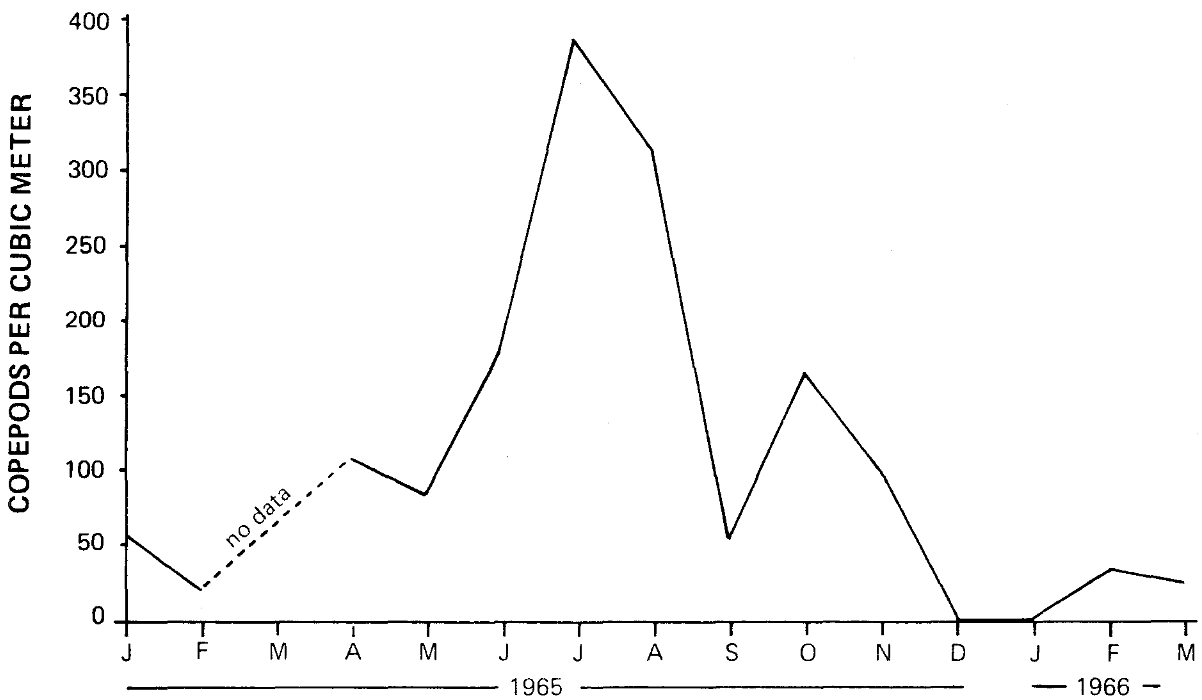


Figure 75. Average number of adult copepods per cubic meter by months (McIlwain 1968).

Table 49. Monthly occurrence of copepods collected in Mississippi Sound (McIlwain 1968).

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Eucalanus pileatus		X				X	X	X	X		X	
Paracalanus parvus			X	X	X	X	X		X	X	X	
Centropages hamatus		X									X	X
Centropages furcatus			X			X	X	X	X	X	X	X
Temora stylifera								X				
Temora longicornis			X			X	X	X	X	X	X	
Labidocera aestiva				X	X	X	X	X	X	X	X	
Labidocera sp.	X	X	X				X		X	X	X	
Acartia tonsa	X	X	X	X	X	X	X	X	X	X	X	X
Oithona brevicornis			X	X	X	X	X	X	X	X	X	X
Oithona sp.		X					X					
Oncaea venusta					X	X	X					
Corycaeus sp.					X	X	X	X				
Sappharina nigromaculata		X						X				
Euterpina acutifrons		X				X	X	X	X		X	X

Table 50. Freshwater crayfishes of Mobile and Baldwin Counties (modified from Hobbs 1974).

Species	Streams	Burrows	Springs	Ditches	Ponds
Cambarellus diminutus	X	X		X	X
Cambarellus schmitti	X		X		
Cambarellus shufeldti	X			X	X
Fallicambarus byersi		X			
Orconectes immunis	X			X	X
Procambarus acutissimus	X			X	X
Procambarus acutus acutus	X				
Procambarus bivittatus	X				
Procambarus evermanni	X	X			
Procambarus habenianus		X			
Procambarus lecontei	X				
Procambarus versutus	X				

Table 51. Shrimp species occurring in coastal Alabama (Swingle 1971).

Scientific name	Common name
Acetes americanus	Sergistid shrimp
Alpheus heterochaelis	Snapping shrimp
Macrobrachium acanthurus	River shrimp
Macrobrachium ohione	River shrimp
Paleomonetes paludosus	Grass shrimp
Paleomonetes pugio	Grass shrimp
Paleomonetes vulgaris	Grass shrimp
Penaeus aztecus	Brown shrimp
Penaeus duorarum	Pink shrimp
Penaeus setiferus	White shrimp
Sicyonia brevirostris	Rock shrimp
Sicyonia dorsalis	Rock shrimp
Trachypenaeus constrictus	Hardback shrimp
Trachypenaeus similis	Hardback shrimp
Xiphopeneus kroyeri	Seabob

Shrimp

Fifteen species of shrimp (Table 51) occur in Mobile Bay but only the brown shrimp (*Penaeus aztecus*), white shrimp (*Penaeus setiferus*), and pink shrimp (*Penaeus duorarum*) are of commercial value. White shrimp was the major commercial species harvested until 1945, but by 1959 it was replaced by the brown shrimp. Pink shrimp are only occasionally found in Mobile Bay and account for about 1% of total shrimp landings (Heath 1979a). Total landings of shrimp in Alabama since 1950 can be found in Figure 76.

Brown and white shrimps have similar life cycles (Christmas and Etzold 1977). Both species spawn offshore, larvae undergo several molts as planktonic larvae, metamorphose into postlarvae (shrimp less than 25 mm or 1 inch total length) and appear in estuarine waters at about 9 mm (0.35 inch) total length (Figure 77). Loesch (1965) indicated that postlarvae were less than a month old when they appeared in Mobile Bay. Christmas and Etzold (1977) indicated that shrimp hatched in late summer and fall may overwinter in the Gulf of Mexico. The growth rate of these shrimp during early life stages is very slow and they enter the bay as postlarvae the following spring. Postlarval shrimp immigrate to the bayous and marshes along Mobile Bay where they find protection and grow rapidly on the abundant detrital food supply. Juvenile shrimp more than 25 mm (1 inch) total length move into the open bay prior to their emigration to the Gulf of Mexico. Emigration lasts several months, and during this period shrimp are heavily exploited by inshore fishermen. Shrimp become sexually mature during emigration and those that escape capture return to the Gulf of Mexico to spawn (Heath 1979a).

Brown and white shrimps differ in seasonal migration patterns. The peak spawning period for brown shrimp is in December and January. Brown shrimp postlarvae appear in estuaries from February through May and sometimes as late as August. The peak month of white shrimp postlarvae immigration is July and usually continues through August. Emigration of white shrimp usually begins in August and continues through October with the peak in September.

Figure 76. Total landings of shrimp in Alabama since 1950.

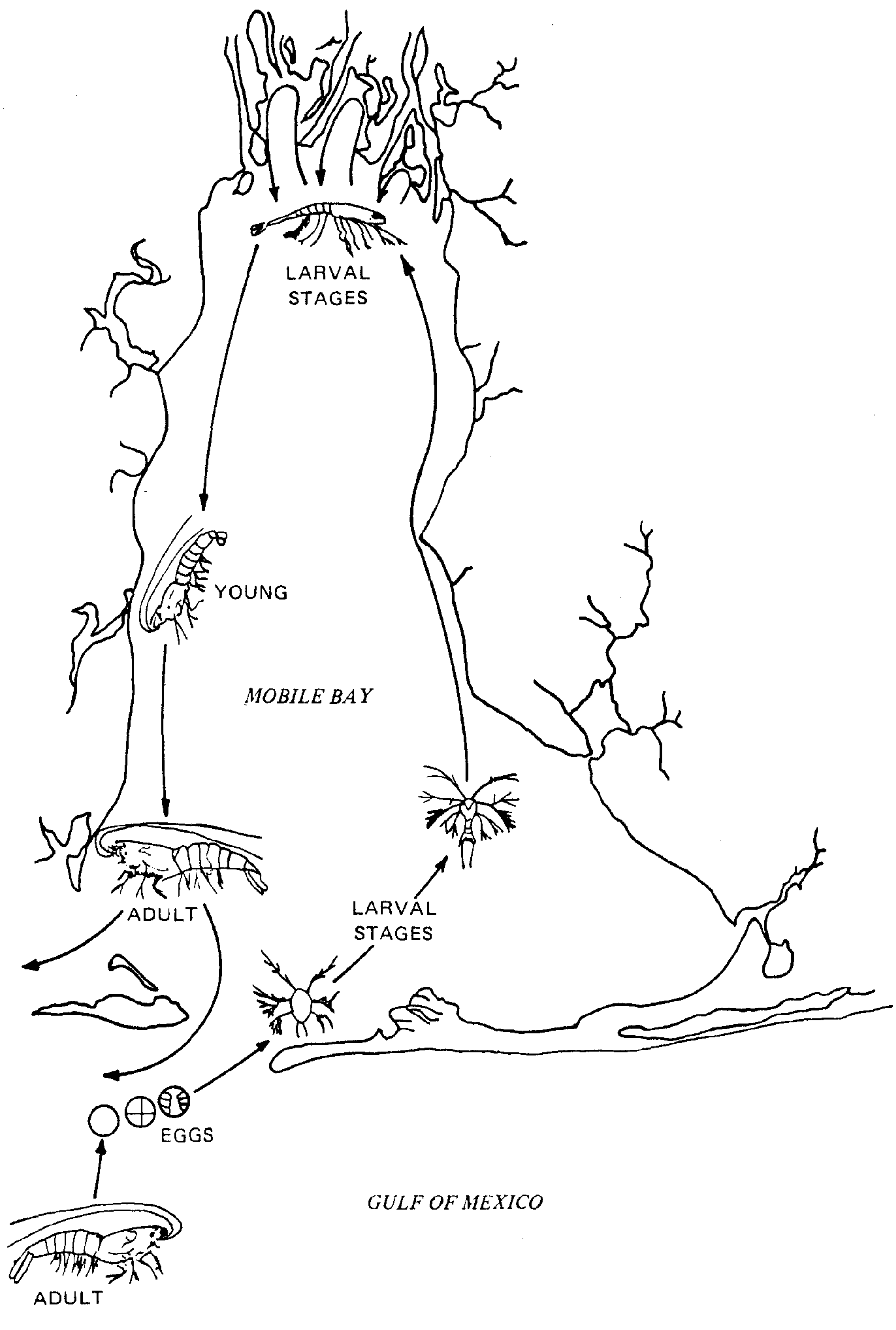


Figure 77. Generalized schematic of shrimp life cycle in coastal Alabama.

Loesch (1965) found more shrimp in the western half of Mobile Bay than in the eastern half. He found small brown shrimp less than 20 mm (0.8 inch) total length in greatest abundance in water less than 1.2 m (4 ft) deep. Abundance decreased with depth. Small white shrimp were in greatest abundance in water less than 0.6 m (2 ft) deep. A similar distribution of brown and white shrimp also occurred in samples taken in Mobile Bay in 1977 to 1978 (Heath 1979a). Juvenile brown shrimp usually appear later in Mobile Bay than in other estuarine waters of Alabama. Juvenile white shrimp generally appear north of the Intracoastal Waterway in July and August but in far greater numbers in upper Mobile Bay. This general distribution is probably determined by salinity regimes of the bay.

Apparently, no relationship exists between shrimp spawning stock and the population available for harvest at the present rate of exploitation (Heath 1979a). Population size from year to year appears to be controlled more by environmental factors such as pollution, hydrology, and loss of habitat than by exploitative practices (Heath 1979a). Protection and allocation of shrimp resources is accomplished by permanently or temporarily closing certain estuarine areas to all shrimping (Figure 78). Permanently closed zones occur in marsh areas, which provide food and protection for juvenile shrimps. Other areas are closed to commercial shrimping but remain open to bait shrimping.

Blue Crab

For most marine species, mating and spawning are synonymous; however, in the case of the blue crab the two events occur at different times. Mating occurs after the juvenile female has had her terminal molt. The male assumes a protective position over the juvenile female immediately prior to the terminal molt. After molting, the male implants the female's seminal receptacles with sperm and retains his protective position until the new chitinous shell hardens (Tatum 1979). Spawning may occur until the female dies but mating occurs only once. Spawning usually occurs within two months after mating, but may be delayed for as long as five months depending upon the temperature. During ovulation, eggs are forced from the ovaries through the seminal receptacles containing spermatozoa where they are fertilized and then exuded onto fine hairs located on the abdominal swimmerettes. The eggs form a mass which occupies a space approximately 33% of the size of the crab and forces the abdomen, normally folded under the cephalothorax (carapace), away from the carapace area.

Spawning normally takes place in the lower estuary where salinity is over 20 ppt and in the Gulf of Mexico. Extreme drought conditions with subsequent high salinities may expand the estuarine area where successful hatching can take place (Tatum 1979). The eggs when first deposited are light yellow-orange in color, turning darker to a gray color as the yolk is absorbed by the developing unhatched larvae.

The first larval stages of the blue crab, usually found offshore, are called zoeae. There are seven molts in the zoeal stage and each molt results in a slight morphological change. Blue crab zoeae are approximately 1 mm (0.04 inch) in length and in no way resemble the adult crab. Blue crabs remain in this planktonic, free floating, stage for 31 to 49 days (depending upon temperature and salinity). Zoeal stages of blue crab rarely complete the first molt in salinities lower than 20 ppt and, consequently, are rarely found in the estuarine waters of Mobile Bay.

The second larval stage of the blue crab is called the megalopa, and it is this stage which first enters the estuarine area. Blue crab megalops are 2 to 5 mm (0.08 to 0.2 inch) total length and approximately 1 mm (0.04 inch) wide. They remain in this stage for 6 to 20 days again dependent upon temperature and salinity, after which they metamorphose to the adult crab stage. Growth is quite

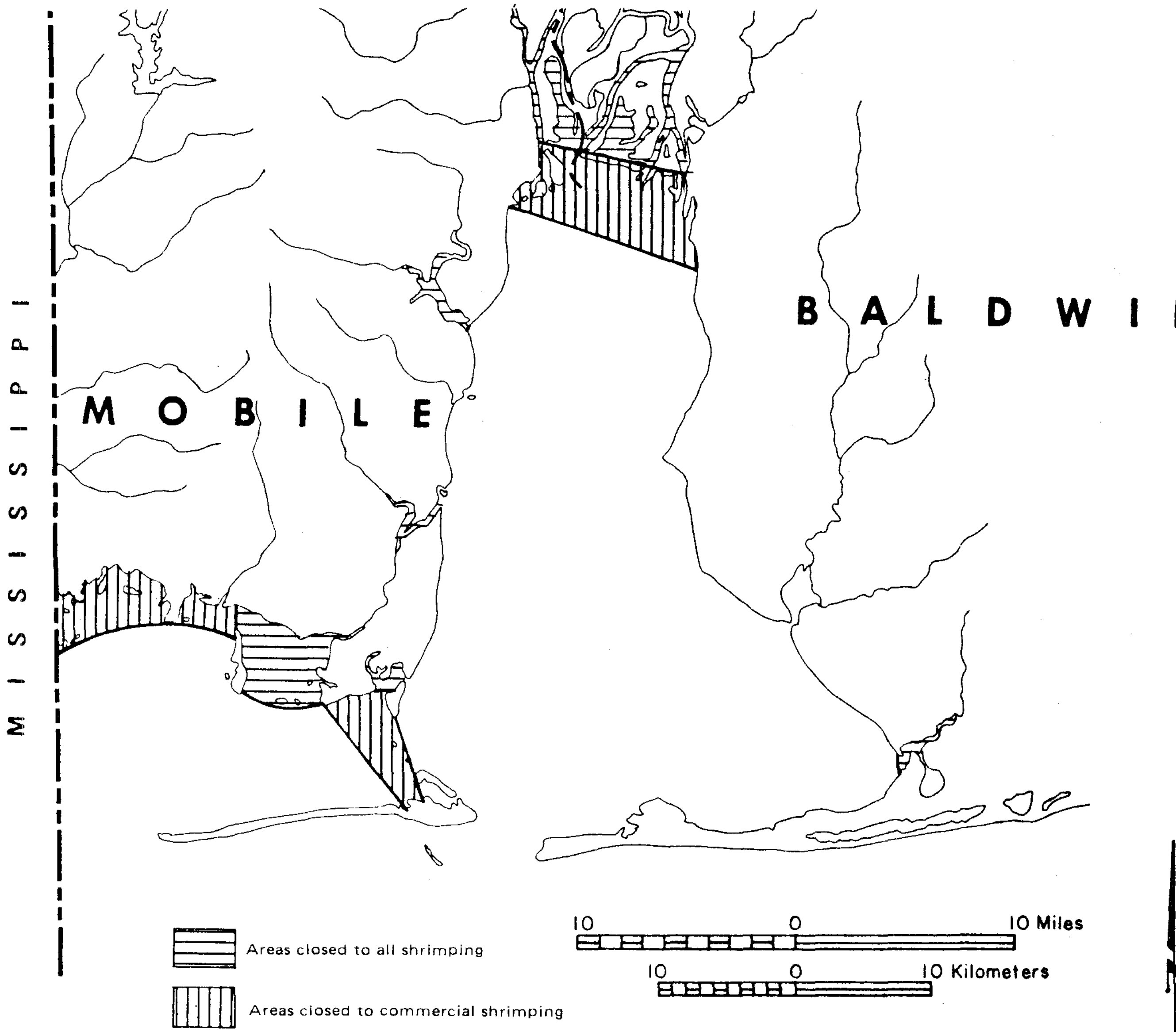


Figure 78. Controlling shrimping areas of coastal Alabama (Heath 1979b).

rapid after metamorphosis. The legal harvest size in Alabama of 10.2 cm (4 inches), measured from the widest point on the carapace, is attainable within one year. Total blue crab harvest since 1950 is seen in Figure 79.

Estimated monthly growth of blue crabs from Galveston Bay, Texas, was 15.3 to 17.8 mm (0.6 to 0.7 inch). Based on data collected in 1968 and 1969 (Swingle 1971), there appear to be three major juvenile crab recruitment peaks in coastal Alabama (April, August, and December) with growth among periods differing greatly. Juvenile crabs recruited in April, August, and December grew at monthly rates of 20, 10, and 5 mm (0.8, 0.4, and 0.2 inch), respectively (Figure 80). Juvenile crabs recruited in April are likely the progeny of late fall spawns; those in August from late spring spawns; and those in December from early fall spawns. One would expect the growth from both the latter two spawns to increase considerably and equal the former as spring approaches and the water begins to warm.

MOLLUSCA

Data concerning the abundance and occurrence of benthic mollusks within coastal Alabama is very incomplete. Studies by Parker (1960), Parker et al. (1974), Chermock (1974), and TechCon, Inc. (1980) have provided information as to species composition and limited abundance data on the coastal mollusk fauna. A list of mollusks reported from coastal Alabama can be found in Table C-1.

Information on freshwater mollusks is also very limited. Burch (1972, 1973) lists 14 species of freshwater clams as probably occurring in coastal Alabama: *Amblema plicata*, *Corbicula manilensis*, *Eupera cubensis*, *Lampsilis anodontoides*, *L. excavata*, *Leptodea fragilis*, *Pisidium dubium*, *P. casertanum*, *P. compressum*, *P. variabile*, *Plectomerus dombeyanus*, *Tritogonia verrucosa*, *Truncilla donaciformis*, and *Villosa vibex*. A number of species of land snails (Table 52) have been recorded from Mobile and Baldwin Counties (Rawls 1953).

Oysters

The oyster (*Crassostrea virginica*) is an estuarine species that can live under wide ranges of temperature and salinity. Optimum salinities and temperatures necessary to produce maximum growth rates in oysters vary from 10 to 28 ppt and 22° to 27°C (72° to 81°F), respectively.

The distribution of living oyster reefs in Mobile Bay is seen in Figure 81. The total area of oyster reefs is approximately 1,239 ha (3,064 acres). In addition, approximately 374 ha (924 acres) of State-owned bottoms are leased to oystermen and 425 ha (1,050 acres) of riparian bottoms are being used by private individuals to grow oysters (Crance 1971).

Larval oysters, or spat, are planktonic and are dispersed by tides and currents. They eventually attach to a variety of hard or semihard, clean surfaces including existing oyster reefs. They then metamorphose and begin to grow. Normally, the growth rate of oysters in Alabama is rapid and they reach marketable size in a year.

Oysters from Alabama have long been used as a source of food. Large mounds or middens of shucked oyster shells built by Indians are found along the shores of Mobile Bay and Mississippi Sound and the offshore islands. Artifacts and skeletal material indicate they date to the Woodland Culture about 2000 B.C. (Wimberley 1960). Today, oysters are still used as food and their shells utilized in establishing new reefs or supplementing old ones, for road building, and other commercial uses.

Oyster shell deposits (Figure 82) have been dredged in Alabama for commercial use since 1946. From 1947 through 1968, 30,863,312 m^3 (40,338,220 yds^3) were dredged. The average annual production for 1947 through 1969 was 1,402,872 m^3 (1,833,555 yds^3).

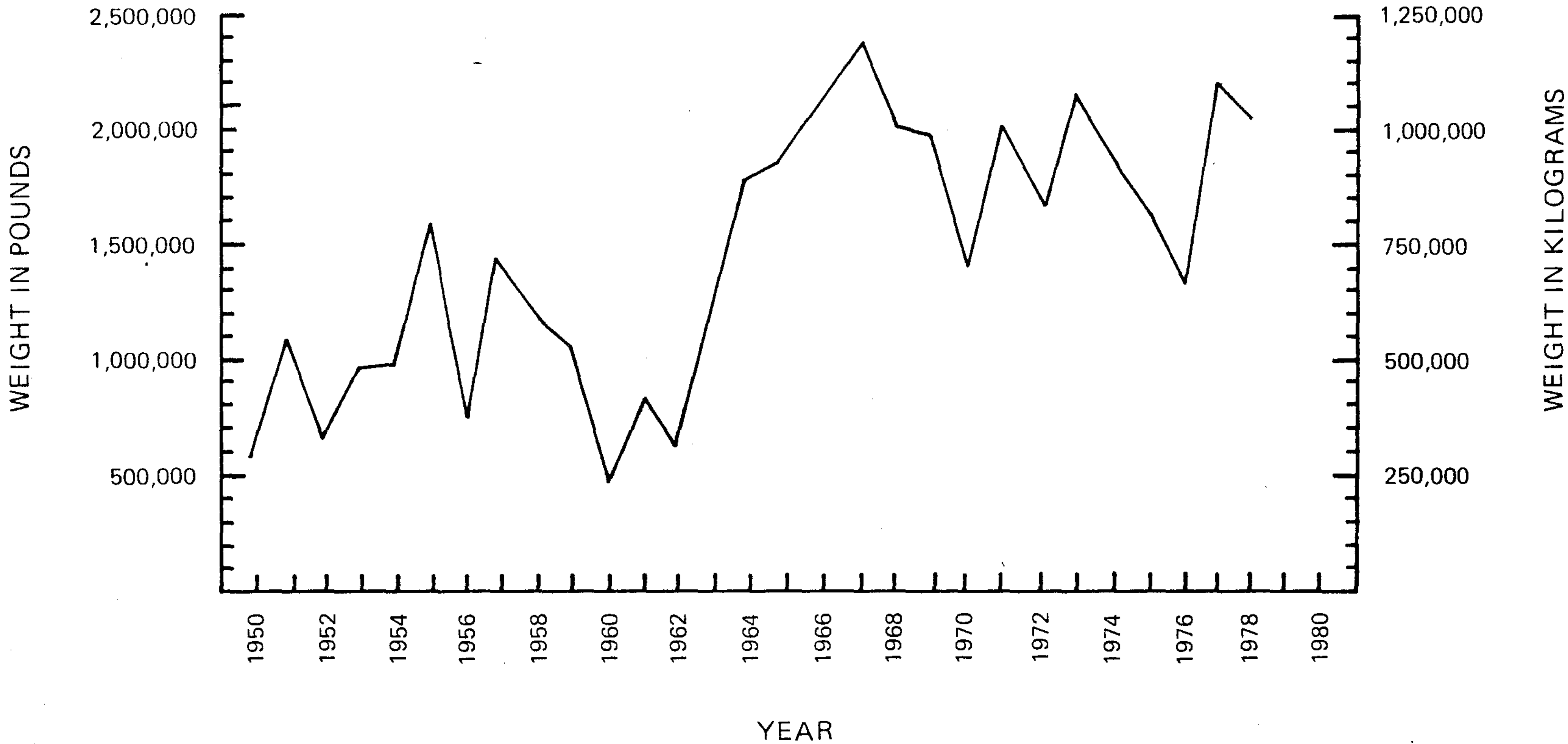


Figure 79. Total landings of blue crab in Alabama since 1950.

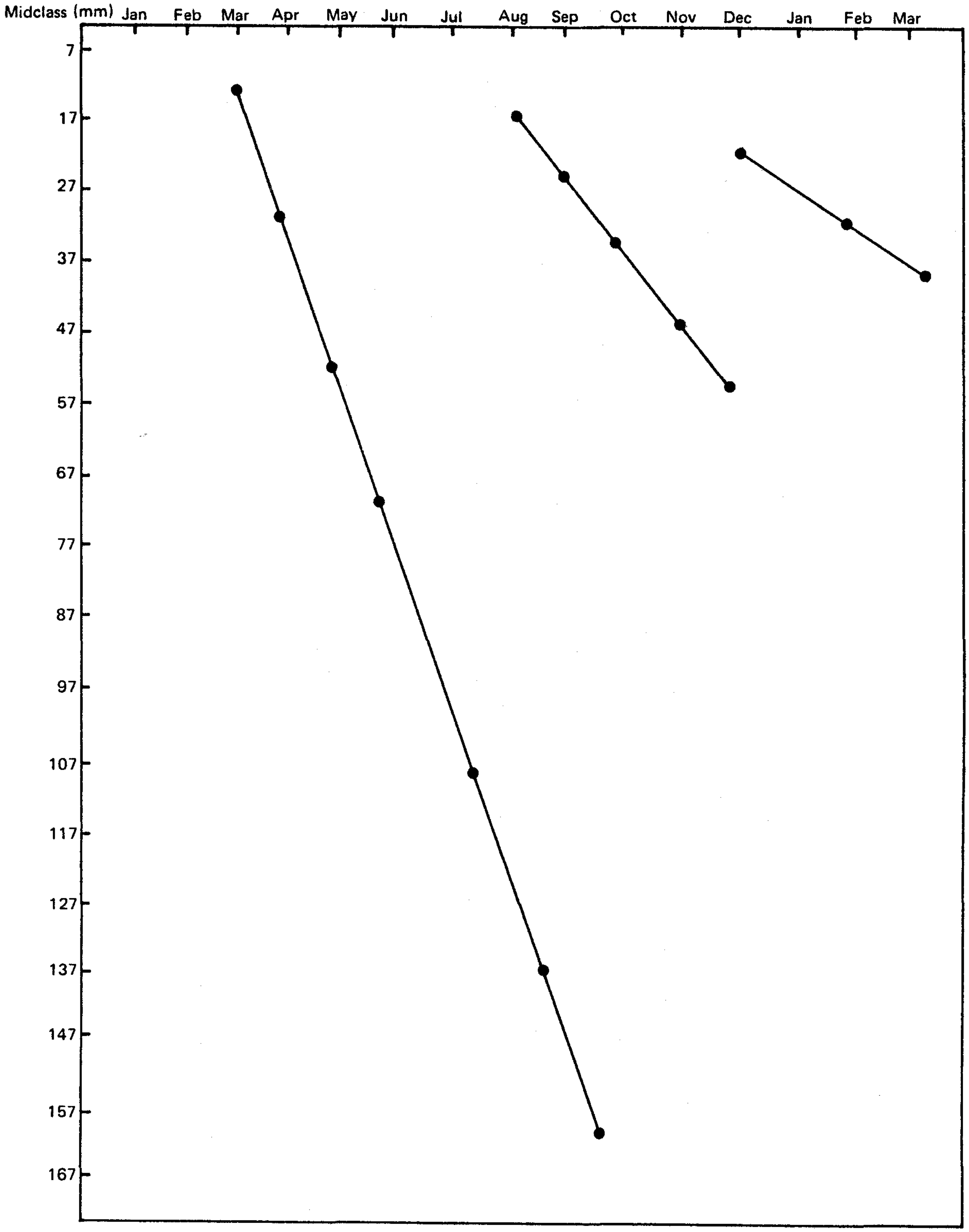


Figure 80. Size distribution of blue crab taken in Alabama during 1968 and 1969 (Tatum 1979).

Table 52. Land snails of Mobile and Baldwin Counties (Rawls 1953).

Anguispira alternata macneilli	*Polygyra septemvolva febigeri*
Anguispira crassa	*Polygyra septemvolva volvoxis*
Bulimulus dealbatus dealbatus	*Praticolella mobiliana mobiliana*
Carychium exile	*Punctium minutissimum*
Coccinea ovalis	*Pupisoma macneilli*
Discus patulus	*Pupoides albilabris*
Euconulus chersinus chersinus	*Retinella circumstriata*
Euglandina rosea	*Retinella carolinensis*
Gastrocopta armifera	*Retinella cryptomphala*
Gastrocopta contracta	*Retinella indentata paucilirata*
Gastrocopta corticaria	*Retinella lewisiana*
Gastrocopta pellucida	*Rumina decollata*
Gastrocopta pentodon	*Stenotrema leai aliciae*
Gastrocopta procera procera	*Stenotrema spinosum*
Gastrocopta rupicola	*Stenotrema stenotrema*
Gastrodonta interna	*Striatura meridionalis*
Guppya sterki	*Strobilops aenea*
Haplotrema concavum	*Strobilops hubbardi*
Hawaiia miniscula	*Strobilops labyrinthica*
Helicina orbiculata	*Strobilops texasiana texasiana*
Helicodiscus parallelus	*Strobilops texasiana floridana*
Lamellaxis gracilis	*Succinea avara*
Mesodon inflectus inflectus	*Succinea campestris*
Mesodon inflectus mobilensis	*Succinea concrodialis*
Mesodon perigraptus	*Succinea unicolor*
Mesodon rugeli	*Triadopsis obstricta obstricta*
Mesodon thyroidus	*Ventridens demissus*
Mesomplix vulgatus	*Ventridens gularis gularis*
Paravitrea capsella	*Ventridens intertextus*
Polygyra auriformis	*Ventridens ligera*
Polygyra leporina	*Vertigo oralis*
Polygyra plicata	*Vertigo ovata*
Polygyra pustuloides	*Zonitoides arborius*

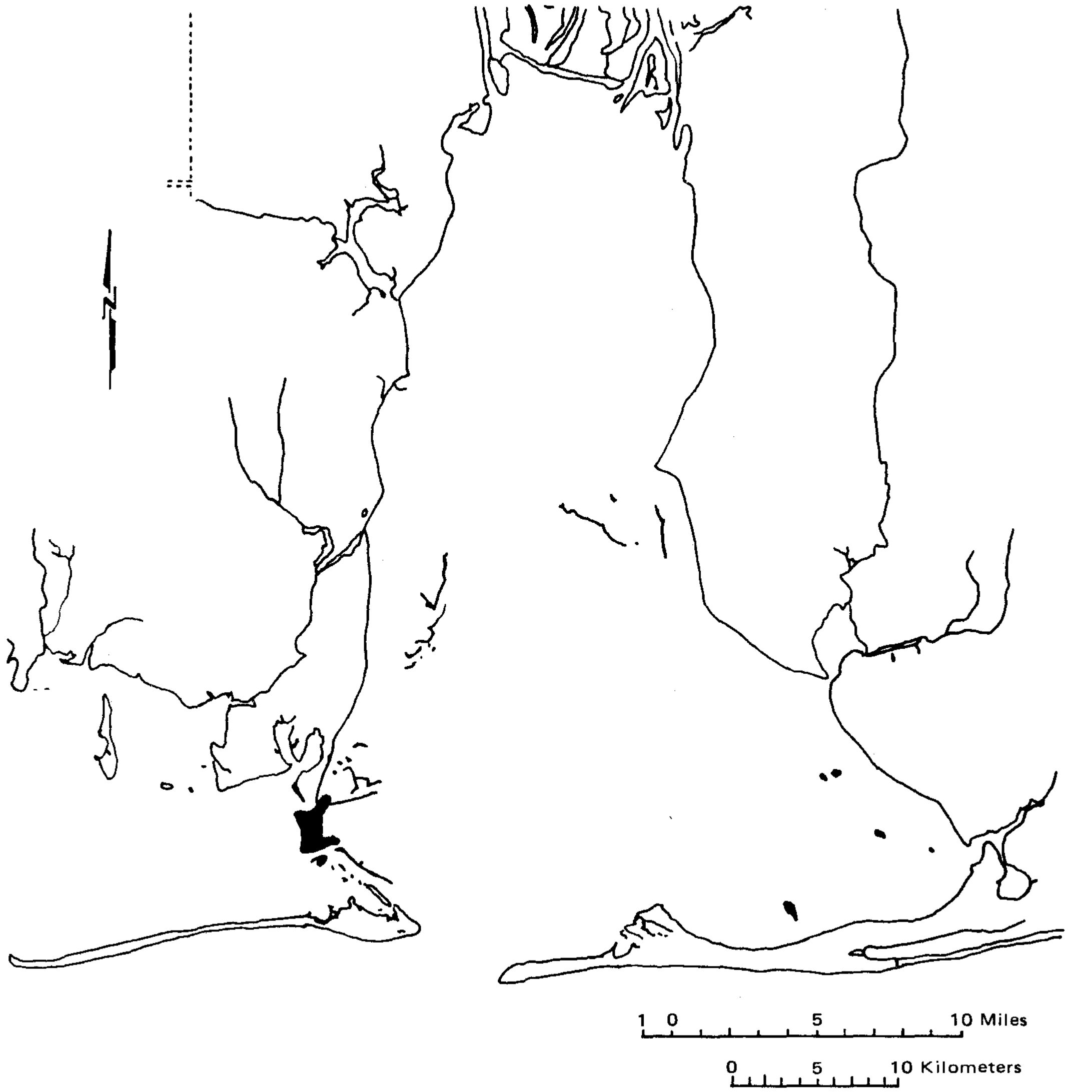


Figure 81. Living oyster reefs in Mobile Bay and eastern Mississippi Sound (May 1971b).

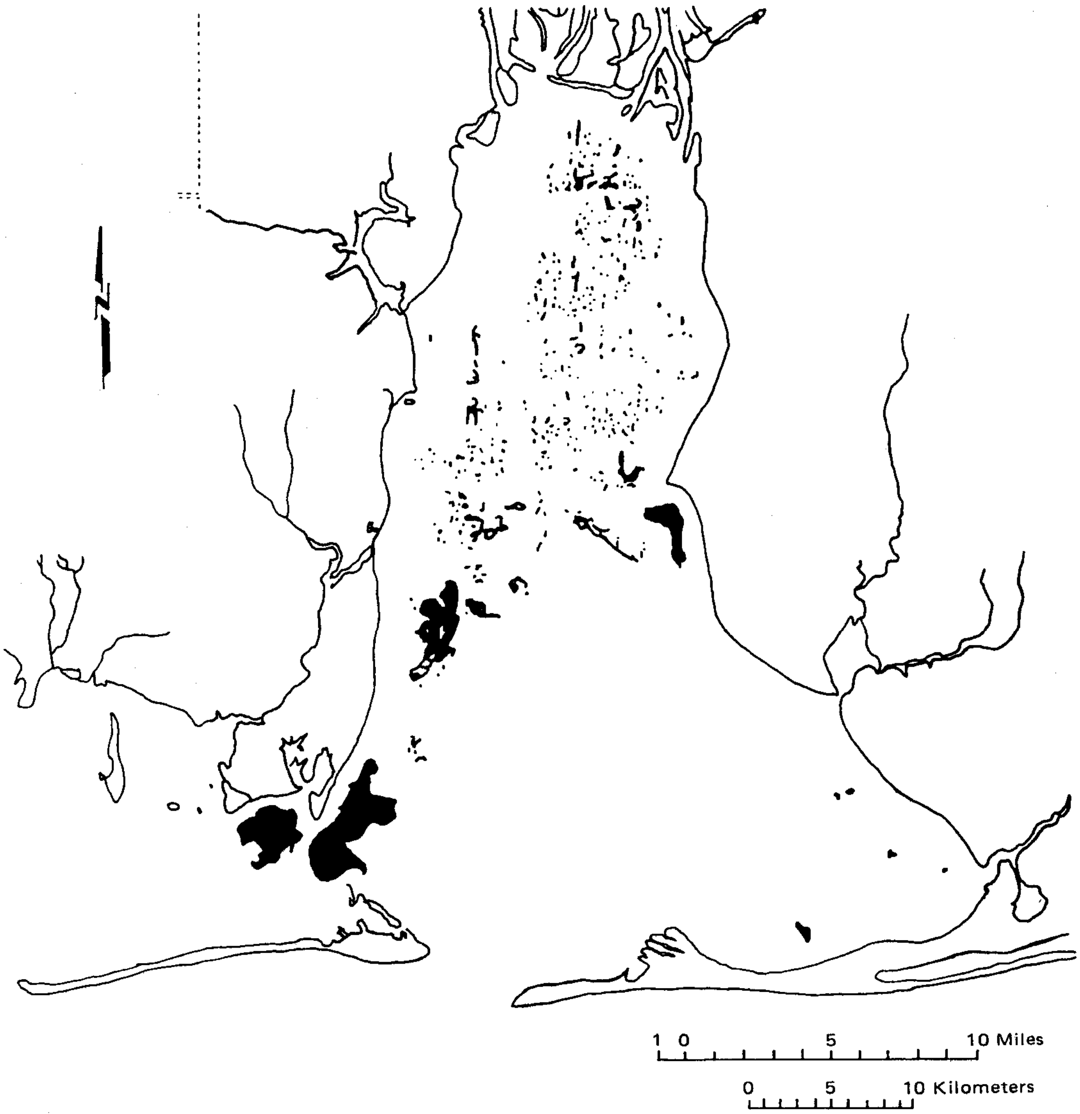


Figure 82. Oyster shell deposits, living and dead, in Mobile Bay and eastern Mississippi Sound (May 1971b).

Oyster landings at Alabama ports have fluctuated considerably from 1950 through 1979 (Figure 83). Several environmental stresses account for this irregular pattern. The major cause of oyster kills in the Mobile Bay-Mississippi Sound area is prolonged periods of lowered salinity called "freshies" caused by heavy inland rainfall. May (1972) reported that Mobile Bay oysters can survive salinities below 3.0 ppt for about 4 or 5 weeks whereas prolonged periods of exposure (>7 weeks) of salinities ≤1.0 ppt can cause significant mortality. Large volumes of freshwater usually carry large silt loads which can partially cover oyster beds and reduce setting of spat (May 1972). Increased siltation due to dredging operations similarly retards oyster population growth (May 1968).

Although no mortality in oysters has been directly attributed to the organic and inorganic wastes produced by municipal and industrial sources in northern Mobile Bay (May 1971a), it has resulted in the permanent closing of 29,288 ha (72,370 acres) of oyster bottoms to shellfish harvesting. Additional acreage closed to oystering around Bayou La Batre, Coden Bayou, Dauphin Island Bay, and Bon Secour River brings the total acreage closed to oyster harvesting to 29,779 ha (73,584 acres).

Biological factors, including "dermo" (*Perkinsum marinus*) and the oyster drill (*Thais haemastoma*) (May 1968; Crance 1971), have adversely affected the oyster harvest in Mobile Bay. Average salinities in excess of 15 ppt are optimum for oyster drill survival and their destruction of oyster beds (May and Bland 1969). Although the bottoms in Heron Bay, Dauphin Island Bay, Portersville Bay, and Grand Bay are very suitable for oyster productions, no marketable oysters (over 3 inches) are harvested there due to the extensive destruction of oyster populations by the oyster drill. "Dermo" is caused by a protozoan usually transmitted by crabs, leeches, or planktonic animals. Susceptibility of oysters to "dermo" is greatest during the summer when water is warm and salty. "Dermo" causes the most destruction to oyster reefs because it attacks and spreads rapidly and no preventative or cure is known (Echmayer 1979). Percent infection and weighted incidence of "dermo" in Mobile Bay oysters during 1968 and 1969 averaged 75.2% and 1.79 for southern reefs and 27.6% and 0.29 for northern reefs, respectively (Beckert et al. 1972). These observations were attributed to salinity and temperature differences among reefs. In addition, infection was greatest on reefs with more large oysters (>50 mm or 4 inches) and reefs with denser populations (Beckert et al. 1972).

During 1979, the Alabama oyster population was reduced by 85% because of a severe flood in the spring and Hurricane Frederic in the fall (Echmayer 1980). When the eye of Hurricane Frederic moved ashore, the wind direction changed and covered oyster reefs with sand and mud. About 64% of the spat and 90% of the oysters were lost. During 1980 the Marine Resources Division of the Alabama Conservation Department aided in reef recovery by planting 93,986 m^3 (122,922 yds^3) of clam shells in six different locations within the bay (Figure 84). The planted area totaled 320 ha (791 acres) and was completed by June 1980. Harvestable quantities of oysters are expected by 1982.

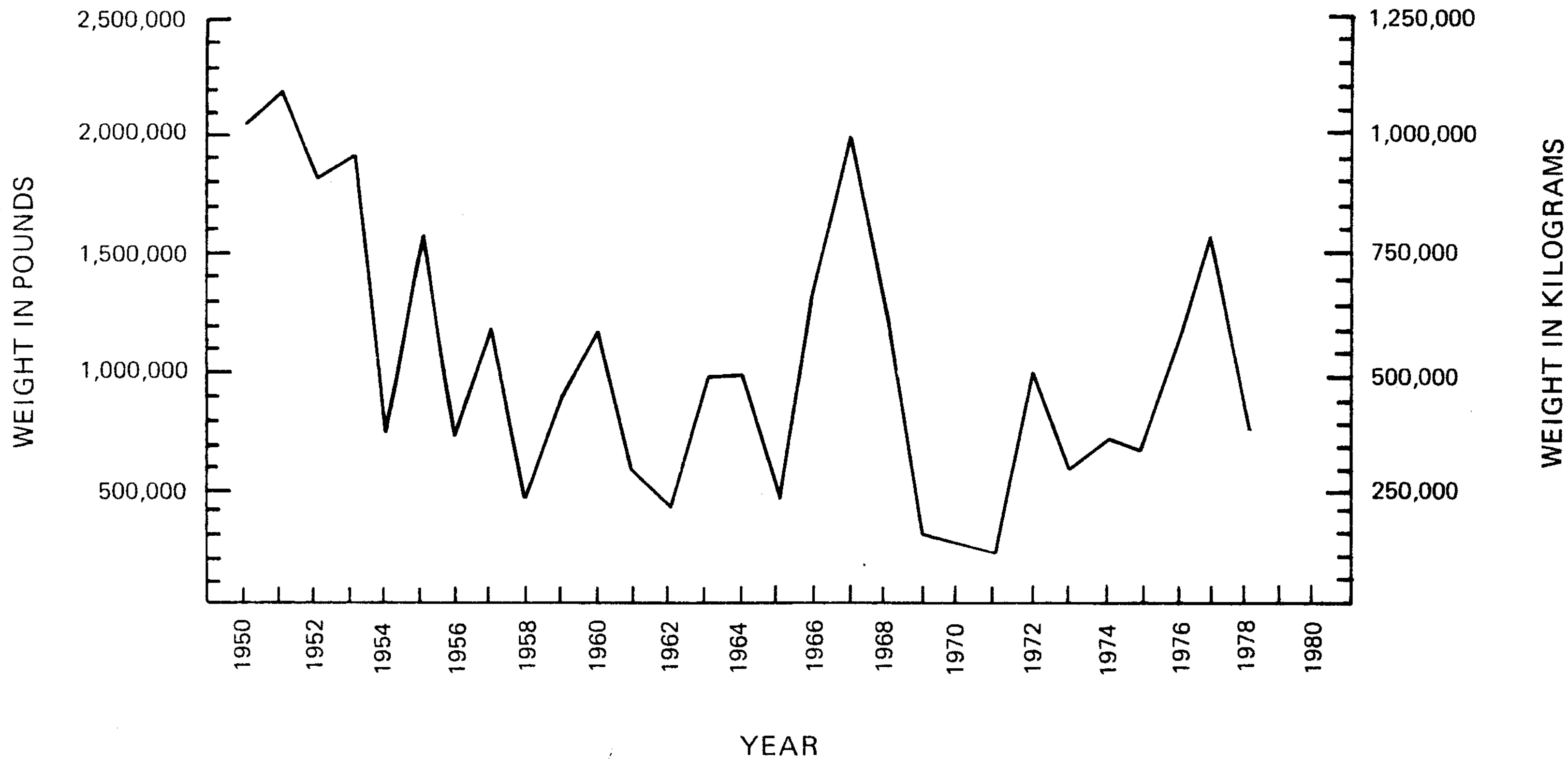


Figure 83. Total landings of oysters in Alabama since 1950.

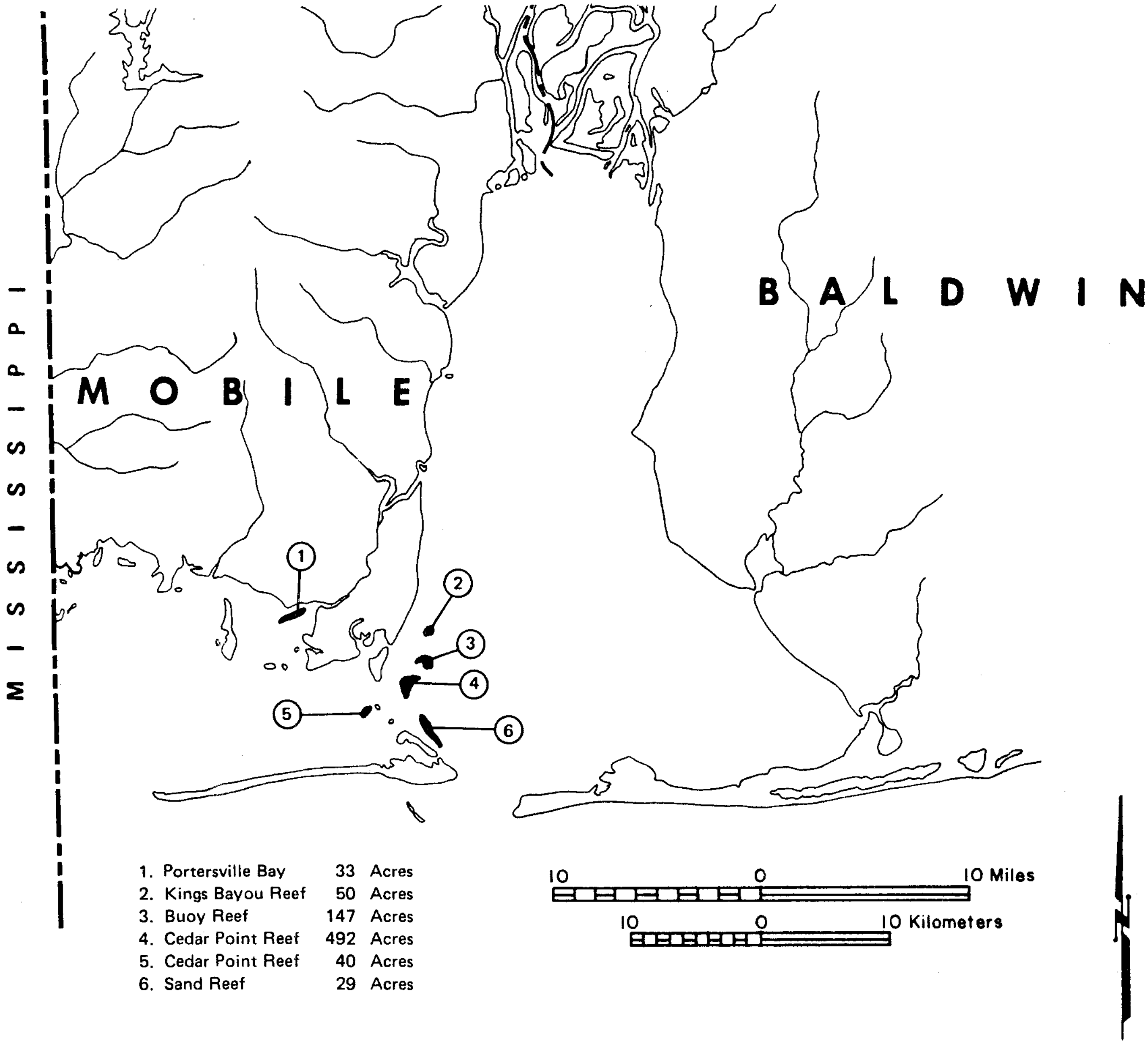


Figure 84. Clam shell plantings in lower Mobile Bay and eastern Mississippi Sound in 1980 following Hurricane Frederic (Echmayer 1980).

FISHES

South and coastal Alabama contains a wide variety of habitats for fishes. These habitats may be classified into three major types: the open gulf, the estuary, and freshwater streams. Previous studies on fish species of the area include Boschung (1957), Hemphill (1960), Swingle (1971), Beckham (1973), Swingle and Bland (1973, 1974a), Chermock (1974), Shipp (1979), and Tucker (1979).

A total of 310 fish species belonging to 83 families have been recorded from south and coastal Alabama (Table C-2). Of these, 134 were distributed in only one habitat with the greatest number (70) occurring in freshwater and the least (21) in the estuary (Table 53). Gunter et al. (1974) indicated that the fewest permenent residents were found in estuaries because of wide variations in salinity found there. Most of the 176 species that are distributed in more than one habitat, however, do occur in the estuarine area at sometime during an annual cycle.

The economic importance of Alabama's estuarine fishes has been emphasized by numerous authors. The estuary is the base of this commodity since it serves as a valuable source of food products as well as an excellent breeding ground and nursery for many gulf and estuarine residents. Both Swingle (1971) and Chermock (1974) indicated that over 80% of Alabama's estuarine fish species were important to coastal fisheries. Gunter (1961) stated that the most important fishery industry in North America was located on the northern Gulf of Mexico coast and that 98% of the animals utilized in this fishery spent some stage of their life in the estuary.

Sport and Commerical Fishes

The largemouth bass (*Micropterus salmoides*) or "green trout" as locally known, is a popular sport fish in the Mobile Delta. Approximately 20% of the fishes caught by sport fishermen are largemouth bass (Tucker 1979). Although bass productivity is high in the Mobile Delta, the average size of individuals in this region is smaller than in inland freshwaters of the State. Swingle et al. (1966) reported that the average size of largemouth bass in the delta was 275 g (0.6 lb). Crowding is usually attributed as the cause of this reduced size condition.

Spawning of largemouth bass occurs during spring flooding which usually yields good conditions for a successful spawn. Swingle and Bland (1974a) reported that all age groups of bass were present in the lower delta during winter and spring, but as salinity increased, only age 0 bass were present.

To satisfy the demand for larger bass within the delta, the Alabama Department of Conservation recently introduced 979 fingerling Florida largemouth bass (*Micropterus salmoides floridanus*). The Florida bass can attain larger sizes than the native northern subspecies (*Micropterus salmoides salmoides*) and hybrids of the two subspecies usually grow faster and to larger sizes than either of the two subspecies.

Several species of sunfish known collectively as "bream" occur throughout the delta.

Table 53. Species restricted to one habitat or dispersed within various habitats in coastal Alabama.

Habitat	Restricted species	Dispersed species	Total
Open gulf	43	144	187
Estuary	21	165	186
Freshwater	70	40	130

These fishes comprise about 45% of the harvest by sport fishermen (Tucker 1979). Species usually caught are rock bass (*Ambloplites ariommus*), redear sunfish (*Lepomis microlophus*), bluegill (*L. macrochirus*), spotted sunfish (*L. punctatus*), longear sunfish (*L. megalotis*), green sunfish (*L. cyanellus*), and warmouth (*L . gulosus*). Black and white crappie (*Pomoxis nigromaculatus* and *P. annularis*) make up about 9% of the game-fish harvest in the delta.

The striped bass (*Morone saxatilis*) was once very common throughout coastal Alabama. Impoundments on larger rivers throughout the State have blocked spawning migrations of these fishes so that only a vestige of the former fishery exists today. The striped bass spawns in flowing freshwater and returns to the sea for growth. Since 1967, 2,652,503 fingerlings have been stocked in the Mobile Delta and surrounding waters. These fishes have not spawned naturally and a stocking program is required to maintain this sport fishery.

The singlemost important sport fishery of Mobile Bay is the spotted seatrout (*Cynoscion nebulosus*) (Wade 1979). Seatrout reach sexual maturity between the ages of one and four years with males maturing earlier (Guest and Gunter 1958). Most females do not spawn until their second or third summer while some males spawn at age one. The spawning season ranges from May through September along the northern gulf. Seatrout are resident fishes with movements usually restricted to a 48-km (30-mi) area. Optimum habitat consists of grassy flats in brackish water. There is a commerical fishery for seatrout in Mobile Bay that operates during winter months when seatrout have migrated into deep channels and holes in the upper bay. The biology of the seatrout has been summarized by Wade (1979).

The Atlantic croaker (*Micropogonias undulatus*) is very common throughout Mobile Bay and surrounding waters (Swingle 1971). Croakers occur in water with salinities from 0 to over 35 ppt and are present in the bay throughout the year. Peak spawning occurs offshore at depths up to 20 m (65 ft) from October through February. Larvae enter Mobile Bay and Mississippi Sound at a length of about 5 mm (0.2 inch). Growth is rapid within the estuary with emigration back into the gulf occurring in the fall at a size of about 20 mm (5 inches). Croaker feed extensively on benthic animals, small fishes, and shrimps. Annual mortality rates of croaker have been estimated to range from 57 to 95% (Swingle 1979).

Several other species of sportfish caught within Mobile Bay and the surrounding gulf include bluefish (*Pomatomus salatrix*), crevalle jack (*Caranx hippos*), king mackerel (*Scomberomorus cavalla*), Spanish mackerel (*Scomberomorus maculatus*), little tunny (*Euthynnus alletteratus*), red drum (*Sciaenops ocellata*), sand seatrout (*Cynoscion arenarius*), and various species of sharks (Table 54).

AMPHIBIANS

The majority of amphibians spend their larval stages in fresh water, breathing by means of gills. They then undergo metamorphosis, developing lungs permitting them to directly breathe air. Their bodies undergo structural changes, such as developing legs, which adapts them for movement on land. Like frogs, most salamanders have an aquatic larval stage in their life cycle. The one exception to this general life history strategy is the slimy salamander (*Plethodon glutinosus*). This species lays its eggs on land in a protected damp habitat. Metamorphosis takes place within the egg; and the young, on hatching, are adapted for terrestrial survival. Amphibians, therefore, are dependent upon the availability of freshwater for their survival.

Eighteen species of salamanders are found in coastal Alabama (Chermock et al. 1975; Mount 1975) (Table C-3). Some, such as the waterdogs (*Necturus* spp.), do not

Table 54. Estimated catch (pounds) of marine sportfish in Alabama during 1975 (Wade 1979).

Common name	Private boat	Pier	Shoreline	Charter boat	Total
Amberjack	10,306	--	--	133,144	143,450
Black drum	--	5,285	5,147	--	10,432
Bluefish	885,182	17,155	5,923	--	908,260
Blue runner	63,560	1,503	--	--	65,063
Catfish	80,699	51,360	8,909	--	140,968
Cobia	100,565	32,673	--	5,544	183,782
Croaker	441,477	40,715	43,957	--	526,149
Dolphin	51,689	--	--	6,028	57,717
Flounder	76,884	44,869	4,476	--	126,229
Grouper	--	--	--	3,850	3,850
Jack crevalle	156,051	39,283	15,989	4,969	216,292
Kingfish	70,092	53,029	17,641	--	140,762
King mackerel	939,054	38,438	--	76,494	1,053,986
Ladyfish	163,972	5,652	--	--	169,624
Little tunny	333,506	7,396	--	47,542	388,444
Mullet	42,583	2,855	35,062	--	80,500
Pompano	--	1,267	64	--	1,331
Red drum	306,719	35,723	44,690	--	387,132
Sand seatrout	483,822	17,586	18,893	--	520,301
Shark	563,028	33,662	--	--	596,690
Sheepshead	145,030	49,208	10,698	--	204,936
Snapper	79,410	1,750	--	57,882	139,042
Spanish mackerel	920,622	26,589	--	14,498	961,709
Spotted seatrout	774,740	14,679	9,218	--	798,627
Miscellaneous	195,568	34,413	17,512	--	247,493
Total	6,884,559	555,090	238,179	349,951	8,027,779

undergo metamorphosis and are permanently aquatic. The central newt (*Notopthalmus viridescens*) has three stages in its life cycle. Their larvae are aquatic with gills. These transform into an eft stage which is terrestrial and breathes with lungs. The adults again become aquatic but still breathe with lungs. Some salamanders, although terrestrial as adults, lack lungs and respire through their moist skin. Because of potential loss of body water by evaporation, these salamanders are normally restricted to moist habitats with high humidity or are semiaquatic (Orr 1971).

Twenty-two species of frogs and toads occur in coastal Alabama (Chermock et al. 1975) (Table C-3). All have an aquatic tadpole stage. The adults of some genera (*Rana*, *Acris*) are semiaquatic and are usually found in or near water. Others, such as members of the genera *Bufo* and *Hyla*, have a dry cornified skin which prevents excessive loss of body water by evaporation and allows them to live in relatively dry environments, although they return to water to breed.

In general, amphibians are beneficial because they feed to a great extent on insects and other small animals. The legs of the larger species such as the pig frog, river frog, and bullfrog are prized by many as food.

REPTILES

Coastal Alabama has a great variety of reptiles occurring within its boundaries including 21 species of turtles, 10 species of lizards, 36 species of snakes, and the alligator (Chermock et al. 1975; Mount 1975) (Table C-4). Five species of sea turtles are found offshore. Two of these, the green turtle (*Chelonia mydas*) and the Atlantic ridley (*Lepidochelys kempi*) may at times enter estuaries. The loggerhead turtle (*Caretta caretta*) at one time nested on the gulf beaches of Dauphin Island (Jackson and Jackson 1970), but the incursion of civilization has reduced their numbers. Two reptiles the diamondback terrapin (*Malaclemys terrapin*) and the salt marsh water snake (*Nerodia fasciata clarki*) normally occur in brackish water of the estuarine tidal marshes. Occasionally, the alligator (*Alligator mississippiensis*), Florida cooter (*Pseudemys floridana*), and red-bellied turtle (*Pseudemys alabamensis*) will enter brackish water. Of the other species of turtles found in coastal Alabama, the box turtle (*Terrapene carolina*) and the gopher tortoise (*Gopherus polyphemus*) are terrestrial, and the remaining species are normally associated with freshwater habitats.

Many turtles are used for food in the coastal area. Among these are the snapping turtle (*Chelydra serpentina*), softshell turtles (*Trionyx* spp.), chicken turtle (*Deirochelys reticularia*), and gopher tortoise. Among the sea turtles, the green turtle is widely hunted for food. The diamondback terrapin of the gulf coast is related to the famous terrapin of Maryland which is highly prized for food.

All snakes occurring in coastal Alabama are classified into three families: Colubridae, non-poisonous snakes; Elapidae, coral snakes; and Viperidae, poisonous pit-viper snakes, which include the copperhead, cottonmouth, and rattlesnakes. Snakes are ecologically important in that they can control population levels of crop damaging rodents and sometimes disease-carrying animals such as rats and some mice.

The coral snake (*Micrurus f. fulvius*) is highly poisonous, having a neurotoxic venom which affects the central nervous system. These snakes are fairly small, usually 0.5 to 0.8 m (1.6 to 2.6 ft) long and are brightly colored with rings of yellow, black, and red. Because the coral snake has a small mouth and short fangs, it is difficult for it to bite man. These snakes are secretive, usually found under leaves, debris, or in rotten logs in wooded areas.

The copperhead (*Agkistrodon contortrix*) adult measures 0.6 to 0.9 m (2 to 3 ft) in length. It is pinkish-tan with a series of chestnut-colored hourglass markings across the back. These snakes are often found in lowland wooded areas, but they also occur in upland forests.

The cottonmouth (*Agkistrodon piscivorus*) adult measures 0.8 to 1.2 m (2.5 to 4 ft). The young are brightly colored and resemble the copperhead. As they mature, they become dark brown to black with obscure markings. Individuals are found in or near freshwater throughout coastal Alabama and are particularly abundant in lowland swampy areas.

The pigmy rattlesnake (*Sistrurus miliarius*) is a small snake rarely exceeding 0.6 m (2 ft) in length. Body color is grayish-tan with dark rounded spots. Individuals are most frequently found in flatwoods, near lakes or marshes.

The timber or canebrake rattlesnake (*Crotalus horridus*) varies in length from 1.1 to 1.5 m (3.5 to 5 ft) as adults. The ground color is pale grayish-brown with black cross-bands. A reddish stripe extends lengthwise along the back on the front end of the body. This snake is most commonly found in lowland cane thickets and swamps.

The diamondback rattlesnake (*Crotalus adamanteus*) adult measures from 0.9 to 1.8 m (3 to 6 ft). The dark brown or black diamonds, outlined with cream-colored scales on the back, make this dangerous snake easy to identify. They are most common in pine and palmetto flatwoods.

The ten lizard species found in coastal Alabama are terrestrial. Skinks (*Eumeces* spp.) are active during the daytime but often take shelter under rocks, logs or litter where the ground is humid. The racerunner (*Cnemidophorus sexlineatus*) is found in open dry areas of sand or loose soil. The green anole (*Anolis carolinensis*) is usually seen crawling over vines or shrubs. Fence lizards (*Sceloporus undulatus*) are most abundant in the open pine savannahs. Glass lizards (*Ophisaurus* spp.), which are legless burrowing reptiles, are most abundant in pine savannahs and grasslands. None of the lizards found in coastal Alabama are poisonous.

BIRDS

No region of Alabama has as rich and varied a birdlife as the coastal area of the State. Imhof (1976) indicated that more than 300 species occur in coastal Alabama (Table C-5) primarily due to the great diversity of habitats. These species include marine birds such as gulls, terns, frigatebirds, skimmers,and pelicans. Numerous species are also found on beaches and mudflats including sand pipers and plovers. In the tidal marshes are rails, herons, and egrets. Ducks, coots, and cormorants abound in open waters of the delta each winter. In spring, thousands of thrushes, warblers, and other birds stop on Dauphin Island after crossing the Gulf of Mexico during their northward migration. People from throughout the State and other parts of the country visit coastal Alabama throughout the year to observe and study its birdlife.

Coastal birds are usually grouped into categories which reflect their primary pattern of occurrence in the region. Permanent residents are those species which nest and are found throughout the year in an area. About 70 species can be considered permanent residents and include such birds as the great blue heron, vultures, several hawk species, woodpeckers, starlings, and a few species of perching birds.

Summer residents nest in the region during the summer and migrate further south for the winter. Examples include cattle egrets, frigatebirds, white ibis's, hawks, terns, and a few species of warblers.

Migrants pass through coastal Alabama in the fall and spring as they migrate between summer nesting grounds in the north and wintering grounds in the south. Examples of migrants include the American bittern, geese, several species of wading birds, cliff swallows, and the blue wing teal.

Winter visitors include those species which nest in the North during summer and overwinter in the coastal area. Around 100 species are considered winter visitors and includes loons and grebes, ducks and coots, whip-poor-will's, wrens, and several species of warblers and blackbirds.

Casuals are those species which normally do not occur in the area but are occasionally seen. The brown booby, white-faced ibis, short-eared and burrowing owls, and black-necked stilt, to name a few, have been reported as casuals along coastal Alabama (Imhof 1976).

Of special interest in estuarine ecosystems are wading birds and their associated nesting colonies. Wading birds provide a terminal link in many food webs and their presence or absence can be indicative of environmental trends within the estuary (Johnson 1979). Wading birds will usually nest on isolated coastal islands or in secluded marshes and wetlands. Despite conservation efforts, wading bird populations are declining in size along the entire gulf coast. Thirteen species of wading birds (Table 55) either currently or in the past have utilized nesting areas within coastal Alabama (Figure 85; Table 56). Of the more common species, the great blue heron (*Ardea herodias*), little blue heron (*Florida caerulea*), Louisiana heron (*Hydranassa tricolor*), green heron (*Tutorides striatus*), and snowy egret (*Egretta thula*) commonly nest in the more saline marshes along the coast whereas the cattle egret (*Bubulcus ibis*) nests more commonly in inland marshes and swamps (Johnson 1979).

Table 55. Wading birds nesting in coastal Alabama, the number of colonies in which they occur, and their present status in three habitat types (Johnson 1979).

Species	Coastal				Inland				Mobile River--Delta			
	A[a]	NA	UK	T	A	NA	UK	T	A	NA	UK	T
Great blue heron	2	2	2	6								
Little blue heron	2	1	3	6	2	1	3	6	--	--	3	3
Louisiana heron	2	2	2	6								
Green heron	3	1	--	4	--	1	2	3	--	--	2	2
Snowy egret	2	--	1	3								
Cattle egret	1	1	1	3	2	1	2	5	--	--	1	1
Great egret	1	1	--	2					--	--	1	1
Reddish egret	--	--	1	1								
Glossy ibis	1	--	--	1								
White-faced ibis	1	--	--	1								
White ibis	--	--	1	1	1	--	--	1	--	--	2	2
Yellow-crowned night heron									--	--	2	2
Black-crowned night heron	1	--	--	1								

[a]A--Active, currently nesting; NA--Not active, has nested in the past 20 years but not observed recently; UK--Unknown, data is older than 20 years and a status is not known; T--Total.

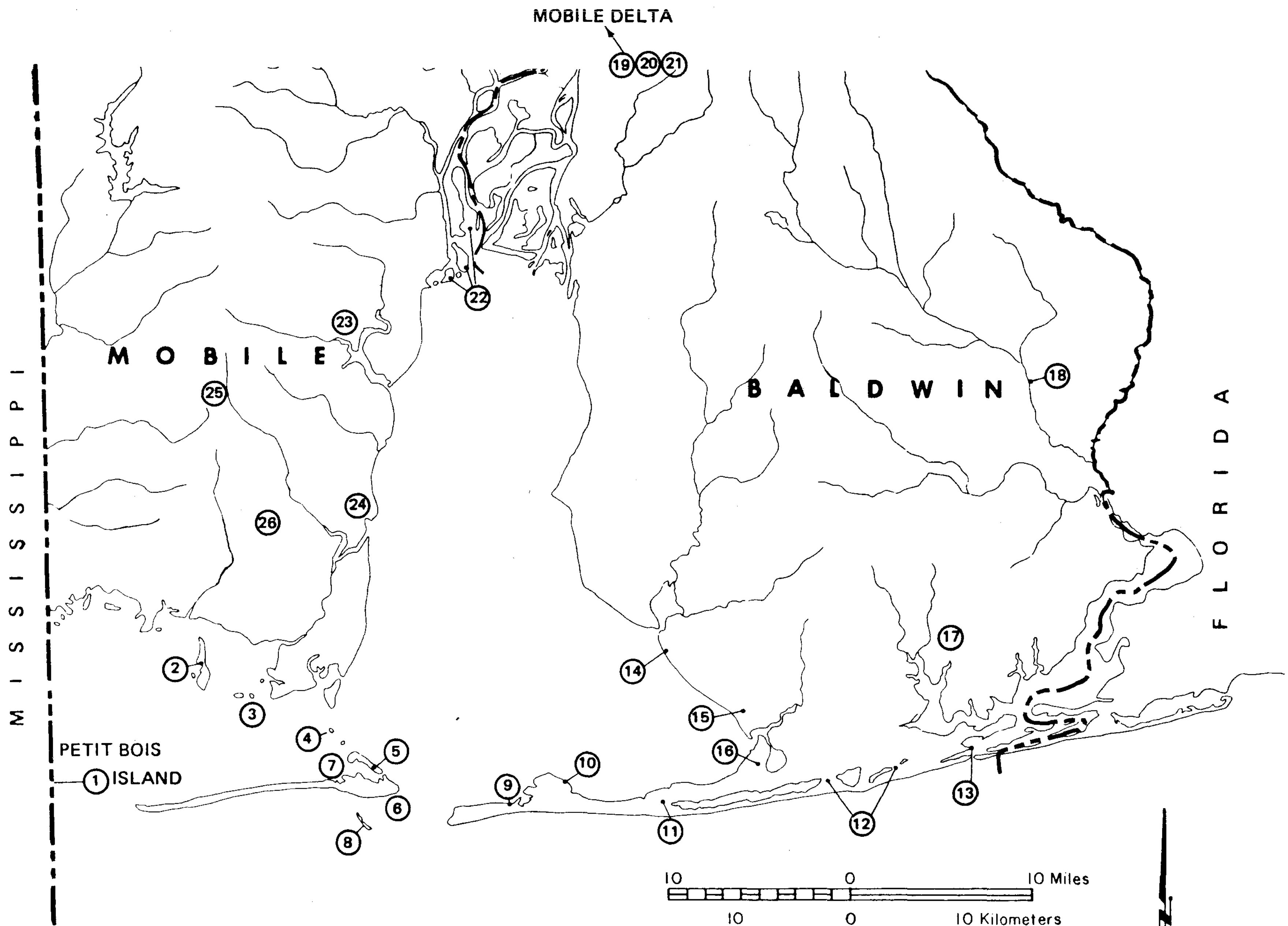


Figure 85. Distribution of wading bird nesting colonies in coastal Alabama (Johnson 1979).

Table 56. Wading bird nesting colonies identified for coastal Alabama, species present, and their present status (Johnson 1979).

Colony[a] number	Colony location	Species present[b]	Present[c] status
1	Petit Bois Island	CE,GE,LH	NA
2	Isle Aux Herbes	LH	NA
3	Cat Island	CE,GE,SE,RE,GH,LH LB,WG,GI,WI	A
4	Grant's Isle	LH,SE	A
5	Pass Drury	LB,GH	NA
6	Dauphin Island Audubon Sanctuary	GB,LB,GH	A
7	Salt Creek	GH,BC	A
8	Sand Island	Colonial Seabirds (see text)	--
9	Navy Cove	GB	NA
10	Little Point Clear	GB	UK
11	Little Alligator Lake	GB	NA
12	Gulf Shores-- Orange Beach	GB	UK
13	Walker Island	GB	A
14	Weeks Bay	SE,LH,LB	UK
15	Bon Secour River	CE	UK
16	Oyster Bay	LH,LB	UK
17	Miflin Creek	LB,CE	NA
18	Gatewood Colony	CE,LB,WI	A
19	Southfield and Mims Lake	WI,GE,LB,YC	UK
20	Miflin Lake	GH,LB	UK
21	Negro Lake	GH,LB,WI,CE,YC	UK
22	Blakeley Island	Colonial Shore birds	--
23	Dog River	GH,LB,CE	UK
24	East Fowl River	GH,LB	UK
25	Theodore-Dawes Road	LB	A
26	Deakle's Farm	CE	UK

[a]Colony numbers used in Figure 85.

[b]Species abbreviations: GB (Great Blue Heron), LB (Little Blue Heron), LH (Louisiana Heron), GH (Green Heron), SE (Snowy Egret), CE (Cattle Egret), GE (Great Egret), RE (Reddish Egret), GI (Glossy Ibis), WFI (White-faced ibis), WI (White ibis), YC (Yellow-crowned Night Heron), BC (Black-crowned Night Heron).

[c]Colony status abbreviations: A (Active), NA (Not Active), and UK (Unknown).

Table 57. Wintering populations of ducks and coots in the lower Mobile Delta (Beshears 1979).

	November		December		January	
Year	Ducks	Coots	Ducks	Coots	Ducks	Coots
1952	39,925	26,065	36,065	20,280	37,222	18,600
1953	20,810	25,000	32,342	12,000	18,488	15,000
1954	23,268	15,150	29,420	15,800	21,545	19,000
1955	12,750	10,000	17,045	11,800	14,930	8,600
1956	19,200	15,000	27,150	18,000	21,310	17,005
1957	11,870	6,300	9,715	11,800	12,627	12,000
1958	25,000	25,000	18,800	16,000	18,625	16,275
1959	14,060	13,050	16,000	15,000	13,165	19,450
1960	23,146	21,440	18,250	25,000	19,759	29,500
1962	11,700	13,925	17,151	18,760	18,800	18,300
1962	22,000	17,975	29,935	36,265	28,599	28,825
1963	28,050	27,175	24,170	23,225	17,850	19,950
1964	17,842	24,700	17,200	15,000	18,922	17,600
1965	36,805	35,550	20,000	12,000	22,500	16,225
1966	25,000	25,000	18,450	27,200	18,475	20,600
1967	5,560	8,200	11,743	14,644	10,000	10,000
1968	17,500	7,250	19,175	22,580	7,575	7,625
1969	12,303	20,825	14,778	12,115	10,600	10,000
1970	15,126	31,240	7,116	20,905	6,765	14,035
1971	13,387	35,225	8,365	17,760	7,198	12,725
1972	8,559	16,745	5,160	11,550	5,043	11,595
1973[a]			12,108	35,100	6,300	21,800
1974			22,948	28,150	4,918	15,595
1975			13,476	36,360	5,610	27,570
1976			13,931	37,942	10,895	28,722
1977			11,990	19,050	10,680	22,900
1978[b]	12,300	16,600			12,000	14,000

[a]Only two counts per year have been made since 1973.
[b]The 1978 census was on 11/13/78 because of the zoning of Mobile and Baldwin Counties and early opening of the duck season on 11/16/78. From 1973 through 1977, the first inventory was about December 1, or just prior to opening of the hunting season.

Cat Island, located 11 km (6.8 mi) north of Dauphin Island, is an important reproductive area for several species of wading birds (Table 56). About half of the island is covered by tidal marsh, which provides ideal nesting habitat. Johnson (1979) reported about 2,500 nests as occurring on Cat Island during the breeding season making it the largest nesting colony in coastal Alabama.

In addition to wading birds, colonial shore and sea birds maintain active colonies in coastal Alabama. The largest is located on Sand Island, just south of Dauphin Island. Species known to nest on Sand Island include the black skimmer (*Rynchops nigra*), common tern (*Sterna hirundo*), gull-billed tern (*Gelochelidon nilotica*), least tern (*Sterna albifrons*), and the snowy plover (*Charadrius alexandrinus*). Another nesting area for colonial birds are dredge spoil areas of Blakeley, Pinto, and McDuffie Islands. This area is the only known nesting site for the black-necked stilt (*Himantopus mexicanus*) in coastal Alabama.

A component of the coastal Avian fauna of great economic importance are the waterfowl populations which inhabit the lower Mobile Delta. Approximately 95% of the total yearly waterfowl harvest within the State is taken in the delta (Beshears 1979). Twenty duck species have been reported from the delta. The more abundant duck species include the lesser scaup (*Aythya affinis*), gadwall (*Anas strepera*), green-winged teal (*Anas carolinensis*), mallard (*Anas platyrhynchos*), wigeon (*Anas americana*), ringneck (*Aythya collaris*), and pintail (*Anas acuta*). Coots (*Fulica americana*) are harvested in greater numbers than any other species in the delta (Table 57). Geese occur only as transients, flying through on their migratory routes. Most species of ducks are either migrants or winter residents in the lower delta. Only the wood duck (*Aix sponsa*) and mottled duck (*Anas fulvigula*) are breeders and summer residents.

MAMMALS

There have been 57 species of mammals (Table C-6) reported from coastal Alabama and surrounding waters (Howell 1921; White 1959; Holliman 1963; Linzey 1970; Caldwell and Caldwell 1973; Chermock et al. 1975; and Holliman 1979). Seven of these are marine whales and dolphins found offshore in the Gulf of Mexico.

The Florida manatee (*Trichecus manatus latirostris*) is usually found in the warmer waters of southern Florida and the West Indes. However, individuals occasionally wander north during the summer and have been seen on the northern gulf coast from Pensacola to New Orleans (Gunter 1954). Caldwell and Caldwell (1973) recorded its occurrence off Alabama's coast.

Feral specimens of the California sea lion (*Zalophus californianus*) have been recorded from the Gulf of Mexico (Gunter 1968). One of these specimens was seen in 1966 resting on a channel buoy just south of Sand Point Light near the mouth of Mobile Bay.

The raccoon (*Procyon lotor*), a widely distributed species in North America, normally prefers wooded areas. However, the subspecies *P. l. varius* is found in the salt marshes of coastal Alabama and often may be seen along the shores feeding on small oysters and other seafood (Howell 1921).

Mink (*Mustela vison*) are semiaquatic mammals that are found throughout Alabama. They are scarce in the Mobile area but are occasionally found along freshwater streams or in swamps or marshes. Linzey (1970) recorded this mammal from several localities in Mobile and Baldwin Counties, including the Mobile delta.

The river otter (*Lutra canadensis*) is more aquatic than the mink and is more abundant in Mobile and Baldwin Counties. It also prefers freshwater habitat and feeds primarily on fishes.

The Florida black bear (*Ursus americanus floridanus*), considered endangered in Alabama (Dusi 1976), at one time was abundant in the swamps of southern Mobile County. Today, they are more or less restricted to the large swamps bordering the Mobile and Tensaw Rivers (Chermock 1957; Linzey 1970) and remote areas along the coast.

The Louisiana muskrat (*Ondatra zibethicus rivalicus*) is widespread through Alabama and North America. In the coastal area it is found in freshwater and salt-water marshes, being most abundant in Mobile County and the delta where it is trapped for its fur.

The Bayou gray squirrel (*Sciurus carolinensis fuliginosus*) is listed as special concern in Alabama (Dusi 1976). Howell (1921) states that it is confined to bayous and deep cypress swamps. Although recorded from Bayou La Batre, it is most abundant in the Mobile delta (Holliman 1963).

One of the most abundant mammals of coastal salt marshes of the area is the rice rat (*Oryzomys palustris palustris*). Rice rats feed on the seeds of grasses, sedges, and other plants. It is found throughout the State, usually living in marshes and swamps along rivers and lakes.

Although normally occurring in grassy areas beyond the beach, the cotton rat (*Sigmodon hispidus hispidus*) will venture into the shallow marshes where it feeds on seeds of plants. It is less abundant than the rice rat in these habitats.

Two subspecies of the beach mouse occur in Alabama (Bowen 1968) and are listed as endangered species within the State (Dusi 1976). These are the white-fronted beach mouse (*Peromyscus polionotus ammobates*) that is endemic to the gulf beaches of Baldwin County and the Perdido Bay beach mouse (*Peromyscus polionotus trissyllepsis*) that is endemic along the beaches of Perdido Bay in Baldwin County. Their burrows are usually found within the line of dunes nearest the shore, usually beneath a clump of grass or small bushes. Their numbers diminish with distance from the beach. Although at one time they were apparently quite abundant in the area (Howell 1921), their numbers are decreasing because of encroachment and development within the coastal-beach zone.

The marsh rabbit (*Sylvilagus palustris palustris*) is found in the extreme Southeastern United States and westward to the eastern shore of Mobile Bay (Hamilton 1943) where they were relatively abundant in the salt marshes until their habitat was reduced in area. This species is listed as having an undetermined conservation status in Alabama (Dusi 1976), although it is not seriously endangered throughout the remainder of its distribution. Linzey (1970) states that they are still abundant in the salt marshes of Perdido Bay and Bon Secour River.

The coastal race of the swamp rabbit (*Sylyilagus aquaticus littoralis*) is confined to a narrow belt along the gulf coast in Alabama. It moves only short distances from coastal marshes and is practically limited to the tidewater region. Linzey (1970) recorded it from Bayou La Batre, Theodore, and numerous localities in the Mobile delta. Apparently, its range does not overlap with that of the marsh rabbit.

The red wolf (*Canis n. niger*) was probably extirpated throughout coastal Alabama as the area was settled (Howell 1921). Linzey (1970, 1971) recorded a specimen of what he thought was probably a coyote-red wolf hybrid from Mt. Vernon, Mobile County. Allen (1975), however, indicates that this specimen was probably a coyote (*Canis latrans*) rather than a hybrid. The red wolf is included in the Federal list of endangered species.

The bottlenose dolphin (*Tursiops truncatus*) and spotted dolphin (*Stenella plagiodon*) are the only marine mammal species of commercial importance throughout the Gulf of Mexico (Caldwell and Caldwell 1973). They regularly occur throughout coastal Alabama. The ecology and population dynamics of these species is poorly known, which is currently preventing a thorough management analysis of them. Although dolphins are not excessively fished, their exploitation could cause population size reductions in the future (Caldwell and Caldwell 1973).

Five species of mammals found in the area are not native but have been introduced and expanded their ranges of distribution into the area. These include the nine-banded armadillo, the black rat, the Norway rat, the house mouse, and the nutria.

Since 1950 the nine-banded armadillo (*Dasypus novemcinctus mexicanus*) has expanded its range from Mobile and Baldwin Counties northward (Holliman 1979). Armadilloes construct burrows in sandy soils which serve as a refuge for a variety of animals. Their food consists mainly of insects and other invertebrates (Hall and Kelson 1959). Any damage the armadillo may occasionally do is thought to be counterbalanced by its control of noxious insects and the habitats it produces for other animals by its burrowing activities.

The black rat (*Rattus rattus* subspp.) and Norway rat (*Rattus n. norvegicus*) are common inhabitants in urban and suburban areas of coastal Alabama. The black rat was probably introduced in North America from the ships of early explorers whereas the Norway rat arrived about 1775 (Hall and Kelson 1959). Damage caused by these rodents annually is in the millions of dollars.

The house mouse (*Mus musculus brevirostris*) has rapidly adapted to the habits of humans and is considered a commensal species of man. House mice are found throughout Alabama's coastal area.

Nutria (*Myocastor coypus bonariensis*) are native to South America (Hall and Kelson 1959) and were accidentally introduced into the United States in Louisiana in 1940 (Adams 1957). They were released in the Mobile delta in 1949 and 1950 (Lueth 1963) then spread to other parts of the State. Nutria are abundant in salt and freshwater marshes of the gulf coast where they feed on various reeds, grasses, and other plants in competition with the muskrat. They are trapped for their fur, but the low value and quality of the pelts limits this activity.

ENDANGERED AND THREATENED SPECIES

By Patrick E. O'Neil

Within historical times, a number of plant and animal species have become extinct in the world. Included in this list are two plant and three animal species that formerly lived in Alabama. The hairlip sucker (*Lagochila lacera*), the passenger pigeon (*Ectopistes migratorius*), the Carolina parakeet (*Conuropsis carolinensis*), a flax (*Linum macrocarpum*), and a sunflower (*Helianthus smithii*). A number of other species have become extirpated from Alabama although they still exist in other areas. Included in this list are 6 fish species, 2 reptiles, 6 birds, and 2 mammals. Population levels of several other species have declined in Alabama to the extent that they could become extirpated from the State within the not too distant future.

Reasons that account for the disappearance or decline in population numbers of many species vary but almost always involve direct or indirect influence by man. Terrestrial and aquatic habitat alteration or destruction has dramatically affected population levels of many species of mollusks, fishes, amphibians, reptiles, birds, and mammals. Several larger mammals and exotic species of birds were hunted in Alabama for food, fashionable products, and sport to the extent that they disappeared from the State or exist only in its remotest areas. Accumulation of harmful substances such as pesticides in adult organisms have lowered their reproductive rates and decreased the fecundity of their offspring. In coastal Alabama, devastating natural events such as hurricanes, tornadoes, and floods have destroyed moderate to large habitat areas which in turn temporarily displaced many organisms. Recovery of these areas in time, however, has been usually followed by a return or recovery to natural population levels of some species.

Because of increasing concern over the declining status of many species, the U.S. Congress has passed several acts designed to protect and manage wildlife populations, the most recent of which is the Endangered Species Act of 1973. In addition to protecting individual species of animals and plants, the Endangered Species Act of 1973 also recognized the need to protect and preserve critical habitats occupied by endangered species. Within the framework of the law, the following criteria were used to determine levels of endangerment and which species would qualify for listing on the United States list of endangered species.

> Endangered—Any species which is in danger of extinction throughout all or a significant portion of its range other than a species of the class Insecta determined by the Secretary of Interior to constitute a pest whose protection under the provisions of the endangered species

act would present an overwhelming and overriding risk to man.

Threatened—Any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

Two endangered and threatened species symposia have been held in Alabama, the results of which were edited by Keeler (1972) and Boschung (1976). Attendees at both symposia included scientists, governmental representatives, and interested citizens. The first symposium (Keeler 1972) included only vertebrate animals. Subject treatment in the second symposium (Boschung 1976) was expanded to include plants, shrimps and crayfishes, gastropods and pelecypods, and all classes of vertebrates. Definitions used to categorize species for the 1976 symposium were as follows:

Endangered—Those species in danger of extinction throughout all or a significant portion of their range in Alabama.

Threatened—Those species which are likely to become endangered within the foreseeable future throughout all or a significant portion of their range in Alabama.

Special Concern—Those species which must be continually monitored because of degrading factors, limited distribution or other physical or biological characteristics that may cause them to become endangered or threatened.

The list of endangered and threatened plants (Thomas 1976) listed in the 1976 symposium was revised and updated by Freeman et al. (1979). Although results of the second symposium (Boschung 1976) are accepted by the Alabama Conservation Department as their list, the State legislature has not passed legislation to legally accept it as the State list.

In Mobile and Baldwin Counties, several habitat types exist, each with its own distinctive associations of plants and animals. The extent and abundance of these habitats has steadily decreased because of man's activities in the area. Among these are the dunes on Dauphin Island, the Indian shell middens along the shores of Mississippi Sound, the bogs scattered through the pine savannahs, and the coastal hardwood hammocks. A large number of species considered to be threatened or endangered occur in these sensitive habitats and need protection if they are to survive within coastal Alabama. In the following species accounts, (S) will indicate State listing and (F) will indicate federal listing.

PLANTS

Fifty-eight species of plants found in Mobile and Baldwin Counties (Table 58) are classified as endangered, threatened, or of special concern (Freeman et al. 1979; U.S. Department of the Interior 1975). Eleven of these are included in the Federal list, three being endangered and the remaining eight threatened. On the State list, seven species are identified as endangered, 19 as being threatened, and 32 of special concern. Several endangered species on the list are associated with the low bog habitats found scattered through the pine savannahs.

Table 58. Endangered and threatened plants of Mobile and Baldwin Counties.

Scientific name	Common name	Freeman et al. (1979)	U.S. Dept. of Interior (1975)
Aquifoliaceae			
Ilex amelanchier		E[a]	E
Araceae			
Acorus calamus	Sweet flag	T	
Peltandra sagittaefolia	Spoon flower	T	
Aspidiaceae			
Thelypteris dentata	Fern	SC	
Thelypteris ovata	Fern	SC	
Thelypteris quadrangularis	Fern	SC	
Asteraceae			
Liatris chapmanii	Blazing star	SC	
Cannaceae			
Canna flaccida	Golden canna	T	
Capparidaceae			
Cleome tenuifolia	Spider flower	SC	
Caryophyllaceae			
Pieris phillyreifolia		T	T
Clethraceae			
Clethra alnifolia	White alder	SC	
Cupressaceae			
Chamaecyparis thyoides	Juniper	SC	
Cyperaceae			
Rhynchospora crinipes	Horned rush	E	E
Ericaceae			
Kalmia hirsuta		SC	
Rhododendron austrinum		SC	T
Eriocaulaceae			
Eriocaulon lineare	Pipewort	SC	
Eriocaulon texenes	Pipewort	SC	
Fabaceae			
Psoralea simplex		E	
Fagaceae			
Quercus minima	Dwarf live oak	SC	
Quercus pumila	Running oak	SC	
Gentianaceae			
Eustoma exaltatum		SC	
Sabatia brevifolia		T	
Sabatia foliosa		SC	
Hamamelidaceae			
Fothergilla gardenii	Witch-alder	SC	
Hypericaceae			
Hypericum nitidum	St. Johns wort	T	
Hypericum reductum	St. Johns wort	SC	
Lamiaceae			
Utricularia floridana	Bladderwort	T	
Utricularia inflata	Bladderwort	T	
Utricularia puppurea	Bladderwort	T	

Table 58. Continued.

Scientific name	Common name	Freeman et al. (1979)	U.S. Dept. of Interior (1975)
Lentibulariaceae			
Pinguicula planifolia	Butterwort	SC	
Pinguicula primuliflora	Butterwort	SC	
Liliaceae			
Lilium iridollae	Lily	E	E
Pleea tenuifolia	Rush featherline	SC	
Lycopodiaceae			
Lycopodium cernuum	Clubmoss	SC	
Onagraceae			
Ludwigia arcuata		T	
Oneothera grandiflora	Evening primrose	E	
Ophioglossaceae			
Botrychium alabamense	Alabama grapefern	SC	
Botrychium lunarioides	Winter grapefern	SC	
Ophioglossum crotalophoroides	Bulbous adder's-tongue	SC	
Ophioglossum nudicaule	Least adder's-tongue	SC	
Orchidaceae			
Cleistes divaricata	Spreading pogonia	T	
Epidendrum conopseum	Green-fly orchid	E	
Platanthera integra	Yellow fringeless orchid	SC	
Poaceae			
Manisuris tuberculosa	Jointgrass	SC	T
Panicum nudicaule		T	T
Potamogetonaceae			
Potomogeton robbinsii	Pondweed	E	
Rhamnaceae			
Segeretia minutiflora		T	
Sarraceniaceae			
Sarracenia psittacina	Pitcher-plant	T	T
Sarracenia rupra	Sweet pitcher-plant	T	T
Scrophulariaceae			
Agalinis pseudophylla		SC	
Penstemon multiflorus		SC	
Selaginellaceae			
Selaginella ludoviciana	Spikemoss	SC	
Theaceae			
Gordonia lasianthus	Loblolly bay	T	
Stewartia malacodendron	Silky camellia	SC	
Ulmaceae			
Mornisia iguanea		T	
Vitaceae			
Vitis munsoniana	Grape	SC	

Table 58. Concluded.

Scientific name	Common name	Freeman et al. (1979)	U.S. Dept. of Interior (1975)
Xridaceae			
Xyris drummondii	Yellow-eyed grass	T	T
Xyris scabrifolia	Yellow-eyed grass	T	T

[a]E--Endangered, T--Threatened, SC--Special concern.

ANIMALS

CRAYFISHES

Five species of crayfishes belonging to two genera (*Cambarellus* and *Procambarus*) were listed by Bouchard (1976) as special concern (Table 59). *Cambarellus diminutus*, the smallest crayfish in the world—approximately 12 mm (0.5 inch)—is known from two localities in south Mobile County. Alabama is at the eastern edge of the range of *Cambarellus shufeldti*. Both species of *Cambarellus* prefer backwater areas of streams and ponds. Specimens of *Procambarus bivittatus* and *Procambarus lecontei* have been collected from the pool areas of several low-gradient streams in Alabama while the only Alabama record of *Procambarus evermanni* is from a slow-flowing stream in Mobile County.

FISHES

Six species of fishes from Mobile and Baldwin Counties (Table 59) are considered as endangered, threatened, or of special concern (S) (Ramsey 1976). Three of these—Atlantic sturgeon (*Acipenser oxyrhynchus*), Alabama shovelnose sturgeon (*Scaphirhynchus* sp.), and blue sucker (*Cycleptus elongatus*)—are primarily river species, while the pygmy killifish (*Leptolucania ommata*) is usually found in small streams and isolated overflow pools. The one specimen of the crystal darter (*Ammocrypta asprella*) reported by Swingle and Bland (1974a) from the Mobile Delta was considered to be a displaced individual because of severe flood conditions. The freckled darter (*Percina lenticula*) was reported as occurring in the lower Alabama River by Shipp and Hemphill (1973).

Sturgeons are anadromous species, which means that individuals ascend rivers to spawn in freshwater. Numerous reports have indicated that these species as well as many others have been hampered during their spawning migrations by dams on the major rivers in the Mobile Basin (Ramsey 1976). It is doubtful that any of the streams and small rivers in coastal Alabama, because of their small size and infrequent periods of brackish water influx, fulfill the spawning habitat requirements of these species.

The record of a blue sucker from coastal Alabama is based on the collection of a single specimen from the boat slip at the Alabama Marine Resources Laboratory (Swingle 1971). According to Swingle, the specimen was in distress at the time it was collected and probably would have been washed out to sea. Since the Blue sucker is a primary division (strictly freshwater) species, it is doubtful that it naturally occurs in the estuary; and, were it not for this single record, it would not have been included in the list of rare fishes of coastal Alabama.

Individuals of the pygmy killifish are known to occur in streams that empty into estuaries. This species is widespread in Florida and occurs peripherally in coastal Alabama. Smith-Vaniz (1968) and Swingle and Bland

Table 59. Endangered and threatened animals of Mobile and Baldwin Counties.

Scientific name	Common name	Boschung (1976)	U.S. Dept. of Interior (1980)
Crayfishes			
Cambarellus diminutus		SC[a]	
Cambarellus shufeldtii		SC	
Procambarus bivittatus		SC	
Procambarus evermanni		SC	
Procambarus lecontei		SC	
Fishes			
Acipenser oxyrhynchus	Atlantic sturgeon	T	
Ammocrypta asprella	Crystal darter	T	
Cycleptus elongatus	Blue sucker	T	
Leptolucania ommata	Pygmy killifish	SC	
Percina lenticula	Freckled darter	T	
Scaphirhynchus sp.	Alabama shovelnose sturgeon	E	
Amphibians			
Ambystoma cingulatum	Flatwoods salamander	E	
Rana heckscheri	River frog	SC	
Rana areolata sevosa	Dusky gopher frog	T	
Siren lacertina	Greater siren	SC	
Reptiles			
Alligator mississippiensis	American alligator	T	E
Caretta caretta caretta	Atlantic loggerhead turtle	E	T
Chelonia mydas	Green sea turtle	E	T
Crotalus adamanteus	Eastern diamondback rattlesnake	SC	
Dermochelys coriacea	Leatherback sea turtle	T	E
Drymarchon corais couperi	Eastern indigo snake	E	T
Eretmochelys imbricata imbricata	Atlantic hawksbill turtle	E	E
Gopherus polyphemus	Gopher tortoise	T	
Lepidochelys kempi	Atlantic ridley turtle	E	E
Nerodia cyclopion floridana	Florida green water snake	SC	
Pitophis melanoleucas lodingi	Black pine snake	E	
Pseudemys alabamensis	Alabama red-bellied turtle	T	
Rhadinaea flavilata	Pine woods snake	SC	
Trionyx ferox	Florida softshell turtle	SC	

Table 59. Concluded.

Scientific name	Common name	Boschung (1976)	U.S. Dept. of Interior (1980)
Birds			
Accipiter cooperii	Cooper's hawk	SC	
Accipiter striatus	Sharp-shinned hawk	SC	
Aimophila aestivalis	Bachman's sparrow	SC	
Anas fulvigula	Mottled duck	T	
Buteo lineatus	Red-shouldered hawk	SC	
Charadrius alexandrinus	Snowy plover	E	
Dichromanassa rufescens	Reddish egret	T	
Elanoides forficatus	Swallow-tailed kite	SC	
Falco columbarius	Merlin	SC	
Falco peregrinus	Peregrine falcon	E	E
Florida caerulea	Little blue heron	SC	
Grus canadensis	Sandhill crane	SC	
Haematopus palliatus	American oyster-catcher	SC	
Haliaeetus leucocephalus	Bald eagle	E	E
Laterallus jamaicensis	Black rail	SC	
Limnothlypis swainsonii	Swainson's warbler	SC	
Mycteria americana	Wood stork	SC	
Nycticorax nycticorax	Black-crowned night heron	SC	
Pandion haliaetus	Osprey	E	
Pelecanus occidentalis	Brown pelican	E	E
Picoides borealis	Red-cockaded wood-pecker	E	E
Thryomanes bewickii	Bewick's wren	SC	
Mammals			
Balaenoptera physalus	Finback whale		E
Felis concolor coryi	Florida panther	E	E
Lasiurus floridanus	Florida yellow bat	SC	
Myotis austroriparius austroriparius	Southeastern myotis	SC	
Peromyscus polionotus ammomates	Alabama gulf beach mouse	E	
Peromyscus polionotus trissyllepsis	Perdido Bay beach mouse	E	
Sciurus carolinensis fuliginosus	Bayou gray squirrel	SC	
Ursus americanus floridanus	Florida black bear	E	

[a]E--Endangered, T--Threatened, SC--Special concern.

(1974a) have reported specimens occurring in Baldwin County. The species is probably more widespread in Alabama than available data indicates.

AMPHIBIANS

Flatwood salamanders (*Ambystoma cingulatum*) usually inhabit low, damp, pine flatwoods and are usually found near small, shallow cypress ponds. Loding (1922) recorded this species from Dog River, Mobile County, and Magnolia Springs, Baldwin County. However, it has not been collected since that time in the study area. This species is considered to be Alabama's rarest salamander (Mount 1976).

The dusky gopher frog (*Rana areolata sevosa*) is a rare species which has only been reported from a few localities in Alabama. The only record from the study area was a specimen from the Dog River collected in 1919 (Loding 1922). This frog lives in the burrows of the gopher tortoise and breeds in shallow ponds of pine flatwoods. The destruction of gopher tortoise burrows and the draining of breeding ponds threatens the continued survival of this frog (Mount 1976).

The river frog (*Rana heckscheri*) inhabits river swamps and the swampy shores of ponds and bayous. Mobile and Baldwin Counties are at the western periphery of its range. It is considered to be of special concern (S) because of its scarceness in Alabama, although it is locally common in parts of Georgia and Florida.

REPTILES

The Mississippi alligator (*Alligator mississippiensis*) is included in the Federal list of endangered species (U.S. Department of Interior 1980). In Alabama, it is protected by law. Alligators were steadily declining throughout their range because of excessive hunting and poaching. However, as a result of protective measures, their numbers have recently increased to the level that they have been reduced in status on Alabama's endangered list but still are considered as being threatened.

Sea turtles live in the open ocean and normally nest in the sand on open beaches. Throughout the world, there has been a steady decline in the abundance of these turtles because of excessive predation by man for food, the invasion of their nesting sites by civilization, and the destruction of their nests for their eggs.

Five species of sea turtles probably occur in Alabama waters (Chermock 1952; Mount 1975). These are the Atlantic green turtle (*Chelonia m. mydas*), Atlantic hawksbill turtle (*Eretmochelys i. imbricata*), Atlantic loggerhead turtle (*Caretta c. caretta*), Atlantic ridley (*Lepidochelys kempi*), and Atlantic leatherback turtle (*Dermochelys c. coriacea*). Both the green turtle and the ridley have been recorded from Mobile Bay and Mississippi Sound (Loding 1922), and the loggerhead has been known to nest on Dauphin Island and Fort Morgan Peninsula (Jackson and Jackson 1970; Mount 1975). Because of continued hunting pressure and increased disturbance of their nesting sites, all five species are included on both the State and Federal lists.

The Alabama red-bellied turtle (*Pseudemys alabamensis*) is endemic to the State, known only from the lower Mobile drainage from Mobile, Baldwin, and Monroe Counties. This aquatic turtle is considered threatened (S) because of its small range and population size.

The gopher tortoise (*Gopherus polyphemus*) at one time was abundant throughout most of southern Alabama. Three factors have contributed to its placement on the State's list of threatened animals: habitat destruction, intensive predation by man for food, and increased mortality as a result of rattlesnake hunts or rodeos. Many other animals often seek shelter in gopher burrows. Among these are the dusky gopher frog, indigo snake, and diamondback rattlesnake. Rattlesnake hunters pour gasoline into gopher tortoise holes to drive out the snakes. Other inhabitants often may be killed by the fumes. Because of this practice, the indigo snake is on the State's endangered list; the gopher frog and gopher tortoise are on the threatened list; and the diamondback rattler is of special concern (Mount 1976).

The black pine snake (*Pituophis melanoleucus lodingi*) is known only from Washington, Mobile, and Clarke Counties of Alabama and adjacent southeastern Mississippi. It is most abundant in sandy areas of longleaf pine forests. Its numbers are declining because of habitat alteration and intensive collecting for sale to dealers of live animals. For this reason, it is classified as endangered (S).

The pine woods snake (*Rhadinea flavilata*) is a small secretive snake found in the coastal flatwoods of Mobile and Baldwin Counties. Because of its rarity, and lack of knowledge about them, they are considered as special concern (S).

BIRDS

A number of birds have been recorded from coastal Alabama which are considered to be endangered, threatened, or of special concern (Table 59). Some species, such as the peregrine falcon and the pigeon hawk (merlin), usually migrate through the area and are not an important component of the resident bird population. The sharp-shinned hawk, sandhill crane, and Bewick's wren are winter visitors. The remainder are summer or permanent residents which nest within the area.

The reddish egret (*Dichromanassa rufescens*) normally occurs in Alabama from mid-March to late-April and mid-July to late-December (Imhof 1976) and are considered threatened in the State (Keeler 1976). They are most abundant on Dauphin Island where they frequent shallow bays and mud flats along Mississippi Sound. They feed on small marine animals. Habitat destruction due to development of the island is probably causing their decrease in numbers.

The black-crowned night heron (*Nycticorax nycticorax*) and the little blue heron (*Florida caerulea*) nest within the area, usually in mixed rookeries with other species. In recent years, their numbers have decreased so they now are considered to be of special concern (S). Since their introduction, cattle egrets have increased tremendously in numbers. Their competition for habitat and rookery space may be contributing to the decline in numbers of our native herons.

The brown pelican (*Pelecanus occidentalis*) was a common resident of Alabama, but the population has declined sharply since 1956. Currently, the pelican nests in colonies on the offshore islands of Louisiana. In the early part of this century, pelicans nested on Dauphin Island and the eastern end of Petit Bois Island (Howell 1928). Their food consists of fish, primarily menhaden, which they catch in open waters. They rest on pilings, sand spits, or float in open water. Declines in population size of the brown pelican have been explained by Imhof (1976) as due to pesticide concentrations. Keeler (1976) says, "The local population has been decimated by the widespread use of chlorinated hydrocarbon pesticides, especially DDT." Both authorities failed to consider that in September of 1956, Hurricane Flossy passed over southeast Louisiana and its offshore islands where it seriously affected the nesting pelican population. It is probable that pesticides have also contributed to population failure in the northern gulf. However, the brown pelican's increasing numbers indicate that it is making a comeback.

The mottled duck (*Anas fulvigula*) is a permanent resident and a threatened species (S) in the area. Individuals are found primarily in saltwater and brackish water areas, especially marshes where they build a well-concealed nest on the ground, in or near a marsh, or on an island (Keeler 1976). The diet of this duck consists of snails, other mollusks, and aquatic insects. Two factors have contributed to their decreasing numbers in Alabama: habitat destruction and hunting pressure (Keeler 1976).

The bald eagle (*Haliaeetus leucocephalus*) is a breeding resident along the gulf coast. After nesting is completed, these birds usually migrate northward so that by mid-summer, they are only rarely observed in Alabama (Imhof 1976). Bald eagles construct huge nests in the top of large living trees that are used repeatedly. Individuals usually feed on fish but often are scavengers, feeding on dead animals found along the shore. Bald eagles' numbers have steadily declined throughout its range, including Alabama. Numerous factors contribute to this, including illegal shooting, reduction of prime nesting areas, and reduced reproduction as a result of pesticides (Keeler 1976).

The osprey (*Pandion haliaetus*) formerly was a common breeding summer resident along the gulf coast of Alabama, their numbers increasing during spring and fall by birds in migration. Specimens were frequently observed flying over open water and diving for fish, which are the principal component of their diet. Ospreys build large nests in the tops of large dead trees that are used year after year. The osprey is considered to be endangered (S) in Alabama. Factors contributing to their decreasing numbers are similar to those of the bald eagle.

The swallow-tailed kite (*Elanoides forficatus*) breeds in the southern United States and migrates to Central and South America in the winter. At one time, it was abundant in Alabama (Howell 1928) but is now rare because its habitats are being destroyed (Keeler 1976). Individuals normally inhabit river swamps where they feed on snakes, lizards, and insects. In the coastal area, kites are known from Bayou Coden and from the Tensaw River in upper Mobile Bay.

The sharp-shinned hawk (*Accipiter striatus*), Cooper's hawk (*Accipiter cooperii*), and red-shouldered hawk (*Buteo lineatus*) are considered to be of special concern (S) in Alabama. Primary factors contributing to their status are illegal shooting and reduced reproduction as a result of the use of insecticides such as DDT in agriculture.

The sandhill crane (*Grus canadensis*) was formerly abundant in Eastern North America. Breeding populations nested in the Northern United States and Canada and wintered along the northern gulf coast and Florida. Some birds were also permanent residents in the wintering grounds. In the early part of this century, sandhill cranes were known to breed in Baldwin County (Howell 1928), and it is possible that a few pairs still nest there (Imhof 1976). Breeding populations are still known from coastal Mississippi, southern Georgia, and Florida. Local residents of south Mobile County claim that a few northern birds still winter in that county. These cranes are found in open pine woods with small bogs of freshwater marshes. They are extremely wary and usually avoid man.

American oystercatchers (*Haematopus palliatus*) are permanent breeding residents, usually seen on sand flats or beaches near oyster reefs. They feed primarily on mollusks and crustaceans. Their nest is a shallow depression lined with bits of shell located on deserted upper beaches of sandbars in shallow bays (Pough 1951). They have been rare in the State since the turn of the century (Howell 1928). Reduction of their nesting habitats and disturbance by man are contributing to the decrease in numbers.

The snowy plover (*Charadrius alexandrinus*) is a permanent breeding resident along the Alabama coast and is considered to be an endangered species (S). They are found on the outer beaches of Baldwin and Mobile Counties where they feed on a variety of small invertebrates and seeds. The nest is a hollow in the sand that is lined with shells or stones. These nests are located on deserted beaches close to the gulf. The snowy plover's rare status is attributed to disturbance and loss of habitat.

MAMMALS

The Florida yellow bat (*Lasiurus floridanus*) is found in peninsular Florida, extends north along the Atlantic coast to Charleston, South Carolina, and is found along the gulf coast west to the delta region of Louisiana where it is common (Hamilton 1943). There is only one record from Alabama in 1969 in Chickasaw, Mobile County (Linzey 1970). It is a solitary bat, and little is known of its habits.

In earlier years, the Florida black bear (*Ursus americanus floridanus*) ranged throughout Alabama. By the beginning of this century, they were exterminated everywhere except remote areas in the northern part of the State (ssp. *americanus*) and the swamps of southwestern Alabama (ssp. *floridanus*) where they were still common (Howell 1921). Since that time, their numbers have further decreased until now the Florida black bear is restricted to the large isolated swamps in the Mobile Delta, along the Mobile and lower Tombigbee and Alabama Rivers, and rarely in the southern part of Mobile County and eastern Baldwin County. They possibly occur in other isolated areas in southern Alabama (Dusi 1976).

Like the black bear, the Florida panther (*Felis concolor coryi*) occupied the greater part of the State in early times. With the advent of settlers, it quickly disappeared and retreated to more secluded regions. By the turn of the century, they were limited to the remotest parts of forests, cliffs in mountainous areas, and deep canebrakes of the river-bottom swamps where they were very rare (Howell 1921). Today, the cougar is nearly extirpated in the State. In recent years, there have been scattered reports of cougars in DeKalb, St. Clair, and Tuscaloosa Counties (Holliman 1963). Positive sight identifications of a pair of panthers with cubs was reported in 1974 and 1975 in Baldwin County (Dusi 1976). They probably still occur in Alabama but, because of very small numbers and secretive habits, are rarely seen.

Alabama represents the easternmost range of the Bayou gray squirrel (*Sciurus carolinensis fuliginosus*). It is found in Mobile, Baldwin, and Washington Counties, primarily in river-bottom swamps and wooded areas along bayous and cypress swamps. Since the periphery of its range is in coastal Alabama, it is considered special concern (S) (Dusi 1976).

Two species of whales, finback whale (*Balaenoptera physalus*) and sperm whale (*Physeter catodon*) have been recorded from Alabama's gulf waters and are considered as endangered in the Federal list (U.S. Department of Interior 1980). The Florida manatee or sea cow (*Trichechus manatus*) has been reported from coastal Alabama by Caldwell and Caldwell (1973). The presence of marine mammals such as whales and the manatee are only sporadic and probably no resident populations exist in coastal Alabama.

CONCEPTUAL MODEL

By Maurice F. Mettee
and Patrick E. O'Neil

In the previous sections of this document, available sources of environmental and ecological information concerning coastal Alabama were compiled following conventional disciplinary boundaries. The information contained in these sections will serve as a reference source for those interested in known information about the coastal Alabama environment.

In contrast, the present section deliberately synthesizes the information presented in the preceding text. The aim of this synthesis is to describe the ecological interrelationships that exist between the physical, chemical, and biological resources of coastal Alabama. At the core of this synthesis effort is the building of a conceptual model of energy and material flow through coastal Alabama.

The central purpose of this conceptual model is to comprehend coastal watersheds as integrated systems of physical, chemical, and biological forces. For example, components of coastal Alabama, such as precipitation, river discharge, marshes, oysters, fishes, plankton, urban and industrial systems, seen in the upper part of Figure 86, can be abstractly and symbolically represented, as seen in the lower part of Figure 86, in terms that allow understanding of component interactions. The conceptual model as a synthesizing device identifies where the major flows of energy and materials occur, interconnect, and thus affect each other. In this manner one visualizes how hydrology, meteorology, soil science, ecology, as well as many other scientific disciplines, fit into the collective understanding of ecosystem interaction and function.

The conceptual model represents only a "model" of coastal Alabama. It should never be viewed as an inflexible end product. With further data collection and analysis, new insights into coastal processes will result in continual revision of the model.

COASTAL ALABAMA CONCEPTUAL MODEL

Building on the simple model presented in the introduction (Figure 1), a more complete conceptual model of coastal Alabama as a single energy system can be constructed (Figure 87). The model is comprised of two basic units. The first unit consists of the four natural ecosystems: coastal terrestrial, stream and freshwater, estuarine and continental shelf, and their associated connective pathways and energy inputs. This unit is self-sustaining and requires only natural inputs from primary energy sources and other natural ecosystems. The second unit consists of the agricultural ecosystem, urban/industrial systems, and their associated pathways and energy sources. This unit requires extensive inputs from external energy sources such as imported goods and services, resources and products from other ecosystems and primary energy inputs. The concept emphasizes the dependence of these manipulated and modified subsystems on natural coastal processes and resources. In addition, these manipulated subsystems require outside markets, composed of other manipulated subsystems, to transfer their exports. Without these markets, the agricultural, urban, and industrial subsystems become stagnant and non-productive.

The subsystems are connected by interactive pathways of three different types:

1. Input/output pathways. These include natural energy functions such as sunlight, tides, winds, and the migratory and dispersive activities of plants and animals; imported goods and services such as fossil fuels, industrial and construction products, human labor, population

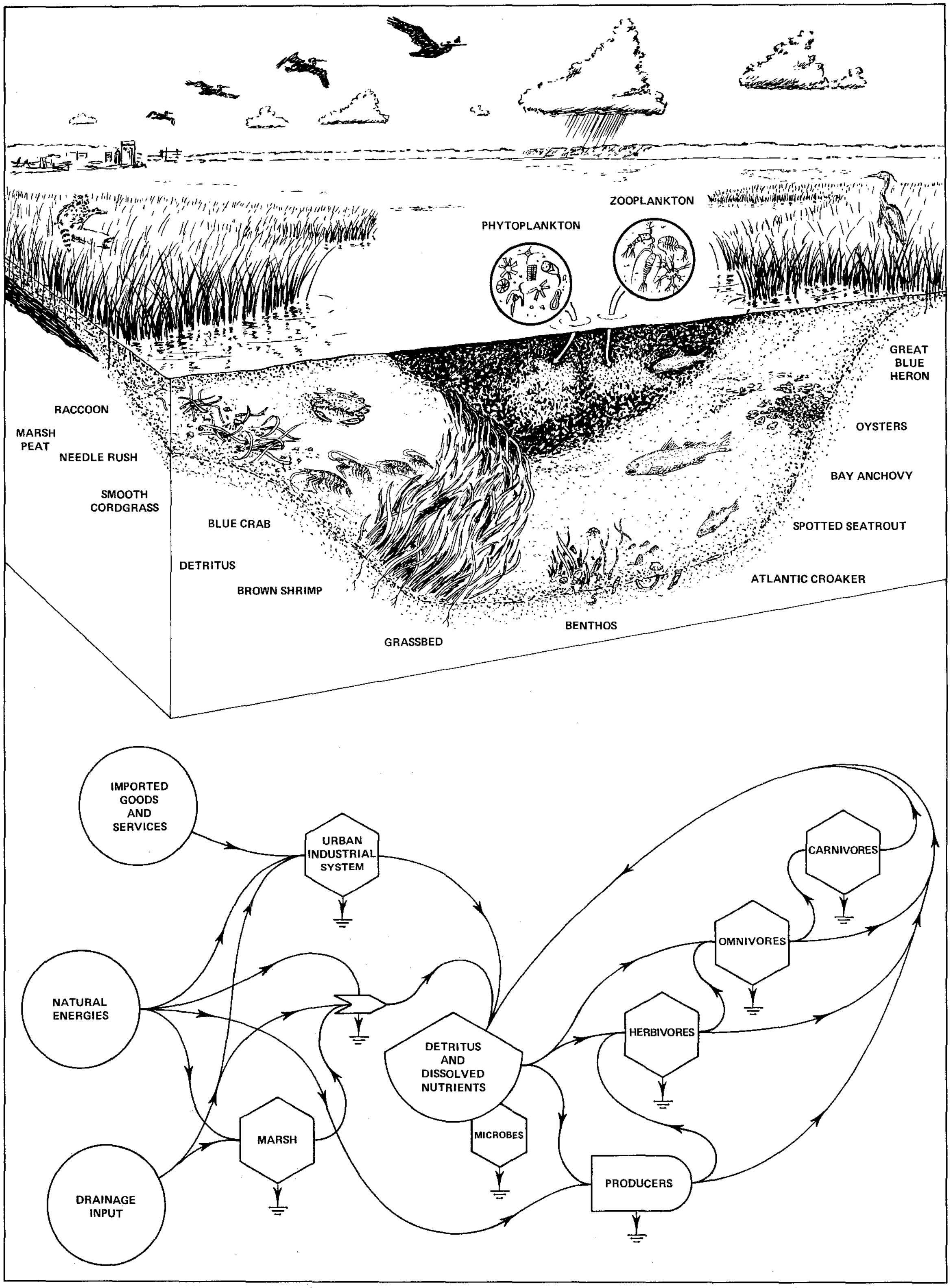


Figure 86. The estuarine ecosystem of coastal Alabama and representative energy symbols.

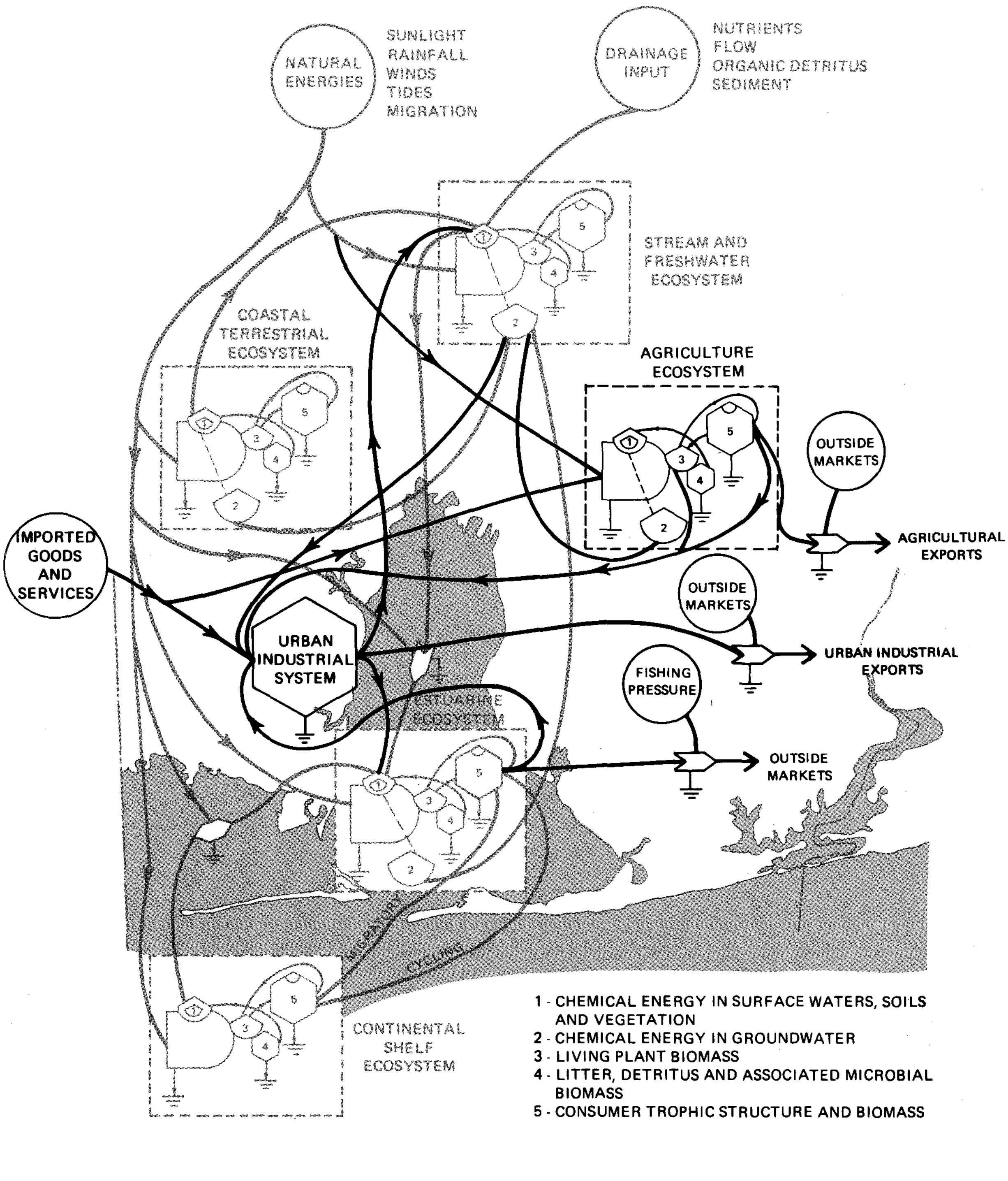


Figure 87. Coastal Alabama conceptual model.

movements, and information; drainage inputs, primarily from the Mobile and Perdido Rivers, such as nutrients, organic detritus, sediments, and river flow; and exported goods and services such as seafoods, timber, paper, petroleum products, chemicals, soybeans, nursery products, vegetables, and beef.

2. Pathways of the hydrologic cycle. These include water storage in surface basins, evapotranspiration, stream runoff, overland flow, tidal circulation and flushing, and ground-water seepage, recharge and movement. The movement of nutrients between and within ecosystems is closely associated with the hydrologic cycle.
3. Biological productivity and recycling of water and chemical energy. These pathways include the production, use and cycling of energy and materials through the subsystems of Figure 87.

To better understand processes presented in Figure 87, it is necessary to understand the concepts of "energy" and "work" in relation to the physical, chemical, and biological forces operating within coastal Alabama. Energy, defined in its broadest sense, is the sum total of all matter and force existing within the universe: air, trees, water, humans, birds, rocks, sunlight, automobiles, and buildings. The total energy of the universe is constant, neither created or destroyed, and only changes from one form to another (first law of thermodynamics). Without external forces, energy tends to run to its lowest most disordered state (second law of thermodynamics).

"Work" occurs whenever energy is either transformed from one state to another (sunlight and nutrients to plant tissue) or is transferred from one point to another by the application of a force (e.g., the movement of air masses as wind, tidal fluctuations due to gravitational attractions, runoff due to elevational differences).

Within the subsystems of coastal Alabama, energy and matter are continually being captured, transformed, and transferred to produce a variety of products ranging from fish and wildlife to hydroelectric power and industrial goods. The artificial manipulation of watershed resources to produce one kind of work environment (e.g., industrial production) often affects the survival of other work environments (e.g., fish and wildlife production). Generally each work environment within a subsystem produces and survives in direct proportion to how much that environment is subsidized, or worked upon, by other supporting subsystem forces. For example, manipulating the upstream quality and quantity of water to produce pulp and paper products, soybeans, cattle, timber, or minerals may, depending on specific management practices, precipitate changes in the background conditions of downstream work environments.

To understand the interaction and balance of how forces work within a watershed, it is essential to incorporate the basic organizing principles of hydrology within those of ecological systems. In ecological systems organisms perform work within the limitations of their life history cycles, physiological capacities and behavioral flexibilities. As ecological systems develop, organisms with specific life history requirements co-evolve with one another under similar physical/chemical conditions. The result is the formation of a group of species occupying a common habitat and is referred to as a community. The term "community" describes species assemblages that characteristically develop on specific habitats or substrates such as mud flats, sand and silt bottoms, streams, and upland hills.

Where many communities overlap and interconnect through mobile species, flooding, runoff, wind dispersion, or tidal mixing, the concept of ecosystem emerges. As a multitude of communities, the ecosystem provides an integrating framework for use in the conceptual model. In the Mobile Bay estuary, for example, the ecosystem refers to overlapping communities such as the submerged aquatic vegetation beds, oyster reefs, benthic communities, marshes, and sand bottoms. These communities are interconnected by wind and tidal mixing, freshwater discharge and a variety of seasonal and resident species. Thus, the term ecosystem refers to a broad spatial scale of overlapping communities integrated through physical, chemical, and biological interconnections.

The overlapping of ecological and hydrological organizing principles acts to stabilize the responses of ecosystems to both natural and man-induced perturbations by providing constant interconnecting sources of resources between habitats. As conditions are disturbed in a community, the flux of pioneer organisms from neighboring communities helps to rapidly regenerate local structure and function. The net result, on an ecosystem basis, is a continual readjustment or modification of populations and communities in response to natural and induced variations in background conditions.

NATURAL ECOSYSTEMS

The four natural ecosystems comprising Figure 87 have a similar internal arrangement and function of component parts. These parts (Figure 88) are represented by symbols which have specific meanings (Table 60). For example, within the coastal terrestrial ecosystem clearly defined trophic structures, species diversity, and nutrient cycles have developed.

Functionally, the ecosystem is composed of producers, green plants capturing and converting incoming energies to plant biomass; consumers, organisms which eat plant and animal material; and decomposers, organisms which degrade plant and animal tissues into simpler compounds. Within the model (Figure 88), producers and associated biomass storage are represented by the plant population and attached passive storage symbols (Table 60). Energy is transferred and transformed from a lower trophic level to a higher one when producers are preyed upon by consumers which are represented by the hexagon (Table 60). Energy found in metabolic wastes and dead organisms from producers and the trophic structure is processed by microbes and returned to a nutrient pool that can be reutilized by animals and plants. The potential chemical energy found in these nutrients is represented by the passive storage symbol (Table 60). Surface and ground waters serve as energy storage and transport mechanisms and are also represented by the passive storage symbol. The ground symbols represent a very disordered and useless form of energy, heat, that results from any energy transformation (second law of thermodynamics). This energy, called an energy sink, is lost and unavailable to perform work.

Natural ecosystems "work" by applying their behavioral and structural resources to solve individual problems and satisfy basic needs. One of the most basic work processes in natural ecosystems is the physiological capacity of organisms to feed upon, digest, and assimilate one another. These "trophic" processes mediate a large portion of energy flow and nutrient cycling within the ecosystem and comprise the wide variety of food webs found in ecosystems.

MODIFIED AND MANIPULATED SUBSYSTEMS

The structural composition of agricultural, urban and industrial systems is identical to natural systems except that the components have different labels and, in some instances, a modified function from its natural counterpart (Figure 89).

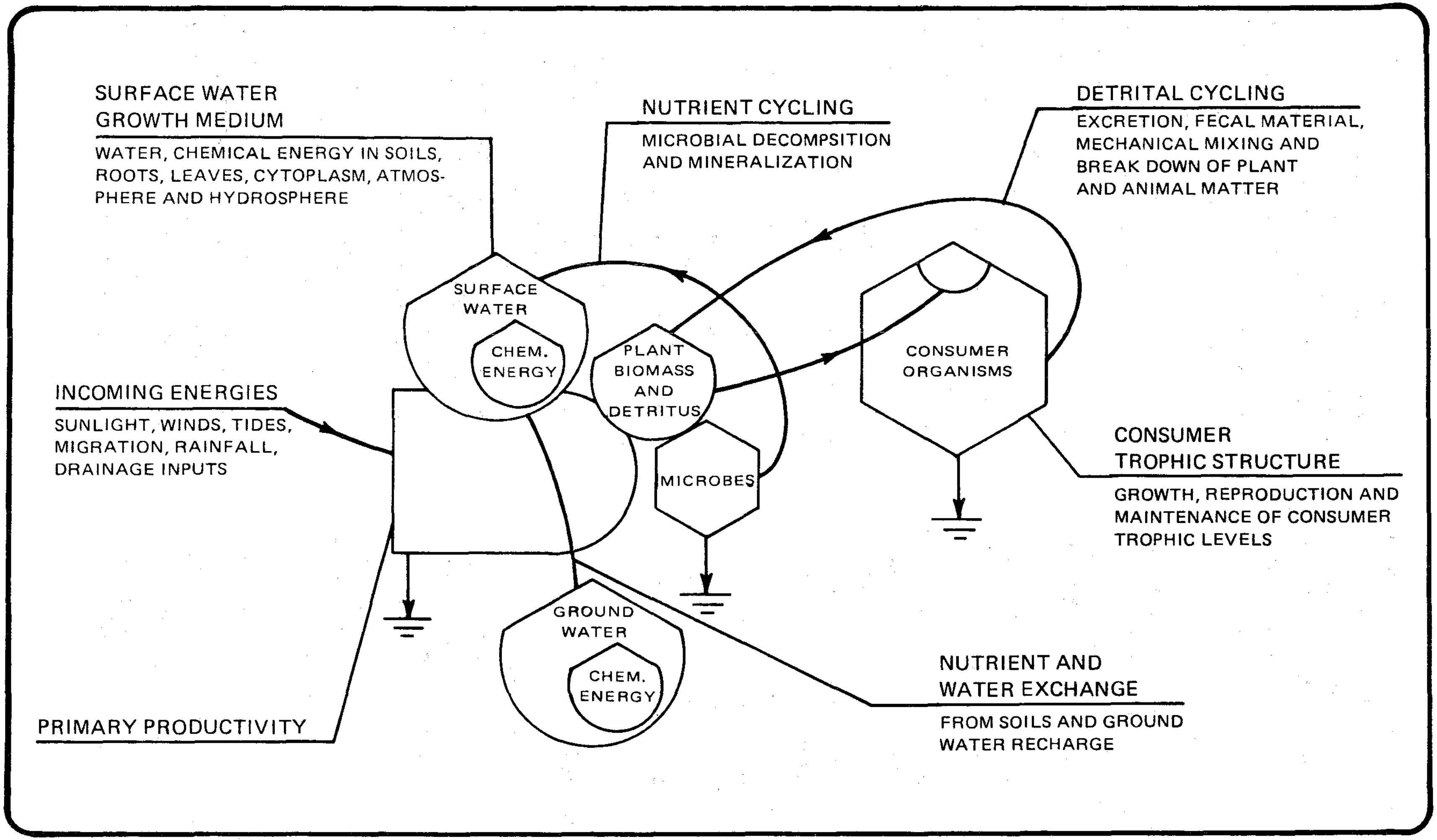
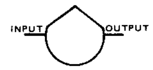


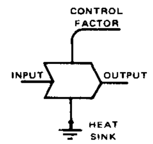
Figure 88. Conceptual model of energy and material flow through natural ecosystems.

Table 60. Symbol explanations for energy-flow models (modified from Snedaker and Lugo 1974).



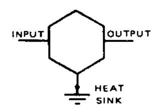
Passive Storage

This symbol represents the passive storage of materials or biomass in the system. No new potential energy is generated and some work must be done in moving potential energy in and out of storage by some other unit.



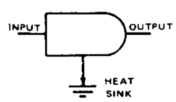
Workgate

The Workgate module indicates a flow of energy (control factor) which makes possible another flow of energy (input-output). This action may be as simple as a person turning a valve, or it may be the interaction of a limiting factor in photosynthesis. It is used to show the multiplier interaction of two system components.



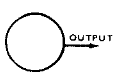
Self-Maintaining Consumer Population

The self-maintaining consumer population symbol represents a combination of "active storage" and a "multiplier" by which potential energy stored in one of more sites in a subsystem is fed back to do work on the successful processing and work of that unit.



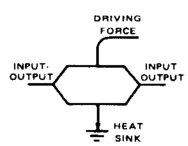
Plant Population

The plant population symbol is a combination of a "consumer unit" and a "pure energy receptor." Energy captured by a cycling receptor unit is passed to a self-maintaining unit that also keeps the cycling receptor machinery working, and returns necessary materials to it. The green plant is an example.



Energy Source

The energy source symbol represents a source of energy such as the sun, fossil fuel, or water inputs from reservoirs or rivers and streams.



Two-Way Workgate

The two-way workgate or forced diffusion module represents the movement of materials in two directions as in the vertical movement of minerals and plankton in the sea. The movement is in proportion to a concentration gradient or a causal force shown operating the gate. The heat sink shows the action to follow the second law of thermodynamics.

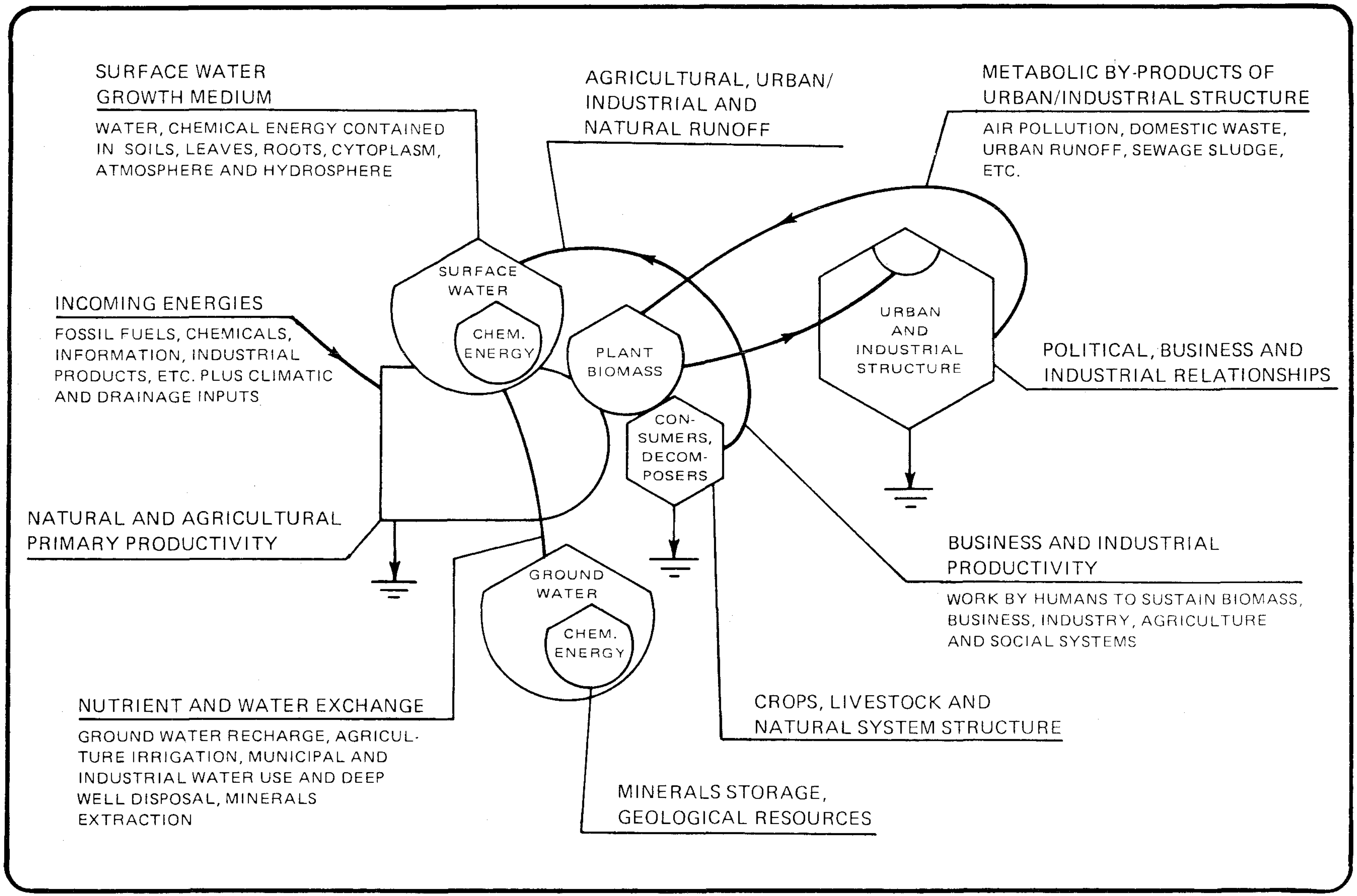


Figure 89. Conceptual model of energy and material flow through agricultural and urban/industrial systems.

AGRICULTURAL ECOSYSTEMS

In contrast to the diverse organization of work in natural ecosystems, agricultural "work" tends to be more intensively concentrated along fewer energy-flow pathways. In natural ecosystems, the work of many species produces complex food webs and diversification of the environment indirectly leading to nutrient, water, and soil conservation. In agricultural ecosystems, most work is devoted to alteration and modification of the natural ecosystem setting in an effort to maximize production of a few selected species. The forms of agricultural work include clearing, plowing, tilling, harvesting, application of fertilizers, lime, and pesticides. Land responses are controlled by management decisions such as drainage, ditching, irrigation, application of chemicals, and crop rotation. Agricultural ecosystems are highly subsidized by technologies and resources that originate in locations far removed from the farm.

As a consequence of changing the scale of diversification and in the process modifying local habitats, agriculture often results in locally high costs to the ecosystem such as:

1. The loss of soil and water due to agricultural activities on the land results in a direct gain of soil and water to downstream aquatic communities. Soil and water from agricultural runoff may result in elevated turbidity, pesticides, nutrients, organic matter, and pathogen loads to surface and ground waters. Drainage, irrigation and land cover alterations for agricultural purposes also tend to affect the runoff hydrograph to surface waters. These effects constitute significant changes in background conditions of aquatic communities leading to qualitative and quantitative changes in their metabolism.
2. By excluding natural competitive forces that lead to free soil and water conservation work, agriculture must itself bear the cost of providing technological solutions for these essential processes. A vicious cycle is thus precipitated. As more intensive agriculture "burns out" the natural land and water resource, ever more fossil fuel technology is required to "rebuild" the resource and maintain its productivity.

URBAN SYSTEMS

Through tremendous abilities to conceptualize, learn, and communicate, man discovers and applies principles which help to perform work beyond anatomical and physiological tolerance limits. By creating physical extensions of work principles, tools and machines are constructed that increase the collective and individual work capacity. This is the familiar technology of the human culture. Given sufficient fossil fuel, information flow and other subsidies required to produce and maintain machines, technology generally increases the rate at which work can be done.

In terms of its working usefulness, the urban habitat represents a concentrated center of exchange pathways for goods and services such as food stuffs, fuels, building materials, and servies (or labor). In addition to the pathways of physical goods and services, the urban system serves as a central focus for exchanging flows of intangible energies such as information.

Metabolically, the urban system is extremely heterotrophic, consuming many different imported resources. Natural energy subsidies such as wind and rainfall removal of airborne pollutants play an essential role in maintaining the urban habitat. Overall, the secondary production, services, administrative and maintenance work that so characterize urban habitats are externally fueled. Food, transportation, building construction, electricity, information transfer and all activities related to the maintenance of these exchange pathways are directly and indirectly supported by fossil fuels.

Internally, the urban/commerical/residential system, as the full name implies, is made up of numerous subhabitats such as suburbs, shopping centers, malls, downtown commerical areas, apartment buildings, high rise condominiums, and office parks. These subhabitats are interconnected by networks of roads, electrical transmission lines, communication networks, water supply lines, surface-water drainage systems and sewage collection pipes. Temporally, metabolism along these networks and in between subhabitats is extremely diurnal and seasonal. Generally, metabolism on road networks peaks in the early morning and early evening rush hours. Water and sewage metabolism also peaks high in the mornings, and again, but slight lower, in the evening. Electrical and communication network activity peaks during business hours when schools, industries and offices are heated or cooled. Overall, the various subhabitats of the urban setting are well mixed by daily activity pulses. Spatially, these subhabitats tend to be separated by zoning ordinances, restricted uses, neighborhood group pressures and other social devices.

As a component of the extended human ecosystem, the major work function of the urban system is management through consumption. In the natural system, consumer organization is partitioned into trophic levels which stimulate productivity. The net dynamic balance and composition of the consumer trophic structure depends upon which populations simultaneously maximize their individual and collective survival with respect to the availability of energy and material resources. In an urban setting, the same principles and roles apply though they are, as in agriculture, spread across the far reaches of the human ecosystem.

INDUSTRIAL SYSTEMS

Industries that produce chemical or structural items are often, but not always, closely associated with urban systems. The proximity afforded by urban habitats to large consumer markets, business centers, labor forces, power supplies, transportation networks, information flows and monetary exchange routes makes the industrial habitat an integral symbiont of urban metabolism. As in agriculture, industries supply a basic need for the extended human ecosystem, such as the extraction and processing of minerals or the manufacturing of tools and other end products. These tools, processes and products, which are utilized in agricultural, urban or other industrial systems, amplify the flow of energy through the extended human ecosystem, thus hastening its rate of metabolism. In essence, industries perform the life-sustaining work that supports business and government. Within the extended human ecosystem they represent the biochemical templates that transform energy and materials into its physiological and anatomical structures.

As with urban and agricultural habitats, the use of technology and the flow of information in industrial systems is humanly mediated. Mechanical and electronic technology, concentrated abstract knowledge and the application of scientific and engineering principles replace the diverse organic technology and behavior of organisms operating in natural systems. At the same time, virtually all work in industrial systems is heavily subsidized by fossil fuel, either directly in the form of natural gas, oil and gasoline (for transportation, heating, internal combustion engines), or indirectly through electricity (oil or coal based) for light and electrically driven motors.

Industrial technology often receives intense public attention due to its obvious contrasts and conflicts with natural systems. The metabolic transformation processes accomplished by industries, though adaptively positive for the extended human ecosystem, often result in high concentrations of metabolic wastes and by-products that negatively affect natural ecosystem habitats. Noxious or toxic fumes emanating from the stacks or effluent pipes of industries often affect human and ecological health and comfort. Intense industrial development also tends to cover large areas with impermeable surfaces leading to runoff problems and the destruction of useful habitats.

With the following concepts and principles in mind, it is very instructive to examine, in detail, a keystone ecosystem of coastal Alabama. The estuarine ecosystem provides resources and services which are integral to the economic productivity of coastal Alabama and in this regard deserves a thorough examination.

ESTUARINE ECOSYSTEM

By Patrick E. O'Neil

Estuaries are extremely important to coastal areas because of their role in the production and maintenance of commerically important seafood species along the gulf coast. Additionally, estuaries provide protection to shores from storm surges, filter water-borne elements and sediments, and provide habitat for unique coastal plants and animals.

Energy to drive the estuarine ecosystem originates from four sources (Figure 90): (1) natural energies such as winds, tides, sunlight, and precipitation; (2) river and stream inputs of sediments, dissolved nutrients, organic matter, and flow; (3) urban-industrial inputs such as organic pollutants, agricultural runoff, heated water, suspended particles, and inorganic products; (4) tidal marsh contributions of detritus, sediments, and dissolved nutrients. These energy sources contribute to establishing and maintaining the detritus-dissolved nutrient resource base for the estuarine trophic structure. Energy flow through the trophic structure progresses from producers to top carnivores with a subsequent loss of energy at each level. Marsh plants, benthic algae, phytoplankton, and submerged aquatic vegetation are primary producers within the estuarine ecosystem. Herbivores such as shrimp, polychaetes, menhaden, nutria, and rice rats consume live plant biomass and (or) organic detritus as their resource base. Herbivores are preyed on by carnivores which primarily consume animal flesh but at times also ingest plant material. This group includes such animals as croakers, anchovies, and scavenging organisms. Top carnivores complete the trophic structure by exclusively consuming other animals and include such organisms as seatrout, bluefish, racoons, hawks, and alligators. After death, plant and animal tissues are microbially and bacterially degraded to simpler components which enter the detritus-dissolved nutrient pool. These nutrients then re-enter the estuarine trophic structure (Figure 90). Energy conversion efficiency within successively higher levels of the trophic structure ranges from 5 to 30% (Kormondy 1969) with the average for most ecosystems around 10%. For example, 100 g of detritus would support 10 g of herbivore which would support 1 g of carnivore. This fact serves to illustrate the importance of maintaining healthy productive regions within the estuary to support local fishery resources. Organisms that have short food chains and feed near the trophic structure base, such as shrimp and menhaden, maintain larger populations because more high-energy resources are available to them. Estuarine life histories have evolved so that high productivity and short food chains contribute to the large fishery within coastal areas.

ESTUARINE NUTRIENTS

For estuaries to maintain their productivity, nutrients in many forms must be continually supplied. Ketchum (1967) proposed three ways in which estuaries can be fertilized:

1. River waters leach plant nutrients from soils as well as transport detrital material, dissolved organic compounds, and colloidal suspensions from tidal marshes.
2. Pollution, either locally produced or transported by rivers, contributes to the nutrient base. This is an important mechanism for Mobile Bay because

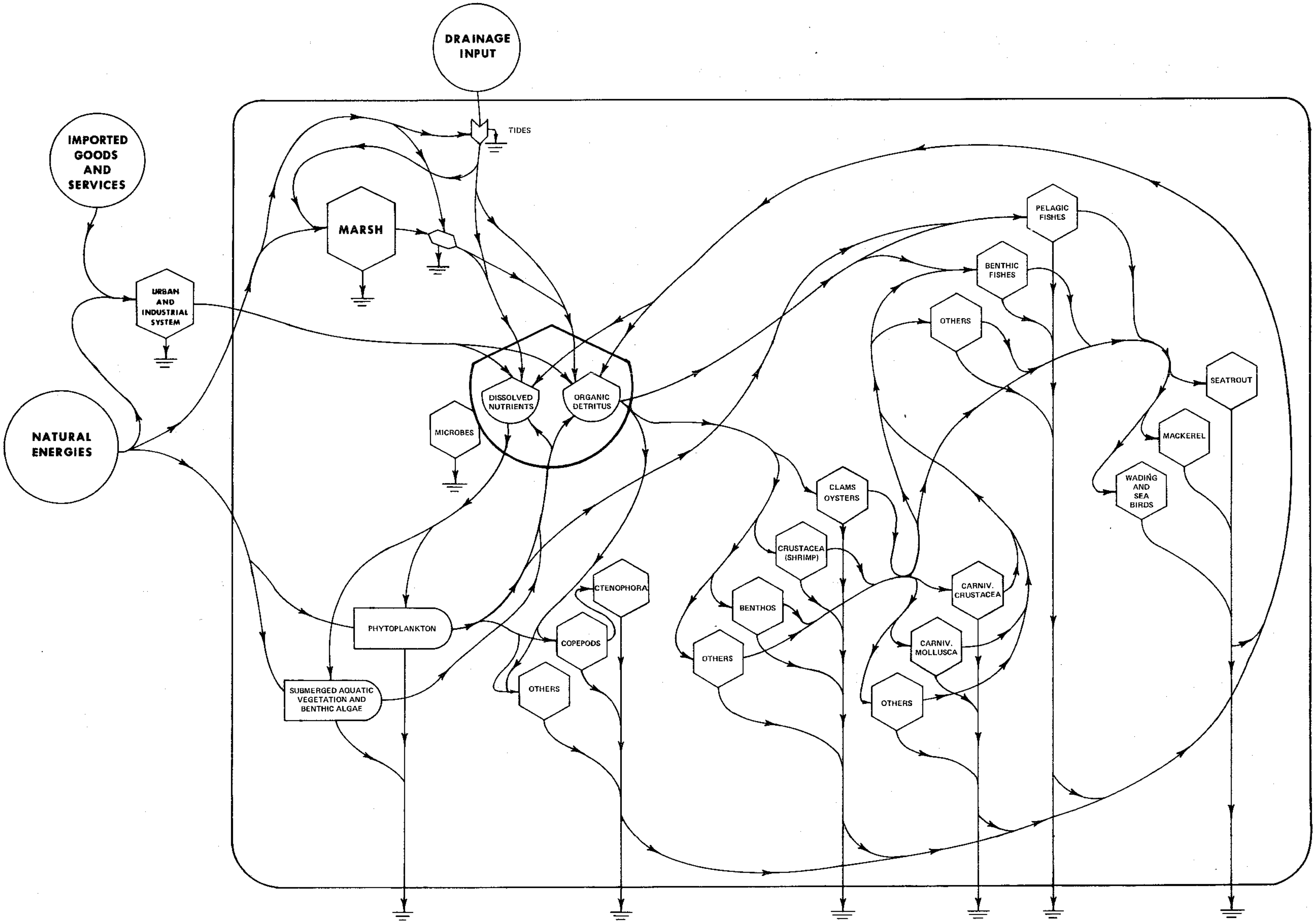


Figure 90. Energy-flow model of the coastal Alabama estuarine ecosystem.

runoff from the Mobile basin is a mixture of agricultural fertilizers and domestic sewage from a large portion of the State.

3. Subsurface countercurrents enrich estuaries by transporting nutrient-rich seawater (the layer beneath the photosynthetic zone) during times of low river discharge.

Estuarine nutrients are comprised of three groups. First, particulate organic matter (detritus) consists of degraded plant and animal remains still in a solid state. Second, dissolved organic substances consist of carbon compounds in solution with water. Third, dissolved inorganic substances consist of noncarbon elements (e.g., nitrogen, phosphorous) in solution with water.

Cycling of these nutrients and elements through the estuarine ecosystem occurs through basic pathways (Figure 91). The relationships presented in Figure 91 illustrate major routes and do not depict actual chemical conversions or trophic components involved in the cycling process. The biotic trophic structure mediates the flow of nutrients by demands of its metabolism and release of byproducts. Once a nutrient leaves the biotic trophic structure, it is either recycled within the biotic system, temporarily stored in shallow bottom sediments, lost to deeper marine sediments, or released to the atmosphere only to return later.

The concentration and composition of the nutrient pool within Mobile Bay is influenced by several interrelated factors. Flood and ebb tides, river and stream discharge, and wind mix estuarine waters releasing nutrients trapped in sediments and adding more nutrients to the pool. During summer months, horizontal stratification occurs causing many nutrients to become unavailable to potential users. Large concentrations of bacteria and microorganisms utilize vast quantities of nutrients and dissolved gases. This situation can at times produce severe nutrient and oxygen depletions causing stress among organisms.

Nutrient concentrations in estuarine sediments and waters vary seasonally depending on biological and physical conditions. In a study of the Patuxent River estuary in Maryland, Boynton et al. (1980) reported that nitrate and nitrite flux across the sediment-water interface was small during summer when water column concentrations were low, but high and directed into the sediments during winter when water column concentrations were high. Boynton et al. (1980) concluded that, in general, nutrient flux across the sediment-water interface is a source to the water column in summer when photosynthesis is high and water column stocks low, and a nutrient sink in winter when photosynthesis demand is low and water column stocks high.

The control of ammonia within an estuary by salt marshes was studied by Wolaver et al. (1980) in the York River estuary of Virginia. They concluded that salt marshes act as a source and a sink for ammonia depending on the time of year. During winter, marshes removed a small amount of the ammonia load. During spring, marshes were an active site of ammonia uptake. In the late summer, marshes are net exporters of ammonia if oxygen levels are depressed; and during fall, marshes were once again a sink for ammonia (Wolaver et al. 1980).

Dissolved inorganic nutrients are utilized primarily by phytoplankton and other photosynthesizing organisms. The extent to which animals utilize dissolved organic compounds is not fully known. Stephens (1967) reported that certain species of bivalves, echinoderms, and segmented worms can directly utilize organic compounds of low molecular weight. Stephens suggested that the role of dissolved organic nutrients is probably as a supplemental source of reduced carbon. Particulate organic matter is utilized as a primary food source by various animals including shrimp, oysters, and several fish species.

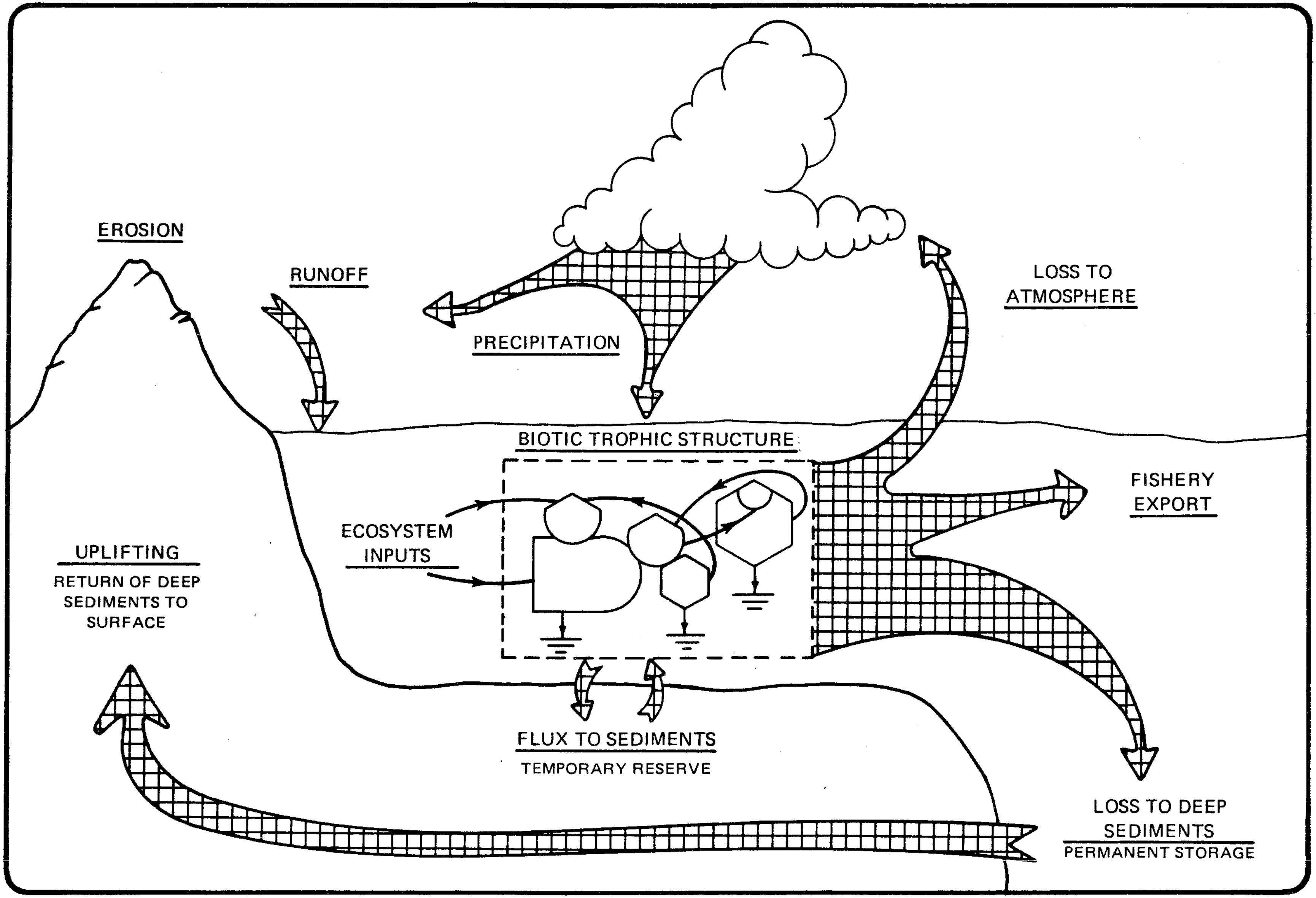


Figure 91. Generalized scheme of biogeochemical nutrient cycling in coastal Alabama.

MARSHES

Tidal marshes are composed of emergent grasslands (see Plant Life section), associated tidal creeks, and faunal components including benthos, fishes, and terrestrial consumers. Tidal marshes of coastal Alabama are basically similar to those along the south Atlantic and gulf coastal regions.

Marshes form where emergent and submerged aquatic plants invade shallow protected tidal flats. An integral requirement for marsh development is regular flooding and draining of a flat by estuarine water. Tidal marshes within Alabama are flooded once daily by a diurnal tide. Severe river flooding and wind-produced tides will occasionally disrupt the rhythmic flooding pattern.

Within the coastal Alabama marsh model (Figure 92), four main components are identified: plant production, detritus system, basic food webs, and marsh inputs.

Plant production within a tidal marsh is quite high and utlimately provides nourishment for many estuarine organisms including a variety of fishery species. Primary production within marshes occurs in grasses and benthic algae (Odum et al. 1974). Stout (1978) studied the primary productivity of two grass species commonly found in saline marshes of coastal Alabama: the needle rush (*Juncus roemerianus*) and smooth cordgrass (*Spartina alterniflora*) (Table 61). In terms of overall net primary production (NPP) or total production less respiration, the Alabama marshes ranked as well or better than Atlantic and gulf marshes in aboveground NPP and total NPP. This phenomena was attributed to the favorable growing season along the northern Gulf of Mexico. The belowground NPP within the root and rhizome system of marsh plants may be more important in terms of detrital production for marshes in coastal Alabama because belowground biomass levels were several times greater than aboveground biomass levels for both needle rush and smooth cordgrass (Stout 1978).

The aboveground live plant tissues are directly utilized by only a small portion of the marsh fauna such as herbivorous insects, nutria, rice rats and muskrats. Herbivorous insects are in turn eaten by insect-consuming birds and carnivorous insects. Herbivorous animals are preyed on by wading birds, alligators, and birds of prey (Figure 92). The aquatic faunal component of marshes derives its energy primarily from organic detritus. Detritus is available to consumers in various sizes and forms.

Odum et al. (1974), summarizing from studies conducted in Georgia tidal marshes, determined that about 50% of marsh grass NPP enters the marsh detrital pool; and, after accounting for detrital use within the marsh, approximately 45% of marsh NPP is flushed into the estuary as particulate and dissolved organic material.

Darnell (1967) presented a scheme for the breakdown of detritus in estuarine systems (Figure 93). Organic detritus originates from autochthonous sources (phytoplankton, emergent and submerged vegetation, benthic and filamentous algae) and allochthonous sources (marginal marsh and swamp vegetation, river-borne phytoplankton and detritus, beach and shore materials transported into the estuary, and wind-borne leaves and pollen). Processes which degrade plant and animal material into detritus include hydrolysis, oxidation, autolysis (breakdown by inherent enzymes), chemical effects by passing through the guts of consumers, and the chemical activity of saprophytic bacteria, fungi, and microorganisms (Darnell 1967). Studies conducted in Georgia tidal marshes have shown that approximately 94% of detrital particles are of vascular plant origin, about 5% originate from benthic and filamentous algae, and about 1% of the particles are of animal origin (Odum and de la Cruz 1967). The size distribution of detritus flushed from the tidal marsh is dominated by very small particles, "nanno" portion (the portion retained by a HA millipore mem-

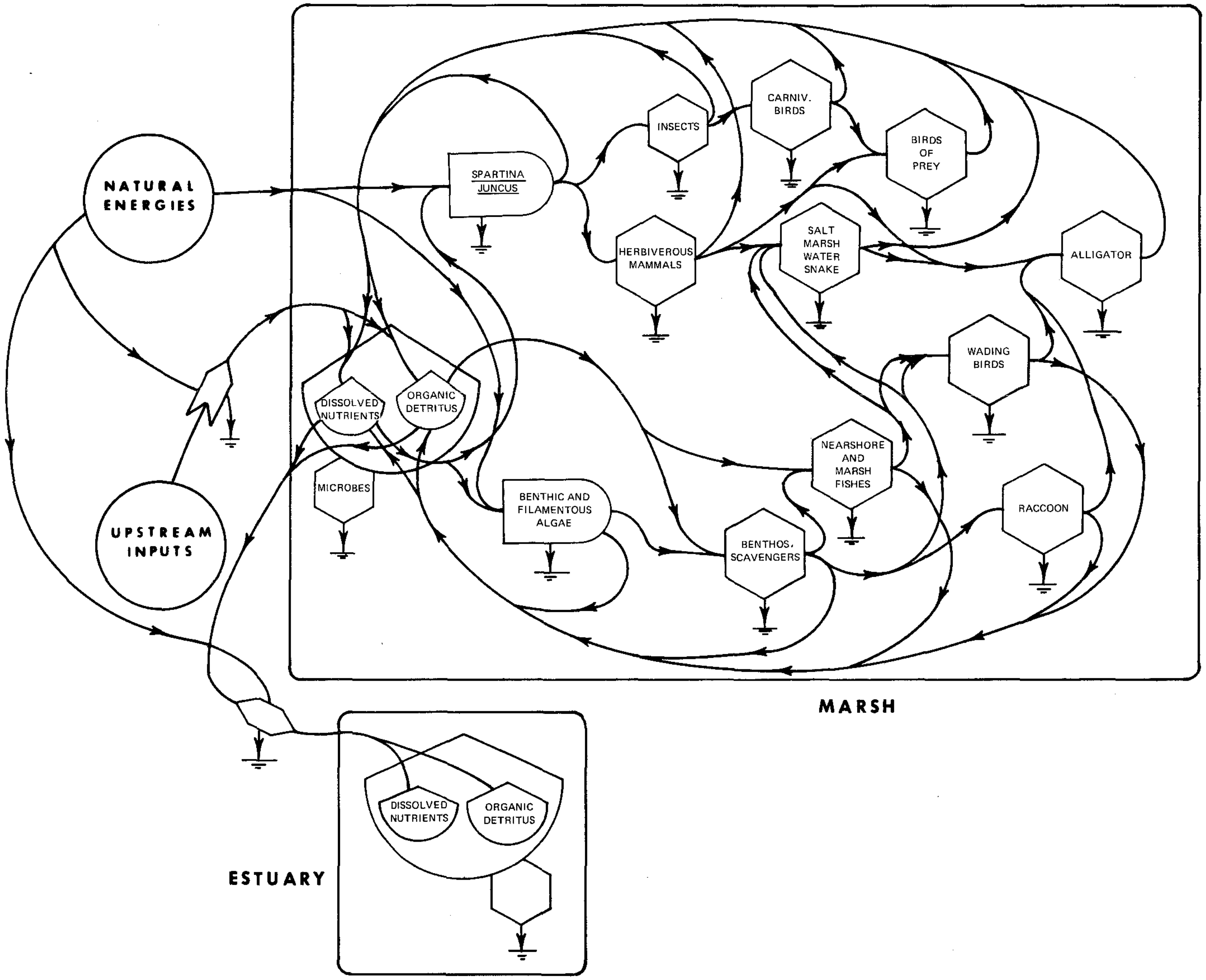


Figure 92. Marsh energy-flow model of the estuarine ecosystem of coastal Alabama.

Table 61. Growth and primary productivity of *Juncus roemerianus* and *Spartina alterniflora* within saline marshes of coastal Alabama (modified from Stout 1978).

Parameter	*Juncus roemerianus*	*Spartina alterniflora*
Annual mean stem density (m^2)	553.4	236.8
Annual mean stem height (cm)	84.5	51.3
Annual mean total biomass (g/m^2)[a]	5,974.3	4,598.2
Net annual primary productivity ($g/m^2/yr$)[a]		
Change in living and dead biomass	10,656	8,247
Mean monthly standing crop	5,872	4,625
Change in standing crop	6,392	6,708
End of season standing crop	8,085	6,308

[a]Includes both aboveground and belowground measurements.

brane filter). The "nanno" portion composed about 95% of the detritus fraction from a Georgia salt marsh, whereas the "fine" and "coarse" portions comprised 4% and 1%, respectively. Estuarine seston (suspended living and detrital organic matter) under normal conditions consists of 90% organic detritus and 10% plankton (Darnell 1967).

Organic detritus represents a major storage mechanism (produced at one time and released later), transport mechanism (downstream movement away from origin), and buffer mechanism (available during seasons of low or no primary productivity) for available food materials. Major energy-flow mechanisms between producers and consumers within the marsh are mediated by a detrital food chain rather than through a grazing food chain (Odum and de la Cruz 1967) (Figure 92).

Three differences distinguish the detritus food chain from the grazing food chain. First, bacteria and microorganisms initially break down cellulose found in most plants. Cellulose is non-digestable to many carniverous animals since they lack specific cellulose-digesting enzymes. Second, because most decomposition occurs on or near bottom sediments, scavengers which utilize detritus are predominantly benthic animals, e.g., nematodes, isopods, and (or) bottom-feeding fishes and shellfish. These organisms ingest the detritus-microbial particles, assimilate the microbes, and egest the remains as fecal matter. Lastly, tides, river discharge, and storms flush detritus out of the marsh into shallow estuarine areas where it becomes available to other aquatic animals (Gosselink 1980).

The marsh surface/open estuary interface is an important region (Gosselink et al. 1979). Production and biomass of plants and animals is high within the interface. Large quantities of marsh detritus and river-borne nutrients concentrate in the interface, providing excellent conditions for growth. The interface area is maximized by the sinuous winding of marsh tidal creeks which allows more plant and animal production to occur.

Wetlands function not only as a primary manufacturer of detritus but also as a physical refugia and nursery for juveniles of many organisms. Turner (1977) presented evidence relating commercial yields of penaeid shrimp to area of intertidal marsh and latitude (Figure 94). Maximum shrimp yields origi-

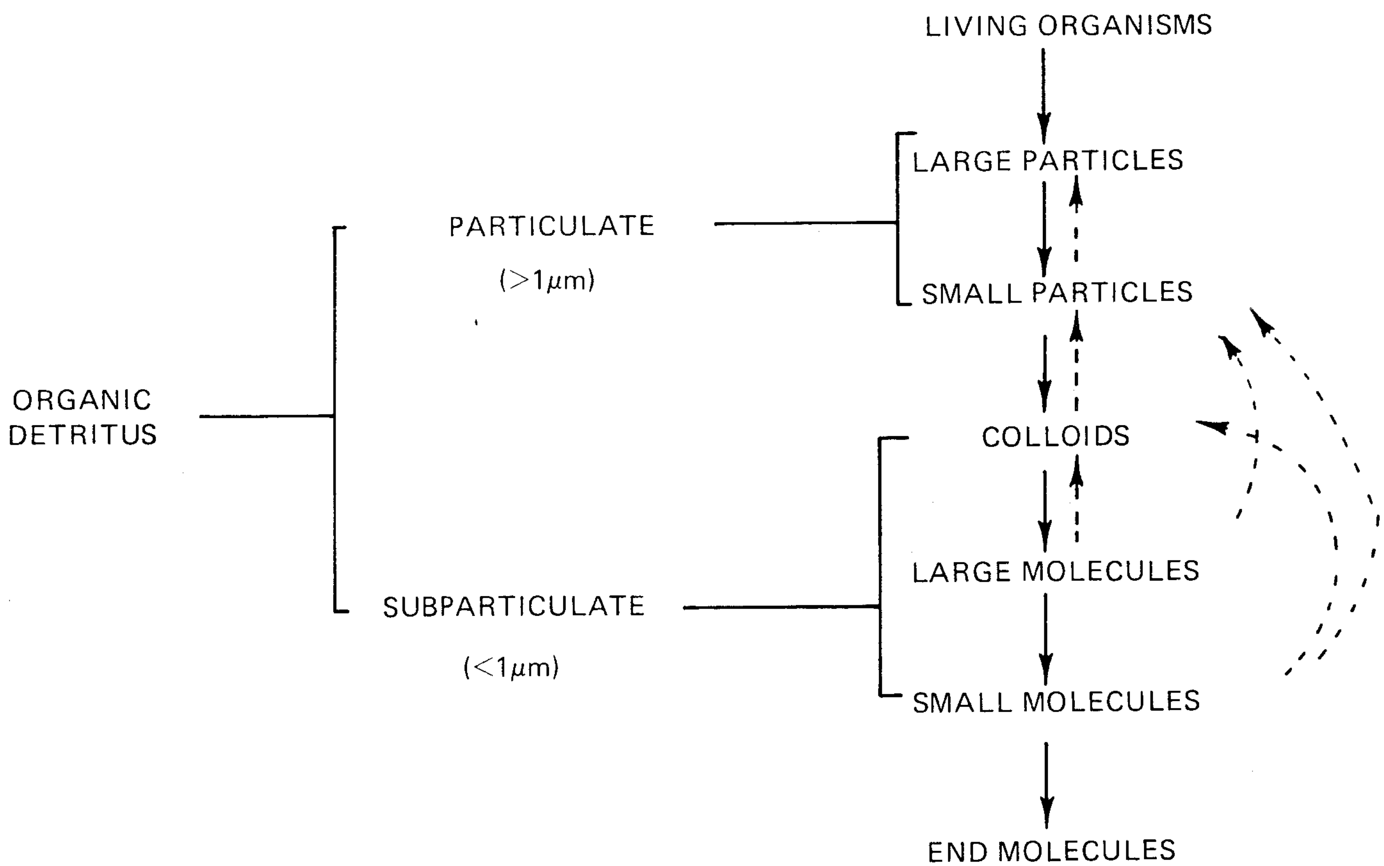


Figure 93. Components of organic detritus (Darnell 1967).

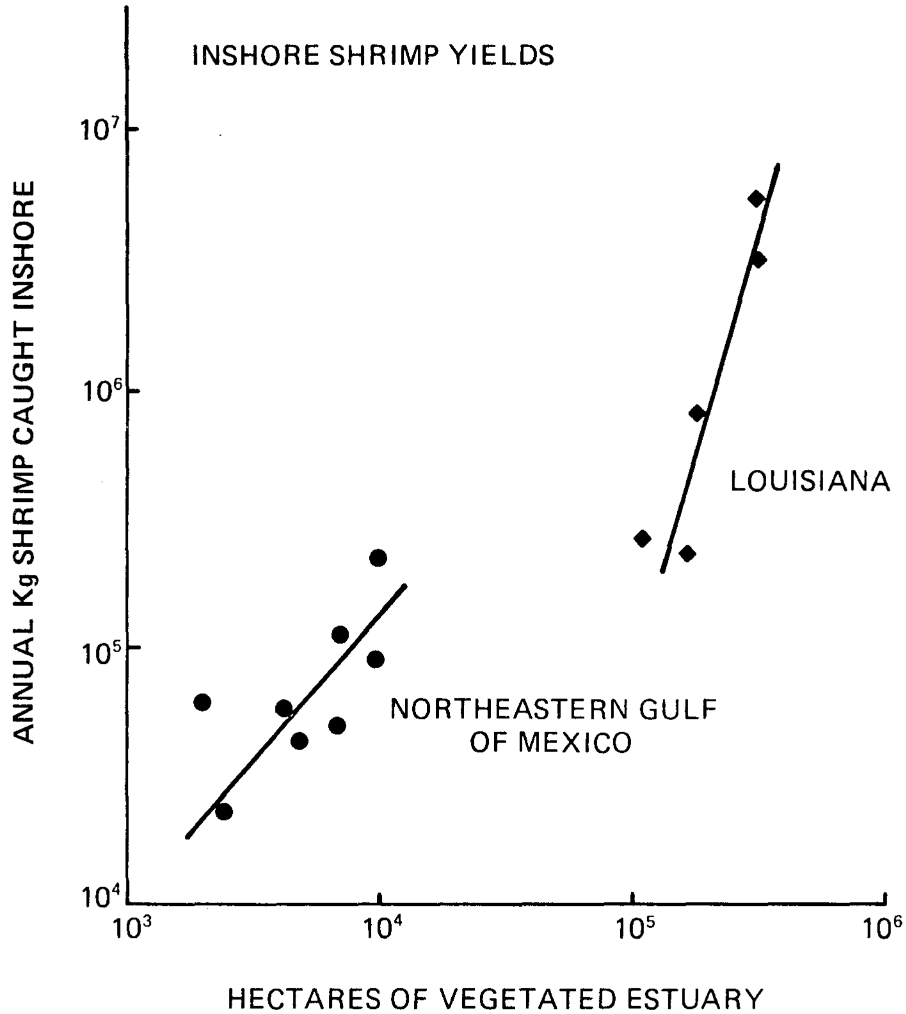


Figure 94. Relationship between the average annual yield of shrimp caught inshore (heads off) and the area of vegetated estuary (Turner 1977).

nated from regions of maximum marsh area. This data serves to again illustrate the importance of wetland areas to estuarine productivity.

Historically, significant impacts on Alabama's marshes has been a result of dredging activities either directly or indirectly from spoil disposal (Stout 1979). An estimated 2,427 ha (6,000 acres) of marshland has been lost to spoil disposal. Direct dredging has resulted in an estimated loss of 57 ha (138 acres) of marshland. Some new marshes have been created by spoil deposition. Stout (1979) estimates a net loss of 1,596 ha (3,946 acres) or 22% of all natural marshes to dredging activities (Table 62).

Another contributing factor to the loss of marsh habitat is the continued erosion of the Mobile Delta shoreline. Stout (1979) estimates erosion is most severe between the Brookley Aerospace Complex and Cedar Point on the western shore where losses are between 1.5 to 2.6 m (5 to 9 ft). Along the southern shore of Bon Secour Bay, from Three Rivers to the eastern seawall of Fort Morgan, erosional losses of 61 to 244 m (200 to 800 ft) have occurred between 1917 and 1974 (Hardin et al. 1976). No figures on the net impact of shoreline erosion on marshes is available, but results are probably significant (Stout 1979).

Table 62. 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
I10 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 Marshlands

Extensive areas of shoreline have been filled along the delta for residential and industrial development. Specific figures on marsh losses to filling are not available but are likely significant. Hardin et al. (1976) estimated 669 ha (1,651 acres) have been filled in Mobile Harbor alone. Although not all filled areas are marshes, they probably constitute a sizeable portion.

The Alabama Coastal Area Board is currently conducting studies to delineate areal coverage and species composition of freshwater and swamp wetlands north of Battleship Parkway. The studies are similar in scope of work to those of Sapp et al. (1976) and Stout and Lelong (1981).

PHYTOPLANKTON

The phytoplankton of Mobile Bay are poorly known. Although most studies have been conducted in the eastern and open Gulf of Mexico, a few general relationships, probably applicable to Mobile Bay, can be drawn. Phytoplankton populations are composed of microscopic single-celled algae including diatoms, dinoflagellates, and flagellated phytoplankton. Phytoplankton production within estuaries is poor at best and is generally exceeded by the production of attached seagrasses, algae, epiphytes, and benthic phytosynthetic microflora (Steidinger 1973). Phytoplankton production within bays of the eastern Gulf of Mexico is at a maximum in the upper reaches and decreases toward the mouth. Diatoms generally dominate the winter and early spring flora, usually exhibiting a spring bloom in response to increased concentrations of phosphate and nitrate. Dinoflagellates are common throughout the summer, whereas small flagellated algae are equally present throughout the year but may under conditions of increased nutrients exhibit spring or fall blooms (Bellis 1974).

ZOOPLANKTON

Zooplankton are those animals which are suspended in the water column and passively move with currents and tides. Two groups compose the zooplankton: holoplankton and meroplankton. Holoplankton consists of small crustaceans, ctenophores, and other animals whose entire life is planktonic. In contrast, meroplankton includes animals which have some planktonic stage in their life cycle—"temporary plankton"—such as crabs, shrimps, and some fishes (Odum 1971).

Acartia tonsa has been reported as the most abundant holoplanktonic species in Mobile Bay (Swingle 1971), Biloxi Bay (McIlwain 1968), Mississippi Sound (Perry and Christmas 1973), and generally throughout estuaries of the eastern gulf coast (Hopkins 1973; Bellis 1974). Besides copepods, pelagic Ctenophora were quite abundant throughout lower Mobile Bay (Swingle 1971) (Figure 95; Table 63).

Meroplankton are trophically similar to holoplankton. Swingle (1971) reported 11 species of larval fishes in plankton tows along lower Mobile and Perdido Bays. Largescale menhaden dominated the catch followed by silver perch and spot (Table 64). Shipp (1979) presented data on the larval abundance of 13 decapod crustacean species from the West Fowl River (Table 65). Four species dominated the fauna: fiddle crabs (*Uca* sp., *Sesarma reticulatum*, and *S. cinereum*) and the mud crab (*Rhithropanopeus harrisii*). Hopkins (1973) concluded that meroplankton composed a significant portion of the estuarine zooplankton biomass during summer months.

Zooplankton is an important food resource for many species, primarily fishes. Traditional energy-flow diagrams of phytoplankton/zooplankton/carnivore are being questioned, especially for shallow estuaries such as Mobile Bay. Williams et al. (1968) in a study of Chesapeake Bay suggested that low densities of zooplankton are normal for shallow estuaries and that zooplankton feeding has little effect on the density of phytoplankton. "Nanno" and "fine" detrital portions would serve as a food source for zooplankton though studies to substantiate this theory have not been conducted in the Gulf of Mexico.

Zooplankton composition and distribution are related to estuary shape. Densities are determined by circulation patterns, flushing rate, and grazing pressure from planktivores. Countercurrent circulatory patterns benefit zooplankton by assisting in the maintenance of a preferred depth. The ebb and flood of fresh and saline waters allows some species to be retained within the estuary.

Riley (1967) suggested that rapid tidal mixing in a shallow estuary could quickly mobilize nutrients which would be assimilated into the food chain and eventually become available to zooplankton through an increased food supply. Periodic reductions in copepod density have been attributed to severe predation by ctenophores and larval fishes (McIlwain 1968). Perry and Christmas (1973) suggested that commercial fisheries production may be reduced by ctenophore predation of their larvae. The Alabama Department of Conservation Marine Resources Laboratory is currently conducting plankton trawls in Mississippi Sound, Mobile Bay, and Perdido Bay.

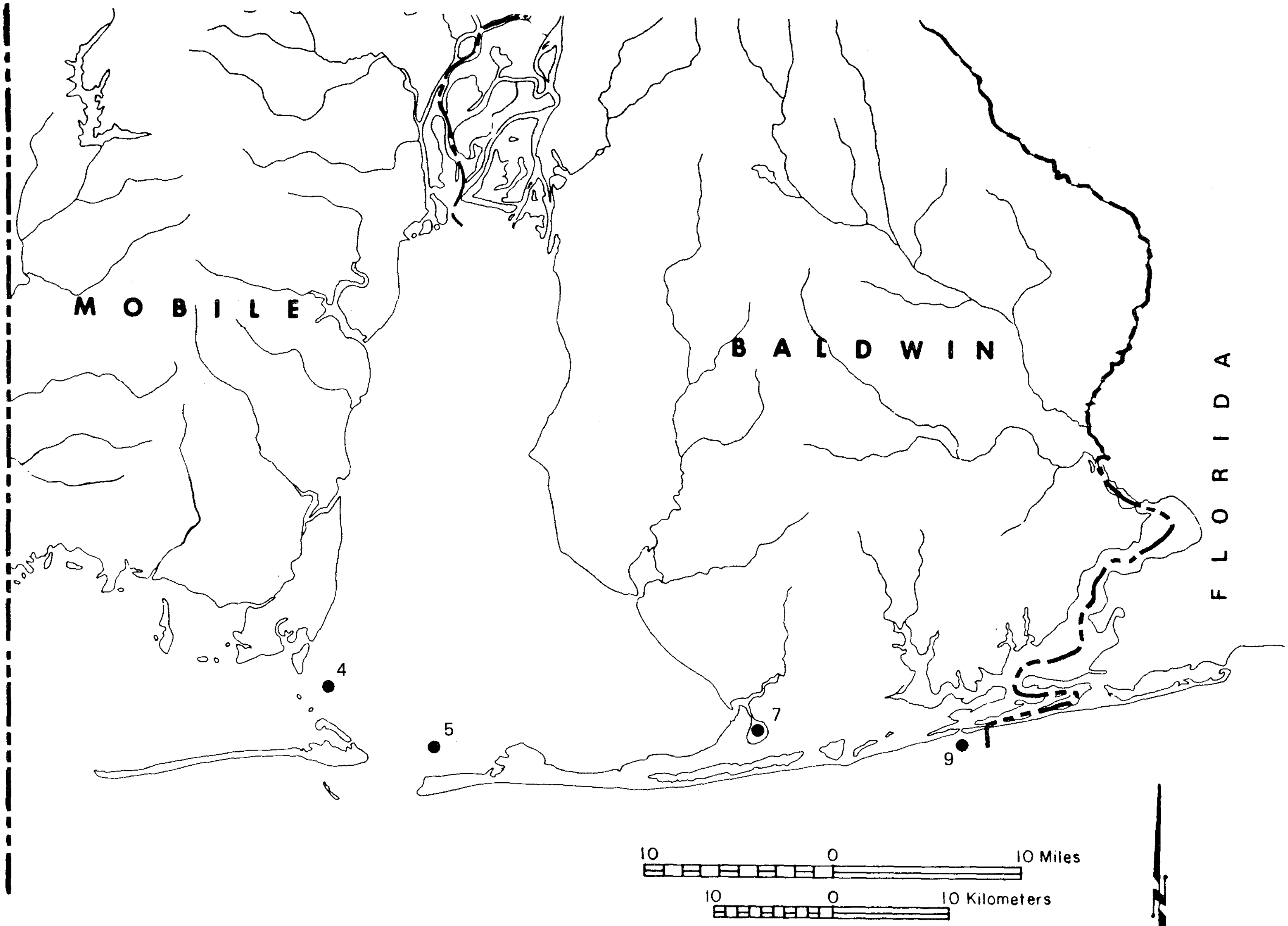


Figure 95. Plankton sampling stations for the cooperative Gulf of Mexico inventory study (Swingle 1971).

Table 63. Species composition and relative abundance of major plankters in monthly plankton sample aliquots with settled volume per 100 m^3; April 1968 through March 1969 (modified from Swingle 1971).

Taxon	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Year
Station 4													
Ctenophora	A[a]				A		A						
Copepoda	18,000	1,000	100	5,000		70	80	700	800	150	675	11,700	3,190
Amphipoda				1,200					2	1			100
Cladocera									1		576		48
Porcellanidae		15							2				1
Branchyrhyncha						25	0.6	12	2	2	1		4
Sagitta spp.		40		60									
Eggs		70	12	40					1				
Station 5													
Ctenophora					A			1,100	500	1,600	900	1,800	1,953
Copepoda	15,000	1,400	100	250	17	720	45		5	5,000	820		485
Cladocera										11			23
Branchyrhyncha			15	1		16	230		7				8
Lucifer faxoni	2	7	17				60				4		17
Sagitta spp.	100	80	20										185
Eggs	2,000	200	14										
Station 7													
Ctenophora	A			A	A	A	A		A	A	A	A	
Copepoda	25	12	80			1,500	40	750	7,680	50		1,350	957
Branchyrhyncha	4		12	6	2	150							15
Eggs		10	7										1
Detritus							A	A				A	
Station 9													
Ctenophora												A	
Copepoda	8,200	750	11,400	4,000	2,500		100	25	10,800	19,060	4,500	140	5,123
Mysidacea		20	40		38								8
Branchyrhyncha	40		132			180			540	4	5	2	75
Lucifer faxoni	3		50	40		3		8					9
Sagitta spp.								6	192	250			37
Eggs		10						80					8

[a]Abundant.

Table 64. Larval fishes collected during plankton tows at four stations in Mobile and Perdido Bays, 1968 to 1969 (modified from Swingle 1971).

Scientific name	Common name	Date	Number of specimens	Total length (mm)	Salinity (ppt)	Temperature (°C)
Brevoortia patronus	Largescale menhaden	01/17/68	7	24-31	6.9	8.4
		02/21/68	1	17	10.8	11.0
		02/21/68	2	18-21	30.3	13.2
		03/06/68	3	18-20	23.3	12.9
		03/07/68	9	11-27	30.5	14.2
		04/16/68	4	6-18	9.5	22.1
		04/17/68	3	14	23.5	22.8
		04/18/68	2	10-40	31.6	22.9
		10/29/68	2	8-11	26.9	18.0
		12/18/68	8	8-22	23.5	10.9
		12/17/68	6	14-24	33.2	12.4
		01/22/69	38	18-25	17.6	15.1
		03/28/69	2	16	6.6	14.5
		03/28/69	1	8	8.5	15.2
Anchoa mitchilli	Bay anchovy	01/17/68	1	42	6.9	8.4
		05/16/68	2	15	16.2	22.8
		05/21/68	3	10-12	18.3	25.0
		06/17/68	2	14-20	19.7	28.4
Synodus foetens	Inshore lizard-fish	04/18/68	6	20-30	31.6	22.9
		05/16/68	4	34-38	12.1	27.0
Myrophis punctatus	Speckled worm eel	03/07/68	1	73	30.5	14.2
Hippocampus erectus	Spotted sea horse	05/16/68	1	30	12.1	27.0
		10/29/68	1	9	26.9	18.0
Oligoplites saurus	Leather jacket	06/17/68	1	22	31.6	30.5
Bairdiella chrysura	Silver perch	05/21/68	5	3- 4	18.3	25.0
		06/19/68	50	2- 4	13.0	30.8
		06/19/68	4	2- 4	31.6	30.5
		06/17/68	2	3- 4	19.7	28.4
Larimus fasciatusa[a]	Banded drum	06/17/68	1	3	13.0	30.8
		06/19/68	1	5	19.7	28.4

Leiostomus xanthurus	Spot	01/17/68	1	24	6.9	8.4
		02/25/68	1	20	12.7	10.2
		02/21/68	38	14-20	14.8	10.5
		03/07/68	1	17	14.2	13.1
		01/07/68	2	28	30.5	14.2
		12/17/68	1	14	33.2	12.4
Micropogon undulatus	Croaker	03/07/68	3	12-14	30.5	14.2
		12/18/68	3	15	23.5	10.9
Lagodon rhomboides	Pinfish	01/17/68	9	14-21	6.9	8.4
		01/17/68	1	17	12.1	8.9
		02/21/68	3	16-20	30.3	13.2
		04/18/68	4	14-20	13.0	23.0
		12/18/68	8	8-22	23.5	10.9

[a]Identification questionable.

Table 65. Abundance of meroplankton in West Fowl River, Alabama, December 1974 through November 1975 (modified from Shipp 1979).

Species	Larval stage									
	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	--[b]	--	--	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	4	0	0	0	X	X	X	X	0	4
Sesarma cinereum	1,262	2	0	0	X	X	X	X	0	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	5,873
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

[a]Stage does not occur for this species.

[b]Data unavailable.

BENTHOS

Estuarine benthic communities are characterized by sessile or inactive animals inhabiting bottom sediments. These animals are an important link for the overall biological production within Mobile Bay. Benthic organisms perform two major functions within the estuarine ecosystem: (1) mobilize and provide nutrients to organisms which feed directly on the benthos, and (2) assist in substrate processing and aeration and release of stored nutrients through burrowing. The benthos is commonly categorized according to size. Meiofauna includes organisms less than 0.5 mm (0.02 inch) and macrofauna those organisms greater than 0.5 mm. The spatial arrangement of benthos relative to the water-sediment interface is also categorized. Epifauna refers to organisms living on the surface, either attached or free-moving, and infauna refers to organisms that dig into the substrate or construct tubes or burrows (Odum 1971).

MEIOFAUNA

Meiofauna include species that perform various functional roles such as autotroph, filter and detritus feeder, and decomposer. Detritus feeders, the most common group, include small copepods, ostracods, turbellarians, nematodes, tardigrades, and certain amphipods and are the primary link in the meiofauna food chain (Odum et al. 1974). Bacterial decomposers are important in the overall control of nutrients released from sediments. Metabolic activities of the meiobenthos in some habitats may account for up to five times the oxygen consumption of macrofauna.

In a study of meiofauna surrounding the Mobil test well near the mouth of Mobile Bay, TechCon, Inc. (1980) reported 13 harpacticoid copepod families, 28 nematode families, 4 gastrotrich families, 3 kinorhynch families, and 1 tardigrade family. Nematodes and Copepods were the most frequently collected taxa with polychaetes and turbellarians the next most frequent groups (Table 66).

Table 66. Number of composite sample station occurrences of meiofaunal groups taken between July 1978 and April 1979 in the vicinity of Mobil exploratory drilling barge in Mobile Bay (TechCon, Inc. 1980).

Group	Occurrence at sampling stations
Nematoda	38
Copepoda	37
Polychaeta	28
Turbellaria	23
Echinoderida	18
Halocarida (mites)	17
Crustacean larvae	16
Molluscan larvae or juveniles	10
Oligochaeta	8
Lepidodasytidae	7
Ostracoda	7
Archiannelida	6
Protozoa	5
Cumacea	1
Cyclopoida	1
Gnathostomulida	1
Polygordiidae	1
Protozoa	1

Nematodes usually comprise the largest diversity and abundance of meiofaunal animals and may account for a large portion of total sediment ATP. In fine sediments, meiofauna are indirectly consumed as food resources by macrobenthos and fishes, whereas in sandy sediments they function primarily to process detrital material and recycle nutrients (Coull and Bell 1979).

Sediment texture, salinity, temperature, and occasionally oxygen are regulating factors of meiofaunal populations. Sediment texture influences species composition because particle size determines interstitial environmental characteristics such as water circulation, oxygen availability, and total space available for occupation.

MACROFAUNA

The ecological role of macrobenthos is similar to that of meiobenthos except that macrobenthos consume in proportion a larger quantity of organic detritus. Factors affecting macrofauna distribution, abundance, and survival within the estuary include temperature, salinity, oxygen, and sediment type. Sediments are particularly important in macrofauna distribution (TechCon, Inc. 1980). Resuspension or alteration of bottom sediments can totally alter benthic community structure. Macrofaunal communities are very dynamic, with species composition and density changing several times throughout the year.

Parker (1960) characterized the mollusk communities of Mobile Bay into several distinct types. In 1974, Parker amended his earlier faunal lists to include more recent data and presented a general community type distribution map for Mobile Bay (Table 67; Figure 96). May (1973a) studied the distribution and abundance of benthic organisms collected from 25 stations in the upper half of Mobile Bay. May concluded that standing crop and diversity of invertebrates was reduced on the west side of Mobile Bay. Using data from various sources, Parker et al. (1974) prepared a map reflecting macrofauna density and diversity throughout the bay (Figure 97). Parker et al. concluded that the Mobile Ship Channel was a natural barrier between habitats and was a severe modifying factor in community structure.

Table 67. Benthic mollusk communities occurring in coastal Alabama (modified from Parker et al. 1974).

Scientific name	Common name[a]	A[b]	B	C	D	E	F	G	H
Polymesoda caroliniana	Carolina marsh clam	X							
Rangia cuneata	Common rangia	X							
Littoridina sphinctostoma	Small-mouthed hydrobid	X							
Cyrenoida floridana	Florida marsh clam	X							
Nassarius acutus	Sharp-knobbed Nassa		X			X			
Retusa (Acteocina) canaliculata	Channeled barrel-bubble		X			X			
Anadara ovalis	Blood ark		X						
Anadara transversa	Transverse ark		X			X			
Callocardia (Agriopoma) texasiana	Texas venus		X						
Macoma mitchelli	Macoma		X			X			
Tellidora cristata	White crested tellin		X						
Tellina versicolor	Dekay's dwarf tellin		X						
Abra aequalis	Common Atlantic abra	X							
Mulinia lateralis	Dwarf surf clam		X			X			
Lolliguncula brevis	Brief thumstall squid		X						
Littorina irrorata	Marsh periwinkle			X					
Caecum cooperi	Cooper's Atlantic caelum		X						
Bittium varium	Horn shell			X					
Crepidula convexa	Convex slipper shell			X					
Crepidula plana	Eastern white slipper shell			X	X				
Polinices duplicatus	Shark eye		X						
Anachis avara	Greedy dove shell			X	X	X			
Anachis obesa	Fat dove shell			X	X	X			
Mitrella lunata	Lunar dove-shell			X	X	X			
Nassarius vibex	Common Eastern Nassa			X					
Terebra dislocata	Common Atlantic auger			X					
Haminoea antillarum	Paper bubble			X					
Melampus bidentatus	Eastern melampus			X					
Modiolus (Geukensia) demissa	Ribbed mussel			X					
Aequipecten (Argopecten) irradians	Atlantic bay scallop			X					
Lucina (Pseudomiltha) floridana	Florida lucine			X					
Laevicardium mortoni	Morton's egg cockle			X					
Gemma gemma	Amethyst gem shell			X					
Mercenaria mercenaria	Northern quahog			X			X		
Macoma constricta	Constricted macoma			X					
Tagelus plebeius	Stout tagelus			X					
Ensis minor	Minor jackknife clam			X					
Mactra fragilis	Fragile Atlantic mactra			X					
Spisula solidissima	Atlantic surf clam			X					
Cyrtopleura costata	Angel wing			X					
Lyonsia hyalina floridana	Florida lysonia			X					
Crepidula fornicata	Common Atlantic slipper-shell				X				
Thais haemastoma	Oyster drill				X		X		
Odostomia impressa	Impressed odostome				X	X			
Brachidontes (Ichadium) recurvum	Hooked mussel				X				
Crassostrea virginica	Eastern oyster				X				
Diplothyra smithii	Smith's martesia				X				
Rissoina chesnelii	Chesnel's rissoina						X		
Meioceras (Caecum) nitidum	Little horn caecum						X		
Seila adamsi	Adam's miniature cerith						X		
Cerithiopsis greeni	Green's miniature cerith						X		
Triphora nigrocincta	Black-lined trifora						X		

Table 67. Concluded.

Scientific name	Common name	A	B	C	D	E	F	G	H
Strombus alatus	Florida fighting conch						X		
Natica pusilla	Southern miniature natica						X		
Cantharus cancellarius	Cancellate cantharus						X		X
Busycon contrarium	Lightning whelk						X		
Olivella mutica	Variable dwarf olive						X		X
Acteon punctostriatus	Adam's baby-bubble						X		
Haminoea succinea	Bubble shell						X		
Odostomia seminuda	Half-smooth odostome						X		
Ostrea equestris	Crested oyster						X		
Crassinella lunulata	Lunate crassinella						X		
Tellina alternata	Alternate tellin						X		
Semele nuculoides	Nucula-like semele						X		
Pandora trilineata	Say's pandora						X		
Oliva sayana	Lettered olive							X	X
Hastula (Terebra) salleana	Salle's auger							X	
Cuna dalli	Dall's cuna clam							X	
Donax variabilis	Coquina shell							X	
Sinum perspectivum	Common baby's ear								X
Phalium granulatum	Scotch bonnet								X
Murex fulvescens	Giant Eastern murex								X
Busycon spiratum	Pear whelk								X
Olivella pusilla	Very small dwarf olive								X
Terebra concava	Concave auger								X
Kurtziella creinella	Mangelia								X
Nuculana acuta	Pointed nut clam								X
Anadara brasiliana	Incongruous ark								X
Noetia ponderosa	Ponderous ark								X
Atrina serrata	Saw-toothed pen shell								X
Lucina amiantus	Lovely miniature lucina								X
Dosinia discus	Disk dosinia								X
Donax tumidus (texasianus)	Fat gulf donax								X
Loligo pealeii	Atlantic long-finned squid								X

[a]Common names are from Abbott (1974).

[b]A--River-influenced, low salinity assemblage, B--Open Sound or open bay center assemblage, C--Open sound or open bay margin assemblage, D--Oyster reef assemblage, E--Enclosed bay or inter-reef assemblage, F--Inlet and deep channel assemblage, G--Surf zone, 0 to 4 m, H--Inner shelf, 4 to 24 m.

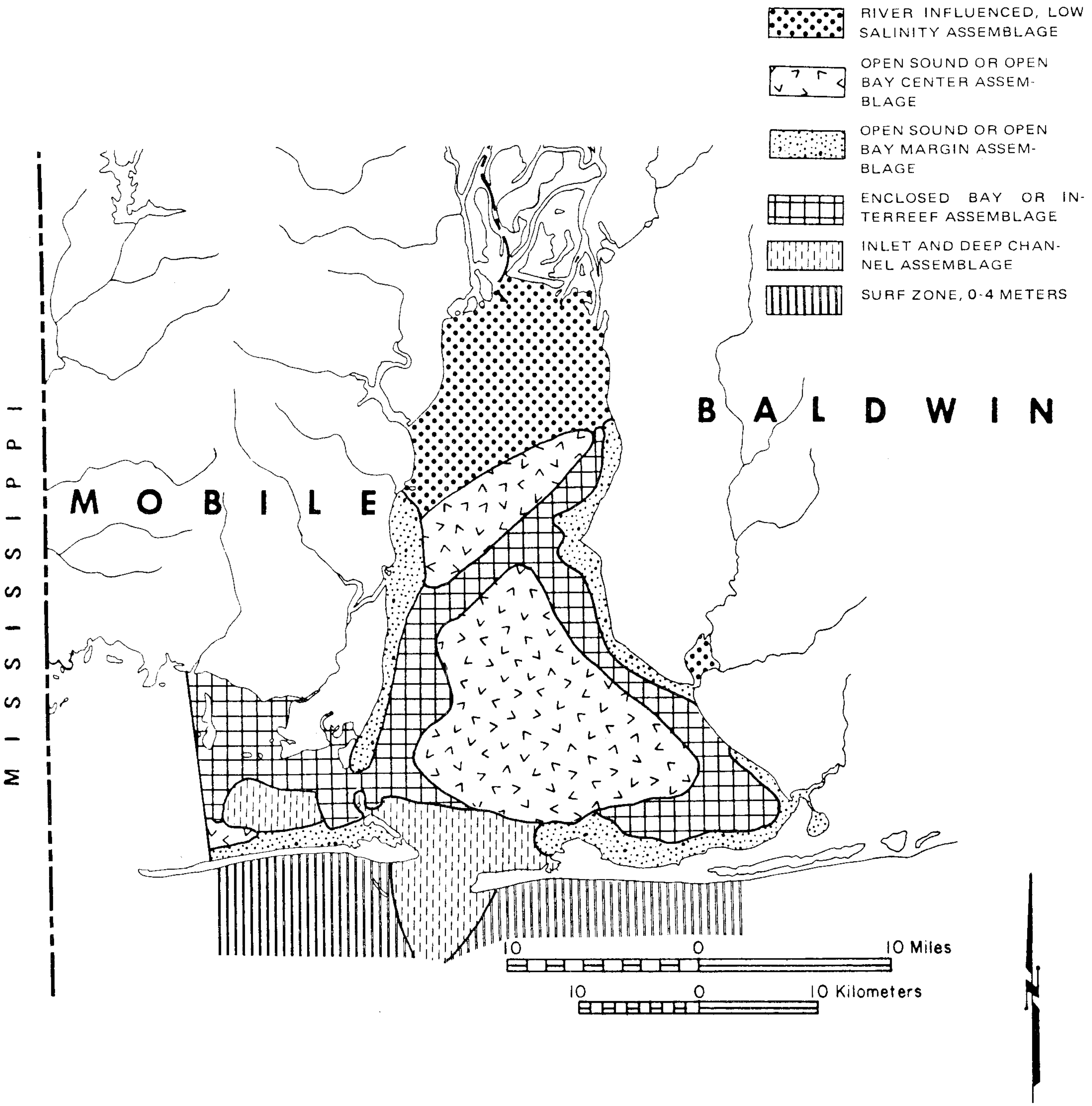


Figure 96. Distribution of benthic mollusk communities within Mobile Bay (modified from Parker et al. 1974).

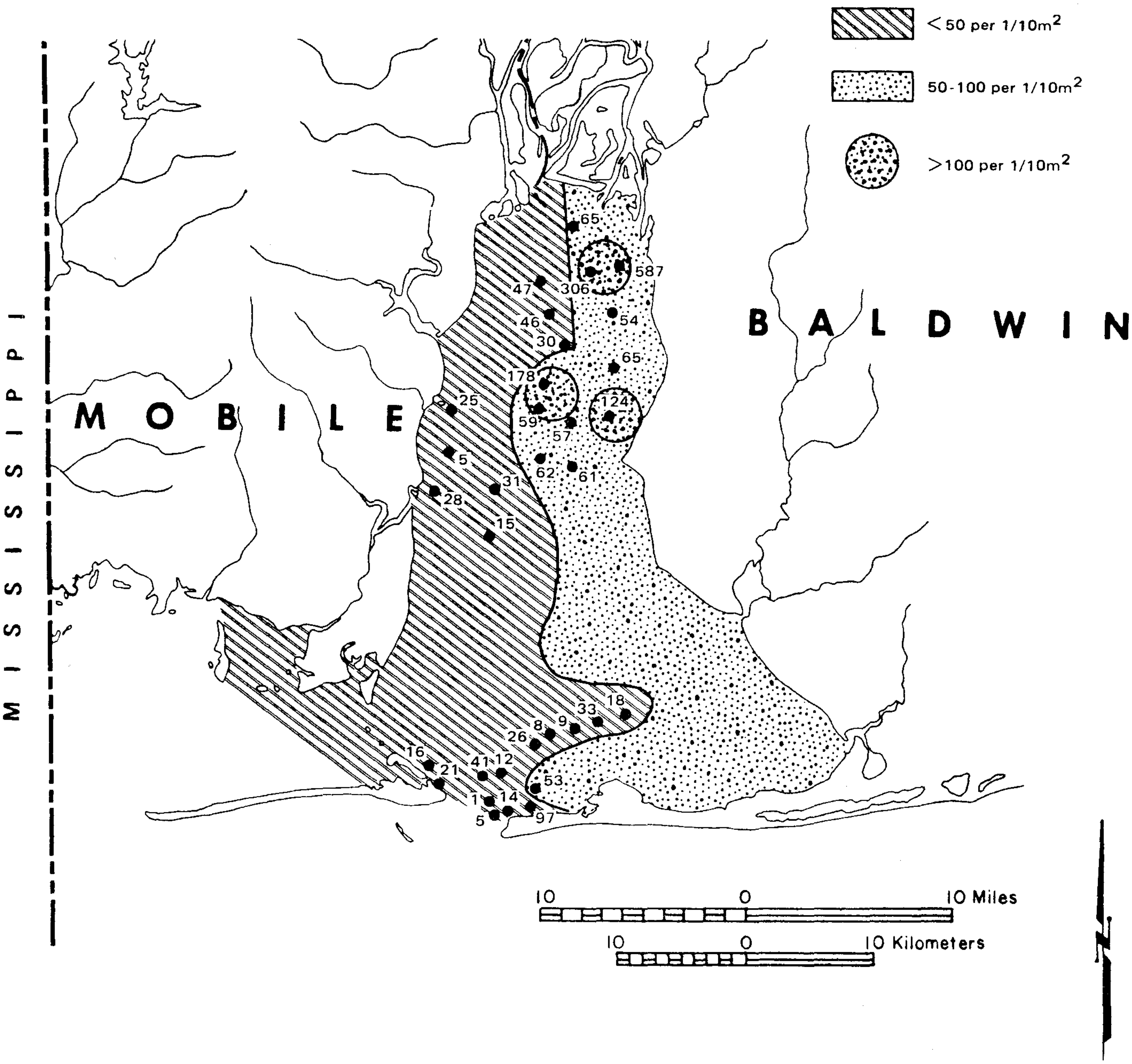


Figure 97. Distribution of benthic invertebrate standing crop from quantitative samples taken in Mobile Bay (Parker et al. 1974).

Recent benthic community data was summarized by Vittor (1979a) (Table 68; Figure 98). Based on this data, Vittor compiled a list of dominant macroinvertebrates in major benthic habitats of Mobile Bay and Mississippi Sound (Table 69). This effort represents the first general classification of the total coastal Alabama macrofaunal community based on location, salinity, and habitat type (sediment texture).

TechCon, Inc. (1980) published results of their comprehensive environmental study of Mobile Bay surrounding the Mobil test well. They reported 401 distinct taxa (317 species) as occurring in sediments surrounding the drilling platform. Annelids, primarily polychaetes, dominated the fauna both in diversity (147 species) and abundance (70% of total individuals collected). Other abundant groups were arthropods (74 taxa), mollusks (53 taxa), and echinoderms (9 taxa). The dominant species in sediments surrounding the well was the polychaete *Mediomastus californiensis* (Table 70).

Macrofaunal communities within coastal Alabama are composed of unique sets of organisms highly adaptive to variable environmental conditions. Most species and about 80% of the individuals occur in the top 15 cm (7 inches) of substrate. The burrowing activities of macrobenthic organisms rework the substrate and bring buried particles back into contact with estuarine waters. Substrate turnover reduces anaerobic conditions and permits oxygen and bacteria to enter the substrate for decomposition (Gray 1974). Macrofauna are trophically classified as deposit feeders, suspension feeders, scavengers, carnivores, or omnivores. Suspension feeders are commonly found in well-sorted sandy substrates, whereas deposit feeders are associated with areas rich in organics, silts, and clays. TechCon, Inc. (1980) reported the greatest diversity of organisms in silty clay substrates and the least diversity in shallow sandy areas for substrates of lower Mobile Bay.

In estuaries like Mobile Bay, which are regularly subjected to modification of benthic habitats either through dredging activities, reef construction, and (or) natural effects such as hurricanes and severe flooding, populations of benthic organisms must have the ability to repopulate a suitable substrate after disturbance. May (1973a) reported no long-term effects of dredging on the benthic communities of Mobile Bay. TechCon, Inc. (1980) reported that variability of macrofaunal community structure in lower Mobile Bay is a natural occurrence. The lower bay fauna was studied during extreme spring flooding and Hurricane Frederic. Therefore, documentation is available concerning community structure changes during stress conditions. Repopulation of macrofaunal communities after stressing conditions occurs by free-swimming pelagic larvae arising sexually; non-pelagic larvae arising sexually in either brookpouches, capsules, or gelatinous masses; and assexual reproduction (Carriker 1967).

The Coastal Area Board is currently conducting a benthic study at seven stations in Mobile Bay. The Department of Conservation Marine Resources Division is also conducting a benthic program in Mississippi Sound, Mobile Bay, and Perdido Bay.

FISHES

Fishes of coastal Alabama feed at all levels of the estuarine food web and occupy all major habitats: marsh, benthic, littoral, and pelagic. Commercial and sport fishes, important to recreational and economic concerns, have been extensively studied. Subsequently, little attention is given to fishes which trophically support some of these fisheries. Shipp (1979) classified estuarine forage fishes into three categories: nearshore and marsh, demersal, and pelagic estuarine.

Nearshore and marsh fishes occupy tidal marshes, shallow beaches, and shallow mud bottoms. Within Mobile Bay, the livebearers (Poeciliidae), killifishes (Cyprinodontidae),

Table 68. Sources of benthic community data for Mobile Bay, Alabama (modified from Vittor 1979a).

Study number[a]	Sample period	Area studied	Number of stations/ Frequency	Reference
1	1970	Tidal streams	23/1-3 times	Bault 1970
2	1972	West shore near Deer River	9/once	Taylor 1972
3	1972-73	D'Olive Bay	18/4 seasons	Vittor 1974
4	1973	Lower Mobile Bay	15/once	Vittor 1973
5	1973	Intersection of Dog River and Mobile Ship Channels	24/once	Lackey et al. 1973
6[b]	1975	Intertidal, Dauphin Island	6/once	Kennedy 1975
7[c]	1977-78	Gulf Intracoastal Waterway	56/once	Taylor 1978
8	1977-78	Theodore Ship Channel project area	3/10 times; 5/5 seasons	Hopkins 1979; Vittor 1979b
9	1978	Garrows Bend	12/once	Vittor 1978
10	1978-79	Lower Mobile Bay, Mobil Oil site	8/2 seasons	TechCon, Inc. 1980

[a]See Figure 98 for location of study number.

[b]Excluding six stations on the gulf side of Dauphin Island.

[c]Work performed by B. Vittor and reported by Taylor (1978).

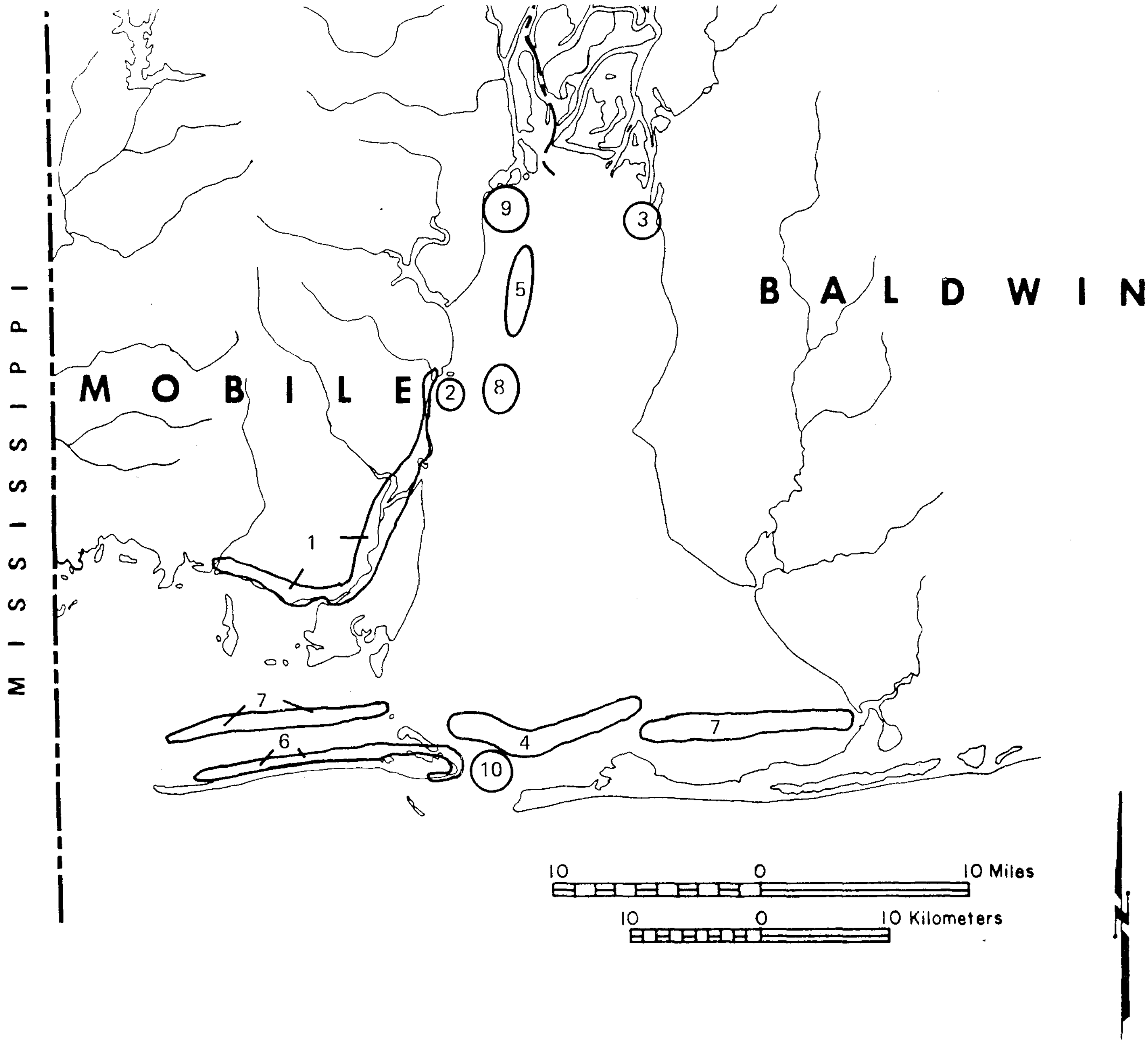


Figure 98. Sampling locations of benthic community investigations in Mobile Bay and Mississippi Sound. Refer to Table 68 for numbering explanation (modified from Vittor 1979a).

Table 69. Occurrence of dominant macroinvertebrates in major benthic habitats in Mobile Bay and Mississippi Sound, Alabama (Vittor 1979a).

Species	Salinity conditions			Sediment texture				Geographic location			
	Fresh brackish	Brackish	Brackish marine	Clay	Silt	Fine sand	Sand	Upper bay	Middle bay	Lower bay	Miss. Sound
Gastropoda											
Neritima reclivata		X			X			X	X		
Probythinella protera	X				X			X			
Texadina sphinctostoma	X				X			X			
Pelecypoda											
Gemma sp.			X			X					X
Macoma mitchelli		X			X	X		X	X		X
Mulinia lateralis		X			X	X			X	X	X
Rangia cuneata	X	X		X	X			X	X		
Annelida											
Heteromastus filiformis		X	X		X	X			X	X	
Laconercis culveri	X	X			X	X		X			
Magelona spp.			X			X	X			X	
Malacoceros vanderhorsti			X			X				X	
Mediomastus californiensis	X	X	X	X	X	X		X	X	X	X
Neanthes micromma			X		X					X	
Neanthes succinea		X	X		X	X		X	X	X	X
Owenia fusiformis			X								
Paramphinome pulchella		X	X			X	X			X	X
Parandalis americana	X	X		X	X			X	X		X
Parapionosyllis longicirrata			X			X				X	
Paraprionospio pinnata		X	X	X	X					X	X
Polydora ligni	X	X		X	X	X			X		
Polygordius sp.			X							X	
Scoloplos foliosus		X	X			X	X			X	X
Streblospio benedicti	X	X		X	X	X		X	X		X
Crustacea											
Corophium lacustre	X					X			X		
Melita nitida		X			X	X			X		
Echinodermata											
Micropholis atra			X		X	X				X	

Table 70. Dominant macrobenthos collected around MOEPSI Well No. 1-76 in Mobile Bay, Alabama (modified from TechCon, Inc. 1980).

Species	Higher taxonomic group	Total specimens	Percent abundance
Mediomastus californiensis	Polychaete	17,012	18.3
Polygordius sp. A	Archiannelid	16,355	17.6
Mulinia lateralis	Bivalve-mollusc	8,152	8.8
Myriochele oculata	Polychaete	7,070	7.6
Branchiostoma caribaeum	Cephalochordate	4,097	4.4
Lepidactylus sp. A	Amphipod-crustacean	3,329	3.6
Magelona pacifica	Polychaete	2,947	3.2
Owenia fusiformis	Polychaete	2,062	2.2
Malacoceros vanderhorsti	Polychaete	2,050	2.2
Parapionosyllis longicirrata	Polychaete	1,940	2.1
Neanthes micromma	Polychaete	1,465	1.6
Micropholis atra	Echinoderm	1,319	1.4
Glycinde solitaria	Polychaete	1,022	1.1
Magelona cf. *cincta*	Polychaete	1,016	1.1
Cossura soyeri	Polychaete	755	0.8
Sigambra tentaculata	Polychaete	716	0.8
Paraprionospio pinnata	Polychaete	711	0.8
Spiophanes bombys	Polychaete	643	0.7
Neanthes succinea	Polychaete	604	0.6
Nemertean sp. A	Rhynchocoel	592	0.6
Diopatra cuprea	Polychaete	547	0.6

and silversides (Atherinidae) dominate the fauna (Table 71). Species most likely to prey on nearshore and marsh fishes are the southern flounder (*Paralichthys lethostigma*), spotted seatrout, sand seatrout (*Cynoscion arenarius*), and red drum (*Sciaenops ocellatus*).

The demersal estuarine fish fauna is dominated by species preferring mud bottoms rich in nutrients and fine sediments. Demersal fishes are carnivorous scavengers and detritus feeders consuming a variety of benthic material. Demersal fishes occurring in estuarine Alabama (Table 72) includes some species which spawn offshore and migrate shoreward to utilize estuarine resources during specific stages of their life cycles.

Pelagic estuarine fishes (Table 73) were considered by Swingle and Bland (1974a) to be the numerically important forage fish group within Mobile Bay. In particular, the bay anchovy (*Anchoa mitchilli*) and gulf menhaden (*Brevoortia patronus*) are the most common fishes within coastal Alabama.

Forage fishes are of great importance to the commercial and sport fishing industries. The majority of forage fishes serve as food for predatory non-game and fishery species, but croakers, seatrout, and menhaden are directly utilized as a fishery.

Fishes represent a major storage, transport, and conversion mechanism for energy flowing through and within the estuary. They serve simultaneously as the ultimate link in many food chains and as intermediate transfer agents in others.

A larval fishes study is being conducted in upper Mobile Bay by the Coastal Area Board, while a similar study in lower Mobile Bay is being conducted by the Alabama Department of Conservation Marine Resources Division.

Table 71. Nearshore and marsh fishes of estuarine Alabama (modified from Shipp 1979).

Scientific name	Common name	Frequency
Lagodon rhomboides	Pinfish	C[a]
Gobionellus boleosoma	Darter goby	C
Gobionellus hastatus	Sharptail goby	C
Gobiosoma bosci	Naked goby	C
Microgobius gulosus	Clown goby	O
Eucinostomus argenteus	Silver jenny	A
Adinia xenica	Diamond killifish	C
Cyprinodon variegatus	Sheepshead minnow	A
Fundulus confluentus	Marsh killifish	C
Fundulus grandis	Gulf killifish	C
Fundulus jenkinsi	Saltwater topminnow	C
Fundulus similis	Longnose killifish	A
Lucania parva	Rainwater killifish	C
Gambusia affinis	Mosquitofish	A
Poecilia latipinna	Sailfin molly	A
Membras martinica	Rough silversides	O
Menidia beryllina	Tidewater silverside	A
Mugil cephalus	Striped mullet	A
Mugil curema	White mullet	O
Syngnathus louisianae	Chain pipefish	O
Syngnathus scovelli	Gulf pipefish	C

[a] A--Abundant, common species present in large numbers; C--Common, species present in most collections; O--Occasional, observed at irregular intervals.

Table 72. Demersal fishes of estuarine Alabama (modified from Shipp 1979).

Scientific name	Common name	Frequency
Synodus foetens	Inshore lizardfish	C[a]
Arius felis	Sea catfish	C
Bagre marinus	Gafftopsail catfish	C
Opsanus beta	Gulf toadfish	C
Porichthys plectrodon	Midshipman	C
Gobiesox strumosus	Skilletfish	C
Polydactylus octonemus	Atlantic threadfin	C
Urophycis floridanus	Southern nake	O
Cynoscion arenarius	Sand seatrout	A
Cynoscion nebulosus	Spotted seatrout	C
Micropogonias undulatus	Atlantic croaker	A
Leiostomus xanthurus	Spot	A
Bairdiella chrysoura	Silver perch	C
Pogonias cromis	Black drum	O
Menticirrhus americanus	Southern kingfish	O
Archosargus probatocephalus	Sheepshead	C
Astrocopus y-graecum	Southern stargazer	O
Hypsoblennius ionthas	Freckled blenny	C
Gobioides broussonnetti	Violet goby	O
Trichiurus lepturus	Atlantic cutlassfish	C
Prionotus rubio	Blackfin searobin	C
Prionotus tribulus	Bighead searobin	C
Citharichthys spilopterus	Bay whiff	C
Etropus crossotus	Fringed flounder	O
Achirus lineatus	Lined sole	O
Trinectes maculatus	Hogchocker	A
Symphurus palagiusa	Black-cheek tonguefish	C
Sphoeroides parvus	Least puffer	C
Chilomycterus schoepfi	Striped burrfish	O

[a]A--Abundant, common species present in large numbers; C--Common, species present in most collections; O--Ocassional, observed at irregular intervals.

Table 73. Pelagic fishes of estuarine Alabama (modified from Shipp 1979).

Scientific name	Common name	Frequency
Brevoortia patronus	Gulf menhaden	A[a]
Dorosoma cepedianum	Gizzard shad	O
Dorosoma petenense	Threadfin shad	C
Harengula jaguana	Scaled sardine	O
Anchoa hepsetus	Striped anchovy	C
Anchoa mitchilli	Bay anchovy	A
Chaetodipterus faber	Atlantic spadefish	C
Peprilus alepidotus	Harvestfish	C
Peprilus burti	Gulf butterfish	C
Strongylura marina	Atlantic needlefish	C
Chloroscombrus chrysurus	Atlantic bumper	C
Oligoplites saurus	Leatherjacket	C
Selene setapinnis	Atlantic moonfish	O
Selene vomer	Lookdown	O

[a] A--Abundant, common species present in large numbers; C--Common, species present in most collections; O--Ocassional, observed at irregular intervals.

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APPENDIXES

Table A-1. Water use classifications for interstate, coastal, and intrastate waters of the Mobile River-Mobile Bay Basin.

Classifications of interstate and coastal waters of the Mobile River-Mobile Bay Basin (adopted by the Alabama Water Improvement Commission on May 5, 1967).

Stream	From	To	1[a]	2	3	4	5	6
Mobile River and all other rivers, creeks, lakes of the Mobile River Delta and their tributaries except as otherwise designated						x		
Mobile River[b]	Tensaw River	Barry Steam Plant	x			x		
Mobile River[b]	Spanish River	its mouth					x	
Tensaw River	two miles above Live Oak Landing	two miles below Live Oak Landing		x		x		
Tensaw River	two miles above the L & N RR bridge	one mile below the upper end of Gravine Island		x		x		
Mobile Bay[b]	west of a line drawn due south from the western shore of Chacaloochee Bay	a point due east of the mouth of Dog River				x		
Mobile Bay[b]	south of a line drawn east from the mouth of Dog River and east of a line drawn due south from the western shore of Chacaloochee Bay and all other portions of Mobile Bay			x		x		

Mobile Bay[b]	all that portion lying south of a line extending in an easterly direction from the south bank of East Fowl River at its mouth through lighted beacon (FL 2 seconds) to lighted beacon (FLG 4 seconds "23") at the Mobile Ship Channel thence in a northeasterly direction to Daphne				x	x
Bon Secour Bay	in its entirety			x	x	x
Mississippi Sound and contiguous waters excepting: that portion of Portersville Bay 1,000 feet on each side of a straight line connecting the shore at Bayou Coden to a lighted beacon (FLR 4 seconds "6") and lighted beacon (FL 4 seconds "1"): that portion of Portersville Bay 1,000 feet on each side of a straight line connecting the shore at Bayou La Batre and lighted beacons (FR) and (FLR 4 seconds "6"): and that portion of Bayou Aloe within 1,000 feet of the outfall of the Dauphin Island sewage treatment plant				x	x	x
Waters excepted in foregoing description of Portersville Bay and contiguous waters						x
Oyster Bay and that portion of Bon Secour River west of a line drawn due north from the east bank of the inlet connecting Oyster Bay and Bon Secour River					x	x
Coastal waters of the Gulf of Mexico	contiguous to the State of Alabama		x			
Intracoastal Waterway	Bon Secour Bay	Oyster Bay				x
Intracoastal Waterway	Oyster Bay	Alabama Highway 59				x
Bon Secour River	Bon Secour River	one mile upstream from first bridge above its mouth	x			x

[a]1--Public water supply; 2--Swimming; 3--Shellfish harvesting; 4--Fish and wildlife; 5--Agricultural, industrial water supply; 6--Navigation.

[b]Waters of the Mobile River-Mobile Bay Basin classified for SWIMMING AND OTHER WHOLE BODY WATER-CONTACT SPORTS, SHELLFISH HARVESTING and/or FISH AND WILDLIFE in which natural conditions provide an appropriate habitat for shrimp and crabs are to be suitable for the propagation and harvesting of shrimp and crabs.

Table A-1. Continued.

Stream	From	To	1[a]	2	3	4	5	6
Boggy Branch	Bon Secour River	its source	x			x		
Weeks Bay	Bon Secour Bay	Fish River	x			x		
Magnolia River	Weeks Bay	its source	x			x		
Fish River	Weeks Bay	Clay City	x			x		
Turkey Branch	Fish River	its source	x			x		
Waterhole Branch	Fish River	its source		x		x		
Cowpen Creek	Fish River	its source		x		x		
Pt. Clear Creek	Mobile Bay	its source				x		
Fly Creek	Mobile Bay	its source		x		x		
Rock Creek	Mobile Bay	its source				x		
D'Olive Creek	D'Olive Bay	its source				x		
West Fowl River	Fowl River Bay	its source		x		x		
Bayou Coden	Portersville Bay	its source				x		
Bayou La Batre	Portersville Bay	its source				x		
Little River	Portersville Bay	its source				x		
East Fowl River	Fowl River	its source		x		x		
Fowl River	Mobile Bay	its source		x		x		

Deer River and its forks	Mobile Bay	their sources			x		
Dog River	Mobile Bay	Halls Mill Creek	x		x		
Dog River	Halls Mill Creek	its source			x		
Halls Mill Creek	Dog River	its source			x		
Alligator Bayou	Dog River	its source			x		
Rabbit Creek	Dog River	its source			x		
Rattlesnake Bayou	Dog River	its source			x		
Robinson's Bayou	Dog River	its source			x		
Three Mile Creek	Mobile River	Conception Street Road					x
Three Mile Creek	Conception Street Road	Mobile Street				x	
Chickasaw Creek	Mobile River	Shell Bayou					x
Chickasaw Creek	Shell Bayou	limit of tidal effects			x		
Hog Bayou	Chickasaw Creek	its source					x
Little Lagoon Baldwin County	in its entirety		x	x	x		
Bayou Sara	Mobile River	U.S. Highway 43	x		x		
Bayou Sara	U.S. Highway 43	its source			x		

Table A-1. Concluded.

Stream	From	To	1[a]	2	3	4	5	6
Cunnison Creek	Bayou Sara	its source		x		x		
Steele Creek	Cunnison Creek	its source		x		x		
Classification of intrastate waters of the Mobile River-Mobile Bay Basin (adopted by the Alabama Water Improvement Commission on June 19, 1967).								
Bon Secour River	one mile upstream from first bridge above its mouth	its source		x		x		
Fish River	Clay City	its source		x		x		
Polecat Creek	Fish River	its source		x		x		
Three Mile Creek	Mobile Street	its source				x		
Chickasaw Creek	limit of tidal effects	Mobile College				x		
Chickasaw Creek	Mobile College	its source		x		x		
Eight Mile Creek	Chickasaw Creek	city of Prichard's water supply intake				x		
Eight Mile Creek	city of Prichard's water supply intake	U.S. Highway 45	x			x		
Eight Mile Creek	U.S. Highway 45	its source				x		
Cold Creek	Mobile River	U.S. Highway 43				x		
Cold Creek	U.S. Highway 43	its source	x			x		

Table B-1. Phytoplankton of the northern Gulf of Mexico (Curl 1959; Simmons and Thomas 1962; Day et al. 1976; Housley 1976).

Scientific name	Habitat		
	Riverine	Littoral -Neritic	Open gulf
Chrysophyta: Diatoms			
Achnanthes clerei		X	
Achnanthes depressus		X	
Achnanthes longpipes		X	
Achnanthes manifera		X	
Achnanthes microcephala		X	
Achnanthes speciosa		X	
Achnanthes tenera		X	
Actinocyclus ehrenbergii		X	
Actinoptychus senarius		X	X
Actinoptychus splendens		X	X
Actinoptychus undulatus		X	
Actimorphycus sp.		X	
Amphipleura sp.	X		
Amphiprora gigantea var. *sulcata*		X	
Amphora arenaria		X	
Amphora marina			X
Amphora micans		X	
Amphora sulcata		X	
Asterionella formosa	X		
Asterionella glacialis		X	X
Asterionella gracillima		X	
Asterionella japonica		X	
Asteromorpha heptactis			X
Auliscus caelatus		X	
Auliscus pruninosus		X	
Auliscus punctatus		X	
Auliscus sculptus		X	
Bacteriastrum comosum		X	
Bacteriastrum delicatulum			X
Bacteriastrum elongatum		X	X
Bacteriastrum hyalinum		X	X
Bacteriastrum varians		X	
Bellerochea malleus		X	
Biddulphia alternans		X	
Biddulphia aurita		X	X
Biddulphia chinensis		X	X
Biddulphia dubia		X	X
Biddulphia granulata		X	
Biddulphia levis		X	
Biddulphia mobiliensis		X	X
Biddulphia obtusa		X	
Biddulphia pulchella		X	

Table B-1. Continued.

Scientific name	Habitat		
	Riverine	Littoral -Neritic	Open gulf
Biddulphia rhombus		X	
Biddulphia sensis		X	
Biddulphia smithii		X	
Blepharisma sp.		X	
Caloneis sp.	X		
Campylodiscus punctulatus		X	
Campylodiscus samoensis		X	
Campylosira cymbelliformis		X	
Cerataulina pelagica		X	
Chaetoceros affine		X	X
Chaetoceros affine var. *willei*			X
Chaetoceros atlanticum			X
Chaetoceros breve			X
Chaetoceros centralis		X	
Chaetoceros coarctatum			X
Chaetoceros compressum		X	X
Chaetoceros concavicorne			X
Chaetoceros constrictum		X	X
Chaetoceros convolutum			X
Chaetoceros costatum		X	X
Chaetoceros curvisetum		X	X
Chaetoceros danicum		X	
Chaetoceros debile		X	
Chaetoceros decipiens		X	X
Chaetoceros decipiens f. *singularis*			X
Chaetoceros dichaeta			X
Chaetoceros didymum		X	X
Chaetoceros diversum		X	X
Chaetoceros glandazii			X
Chaetoceros gracile		X	X
Chaetoceros laciniosum		X	X
Chaetoceros laeve			X
Chaetoceros lorenzianum		X	X
Chaetoceros messanense			X
Chaetoceros mitra		X	
Chaetoceros pelagicum		X	X
Chaetoceros pendulum		X	
Chaetoceros perpsillum		X	
Chaetoceros peruvianum		X	X
Chaetoceros pseudocurvisetum		X	
Chaetoceros radicans		X	
Chaetoceros simile			X
Chaetoceros sociale		X	

Table B-1. Continued.

Scientific name	Habitat		
	Riverine	Littoral -Neritic	Open gulf
Chaetoceros subtilis		X	
Chaetoceros teres			X
Chaetoceros tortissimum		X	
Chaetoceros vanheurckii			X
Chaetoceros vistulae			X
Chaetoceros wighami		X	
Chilomonas marina		X	X
Climacodium biconcavum		X	
Climacosphenia fraunfeldianum			X
Climacosphenia moniligera			X
Cocconeis diminuta		X	X
Cocconeis disculoides		X	
Cocconeis placentula		X	
Cocconeis scutellum		X	
Comphonema vibra	X		
Corethron criophilum			X
Coscinodiscus asteromphalus		X	
Coscinodiscus centralis			X
Coscinodiscus concinnus		X	X
Coscinodiscus curvatus		X	
Coscinodiscus curvisettus		X	X
Coscinodiscus denarius		X	
Cosdinodiscus excentricus		X	X
Coscinodiscus granii		X	X
Coscinodiscus kutzingii		X	
Coscinodiscus lineatus			X
Coscinodiscus marginatus			X
Coscinodiscus nitidus		X	X
Coscinodiscus oculus-iridis			X
Coscinodiscus perforatus		X	
Coscinodiscus radiatus		X	X
Coscinosira polychorda		X	
Cyclotella antiqua		X	
Cyclotella bodanica		X	
Cyclotella caspia		X	
Cyclotella comta	X	X	
Cyclotella meneghingiana	X	X	X
Cyclotella operculata		X	
Cylindrotheca closterium		X	
Cymbella lanceolata	X		
Diatoma elongatum	X		
Diatoma hemale		X	
Diatoma vulgare			X

Table B-1. Continued.

Scientific name	Habitat		
	Riverine	Littoral -Neritic	Open gulf
Dimerogramma pinnale		X	
Diploneis cynthia		X	
Diploneis interrupta	X	X	
Diploneis weissflogii		X	
Ditylum brightwelli		X	X
Epithemia argus	X		
Epithemia sp.	X		
Epithemia zebra		X	
Eucampia cornuta		X	X
Eucampia zoodiacus		X	
Eunofagramma sp.		X	
Eunogramma marinum		X	
Eunotia hebridica			X
Eupodiscus radiatus		X	
Flagilaria cirescens		X	
Fragilaria crotonensis	X	X	X
Flagilaria virescens		X	
Gemphenema sp.	X		
Grammatophora angulosa		X	
Grammatophora marina		X	
Grammatophora oceanica			X
Guinardia flaccida		X	X
Gyrosigma balticum		X	
Gyrosigma peisonis		X	
Gyrosigma spencerii		X	
Hantzschia sp.	X		
Hemiaulus hauckii		X	X
Hemiaulus membranaceus			X
Hemiaulus sinensis		X	
Hemidiscus cuneiformis		X	
Hemidiscus hardmanianus			X
Lauderia borealis			X
Lauderia turris		X	
Leptocylindrus danicus		X	X
Licmophora abbreviata		X	
Lithodesmium undulatum		X	
Mastogloia sp.		X	
Melosira ambigua		X	
Melosira distans	X	X	X
Melosira dubia		X	
Melosira granulata	X	X	X
Melosira islandica		X	
Melosira moniliformis		X	

Table B-1. Continued.

Scientific name	Habitat		
	Riverine	Littoral -Neritic	Open gulf
Melosira nummuloides		X	
Melosira sulcata	X	X	X
Meridion sp.		X	
Navicula distans	X	X	X
Navicula diversistriata		X	
Navicula gracilis	X	X	
Navicula lorenzia		X	
Navicula membranacea			X
Navicula rhynchocephala	X	X	
Navicula simplex		X	
Navicula spuria		X	
Nedium affine	X	X	
Niloschis pungens		X	
Niloschis pungens var. *atlantica*		X	
Nitzschia bilobata var. *minor*		X	X
Nitzschia closterium	X	X	
Nitzschia delicatissima		X	X
Nitzschia distans		X	
Nitzschia insignis		X	
Nitzschia longissima		X	
Nitzschia lorenziana		X	
Nitzschia mollis		X	
Nitzschia obtusa		X	
Nitzschia pacifica		X	
Nitzschia palea		X	
Nitzschia paradoxa		X	X
Nitzschia pungens var. *atlantica*		X	
Nitzschia seriata	X	X	X
Pinnularia biceps	X		
Pinnularia viridis		X	
Plagiogramma inaequale		X	
Plagiogramma tesselatum		X	
Plagiogramma vanheurckii		X	X
Pleurosigma decorum		X	
Pleurosigma elongatum		X	X
Pleurosigma formosum		X	
Pleurosigma intermedium		X	
Pleurosigma normanii		X	X
Pleurosigma peisonis		X	
Pleurosigma rigidum		X	
Pseudodauliscus radiatus		X	
Pseudoeunotia doliolus		X	
Rhabdonema adriaticum		X	

Table B-1. Continued.

Scientific name	Habitat: Riverine	Habitat: Littoral -Neritic	Habitat: Open gulf
Rhaphoneis sp.		X	
Rhizosolenia acuminata			X
Rhizosolenia alata			X
Rhizosolenia bergonii			X
Rhizosolenia calcar-avis			X
Rhozosolenia castracanei			X
Rhizosolenia cylindrus		X	
Rhizosolenia delicatula		X	
Rhizosolenia eriensis		X	
Rhizosolenia fragilissima		X	
Rhizosolenia hebetata			X
Rhizosolenia imbicata			X
Rhizosolenia robusta			X
Rhizosolenia setigera		X	X
Rhizosolenia stolterfothii		X	
Rhizosolenia styliformis			X
Scenedesmus quadricauda	X		
Scenedesmus sp.		X	
Schroederella delicatula			X
Skeletonema costatum		X	X
Stauroneis anceps	X	X	
Stauroneis phoenicenteron		X	
Stephanopyxis palmeriana			X
Stephanopxis turris			X
Streptotheca thamesis		X	
Striatella delicatula			X
Striatella interrupta		X	
Striatella unipunctata		X	
Surirella fastuosa		X	
Surirella fastuosa var. *recedens*		X	
Synedra actinastroides		X	
Synedra fulgens		X	
Synedra ulna			X
Tabellaria fenestrata			X
Tabellaria fenestrata var. *asterionellus*			X
Terpsinoe musica		X	
Thalassionema nitzschioides		X	X
Thalassiosira decipiens		X	X
Thalassiosira rotula			X
Thalassiothrix delicatissima		X	
Thalassiothrix delicatula		X	
Thalassiothrix frauenfeldii	X	X	X

Table B-1. Continued.

Scientific name	Habitat: Riverine	Habitat: Littoral -Neritic	Habitat: Open gulf
Thalassiothrix longissima		X	X
Thalassiothrix mediterranea			X
Thalassiothrix mediterranea var. *pacifica*			X
Trachyneis aspera		X	
Trachysphenia sp.		X	
Triceratium broeckii		X	
Triceratium favus		X	
Triceratium reticulum		X	
Tropidoneis lepidoptera		X	
Tropidoneis maxima		X	
Chrysophyta: Coccolithophores and Silicoflagellates			
Dichtyocha fibula var. *messanensis*		X	
Dinobryon sp.		X	
Ebria tripartita		X	
Mallomonas sp.		X	
Pontosphaerea sp.		X	
Pyrrophyta: Dinoflagellates			
Ceratium furca	X	X	
Ceratium fusus		X	X
Ceratium gibberum			X
Ceratium hirans		X	
Ceratium macroceros			X
Ceratium massiliense		X	
Ceratium pentagonum			X
Ceratium pulchellum			X
Ceratium trichoceros			X
Ceratium tripos	X		
Ceratium tripos var. *atlanticum*		X	
Ceratium vultur		X	
Dinophysis caudata		X	X
Dinophysis tripos			X
Exuviella compressa			X
Glenodinium sp.			X
Gonyaulax monilata		X	
Gymnodinium breve		X	
Gymnodinium sp.			X
Hemidinium nastutum			X
Noctiluca sp.		X	
Oxytoxum scolopax			X

Table B-1. Concluded.

Scientific name	Habitat: Riverine	Habitat: Littoral -Neritic	Habitat: Open gulf
Peridinium depressum			X
Peridinium sp.			X
Podolampas elegans			X
Procontrum gracile		X	
Pyrocystis pseudonoctiluca			X
Chlorophyta: Green algae			
Chara sp.	X		
Chlamydomonas sp.	X	X	
Chlorella sp.	X	X	
Cosmarium sp.		X	
Crucigenia sp.		X	
Cylindroscapa sp.			X
Nedium sp.		X	
Pediastrum sp.	X	X	
Scenedesmus sp.		X	
Selenastrum sp.		X	
Tetraedron trigonium	X		
Tribonema sp.		X	
Cyanophyta: Blue-green algae			
Anabaena sp.	X	X	
Anacystis sp.		X	
Chroococcus sp.	X		
Gleocapsa sp.		X	
Gomphospherea sp.	X		
Lyngbye sp.			X
Merismopedia elegans	X		
Merismopedia sp.	X	X	
Microcystis sp.	X		
Nostoc sp.	X	X	
Oscillatoria erythraea	X	X	
Oscillatoria thiebauti		X	
Polycystis sp.		X	
Spirulina sp.	X		

Table B-2. Benthic algae of coastal Alabama and surrounding area.

Scientific name	Cunningham (1889)	Mohr (1901)	Morrill (1959)
Cyanophyta			
Amphithrix violacea			X
Anacystis aeruginosa			X
Anacystis dimidiata			X
Anacystis marina			X
Calothrix confervicola			X
Calothrix crustacea			X
Entophysalis conferta			X
Entophysalis deusta			X
Gleocapsa fusco-lutea			X
Gomphosphaeria aponina			X
Hydrocoleum lyngbyaceum			X
Lyngbya aestuarii			X
Lyngbya confervoides			X
Lyngbya epiphytica			X
Lyngbya lutea			X
Lyngbya semiplena			X
Mastigocoleus testarum			X
Microcoleus chthonoplastes			X
Microcoleus tenerrimus			X
Nodularia harveyana			X
Oscillatoria nigro-viridis			X
Oscillatoria subuliformis			X
Phormidium submembranaceum			X
Phormidium tenue			X
Plectonema nostocorum			X
Plectonema terebrans			X
Spirulina major			X
Spirulina subsalsa cf. *oceanica*			X
Symploca atlantica			X
Chlorophyta			
Chaetomorpha brachygona			X
Cladophora fascicularis			X
Cladophora gracilis			X
Enteromorpha flexuosa			X
Enteromorpha intestinalis			X
Enteromorpha lingulata			X
Enteromorpha olumosa			X
Entocladia testarum			X
Entocladia viridus			X

Table B-2. Continued.

Scientific name	Cunningham (1889)	Mohr (1901)	Morrill (1959)
Nitella acuminata		X	
Nitella acuminata var. *brachyteles*		X	
Nitella acuminata var. *subglomerata*		X	
Nitella glaziovii		X	
Nitella tenuissima		X	
Ostreobium quekettii			X
Phaeophila floridearum			X
Rhizoclonium riparium			X
Stichococcus marinus			X
Ulva enteromorpha		X	
Ulva lactuca		X	X
Ulvella lens			X
Phaeophyta			
Dictyota cervicornis			X
Dictyota dichotoma			X
Ectocarpus confervoides			X
Ectocarpus dasycarpus			X
Ectocarpus duchassaignianus			X
Ectocarpus elachistaeformis			X
Ectocarpus mitchellae			X
Ectocarpus siliculosus			X
Padina vickersiae			X
Sargassum bacciformis		X	
Sargassum filipendula			X
Sargassum fluitans			X
Sargassum natans			X
Sargassum vulgare		X	
Sphacelaria tribuloides			X
Rhodophyta			
Acrochrotrichia carnea			X
Acrochrotrichia crassipes			X
Argardhiella tenera			X
Bostrichia radicans			X
Bostrichia tenella			X
Calaglossa leprieurii		X	X
Ceramium fastigiatum			X
Champia parvula			X
Chondria leptacremon			X
Dasya pedicellata			X

Table B-2. Continued.

Scientific name	Cunningham (1889)	Mohr (1901)	Morrill (1959)
Erythrotrichia carnea			X
Fosliella farinosa			X
Fosliella lejolisii			X
Gelidium corneum			X
Gelidium crinale			X
Goniotrichum alsidii			X
Gracilaria armigera		X	
Gracilaria foliifera			X
Grateloupia filicina			X
Griffithsia sp.			X
Gymnogongrus tenuis			X
Hildenbrandia prototypus			X
Hypnea musciformis			X
Jania sp.			X
Lophosiphonia sacchoriza			X
Polysiphonia howei			X
Polysiphonia subtilissima			X
Polysiphonia variegata			X
Chrysophyta			
Vaucheria thuretti			X
Chrysophyta: Diatoms			
Actinocyclus areolatus	X	X	
Actinocyclus ehrenbergii	X	X	
Actinocyclus fuscus	X		
Actinocyclus senarius	X	X	
Actinocyclus splendens	X	X	
Amphiprora alata	X		
Amphiprora costata	X	X	
Amphiprora elegans	X		
Amphiprora lepidoptera	X		
Amphiprora vitrea	X		
Amphitetras antediluviana	X	X	
Amphora cingulata		X	
Amphora clevei	X	X	
Amphora donkinii	X		
Amphora obtusa	X		
Amphora proteus	X	X	
Amphora singulata	X		
Asteromphalus brookei	X		
Aulacodiscus argus		X	
Auliscus caelatus	X	X	

Table B-2. Continued.

Scientific name	Cunningham (1889)	Mohr (1901)	Morrill (1959)
Auliscus confluens	X		
Auliscus pruinosus	X	X	
Auliscus pruinosus var. *apiculata*	X		
Auliscus punctatus	X	X	
Auliscus punctatus var. *stigmosa*	X		
Auliscus radiatus	X		
Auliscus sculptus		X	
Bacteriastrum curvatum	X		
Biddulphia aurita	X		
Biddulphia baileyi	X		
Biddulphia levis	X		
Biddulphia rhombus	X		
Biddulphia tuomeyi	X		
Campylodiscus clypeus		X	
Campylodiscus cribosus	X		
Campylodiscus ecclesianus	X		
Campylodiscus echeneis	X		
Campylodiscus limbatus	X	X	
Campylodiscus samoensis	X		
Cerataulus furgidus	X		
Cerataulus smithii	X	X	
Chaetoceros varians		X	
Cocconeis pediculus	X		
Coscinodiscus excentricus	X	X	
Coscinodiscus lineatus	X	X	
Coscinodiscus nitidus	X		
Coscinodiscus radiatus	X	X	
Coscinodiscus subtilis	X	X	
Cymatopleura elliptica	X		
Cymbella cistula	X		
Cymbella heteropleura	X	X	
Cymbella lanceolatum	X		
Dictyoneis marginata		X	
Dimerogramma marinum	X		
Epithemia gibba	X		
Epithemia turgida	X		
Epithemia zebra	X	X	
Eunotia arcus	X	X	
Eunotia diadema	X		
Eunotia diodon	X		
Eunotia parallela	X		

Table B-2. Continued.

Scientific name	Cunningham (1889)	Mohr (1901)	Morrill (1959)
Eunotia tridon	X	X	
Eupodiscus argus	X		
Eupodiscus radiatus	X	X	
Eupodiscus rogersii	X		
Frustulia lewisiana		X	
Grammatophora marina	X	X	
Mastogloia angulata	X		
Melosira borrerii	X		
Melosira punctata	X		
Navicula americana	X		
Navicula aspera		X	
Navicula brasiliensis	X		
Navicula caribaea	X	X	
Navicula clavata	X		
Navicula crabro	X		
Navicula cuspida	X		
Navicula didyma	X	X	
Navicula distans	X	X	
Navicula elliptica	X		
Navicula firma	X		
Navicula firma var. *affinis*	X		
Navicula firma var. *dilatata*	X		
Navicula gomphonemacea	X		
Navicula hennedyi	X	X	
Navicula humerosa	X		
Navicula insignis	X		
Navicula interrupta	X		
Navicula irrorata	X	X	
Navicula jamaicensis	X		
Navicula liber	X		
Navicula longa	X	X	
Navicula lyra	X	X	
Navicula lyra var. *dilatata*	X		
Navicula lyra var. *elliptica*	X		
Navicula lyra var. *recta*	X		
Navicula maculata	X	X	
Navicula major	X	X	
Navicula marginata	X		
Navicula nobilis	X	X	
Navicula peregrina	X		
Navicula permagna	X	X	
Navicula praetexta		X	
Navicula rhomboides	X		

Table B-2. Continued.

Scientific name	Cunningham (1889)	Mohr (1901)	Morrill (1959)
Navicula rostellata	X		
Navicula sculpta	X		
Navicula serratula	X	X	
Navicula smithii	X		
Nitzschia circumsuta	X	X	
Nitzschia dubia	X		
Nitzschia scalaris	X	X	
Nitzschia sigma var. *elongata*	X		
Nitzschia sigmoidea	X	X	
Odontella aurita	X		
Odontella turgida	X		
Orthosira marina	X		
Paralia sulcata		X	
Plagiotropis elegans		X	
Plagiotropis vitrea		X	
Plagiogramma gregorianum	X		
Plagiogramma validum	X		
Pelurosigma accuminatum	X		
Pleurosigma aestuarii	X		
Pleurosigma angulatum	X		
Pleurosigma blaticum	X		
Pelurosigma decorum	X		
Pelurosigma formosum	X		
Pelurosigma validum		X	
Podosira maculata	X		
Pseudauliscus radiatus		X	
Rhabdonema arcuatum	X		
Rhaphoneis amphiceros	X		
Stauroneis gracilis	X		
Stauroneis phoenicenteron		X	
Stauroneis pulchella	X		
Surirella fastuosa	X	X	
Surirella febigerii	X	X	
Surirella nobilis	X		
Surirella ovata	X		
Surirella splendida	X		
Synedra radians	X		
Systephania diadema	X		
Terpsinoe americana	X	X	
Terpsinoe musica	X	X	
Triceratium alternans	X	X	
Triceratium favus	X	X	

Table B-2. Concluded.

Scientific name	Cunningham (1889)	Mohr (1901)	Morrill (1959)
Triceratium punctatum		X	
Triceratium sculptum	X		
Triceratium trydactylum	X		
Tryblionella marginata	X		
Tryblionella punctata	X		

Table B-3. Benthic algae of the northern Gulf of Mexico (Earle 1972; Sullivan 1981).

Cyanophyta

Agmenellum thermale
Anacystis dimidiata
Arthrospira brevis
Calothrix crustacea
Coccochloris elabens
Entophysalis conferta
Entophysalis deusta
Microcoleus lyngbyaceus
Microcoleus vaginatus
Oscillatoria erythraea
Oscillatoria lutea
Oscillatoria submembranacea
Porphyrosiphon kurzii
Porphyrosiphon miniatus
Porphyrosiphon notarisii
Schizothrix arenaria
Schizothrix calcicola
Schizothrix friesii
Schizothrix mexicana
Schizothrix tenerrima
Spirulina subsalsa

Chlorophyta

Acetabularia crenulata
Acicularia schenckii
Anadyomene menziesii
Anadyomene stellata
Avrainvillea levis
Batophora oerstedii
Bryopsis pennata
Caulerpa ashmeadii
Caulerpa cupressoides
Caulerpa mexicana
Caulerpa prolifera
Caulerpa sertularioides
Chaetomorpha aerea
Chaetomorpha brachygona
Chaetomorpha delicatula
Chaetomorpha fascicularis
Chaetomorpha fuliginosa
Chaetomorpha glaucescens
Chaetomorpha gracilis
Chaetomorpha linum
Cladophoropsis membranacea
Codium decorticatum
Codium isthmocladum
Enteromorpha calthrata
Enteromorpha flexuosa
Enteromorpha intestinalis
Enteromorpha lingulata
Enteromorpha plumosa
Enteromorpha prolifera
Enteromorpha ramulosa
Enteromorpha salina
Entocladia viridis
Entocladia wittrockii
Gomontia polyrhiza
Ostreobium quekettii
Phaeophila dendroides
Rhizoclonium kochianum
Rhizoclonium riparium
Stichococcus marinus
Ulva fasciata
Ulva lactuca
Ulvella lens

Chrysophyta

Achnanthes biasolettiana var. *sublinearis*
Achnanthes brevipes var. *intermedia*
Achnanthes coarctata
Achnanthes curvirostrum
Achnanthes hauckiana
Achnanthes lanceolata var. *dubia*
Achnanthes lemmermanni
Achnanthes temperei
Amphiprora gigantea var. *decussata*
Amphiprora hyalina
Amphiprora paludosa
Amphiprora paludosa var. *paludosa*
Amphiprora paludosa var. *duplex*
Amphiprora pulchra
Amphiprora similis
Amphora angusta
Amphora angusta var. *angusta*
Amphora angusta var. *oblongella*
Amphora caroliniana
Amphora coffeiformis
Amphora cymbelloides
Amphora cymbiformis
Amphora exigua
Amphora laevis var. *perminuta*
Amphora libyca
Amphora pediculus
Amphora proteus
Amphora robusta
Amphora sabyii
Amphora tenerrima
Amphora tenuissima
Anaulus balticus
Anomoeoneis vitrea
Bacillaria paxillifer
Berkeleya rutilans
Caloneis westii
Campylosira alexandrica
Campylosira cymbelliformis
Capartogramma crucicula
Cocconeis deperdita
Cocconeis cf. *discrepans*
Cocconeis disculoides
Cocconeis placentula var. *euglypta*
Cocconeis placentula var. *lineata*
Cocconeis scutellum
Cocconeis scutellum var. *scutellum*
Cocconeis scutellum var. *parva*
Cocconeis woodii
Cyclotella caspia
Cyclotella meneghiniana
Cyclotella stylorum

Chrysophyta (continued)
Cylindrotheca gracilis
Cymatosira belgica
Cymbella pusilla
Denticula subtilis
Dimeregramma hyalinum
Dimeregramma minor
Diploneis aestuari
Diploneis elliptica
Diploneis gruendleri
Diploneis mediterranea
Diploneis obliqua
Diploneis pseudovalis
Diploneis puella
Diploneis smithii
Eunotia naegelii
Eunotogramma laevis
Fragilaria atomus
Fragilaria gessneri
Fragilaria hyalina
Fragilaria obtusa
Fragilaria pinnata
Fragilaria schulzi
Frustulia asymmetrica
Frustulia rhomboides var. *saxonica*
Frustulia similis
Grammatophora oceanica
Gyrosigma balticum
Gyrosigma beaufortianum
Gyrosigma macrum
Gyrosigma obliquum
Gyrosigma obscurum
Gyrosigma peisonis
Hantzschia distincte-punctata
Licmophora abbreviata
Licmophora cf. *debilis*
Mastogloia exigua
Mastogloia pumila
Mastogloia pusilla
Melosira dubia
Melosira lineata
Melosira moniliformis
Melosira nummuloides
Melosira westii
Navicula abunda
Navicula accomoda
Navicula aequorea
Navicula alpha
Navicula ammophila
Navicula amphipleuroides
Navicula binodulosa
Navicula capitata var. *hungarica*
Navicula circumtexta
Navicula clamans
Navicula clementis
Navicula cocconeiformis
Navicula creuzburgensis
Navicula digito-radiata
Navicula diserta
Navicula fauta
Navicula fenestrella
Navicula flanatica
Navicula florinae
Navicula gregaria
Navicula hanseni
Navicula hudsonis
Navicula incerta
Navicula incomposita
Navicula longirostris
Navicula maculata
Navicula mendotia
Navicula cf. *menisculus*
Navicula mutica
Navicula nolens
Navicula obsoleta
Navicula orbiculata
Navicula pavillardi
Navicula peregrina
Navicula phyllepta
Navicula pseudo-crassirostris
Navicula pseudony
Navicula pusilla
Navicula radiostriata
Navicula regularis
Navicula rhynchocephala
Navicula salinarum
Navicula salinicola
Navicula schroeteri
Navicula spicula
Navicula subforcipata
Navicula subirritans
Navicula taraxa
Navicula tenera
Navicula teneroides
Navicula tripunctata
Navicula yarrensis
Navicula zostereti
Nitzschia angularis
Nitzschia apiculata
Nitzschia bilobata var. *ambigua*
Nitzschia brevissima
Nitzschia calida
Nitzschia closterium
Nitzschia communis var. *hyalina*
Nitzschia constricta
Nitzschia dissipata
Nitzschia dubia
Nitzschia dubiformis
Nitzschia epithemoides
Nitzschia fasciculata
Nitzschia filiformis
Nitzschia gander-sheimiensis
Nitzschia grana
Nitzschia granulata
Nitzschia hungarica
Nitzschia hustedtiana
Nitzschia levidensis
Nitzschia lorenziana
Nitzschia lorenziana var. *lorenziana*
Nitzschia lorenziana var. *subtilis*
Nitzschia microcephala
Nitzschia minutula
Nitzschia obsidialis

Table B-3. Concluded.

Chrysophyta (continued)	*Striatella unipunctata*	Rhodophyta
Nitzschia obtusa	*Surirella atomus*	*Acrochaetium flexuosum*
Nitzschia obtusa var. *obtusa*	*Surirella litoralis*	*Acrochaetium seriatum*
Nitzschia obtusa var. *nana*	*Surirella ovalis*	*Agardhiella tenera*
Nitzschia palea	*Surirella striatula*	*Bostrychia moritziana*
Nitzschia paleacea	*Synedra fasciculata*	*Bostrychia radicans*
Nitzschia panduriformis	*Synedra fasciculata* var. *fasciculata*	*Bostrychia rivularis*
Nitzschia panduriformis var. *panduriformis*	*Synedra fasciculata* var. *intermedia*	*Bostrychia tenella*
Nitzschia panduriformis var. *continua*	*Thalassiosira eccentrica*	*Caloglossa leprieurii*
Nitzschia perversa	*Trachyneis aspera*	*Centroceras clavulatum*
Nitzschia plana	*Trachysphenia acuminata*	*Ceramium byssoideum*
Nitzschia pseudoamphioxys	*Tropidoneis lepidoptera*	*Ceramium fastigiatum*
Nitzschia recta	*Tropidoneis vitrea*	*Compsopogon caeruleus*
Nitzschia romana		*Dasya pedicellata*
Nitzschia romanoides	Phaeophyta	*Digenia simplex*
Nitzschia scalaris	*Ascocyclus orbicularis*	*Erythrotrichia carnea*
Nitzschia sigma	*Asperococcus fistulosus*	*Fosliella farinosa*
Nitzschia socialis var. *massiliensis*	*Bachelotia antillarum*	*Fosliella lejolisii*
Nitzschia subvitrea	*Cladosiphon occidentalis*	*Gelidium corneum*
Nitzschia tryblionella	*Cladosiphon zosterae*	*Gelidium crinale*
Nitzschia visurgis	*Dictyota cervicornis*	*Goniotrichum alsidii*
Nitzschia vitrea var. *salinarum*	*Dictyota dichotoma*	*Gracilaria caudata*
Opephora pacifica	*Ectocarpus dasycarpus*	*Gracilaria foliifera*
Opephora parva	*Ectocarpus elachistaeformis*	*Grateloupia filicinia*
Opephora schwarzii	*Ectocarpus intermedius*	*Griffithsia tenuis*
Paralia sulcata	*Ectocarpus siliculosus*	*Grinnellia americana*
Plagiogramma tenuistriatum	*Giffordia indica*	*Gymnogongrus tenuis*
Pleurosigma delicatulum	*Giffordia mitchelliae*	*Herposiphonia secunda*
Pleurosigma distinguendum	*Giffordia rallsiae*	*Hypnea crevicornis*
Pleurosigma salinarum	*Myrionema subcorymbosa*	*Hypnea musciformis*
Pleurosigma strigosum	*Nereia tropica*	*Hypnea pannosa*
Rhopalodia gibberula	*Padina vickersiae*	*Kylinia crassipes*
Stauroneis amphioxys	*Rosenvingea intricata*	*Laurencia poitei*
Stauroneis amphioxys var. *amphioxys*	*Rosenvingea orientalis*	*Lomentaria baileyana*
Stauroneis amphioxys var. *obtusa*	*Sargassum filipendula*	*Lophosiphonia saccorhiza*
Stauroneis salina	*Sargassum fluitans*	*Melobesia membranacea*
	Sargassum natans	*Polysiphonia denudata*
	Sphacelaria furcigera	*Polysiphonia echinata*
	Sphacelaria tribuloides	*Polysiphonia harveyi*
	Stilophora rhizodes	*Polysiphonia havanensis*
		Polysiphonia howei
		Polysiphonia ramentacea
		Polysiphonia subtilissima
		Spyridia filamentosa

Table C-1. Invertebrates of coastal Alabama (modified from Brunson 1951; Parker 1954; Phleger 1954; Parker 1960; Anderson 1968; McIlwain 1968; Phillips and Burke 1970; Swingle 1971; Lamb 1972; Collard and D'Asaro 1973; May 1973a; U.S. Army Corps of Engineers 1973; Vittor 1973, 1974; Swingle and Bland 1974a, 1974b; Chermock 1974; Jones 1974; Burke 1975a, 1975b; and Techcon, Inc. 1980).

Scientific name	Common name	A[a]	B	C	D	E
Phylum Protozoa						
Class Zoomastigophora						
Order Choanoflagellida						
Codosiga botrytis			X			
Pterodendron petiolatum			X			
Salpingoeca polygonatum			X			
Order Rhizomastigida						
Mastigamoeba longifilum			X			
Multicilia marina			X			
Order Kinetoplastida						
Rhynchomonas marina		X	X			
Order Diplomonadida						
Tetramitus sulcatus			X			
Class Rhizopoda						
Order Amoebida						
Flabellula citata			X			
Mayorella bicornifrons			X			X
Mayorella microeruca			X			X
Mayorella oclawaha			X			
Mayorella spumosa			X			
Naegleria gruberi			X			
Rugipes vivax		X	X			
Valkampfia avara			X			X
Order Arcellinida						
Arcella atava			X			
Arcella dentata			X			
Arcella discoides			X			
Arcella polypora			X			
Arcella vulgaris			X			
Centropyxus aculeata			X			X
Centropyxus ecornis						X
Centropyxus platystoma			X			X
Order Gromiida						
Amphitrema lemanense			X			
Cochilopodium bilimbosum			X			X
Cochilopodium granulatum			X			
Cyphoderia ampulla			X			
Lecythium hyalinum			X			X
Nadinella mammillata			X			
Parmulina cyathus			X			X

[a] A--Open gulf; B--Estuaries and bays; C--Grass flats; D--Salt marshes; E--Freshwater marshes.

Table C-1. Continued.

Scientific name	Common name	A	B	C	D	E
Order Gromiida (continued)						
Parmulina obtecta			X			
Pseudodifflugia fascicularis			X			X
Pseudodifflugia gracilis			X			
Order Foraminiferida						
Ammobaculites salsus			X			
Ammonia beccarii			X			
Cibicidina strattoni		X				
Discorbis concinnus		X				
Elphidium delicatulum			X			
Elphidium discoidale			X			
Elphidium gunteri		X	X			
Elphidium mexicanum		X	X			
Elphidium poeyanum			X			
Elphidium rugulosum			X			
Gromia fluvialis		X	X		X	X
Gromia nigricans			X			X
Gromia ovoidea		X	X			
Guttulina australis		X				
Hanzawaia concentrica		X				
Microgromia biportalis			X			
Microgromia elegantula			X			X
Miliammina fusca			X			
Miliolinella subrotunda		X	X			
Nonionella atlantica		X	X			
Nonionella opima			X			
Quinqueloculina jugosa			X			
Quinqueloculina poeyana			X			
Quinqueloculina rhodiensis			X			
Quinqueloculina seminulum		X	X			
Streblus beccari		X	X			
Streblus tepidus			X			
Triloculina sidebottomi		X				
Triloculina trigonula			X			
Trochaminoides proteus			X			
Class Actinopodea						
Subclass Radiolaria						
Acathometron pellucidum		X				
Subclass Heliozoa						
Acanthocystis aculeata		X	X			
Acanthocystis myriospina		X	X			
Actinophrys pontica		X	X			
Actinophrys sol			X			
Actinophrys vesiculata			X			
Cienkowskya arborescens		X	X			
Ceinkowskya mereschkowskyi			X			

Table C-1. Continued.

Scientific name	Common name	A	B	C	D	E
Subclass Heliozoa (continued)						
Oxnerella maritima			X			
Pompholyxophrys punicea			X			
Raphidiophrys coerulea			X			
Raphidiophrys infestans			X			
Class Ciliatea						
Order Gymnostomatida						
Chilodonella capucina			X			
Chilodonella caudata			X			
Chilodonella helgolandica			X			
Chilodonella uncinata		X	X			
Chlamydodon mnemosyne			X			
Coleps hirtus			X			
Didinium nasutum			X			X
Dileptus marinus minimus			X			
Dysteria marina			X			
Dysteria navicula			X			
Enchelys pterotracheae			X			
Hartmannula acrobates			X			
Hemiophrys rotunda			X			
Holophrys vesiculosa			X			
Lachrymaria cohni			X			
Lachrymaria coronata			X			X
Lagynophrya muciocola			X			
Litonotus carinatus			X			
Litonotus duplostriatus		X	X			
Litonotus pictus		X	X			
Loxophyllum meleagris			X			
Loxophyllum setigerum			X			
Loxophyllum uninucleatum		X	X			
Mesodinium acarus			X			
Mesodinium pulex			X			
Mycterothrix taumotuensis			X			
Paranassula microstoma			X			
Placus salinus		X	X			
Prorodon marinus			X			
Prorodon opalescens			X			
Stephanaopogon mobilensis			X			
Trachelius tracheloides		X	X			
Trachelocerca subviridis			X			
Order Hymenostomatida						
Cinetochilium marinum			X			
Cohnilembus verminus		X	X			
Cyclidium curvatum			X			
Cyclidium glaucoma			X			
Frontonia marina		X	X			

Table C-1. Continued.

Scientific name	Common name	A	B	C	D	E
Order Suctorida (continued)						
Acineta tuberosa		X	X			
Corynophrya francottei			X			
Dendrosoma radians			X			
Discophrya buckei			X			
Ephelota crustaceorum		X	X			
Ephelota gemmipara		X	X			
Lernaeophrya capitata			X			
Paracineta estuarina			X			
Paracineta limbata		X	X			
Paracineta lineata			X			
Paracineta meridionalis			X			
Paracineta patula		X	X			
Platophrya rotunda			X			
Podophrya maupasi			X			
Order Heterotrichida						
Condylostoma magnum			X			
Condylostoma patens			X			
Condylostoma vorticella			X			
Donsia mirabilis		X	X			
Metafolliculina andrewsi		X	X			
Parafolliculina americana		X	X			
Peritromus faurei			X			
Peritromus montanus			X			
Phacodinium metschnicoffi			X			
Protocrucia adhaerens			X			
Spirostomum intermedium			X			
Spirostomum teres			X			
Stentor auriculatus			X			X
Stentor introversus			X			X
Stentor mulleri			X			
Order Oligotrichida						
Halteria grandinella			X			X
Lohmaniellia oviformis			X			
Strobilidium conicum			X			
Strobilidium gyrans			X			
Strobilidium minimum			X			
Strombidium capitatum			X			
Strombidium elongatum			X			
Strombidium filificum			X			
Strombidium strobilis			X			
Tontonia appendiculariformis			X			
Order Tintinnida						
Codonaria fimbriata			X			
Codonellopsis obesa			X			
Helicostomella fusiformis			X			

Table C-1. Continued.

Scientific name	Common name	A	B	C	D	E
Order Hymenostomatida (continued)						
Frontonia microstoma		X	X			
Glaucoma scintillans			X			
Lembadium lucens			X			
Paramecium woodruffi			X			
Pleuronema coronatum			X			
Pleuronema crassum			X			
Pleuronema setigerum			X			
Tetrahymena vorax			X			
Urocentrum turbo			X			
Order Peritrichida						
Cothurnia fecunda			X			
Cothurnia innata		X	X			
Cothurnia limnoriae			X			
Cothurnia maritima		X	X			
Cothurnia oblonga			X			
Cothurnia poculum			X			
Epistylis bimarginata urnula			X			
Epistylis hentscheli			X			
Epistylis niagarae			X			
Epistylis rotans			X			
Lagenophrys ascelli			X			
Opercularia longigula			X			
Ophistostyla thienemanni			X			
Platycola gracilis			X			
Pyxicola socialis			X			
Thuricola valvata		X	X			
Vaginicola ampulla			X			
Vaginicola crystallina			X			
Vaginicola ingenita			X			
Vaginicola wangi			X			
Vorticella aequilata			X			X
Vorticella monilata			X			
Vorticella nebulifera			X			
Vorticella platysoma			X			
Vorticella procumbens			X			
Vorticella punctata		X	X			
Zoothamnium affine			X			
Zoothamnium alternans			X			
Zoothamnium commune			X			
Zoothamnium duplicatum			X			
Zoothamnium mucedo		X	X			
Order Suctorida						
Acineta corophi			X			
Acineta craterellus		X	X			
Acineta foetida		X	X			

Table C-1. Continued.

Scientific name	Common name	A	B	C	D	E
Order Tintinnida (continued)						
Tintinnopsis beroidea		X	X			
Tintinnopsis beroidea rotunda		X	X			
Tintinnopsis butschli minuta		X	X			
Tintinnopsis butschli mortensi		X	X			
Tintinnopsis gracilis			X			
Tintinnopsis kofoidi		X	X			
Tintinnopsis nana			X			
Tintinnopsis subacuta		X	X			
Tintinnopsis tocantinensis		X	X			
Tintinnopsis tubulosoides			X			
Tintinnus rectus			X			
Order Hypertrichida						
Aspidisca aculeata			X			
Aspidisca baltica			X			
Chaetospira monilata			X			X
Chaetospira mulleri			X			X
Diophrys appendiculata			X			
Diophrys scutum		X	X			
Euplotes harpa			X			
Euplotes nana			X			
Euplotes vannus			X			
Euplotes woodruffi			X			
Gastrostyla pulchra			X			
Holosticha arenicola			X			
Holosticha diademata			X			
Hypotrichidium conicum			X			
Keronopsis monilata			X			
Keronopsis rubra			X			
Keronopsis similis			X			
Onychodromus grandis			X			
Oxytricha ferruginea			X			
Oxytricha marina			X			
Stichotricha gracilis			X			
Stichotricha marina			X			
Stylonychia mytilus			X			X
Trachelostyla pediculiformis			X			
Uronychia heinrothi			X			
Uronychia transfuga			X			
Urostyla grandis			X			
Phylum Porifera						
Axinella polycapella		X				
Cliona celata	Boring sponge	X				
Cliona vastifica	Boring sponge	X	X			
Geodia gibberosa		X				
Ircinia campana	Vase sponge	X				

Table C-1. Continued.

Scientific name	Common name	A	B	C	D	E
Phylum Porifera (continued)						
Ircinia fasciculata	Garlic sponge	X	X	X		
Microciona prolifera		X	X	X		
Speciospongyia vesparia	Loggerhead sponge	X				
Phylum Coelenterata						
Aiptasia pallida	Anemone	X	X			
Astrangia solitaria	Stony coral	X	X			
Aurelia aurita		X	X			
Bunodosoma cavernata	Anemone	X				
Astrangia sp.			X			
Cerianthiopsis americanus		X				
Chiropsalmus quadrumanus		X	X			
Crysaora quinquecirrha		X	X			
Edwardsia sp.			X			
Eudendrium carneum	Hydroid	X	X			
Hydractinia echinata	Hydroid	X	X	X		
Leptogorgia setacea	Soft coral	X	X			
Leptogorgia virgulata	Soft coral	X	X			
Muricea laxa	Soft coral	X				
Pelagia noctiluca		X	X			
Pennaria tiarella	Hydroid	X	X	X	X	
Physalia pelagica	Portuguese man-o-war	X	X			
Physalia physalis		X	X			
Renilla mulleri	Sea pansy	X				
Rhopilema verrilli		X	X			
Scirpearia grandis	Soft coral	X				
Siderastrea siderea	Stony coral	X	X			
Stomolophus meleagris			X			
Tamoya haplonema	Sea wasp	X				
Tubularia crocea	Hydroid	X	X	X		
Phylum Ctenophora						
Pleurobrachia sp.	Comb jelly	X	X			
Phylum Platyhelminthes						
Polycladia sp.			X			
Stylochus frontalis	Oyster worm		X			
Phylum Rhynchocoela						
Cerebratulus lacteus	Ribbon worm		X	X		
Micrura leidyi			X			
Nemertean sp. A			X			
Nemertean sp. B			X			
Nemertean sp. C			X			
Nemertean sp. D			X			
Nemertean sp. E			X			
Nemertean sp. F			X			
Nemertean sp. G			X			

Table C-1. Continued.

Scientific name	Common name	A	B	C	D	E
Phylum Nematoda (Families only)						
Anticomidae			X			
Axonolaimidae			X			
Camacolaimidae			X			
Ceramonematidae			X			
Choniolaimidae			X			
Chromadoridae			X			
Comesomatidae			X			
Cyatholaimidae			X			
Desmodoridae			X			
Desmoscolecidae			X			
Diplopeltidae			X			
Enchelidiidae			X			
Enoplidae			X			
Ironidae			X			
Leptolaimidae			X			
Leptosomatidae			X			
Linhomoeidae			X			
Microlaimidae			X			
Monhysteridae			X			
Monoposthiidae			X			
Oncholaimidae			X			
Oxystominidae			X			
Rhabdodemanidae			X			
Richtersiidae			X			
Selanchonematidae			X			
Siphonolaimidae			X			
Sphaerolaimidae			X			
Tripyloididae			X			
Phylum Annelida						
Class Polychaeta						
Aglaophamus verrilli			X			
Ampharete americana			X			
Amphicteis gunneri		X	X	X		
Amphitrite ornata		X	X	X	X	
Ancistrosyllis commensalis			X			
Ancistrosyllis hamata			X			
Ancistrosyllis hartmanae			X			
Ancistrosyllis jonesi			X			
Ancistrosyllis papillosa			X			
Ancistrosyllis sp. A			X			
Apoprionospio pygmaea			X			
Arenicola caroledna		X	X	X		
Arenicola cristata	Lug worm	X	X			
Aricidea fragilis			X			
Aricidea philbinae			X			

Table C-1. Continued.

Scientific name	Common name	A	B	C	D	E
Class Polychaeta (continued)						
Aricidea pseudoarticulata			X			
Armandia maculata			X			
Axiothella mucosa	Bamboo worm	X	X			
Autolytus sp. A			X			
Boguea sp. cf. *enigmatica*			X			
Branchioasychis americana			X			
Brania wellfleetensis			X			
Cabira incerta			X			
Capitella capitata			X			
Capitella jonesii			X			
Ceratonereis irritabilis			X			
Chaetopteris variopedatus			X	X		
Chaetozone gayheadia			X			
Cirratulus hedgpethi			X			
Cirriformia sp. cf. *filigera*			X			
Cirriformia sp. cf. *granois*			X			
Cirrophorus furcatus			X			
Cirrophorus lyra			X			
Cistenides gouldi			X			
Cossura soyeri			X			
Cymenella sp.			X			
Dasybranchus lunulatus			X			
Diopatra cupraea		X	X	X		
Dispio uncinata			X			
Dorvillea sociabilis			X			
Dorvillea tridentata			X			
Ehlersileanira incisa			X			
Eteone heteropoda			X			
Eteone lactea			X			
Euclymene sp. A			X			
Eupanotus protulicola		X	X	X		
Eurythoe sp. A			X			
Fabrica sp. A			X			
Gattyana cirrosa			X			
Glycera americana			X			
Glycera dibranchiata			X			
Glycera oxycephala			X			
Glycera sp. A			X			
Glycinde solitaria			X			
Goniadides carolinae			X			
Gyptis brevipalpa			X			
Gyptis vittata			X			
Haploscoloplos foliosus			X			
Haploscoloplos fragilis			X			
Harmothoe sp. A			X			

Table C-1. Continued.

Scientific name	Common name	A	B	C	D	E
Class Polychaeta (continued)						
Hemipodus roseus			X			
Heteromastus filiformis			X			
Hydroides hexagonus		X	X	X	X	
Hydroides uncinata			X			
Hypaniola florida			X			
Lepidonotus sublevis			X			
Loimia medusa			X			
Loimia viridis			X			
Lumbrineris bassi			X			
Lumbrineris cruzensis			X			
Lumbrineris ernesti			X			
Lumbrineris impatiens			X			
Lumbrineris parvapedata			X			
Lumbrineris tenuis			X			
Lumbrineris verrilli			X			
Macroclymene elongata			X			
Mediomastus californiensis			X			
Magelona pacifica			X			
Magelona pettibonae			X			
Magelona polydenta			X			
Magelona sp. cf. *cincta*			X			
Magelona sp. cf. *cornuta*			X			
Magelona sp. cf. *lenticulata*			X			
Magelona sp. cf. *riojai*			X			
Magelona sp. C			X			
Magelona sp. F			X			
Magelona sp. I			X			
Malacoceros vanderhorsti			X			
Malacoceros sp. A			X			
Malmgreniella macraraye			X			
Maloade sarsi			X			
Manayunkia sp. A			X			
Marphysa sanquinea			X			
Megalloma bioculatum			X			
Melinna cristata			X			
Melinna maculata			X			
Mytiochele oculata			X			
Myriowenia sp. cf. *californiensis*			X			
Naineris sp. cf. *nanobranchiata*			X			
Neanthes micromma			X			
Neanthes succinea			X	X		
Nephtys bucera			X			
Nereis pelagica			X			
Nicon sp. A			X			
Ninoe nigripes			X			

Table C-1. Continued.

Scientific name	Common name	A	B	C	D	E
Class Polychaeta (continued)						
Ninoe picta			X			
Ninoe sp. A			X			
Notomastus latericeus			X			
Notomastus hemipodus			X			
Notomastus lobatus			X			
Notomastus teres			X			
Notomastus sp. A			X			
Onuphis eremita			X			
Onuphis magna		X	X			
Onuphis nebulosa			X			
Owenia fusiformis			X			
Paleanotus heterosetae			X			
Paramphinome pulchella			X			
Paranaitis speciosa			X			
Paranaitis polynoides			X			
Paraonis sp. cf. *fulgens*			X			
Parapionosyllis longicirrata			X			
Paraprionospio pinnata			X			
Phyllodoce arenae			X			
Piromis sp. cf. *eruca*			X			
Pisione remota			X			
Pista quadrilobata			X			
Podarke obscura			X			
Poecilochaetus johnsoni			X			
Polydora caulleryi			X			
Polydora ligni			X			
Polydora socialis			X			
Polydora websteri		X	X	X		
Polyodontes lupina			X			
Prionospio cirrifera			X			
Prionospio cristata			X			
Prionospio fallax			X			
Prionospio longibranchiata			X			
Prionospio pinnata			X			
Pseudoeurythoe ambigua			X			
Pseudoeurythoe paucibranchiata			X			
Schistomeringos rudolphi			X			
Scolelepis squamata			X			
Scoloplos rubra			X			
Sigambra bassi			X			
Sigambra tentaculata			X			
Sigambra wassi			X			
Sphaerosyllis erinaceus			X			
Spio pettiboneae			X			
Spiophanes berkeleyorum			X			

Table C-1. Continued.

Scientific name	Common name	A	B	C	D	E
Class Polychaeta (continued)						
Spiophanes bombyx			X			
Sternaspis scutata			X			
Sthenelais boa			X			
Sthenelais limicola			X			
Streblospio benedicti			X			
Syllides sp. cf. *longicirrata*			X			
Syllides sp. A			X			
Synelmis albini			X			
Terebellides stroemi			X			
Tharyx marioni			X			
Phyllum Mollusca						
Class Cephalopoda						
Loligo pealeii	Atlantic long-finned squid	X				
Lolliguncula brevis	Brief thumbstall squid	X	X			
Class Gastropoda						
Acteon punctistriatus	Adam's baby-bubble	X				
Anachis avara	Greedy dove shell	X	X	X	X	
Anachis obesa	Fat dove shell	X	X	X	X	
Bittium varium	Horn shell			X	X	
Bursatella leachii	Ragged sea hare			X		
Buscyon perversum	Perversum whelk	X	X			
Buscyon spiratum	Pear whelk	X	X			
Caecum cooperi				X		
Caecum nitidum	Little horn caecum	X	X	X	X	X
Caecum pulchellum	Beautiful little caecum	X	X	X		
Cantharus (Pisania) cancellarius	Cancellate cantharus	X	X			
Cantharus (Pisania) tinctus	Tinted cantharus	X	X			
Cerithiopsis greeni	Green's miniature cerith	X	X			
Cerithium variable (lutosum)	Dwarf cerith	X	X	X	X	X
Cochliolepis parasitica	Parasitic scale snail		X			
Crepidula convexa	Convex slipper shell		X			
Crepidula fornicata	Common Atlantic slipper shell	X	X	X	X	
Crepidula plana	Eastern white slipper shell	X	X	X	X	
Doridella sp. cf. *obscura doridium*			X			
Epitonium humphreysi	Humphrey's wentle trap		X			
Epitonium sp. A			X			
Eulima sp. A			X			

Table C-1. Continued.

Scientific name	Common name	A	B	C	D	E
Class Gastropoda (continued)						
Fasciolaria hunteria	Banded tulip		X			
Fasciolaria tulipa	True tulip	X	X	X		
Ficus communis	Common fig shell	X				
Haminoea antillarum	Paper bubble		X			
Haminoea succinea	Bubble shell		X	X		
Littorina irrorata	Marsh periwinkle				X	X
Littorina ziczac	Zebra periwinkle	X	X			
Martesia cuneiformis	Wedge-shaped martesia	X	X	X	X	
Melampus bidentatus	Eastern melampus		X			
Meioceras (Caecum) nitidum	Little horn caecum	X				
Mitrella lunata	Lunar dove shell	X	X	X	X	
Murex fulvescens	Giant eastern murex	X	X			
Nassarius acutus	Sharp-knobbed nassa		X			
Nassarius vibex	Common eastern nassa	X	X	X		
Natica pusilla	Southern miniature natica	X	X			
Neritina reclivata	Olive nerite			X	X	X
Odostomia impressa	Impressed odostome		X	X	X	
Odostomia seminuda	Half-smooth odostome		X			
Oliva sayana	Lettered olive	X	X			
Olivella mutica	Variable dwarf olive	X				
Olivella pusilla	Very small dwarf olive	X				
Phalium granulatum	Scotch bonnet	X	X			
Pleuroploca gigantea	Florida horse conch	X	X	X	X	
Polinices duplicatus	Shark eye	X	X			
Retusa (Acteocina) canaliculata	Channeled barrel-bubble	X	X			
Rictaxis (Acteon) punctostriatus	Adam's baby bubble		X			
Rissoina chesnelii	Chesnel's rissoina	X	X			
Scaphella dubia	Dubious volute	X				
Seila adamsi	Adam's miniature cerith	X				
Sinum perspectivum	Common baby's ear	X	X			
Strombus pugilis	West Indian fighting conch	X				
Tegula fasciata	Smooth Atlantic tegula			X		
Terebra cinerea	Gray Atlantic auger	X				
Terebra concava	Concave auger	X				
Terebra dislocata	Common american auger	X	X			
Thais haemastoma	Oyster drill	X	X	X	X	
Tonna galea	Giant tun	X				
Triphora nigrocincta	Black-lined trifora	X	X			
Urosalpinx tampaensis	Tampa drill		X			

Table C-1. Continued.

Scientific name	Common name	A	B	C	D	E
Class Pelecypoda						
Abra aequalis	Common Atlantic abra	X	X			
Aequipecten (Argopecten) irradians	Atlantic bay scallop		X			
Amygdalum papyrium	Paper mussel		X		X	
Amygdalum sagittatum	Papper mussel		X			
Anadara brasiliana	Incongruous ark	X				
Anadara ovalis	Blood ark		X			
Anadara simplex		X	X			
Anadara transversa	Transverse ark		X			
Anadara sp. cf. *transversa*			X			
Anadara sp. A.			X			
Anomia simplex	Common jingle shell	X	X			
Argopecten gibbus	Calico scallop	X		X		
Atrina serrata	Saw-toothed pen shell	X				
Atrina sp. A.			X			
Barbatia sp.			X			
Brachydontes exustus	Scorched mussel		X	X	X	
Brachydontes (Ischadium) recurvum	Hooked mussel		X			
Callocardia (Agriopoma) texasiana	Texas venus		X			
Cardiomya gemma (costellata)	Costate cuspidaria	X				
Carditamera floridana	Broad-ribbed cardita			X		
Chione cancellata	Cross-barred venus		X			
Corbicula contracta		X	X			
Corbicula manilensis	Asiatic clam				X	X
Corbula caribaea			X			
Corbula sp. A			X			
Crassinella lunulata	Lunate crassinella		X			
Crassostrea virginica	Eastern oyster	X	X			
Cyclinella tenuis	Atlantic cyclinella	X	X	X		
Cyrtopleura costata	Angelwing		X			
Dinocardium robustum	Giant atlantic cockle	X				
Diplodonta punctata	Common Atlantic diplodon	X	X	X		
Diplothyra smithii	Smith's martesia		X			
Donax dorotheae			X			
Donax variabilis	Coquina shell	X				
Dosinia discus	Disk dosinia	X	X			
Dosinia elegans	Elegant dosinia		X			
Ensis minor	Minor jack-knife clam	X				
Erycina periscopiana			X			
Gemma gemma	Amethyst gem clam		X			
Laevicardium mortoni	Morton's egg cockle			X	X	X

Table C-1. Continued.

Scientific name	Common name	A	B	C	D	E
Class Pelecypoda (continued)						
Limea bronniana	Bronn's dwaft lima		X			
Linga amiantus	Lovely miniature lucina		X			
Lithophaga aristata	Scissor date mussel	X	X			
Lithophaga bisulcata	Mahogany date mussel	X	X			
Lyonsia hyalina	Glassy zyonsia		X			
Macoma constricta	Constricted macoma	X	X			
Macoma mitchelli			X		X	
Macoma tageliformis	Tagelus-like macoma		X		X	
Macoma tenta	Tenta macoma		X			
Mactra fragilis	Surf clam	X	X	X		
Mercenaria campechiensis	Southern quahog	X	X			
Mercenaria mercenaria texana	Northern quahog		X			
Modiolus (Geokensia) demissa	Ribbed mussel		X		X	X
Mulinia lateralis	Dwarf surf clam	X	X			
Mya arenaria	Soft-shell clam				X	X
Mytilopsis leucophaeta	Conrad's false mussel					X
Noetia ponderosa	Ponderous ark	X	X			
Nuculana acuta	Pointed nut clam	X	X			
Nuculana concentrica	Concentric nut clam	X	X			
Ostrea equestris	Crested oyster	X	X	X	X	
Pandora trilineata	Say's pandora	X	X	X		
Papyridea soleniformis	Spiny paper cockle		X			
Parvilucina multilineata	Many-lined lucina		X			
Periploma papyratium	Paper spoon clam	X	X			
Polymesoda caroliniana	Carolina marsh clam		X		X	X
Rangia cuneata	Common rangia		X		X	X
Semele nuculoides	Nucula-like semele	X	X			
Semele proficua	White Atlantic semele	X	X	X		
Spondylus americanus	Atlantic thorny oyster	X				
Spissula solidissima	Atlantic surf clam		X			
Tagelus divisus	Purplish tagelus	X	X	X	X	
Tagelus plebeius	Stout tagelus		X			
Tellidora cristata	White crested tellin		X			
Tellina alternata	Alternate tellin	X	X			
Tellina mera	Mera tellin		X			
Tellina texana	Say's tellin		X			
Tellina versicolor	Dekay's dwarf tellin		X			
Tellina sp. A			X			
Tellina sp. B			X			
Teredo navalis	Common ship worm	X	X			
Trachycardium muricatum	Yellow cockle	X	X	X		

Table C-1. Continued.

Scientific name	Common name	A	B	C	D	E
Phylum Arthropoda						
Class Merostomata						
Limulus polyphemus	Horse-shoe crab	X	X			
Class Crustacea						
Order Copepoda						
Acartia tonsa			X			
Centropages furcatus			X			
Centropages hamatus			X			
Coryeacus sp.		X	X			
Eucalanus pileatus			X			
Euterpina acutifrons		X	X			
Labidocera aestiva		X	X			
Oithona brevicornis			X			
Paracalanus parvus			X			
Sappharina nigromaculata		X	X			
Temora longicornis			X			
Temora stylifera			X			
Order Cladocera (Water fleas)						
Moinodaphnia alabamensis			X			
Order Mysidacea (Opossum shrimp)						
Bowmaniella floridana			X			
Bowmaniella brasiliensis			X			
Mysidopsis sp.		X	X	X	X	X
Mysis stenolepsis			X	X	X	X
Tauromysis sp.		X	X			
Order Amphipoda						
Ampelisca agassizi			X			
Ampelisca verrilli			X			
Ampelisca sp. cf. *abdita*			X			
Ampelisca sp. A			X			
Argissa sp. cf. *hamatipes*			X			
Batea sp. cf. *catharinensis*			X			
Carnogammarus mucronatus		X	X	X	X	
Caprella equipibra			X			
Corophium tuberculatum			X			
Corophium asherusicum			X			
Corophium acutum			X			
Corophium sp. A			X			
Erichthonius brasiliensis			X			
Elasmopus sp. A			X			
Gammarus dubius		X				
Gammarus sp. cf. *mucronatus*			X			
Grandidierella sp. cf. *bonniera*			X			
Haustorius sp. A		X	X			
Lepidactylus sp. A			X			

Table C-1. Continued.

Scientific name	Common name	A	B	C	D	E
Order Amphipoda (continued)						
Listriella clymenellae			X			
Melita sp. cf. *nitida*			X			
Monoculodes sp. A			X			
Microprotopus sp. cf. *raneyi*			X			
Netamelita sp. A			X			
Orchestia grillus	Beach hopper	X	X	X	X	X
Paracaprella sp. cf. *tenuis*			X			
Photis sp. A			X			
Parametopella sp. A			X			
Talorchestia longicornis	Beach hopper	X	X	X	X	X
Synchelidium americanum			X			
Order Cumacea						
Cyclaspis sp. A			X			
Eudorella monodon			X			
Leucon sp. A			X			
Oxyurostylis sp. cf. *smithi*			X			
Spilocuma watlingi			X			
Order Tanaidacea						
Apseudes sp. A			X			
Hargaria rapax			X			
Kalliapseudes sp. A			X			
Order Isopoda						
Cancricepon choprae			X			
Cleantis sp.		X	X			
Cyathura polita			X			
Edotea montosa			X			
Exosphroma diminutum			X			
Lygida exotica		X				
Lygida olfersi		X				
Xenanthura brevitelson			X			
Order Stomatopoda						
Squilla empusa	Mantis shrimp	X	X	X	X	
Order Thoracica (Barnacles)						
Balanus amphitrite		X	X	X	X	
Balanus eburneus		X	X	X	X	
Balanus improvisus		X	X	X	X	
Chthamulus fragilis		X	X	X	X	
Order Decapoda						
Acetes americanus	Sergistid shrimp		X			
Albunea paretii			X			
Albunea sp.	Mole crab	X	X			
Alphaeus heterochaelis	Snapping shrimp				X	

Table C-1. Continued.

Scientific name	Common name	A	B	C	D	E
Order Decapoda (continued)						
Alphaeus normanni					X	
Anasimus latus	Spider crab	X				
Arenaeus cribrarius	Beach crab	X	X			
Automate evermanni			X			
Axiid sp. A			X			
Calappa flammea	Flame crab	X				
Calappa springeri		X				
Calappa sulcata		X				
Callianassa latispina			X			
Callianassa major	Ghost shrimp	X	X			
Callianassa sp. cf. *biformis*			X			
Callinectes ornatus	Ornate crab	X	X	X	X	X
Callinectes sapidus	Blue crab	X	X	X	X	X
Callinectes similis		X	X	X	X	X
Carpoporus populoqus	Mud crab				X	
Clibanarius vittatus	Stripped hermit crab	X	X			
Collodes leptocheles	Spider crab	X				
Dromidia antillensis	Sponge crab	X				
Emerita talpoides	Mole crab	X	X			
Ethusa tenuipes		X				
Euceramus praelongus			X			
Eurypanopeus depressus	Mud crab	X	X		X	
Euryplax nitida			X			
Eurytium limosum	Mud crab				X	
Hepatus epheliticus	Calico crab	X	X			
Heterocrypta granulata		X				
Hexapanopeus angustifrons	Mud crab	X	X			
Latreutes parvulus	Caridian shrimp		X		X	
Lepidopa benedicti	Mole crab	X				
Libinia emarginata	Spider crab	X	X			
Libinia dubia	Spider crab	X	X			
Libinia sp. cf. *dubia*			X			
Lobopilumnus agassizi	Mud crab		X			
Lucifer faxoni	Sergistio shrimp		X			
Macrobrachium acanthurus	River shrimp	X			X	
Macrobrachium ohione	River shrimp	X			X	
Menippe mercenaria	Stone crab	X	X			
Metorhaphis calcarata	Spider crab	X	X			
Micropanope nuttingi			X			
Micropanope pusilia	Mud crab		X			
Myropsis quinquespinosa		X				
Neopanope packardi	Mud crab		X			
Neopanope texana	Mud crab	X	X	X	X	
Ocypode albicans	Ghost crab	X	X			

Table C-1. Continued.

Scientific name	Common name	A	B	C	D	E
Order Decapoda (continued)						
Ogyrides limicola			X			
Ovalipes floridanus			X			
Ovalipes guadulpensis	Beach crab	X	X	X		
Pachygrapsus transverus	Grapsid crab	X	X			
Pagurus longicarpus	Hermit crab	X	X			
Pagurus pollicaris	Hermit crab	X	X	X	X	X
Pagurus pygmeaus			X			
Pagurus sp. cf. *annulipes*			X			
Palaemonetes kadiakensis	Grass shrimp		X			
Palaemonetes paludosus	Grass shrimp		X			X
Palaemonetes pugio	Grass shrimp		X	X	X	X
Palaemonetes vulgaris	Grass shrimp	X	X	X	X	X
Panopeus herbsti	Mud crab		X	X	X	
Panopeus occidentalis	Mud crab		X	X	X	
Panopeus turgidus	Mud crab		X	X	X	
Parthenope serrata		X				
Penaeus aztecus	Brown shrimp	X	X	X	X	X
Penaeus duorarum	Pink shrimp	X	X			
Penaeus setiferus	White shrimp	X	X	X	X	X
Persephona crinita			X			
Persephona punctata		X				
Petrolisthes armatus	Porcelain crab	X	X			
Petrolisthes galathinus	Porcelain crab	X				
Pilumnus sayi	Mud crab	X				
Pinnixa chacei			X			
Pinnixa cylindrica			X			
Pinnixa sp. cf. *pearsei*			X			
Pinnixa sp. A			X			
Pinnixa sp. B			X			
Pinnotheres maculatus	Mussel crab		X			
Podochela sidneyi	Spider crab	X				
Portunus gibbesii	Swimming crab	X	X	X		
Portunus ordnayi	Swimming crab	X	X			
Portunus sayi	Swimming crab	X	X			
Portunus spinicarpus	Swimming crab	X	X			
Portunus spinimanus	Swimming crab	X	X			
Pyromia arachna	Spider crab	X				
Rithropanopeus harrisii	Mud crab		X	X	X	X
Sesarma cinereum	Fiddler crab	X	X	X	X	
Sesarma reticulatum	Fiddler crab		X		X	
Sesarma ricordi	Fiddler crab		X		X	
Sicyonia brevirostris	Rock shrimp		X	X		
Sicyonia dorsalis	Rock shrimp		X	X		
Stenocionops furcata		X				
Stenocionops spinimana		X				

Table C-1. Continued.

Scientific name	Common name	A	B	C	D	E
Order Decapoda (continued)						
Stenorynchus seticornis	Arrow crab	X				
Trachycarcinus spinulifera		X				
Trachypenaeus constrictus	Hardback shrimp		X			
Trachypenaeus similis	Hardback shrimp		X			
Uca minax	Fiddler crab				X	X
Uca mordax	Fiddler crab				X	
Uca pugnax	Fiddler crab				X	
Uca pugilator	Fiddler crab		X		X	
Uca spinicarpa	Fiddler crab				X	
Upogebia affinis			X			
Xiphopenaeus kroyeri	Seabob	X	X			
Class Insecta						
Polypedilum sp.			X			
Pentaneura sp.			X			
Phylum Phoronida						
Phoronis architecta		X	X			
Phoronis sp. A			X			
Phylum Ectoprocta						
Amathia distans			X			
Averilla sp. cf. *armata*			X			
Bugula neritina			X			
Bugula sp.		X	X	X		
Membranopora sp. cf. *arborescens*		X	X	X		
Zoobotryon verticillatum			X			
Phylum Sipuncula						
Golfingia sp. A			X			
Phascolion strombi			X			
Phascolion sp. A			X			
Phylum Echinodermata						
Amphiodia planispina	Brittle star		X			
Amphioplus gracillima	Brittle star	X				
Amphioplus sp. A			X			
Arbacia punctulata	Sea urchin	X	X	X		
Astropecten articulatus	Starfish	X	X	X		
Clypeaster subdepressus	Cake urchin	X				
Encope michelini	Large sand dollar	X	X			
Hemipholis elongata			X			
Leptosynapta sp. cf. *inherins*			X			
Lytechinus variegatus	Sea urchin	X	X	X		
Mellita quinquiesterforata	Small sand dollar	X	X			
Moira atropos	Heart urchin	X	X	X		
Ophiophragmus filograneus			X			

Table C-1. Concluded.

Scientific name	Common name	A	B	C	D	E
Phylum Echinodermata (continued)						
Ophiothrix angulata	Brittle star	X	X	X		
Plagiobrissus grandis	Large heart urchin	X				
Thyonacta mexicana			X			
Phylum Chaetognatha						
Sagitta sp.			X			
Phylum Hemichordata						
Balanoglossus sp. cf. *aurantiac*			X			
Phylum Chordata						
Subphylum Urochordata						
Molgula manhattensis	Sea squirt	X				
Styella partita	Sea squirt	X				
Styella plicata	Sea squirt	X				
Subphylum Cephalochordata						
Branchiostoma caribaeum	Lancelet	X	X			

Table C-2. Fishes of coastal Alabama (modified from Chermock et al. 1975; nomenclature according to Robins et al. 1980).

Scientific name	Common name	A[a]	B	C
Petromyzontidae				
Ichthyomyzon gagei	Southern brook lamprey			X
Lampetra aepyptera	Least brook lamprey			X
Carcharhinidae				
Carcharhinus isodon	Finetooth shark	X	X	
Carcharhinus acronotus	Blacknose shark	X	X	
Carcharhinus leucas	Bull shark	X	X	X
Carcharhinus limbatus	Blacktip shark	X	X	
Mustelus canis	Smooth dogfish	X	X	
Negaprion brevirostris	Lemon shark	X		
Rhizoprionodon terraenovae	Atlantic sharpnose shark	X		
Sphyrnidae				
Sphyrna lewini	Scalloped hammerhead	X	X	
Sphyrna tiburo	Bonnethead	X	X	
Pristidae				
Pristis pectinata	Smalltooth sawfish	X	X	
Rhinobatidae				
Rhinobates lentiginosus	Atlantic guitarfish	X		
Torpedinidae				
Narcine brasiliensis	Lesser electric ray	X	X	
Rajidae				
Raja eglanteria	Clearnose skate	X	X	
Raja garmani	Freckled skate	X	X	
Raja texana	Roundel skate	X	X	
Dasyatidae				
Dasyatis americana	Southern stingray	X	X	
Dasyatis sabina	Atlantic stingray	X	X	
Dasyatis sayi	Bluntnose stingray	X	X	
Gymnura micrura	Smooth butterfly ray	X	X	
Myliobatidae				
Aetobatus narinari	Spotted eagleray	X		
Rhinoptera bonasus	Cownose ray	X	X	
Mobulidae				
Manta birostris	Manta	X	X	
Acipenseridae				
Acipenser oxyrhynchus	Atlantic sturgeon	X	X	
Scaphirhynchus platorynchus	Shovelnose sturgeon			X
Lepisosteidae				
Lepisosteus oculatus	Spotted gar		X	X
Lepisosteus osseus	Longnose gar		X	X
Lepisosteus spathula	Alligator gar	X	X	X
Polyodontidae				
Polyodon spathula	Paddlefish			X

[a]A--Open gulf; B--Estuarine; C--Freshwater

Table C-2. Continued.

Scientific name	Common name	A	B	C
Amiidae				
Amia calva	Bowfin			X
Elopidae				
Elops saurus	Lady fish		X	X
Megalops atlantica	Tarpon	X	X	
Anguillidae				
Anguilla rostrata	American eel	X	X	X
Muraenidae				
Gymnothorax nigromarginatus	Blackedge moray	X		
Nettastomatidae				
Hoplunnis macrurus	Silver conger	X		
Congridae				
Ariosoma balearicum	Bandtooth conger	X		
Hildebrandia flava	Yellow conger	X		
Paraconger caudilimbatus	Margintail conger	X		
Ophichthidae				
Bascanichthys scuticaris	Whipeel	X	X	
Myrophis punctatus	Speckled worm eel	X	X	X
Ophichthus gomesi	Shrimp eel		X	
Clupeidae				
Alosa alabamae	Alabama shad		X	X
Alosa chrysochloris	Skipjack herring		X	X
Brevoortia patronus	Gulf menhaden	X	X	X
Brevoortia smithi	Yellowfin menhaden	X	X	X
Dorosoma cepedianum	Gizzard shad	X	X	X
Dorosoma petenense	Threadfin shad		X	X
Etrumeus teres	Round herring	X	X	
Harengula jaguana	Scaled sardine	X	X	
Opisthonema oglinum	Atlantic thread herring	X	X	
Sardinella aurita	Spanish sardine	X	X	
Engraulidae				
Anchoa hepsetus	Striped anchovy	X	X	
Anchoa lyolepis	Dusky anchovy	X		
Anchoa mitchilli	Bay anchovy	X	X	
Anchoa nasuta	Longnose anchovy	X		
Anchoviella perfasciata	Flat anchovy	X		
Salmonidae				
Salmo gairdneri	Rainbow trout			X
Hiodontidae				
Hiodon tergisus	Mooneye			X
Esocidae				
Esox americanus	Redfin pickerel			X
Esox niger	Chain pickerel			X
Synodontidae				
Saurida brasiliensis	Largescale lizardfish	X		
Synodus foetens	Inshore lizardfish	X	X	

Table C-2. Continued.

Scientific name	Common name	A	B	C
Cyprinidae				
Cyprinus carpio	Carp			X
Hybognathus hayi	Cypress minnow			X
Hybognathus nuchalis	Silvery minnow			X
Ericymba buccata	Silverjaw minnow			X
Hybopsis aestivalis	Speckled chub			X
Hybopsis storeriana	Silver chub			X
Hybopsis winchelli	Clear chub			X
Notemigonus crysoleucas	Golden shiner			X
Notropis atherinoides	Emerald shiner			X
Notropis candidus	Silverside shiner			X
Notropis chalybaeus	Ironcolor shiner			X
Notropis edwardraneyi	Fluvial shiner			X
Notropis emiliae	Pugnose minnow			X
Notropis hypselopterus	Sailfin shiner			X
Notropis longirostris	Longnose shiner			X
Notropis maculatus	Taillight shiner			X
Notropis petersoni	Coastal shiner			X
Notropis roseipinnis	Cherryfin shiner			X
Notropis signipinnis	Flagfin shiner			X
Notropis texanus	Weed shiner			X
Notropis venustus	Blacktail shiner			X
Pimephales vigilax	Bullhead minnow			X
Semotilus atromaculatus	Creek chub			X
Catostomidae				
Carpiodes cyprinus	Quillback			X
Carpiodes velifer	Highfin carpsucker			X
Cycleptus elongatus	Blue sucker		X	X
Erimyzon oblongus	Creek chubsucker			X
Erimyzon sucetta	Lake chubsucker			X
Erimyzon tenuis	Sharpfin chubsucker			X
Ictiobus bubalus	Smallmouth buffalo			X
Minytrema melanops	Spotted sucker			X
Moxostoma erythrurum	Golden redhorse			X
Moxostoma poecilurum	Blacktail redhorse			X
Ictaluridae				
Ictalurus furcatus	Blue catfish		X	X
Ictalurus natalis	Yellow bullhead			X
Ictalurus nebulosus	Brown bullhead			X
Ictalurus punctatus	Channel catfish			X
Noturus funebris	Black madtom			X
Noturus gyrinus	Tadpole madtom			X
Noturus leptacanthus	Speckled madtom			X
Noturus nocturnus	Freckled madtom			X
Pylodictus olivaris	Flathead catfish			X

Table C-2. Continued.

Scientific name	Common name	A	B	C
Ariidae				
Arius felis	Sea catfish	X	X	
Bagre marinus	Gafftopsail catfish	X	X	
Aphredoderidae				
Aphredoderus sayanus	Pirate perch			X
Batrachoididae				
Opsanus beta	Gulf toadfish	X	X	
Porichthys plectrodon	Atlantic midshipman	X	X	
Gobiesocidae				
Gobiesox strumosus	Skilletfish	X	X	
Antennaridae				
Antennarius radiosus	Singlespot frogfish	X	X	
Histrio histrio	Sargassum fish	X		
Ogcocephalidae				
Dibranchus atlanticus	Offshore batfish	X		
Halieutichthys aculeatus	Pancake batfish	X	X	
Ogcocephalus nasutus	Shortnose batfish	X	X	
Ogcocephalus radiatus	Polka-dot batfish	X		
Gadidae				
Urophycis floridana	Southern hake	X	X	
Urophycis regia	Spotted hake	X	X	
Ophidiidae				
Lepophidium graellsi	Blackedge cusk-eel	X	X	
Lepophidium jeannae	Mottled cusk-eel	X	X	
Ophidion welshi	Crested cusk-eel	X	X	
Exocoetidae				
Hemiramphus brasiliensis	Ballyhoo	X		
Hyporhamphus unifasciatus	Halfbeak	X	X	
Belonidae				
Ablennes hians	Flat needle fish	X		
Strongylura marina	Atlantic needlefish	X	X	X
Tylosurus crocodilus	Houndfish	X		
Cyprinodontidae				
Adinia xenica	Diamond killifish		X	
Cyprinodon variegatus	Sheepshead minnow	X	X	X
Fundulus chrysotus	Golden topminnow		X	X
Fundulus confluentus	Marsh killifish		X	X
Fundulus grandis	Gulf killifish		X	
Fundulus jenkinsi	Saltmarsh topminnow	X	X	
Fundulus notti	Starhead topminnow			X
Fundulus olivaceus	Blackspotted topminnow			X
Fundulus pulvereus	Bayou killifish		X	
Fundulus similis	Longnose killifish		X	
Leptolucania ommata	Least killifish			X
Lucania parva	Rainwater killifish		X	X

Table C-2. Continued.

Scientific name	Common name	A	B	C
Poeciliidae				
Gambusia affinis	Mosquitofish	X	X	X
Poecilia latipinna	Sailfin molly		X	X
Atherinidae				
Labidesthes sicculus	Brook silverside			X
Membras martinica	Rough silverside	X	X	
Menidia beryllina	Tidewater silverside	X	X	X
Fistulariidae				
Fistularia tabacaria	Bluespotted cornetfish	X		
Syngnathidae				
Hippocampus erectus	Lined seahorse	X	X	
Syngnathus floridae	Dusky pipefish	X	X	
Syngnathus louisianae	Chain pipefish	X	X	
Syngnathus scovelli	Gulf pipefish		X	X
Serranidae				
Centropristis ocyurus	Bank sea bass	X	X	
Centropristis philadelphica	Rock sea bass	X	X	
Diplectrum formosum	Sand perch	X	X	
Epinephelus drummondhayi	Speckled hind	X	X	
Epinephelus nigritus	Warsaw grouper	X		
Mycteroperca bonaci	Black grouper	X		
Mycteroperca phenax	Scamp	X		
Serraniculus pumilio	Pygmy sea bass	X		
Serranus atrobranchus	Blackear bass	X		
Serranus subligarius	Belted sandfish	X		
Centrarchidae				
Ambloplites ariommus	Rock bass			X
Centrarchus macropterus	Flier			X
Elassoma evergladei	Everglades pygmy sunfish			X
Elassoma zonatum	Banded pygmy sunfish			X
Enneacanthus gloriosus	Bluespotted sunfish		X	X
Lepomis cyanellus	Green sunfish			X
Lepomis gulosus	Warmouth			X
Lepomis humilis	Orangespotted sunfish			X
Lepomis macrochirus	Bluegill		X	X
Lepomis marginatus	Dollar sunfish			X
Lepomis megalotis	Longear sunfish		X	X
Lepomis microlophus	Redear sunfish			X
Lepomis punctatus	Spotted sunfish			X
Micropterus punctulatus	Spotted bass			X
Micropterus salmoides	Largemouth bass			X
Pomoxis annularis	White crappie			X
Pomoxis nigromaculatus	Black crappie			X

Table C-2. Continued.

Scientific name	Common name	A	B	C
Percichthyidae				
Morone mississippiensis	Yellow bass		X	X
Morone saxatilis	Striped bass		X	X
Percidae				
Ammocrypta asprella	Crystal darter			X
Ammocrypta beani	Naked sand darter			X
Etheostoma edwini	Brown darter			X
Etheostoma fusiforme	Swamp darter			X
Etheostoma proeliare	Cypress darter			X
Etheostoma stigmaeum	Speckled darter			X
Etheostoma swaini	Gulf darter			X
Etheostoma zonale	Banded darter			X
Percina caprodes	Logperch			X
Percina lenticula	Freckled darter			X
Percina nigrofasciata	Blackbanded darter			X
Stizostedion vitreum	Walleye			X
Pomatomidae				
Pomatomus saltatrix	Bluefish	X	X	
Rachycentridae				
Rachycentron canadum	Cobia	X	X	
Echeneidae				
Echeneis naucrates	Sharpsucker	X	X	
Carangidae				
Alectis ciliaris	African pompano	X		
Caranx crysos	Blue runner	X	X	
Caranx hippos	Crevalle jack	X	X	
Caranx latus	Horse-eye jack	X	X	
Chloroscombrus chrysurus	Bumper	X	X	
Hemicaranx amblyrhychus	Bluntnose jack	X	X	
Oligoplites saurus	Leatherjacket	X	X	
Selar crumenophthalmus	Bigeye scad	X	X	
Selene setapinnis	Atlantic moonfish	X	X	
Selene vomer	Lookdown	X	X	
Seriola dumerili	Greater amberjack	X		
Seriola rivoliana	Almaco jack	X	X	
Trachinotus carolinus	Pompano	X	X	
Trachinotus falcatus	Permit	X	X	
Trachinotus goodei	Palometa	X		
Trachurus lathami	Rough scad	X	X	
Coryphaenidae				
Coryphaena hippurus	Dolphin	X		

Table C-2. Continued.

Scientific name	Common name	A	B	C
Lutjanidae				
Lutjanus campechanus	Red snapper	X	X	
Lutjanus griseus	Gray snapper	X	X	
Lutjanus synagris	Lane snapper	X	X	
Pristipomoides aquilonaris	Wenchman	X		
Lobotidae				
Lobotes surinamensis	Tripletail	X	X	
Gerreidae				
Eucinostomus argenteus	Spotfin mojarra	X	X	
Eucinostomus gula	Silver jenny	X	X	
Haemulidae				
Haemulon aurolineatum	Tomtate	X		
Orthopristis chrysoptera	Pigfish	X	X	
Sparidae				
Archosargus probatocephalus	Sheepshead	X	X	X
Lagodon rhomboides	Pinfish	X	X	X
Stenotomus caprinus	Longspine porgy	X	X	
Sciaenidae				
Aplodinotus grunniens	Freshwater drum			X
Bairdiella chrysoura	Silver perch	X	X	
Cynoscion arenarius	Sand seatrout	X	X	
Cynoscion nebulosus	Spotted seatrout	X	X	X
Cynoscion nothus	Silver seatrout	X	X	
Larimus faciatus	Banded drum	X	X	
Leiostomus xanthurus	Spot	X	X	
Menticirrhus americanus	Southern kingfish	X	X	
Menticirrhus littoralis	Gulf kingfish	X	X	
Menticirrhus saxatilis	Northern kingfish	X		
Micropogonias undulatus	Atlantic croaker	X	X	
Pogonias cromis	Black drum	X	X	
Sciaenops ocellata	Red drum	X	X	
Stellifer lanceolatus	Star drum	X	X	
Ephippidae				
Chaetodipterus faber	Atlantic spadefish	X	X	
Mugilidae				
Mugil cephalus	Striped mullet	X	X	X
Mugil curema	White mullet	X	X	
Sphyraenidae				
Sphyraena barracuda	Great barracuda	X	X	
Sphyraena borealis	Northern sennet	X		
Sphyraena guachancho	Guaguanche	X	X	
Polynemidae				
Polydactylus octonemus	Atlantic threadfin	X	X	

Table C-2. Continued.

Scientific name	Common name	A	B	C
Uranoscopidae				
Astroscopus y-graecum	Southern stargazer	X	X	
Kathetostoma albigutta	Lancer stargazer	X	X	
Blenniidae				
Chasmodes bosquianus	Striped blenny		X	
Chasmodes saburrae	Florida blenny		X	
Hypleurochilus germinatus	Crested blenny		X	
Hypsoblennius hentzi	Feather blenny		X	
Hypsoblennius ionthus	Freckled blenny		X	
Eleotridae				
Dormitator maculatus	Fat sleeper		X	X
Eleotris pisonis	Spinycheek sleeper		X	
Erotelus smaragdus	Emerald sleeper	X		
Gobiidae				
Bathygobius soporator	Frillfin goby		X	
Bollmannia communis	Ragged goby		X	
Evorthodus lyricus	Lyre goby		X	
Gobioides broussoneti	Violet goby		X	
Gobionellus boleosoma	Darter goby		X	
Gobionellus hastatus	Sharptail goby		X	
Gobionellus shufeldti	Freshwater goby		X	X
Gobiosoma bosci	Naked goby		X	X
Gobiosoma longipala	Twoscale goby		X	
Gobiosoma robustum	Code goby		X	
Microgobius gulosus	Clown goby		X	
Microgobius thalassinus	Green goby		X	
Microdesmidae				
Microdesmus longipinnis	Pink wormfish	X	X	
Gempylidae				
Lepidocybium flavobrunneum	Escolar	X		
Trichiuridae				
Trichiurus lepturus	Atlantic cutlassfish	X	X	
Scombridae				
Acanthocybium solanderi	Wahoo	X		
Euthynnus alletteratus	Little tunny	X		
Sarda sarda	Atlantic bonito	X		
Scomber japonicus	Chub mackerel	X	X	
Scomberomorus cavalla	King mackerel	X	X	
Scomberomorus maculatus	Spanish mackerel	X	X	
Istiophoridae				
Istiophorus platypterus	Sailfish	X		
Stromateidae				
Nomeus gronovii	Man-of-War fish	X	X	
Peprilus alepidotus	Harvestfish	X	X	
Peprilus burti	Gulf butterfish	X	X	

Table C-2. Concluded.

Scientific name	Common name	A	B	C
Scorpaenidae				
Scorpaena brasiliensis	Barbfish	X	X	
Scorpaena calcarata	Smoothhead scorpionfish	X	X	
Scorpaena grandicornis	Plumed scorpionfish	X		
Scorpaena plumieri	Spotted scorpionfish	X	X	
Triglidae				
Peristedion gracile	Slender searobin	X	X	
Prionotus martis	Barred searobin	X	X	
Prionotus roseus	Bluespotted searobin	X	X	
Prionotus rubio	Blackfin searobin	X	X	
Prionotus scitulus	Leopard searobin	X	X	
Prionotus tribulus	Bighead searobin	X	X	
Bothidae				
Ancylopsetta quadrocellata	Ocellated flounder	X	X	
Citharichthys macrops	Spotted whiff	X	X	X
Citharichthys spilopterus	Bay whiff	X	X	
Cyclopsetta chittendeni	Mexican flounder	X	X	
Etropus crossotus	Fringed flounder	X	X	
Paralichthys albigutta	Gulf flounder	X	X	
Paralichthys lethostigma	Southern flounder	X	X	X
Paralichthys squamilentus	Broad flounder	X		
Syacium gunteri	Shoal flounder	X	X	
Soleidae				
Achirus lineatus	Lined sole	X	X	X
Trinectes maculatus	Hogchoker	X	X	X
Cynoglossidae				
Symphurus civitatus	Offshore tonguefish	X	X	
Symphurus plagiusa	Blackcheek tonguefish	X	X	
Balistidae				
Aluterus schoepfi	Orange filefish	X	X	
Aluterus scriptus	Scrawled filefish	X	X	
Balistes capriscus	Gray triggerfish	X		
Monacanthus hispidus	Planehead filefish	X	X	
Ostraciidae				
Lactophrys quadricornis	Scrawled cowfish	X		
Tetraodontidae				
Lagocephalus laevigatus	Smooth puffer	X	X	
Sphoeroides nephelus	Southern puffer	X	X	
Sphoeroides parvus	Least puffer	X	X	
Diodontidae				
Chilomycterus schoepfi	Striped burrfish	X	X	

Table C-3. Amphibians of coastal Alabama (modified from Chermock et al. 1975; nomenclature according to Mount 1975).

Scientific name	Common name	1[a]	2	3	4
Bufonidae					
Bufo quercicus	Oak toad		L[b]		A
Bufo terrestris	Southern toad	A	L	A	A
Bufo woodhousei fowleri	Fowler's toad	A	L	A	A
Hylidae					
Acris crepitans crepitans	Northern cricket frog	A	LA		
Acris gryllus gryllus	Southern cricket frog	A	LA		
Hyla avivoca	Bird-voiced treefrog	A	L		
Hyla cinera	Green treefrog	A	LA	A	
Hyla crucifer crucifer	Northern spring peeper	A	L		A
Hyla femoralis	Pine woods treefrog	A	L		A
Hyla gratiosa	Barking treefrog		L	A	A
Hyla squirella	Squirrel treefrog	A	L	A	A
Hyla versicolor	Gray treefrog	A	L		A
Pseudacris nigrita nigrita	Southern chorus frog	A	L	A	A
Pseudacris ornata	Ornate chorus frog	A	L	A	A
Microhylidae					
Gastrophryne carolinensis	Eastern narrow-mouthed toad	A	L	A	A
Pelobatidae					
Scaphiopus holbrooki holbrooki	Eastern spadefoot toad	A	L		A
Ranidae					
Rana areolata sevosa	Dusky gopher frog		L	A	A
Rana catesbeiana	Bullfrog		LA		
Rana climitans			LA		
climitans	Bronze frog		LA		
Rana grylio	Pig frog		LA		
Rana heckscheri	River frog		LA		
Rana pipens sphenocephala	Southern leopard frog		LA	A	A
Ambystomatidae					
Ambystoma cingulatum	Flatwoods salamander	A	L		A
Ambystoma maculatum	Spotted salamander	A	L		A
Ambystoma opacum	Marbled salamander	A	L		A
Ambystoma talpoideum	Mole salamander	A	L		A

[a] 1--Bottomland forests; 2--Freshwater habitats; 3--Open land; 4--Upland forests.
[b] L--Larval stage; E--Eft stage; A--Adult stage.

Table C-3. Concluded.

Scientific name	Common name	1	2	3	4
Ambystomatidae (continued)					
Ambystoma texanum	Small-mouthed salamander	A	L		A
Ambystoma tigrinum tigrinum	Eastern tiger salamander		L	A	A
Amphiumidae					
Amphiuma means	Two-toed amphiuma		LA		
Amphiuma tridactylum	Three-toed amphiuma		LA		
Plethodontidae					
Desmognathus fuscus auriculatus	Southern dusky salamander	A	LA		
Eurycea bislineata	Two-lined salamander	A	LA		A
Eurycea longicauda guttolineata	Three-lined salamander	A	LA		A
Manculus quadridigitatus	Dwarf salamander	A	L		A
Plethodon glutinosus glutinosus	Slimy salamander	LA			LA
Pseudotriton ruber vioscai	Southern red salamander	A	L		A
Pseudotriton montanus flavissimus	Gulf coast mud salamander	A	L		A
Proteidae					
Necturus beyeri alabamensis	Beyer's waterdog		LA		
Necturus punctatus	Mobile waterdog		LA		
Salamandridae					
Notopthalmus viridescens louisianensis	Central newt	E	LA	E	E
Sirenidae					
Siren intermedia intermedia	Eastern lesser siren		LA		
Siren lacertina	Greater siren		LA		

Table C-4. Reptiles of coastal Alabama (modified from Chermock et al. 1975; nomenclature according to Mount 1975).

Scientific name	Common name	A[a]	B	C	D	E	F	G
Alligatoridae								
Alligator mississippiensis	American alligator		X	X	X	X		
Cheloniidae								
Caretta caretta caretta	Atlantic loggerhead	X						
Chelonia mydas	Green turtle	X	X					
Eretmochelys imbricata imbricata	Atlantic hawksbill	X						
Lepidochelys kempi	Atlantic ridley	X	X					
Dermochelidae								
Dermochelys coriacea coriacea	Atlantic leatherback	X						
Chelydridae								
Chelydra serpentina serpentina	Common snapping turtle				X	X		
Macroclemys temmincki	Alligator snapping turtle					X		
Emydidae								
Deirochelys reticularia reticularia	Eastern chicken turtle				X	X		
Graptemys pulchra	Alabama map turtle					X		
Malaclemys terrapin pileata	Mississippi diamondback terrapin		X	X				
Pseudemys alabamensis	Alabama red-bellied turtle			X	X	X		
Pseudemys concinna concinna	River cooter		X	X	X	X		
Pseudemys floridana floridana	Florida cooter				X	X		
Pseudemys scripta	Pond slider					X	X	
Terrapene carolina major	Gulf Coast box turtle						X	X
Kinosternidae								
Kinosternon subrubrum subrubrum	Eastern mud turtle				X	X		
Sternotherus odoratus	Stinkpot				X	X		
Testudinidae								
Gopherus polyphemus	Gopher tortoise						X	X

[a] A--Open gulf; B--Estuarine; C--Tidal marsh; D--Freshwater swamps; E--Ponds and streams; F--Open fields; G--Forests.

Table C-4. Continued.

Scientific name	Common name	A	B	C	D	E	F	G
Trionychidae								
Trionyx muticus calvatus	Gulf Coast smooth softshell					X		
Trionyx spiniferus asper	Gulf Coast spiny softshell					X		
Anguidae								
Ophisaurus attenuatus longicaudus	Eastern slender glass lizard						X	X
Ophisaurus ventralis	Eastern glass lizard						X	X
Iguanidae								
Anolis carolinensis carolinensis	Green anole						X	X
Sceloporus undulatus undulatus	Southern fence lizard							X
Scincidae								
Eumeces anthracinus pluvialis	Southern coal skink							X
Eumeces faciatus	Five-lined skink							X
Eumeces inexpectatus	Southeastern five-lined skink						X	X
Eumeces laticeps	Broad-headed skink						X	X
Scincella laterale	Ground skink						X	X
Teidae								
Cnemidophorus sexlineatus sexlineatus	Eastern six-lined racerunner						X	X
Colubridae								
Cemophora coccinea copei	Northern scarlet snake						X	X
Coluber constrictor priapus	Southern black racer						X	X
Diadophis punctatus stictogenys	Mississippi ring-neck snake				X		X	X
Drymarchon corais couperi	Eastern indigo snake				X	X	X	X
Elaphe guttata guttata	Corn snake						X	X
Elaphe obsoleta spiloides	Gray rat snake						X	X
Farancia abacura reinwardti	Western mud snake				X			
Farancia erythrogramma erythrogramma	Rainbow snake				X	X	X	X
Heterodon platyrhinos	Eastern hognose snake						X	X
Heterodon simus	Southern hognose snake						X	X

Table C-4. Continued.

Scientific name	Common name	A	B	C	D	E	F	G
Colubridae (continued)								
Lampropeltis calligaster rhombomaculata	Mole snake						X	X
Lampropeltis getulus getulus	Eastern kingsnake				X	X	X	X
Lampropeltis triangulum elapsoides	Scarlet kingsnake							X
Masticophis flagellum flagellum	Eastern coachwhip				X		X	X
Nerodia cyclopion cyclopion	Green water snake			X	X			
Nerodia erythrogaster flavigaster	Yellow-bellied water snake			X	X			
Nerodia fasciata clarki	Gulf salt marsh water snake		X	X				
Nerodia fasciata fasciata	Banded water snake				X	X		
Nerodia rhombifera rhombifera	Diamond-backed water snake				X	X		
Nerodia taxispilota	Brown water snake				X	X		
Opheodrys aestivus	Rough green snake				X	X	X	X
Pituophis melanoleucus lodingi	Black pine snake						X	X
Regina rigida sinicola	Gulf glossy water snake				X	X		
Rhadinea flavilata	Yellow-lipped snake				X			X
Storeria dekayi wrightorum	Midland brown snake						X	X
Storeria occipitomaculata occipitomaculata	Northern red-bellied snake				X		X	X
Tantilla coronata coronata	Southeastern crowned snake				X		X	X
Thamnophis sauritius sauritius	Eastern ribbon snake				X	X	X	X
Thamnophis sirtalis sirtalis	Eastern garter snake				X		X	X
Virginia striatula	Rough earth snake						X	X
Virginia valeriae valeriae	Eastern smooth earth snake						X	X
Elapidae								
Micrurus fulvius fulvius	Eastern coral snake						X	X

Table C-4. Concluded.

Scientific name	Common name	A	B	C	D	E	F	G
Viperidae								
Agkistrodon contortrix contortrix	Southern copperhead				X			X
Agkistrodon piscivorus leucostoma	Western cottonmouth				X	X		X
Crotalus adamanteus	Eastern diamondback rattlesnake							X
Crotalus horridus	Timber rattlesnake				X			X
Sistrurus miliarius barbouri	Dusky pigmy rattlesnake				X			X

Table C-5. Birds of coastal Alabama
(modified from Chermock et al. 1975).

Scientific name	Common name	1[a]	2	3	4	5	6	7
Gaviidae								
Gavia immer	Common loon		W[b]					
Gavia stellata	Red-throated loon		CW					
Podicipedidae								
Podiceps auritus	Horned grebe		W					
Podiceps grisegena	Red-necked grebe		CW					
Podiceps nigriollis	Eared grebe		CW					
Podilymbus podiceps	Pied-billed grebe		W					
Phaethontidae								
Phaethon lepturus	White-tailed tropic bird	C						
Pelecanidae								
Pelecanus erythro-rhynchos	White pelican		W					
Pelecanus occiden-talis	Brown pelican	P	P					
Sulidae								
Morus bassanus	Gannet	W						
Sula leucogaster	Brown booby	C						
Phalacrocoracidae								
Phalacrocorax auritus	Double-crested cormorant		W					
Anhingidae								
Anhinga anhinga	Anhinga					CS		
Fregatidae								
Fregata magnificens	Frigate-bird	S						
Ardeidae								
Ardea herodias	Great blue heron			P	P	P		
Ardea occidentalis	Great white heron				CS			
Botaurus lentiginosus	American bittern				M	M		
Bubulcus ibis	Cattle egret				S	S	S	
Butorides virescens	Green heron			S	S	S		
Casmerodius albus	Great egret			P	P	P		
Dichromanassa rufescens	Reddish egret			M				
Egretta thula	Snowy egret			P	P	P		

[a] 1--Open gulf; 2--Estuaries; 3--Beaches and mudflats; 4--Salt marshes; 5--Freshwater swamps; 6--Open fields; 7--Forests.

[b] C--Casual; M--Migrant; P--Permanent resident; S--Summer resident; W--Winter visitor.

Table C-5. Continued.

Scientific name	Common name	1	2	3	4	5	6	7
Anatidae (continued)								
Lophodytes cucullatus	Hooded merganser		W		W	W		
Melanitta deglandi	White-winged scoter	W	W					
Melanitta perspicillata	Surf scoter	W	W					
Mergus merganser	Common merganser		W					
Mergus serrator	Red-breasted merganser	W	W					
Oidemia nigra	Common scoter		W					
Olor columbianus	Whistling swan		CW					
Oxyura jamaicensis	Ruddy duck		W					
Cathartidae								
Cathartes aura	Turkey vulture			P	P	P	P	P
Coragyps atratus	Black vulture					P	P	P
Accipitridae								
Accipiter cooperii	Cooper's hawk							P
Accipiter striatus	Sharp-shinned hawk					W	W	W
Aquila chrysaetos	Golden eagle						CW	CW
Buteo jamaicensis	Red-tailed hawk						P	P
Buteo lagopus	Rough-legged hawk						W	
Buteo lineatus	Red-shouldered hawk					P	P	P
Buteo platypterus	Broad-winged hawk						P	P
Circus cyaneus	Marsh hawk				W	W	W	
Elanoides forficatus	Swallow-tailed kite					S		
Falco columbarius	Pigeon hawk			M			M	M
Falco peregrinus	Peregrine falcon							M
Falco sparverius	Sparrow hawk					P		
Haliaeetus leucocephalus	Bald eagle			P	P	P		P
Ictinia mississippiensis	Mississippi kite					S		
Pandion haliaetus	Osprey	S	S	S	S			
Phasianidae								
Colinus virginianus	Bobwhite						P	
Meleagrididae								
Meleagris gallopavo	Turkey							P
Gruidae								
Grus canadensis	Sandhill crane					W		W

Table C-5. Continued.

Scientific name	Common name	1	2	3	4	5	6	7
Ardeidae (continued)								
Florida caerulea	Little blue heron			S	S	S		
Hydranassa tricolor	Louisiana heron			S	S	S		
Ixobrychus exilis	Least bittern				S	S		
Nyctanassa violacea	Yellow-crowned night heron			S	S	S		
Nycticorax nycticorax	Black-crowned night heron			P	P	P		
Ciconiidae								
Myceteria americana	Wood stork					CS		
Threskiornithidae								
Ajaja ajaja	Roseate spoonbill			C				
Eudocimus albus	White ibis			S		S		
Plegadis chihi	White-faced ibis			C	C	C		
Plegadis facinellus	Glossy ibis			S	S			
Anatidae								
Aix sponsa	Wood duck					P		
Anas acuta	Pintail		W		W	W		
Anas americana	American widgeon		W		W	W		
Anas clypeata	Northern shoveler		W		W	W		
Anas crecca	Green-winged teal				W	W		
Anas discors	Blue-winged teal				M	M		
Anas fulvigula	Mottled duck					P		
Anas platyrhynchos	Mallard		W		W	W		
Anas rubripes	Black duck		W		W	W		
Anas strepera	Gadwall		W		W	W		
Anser albifrons	White-fronted goose		CM					
Aythya affinis	Lesser scaup		W			W		
Aythya americana	Redhead		W					
Aythya collaris	Ring-necked duck		W					
Aythya marila	Greater scaup	W	W					
Aythya valisneria	Canvasback	W	W					
Branta canadensis	Canada goose		M					
Bucephala albeola	Bufflehead		W					
Bucephala clangula	Common goldeneye		W					
Chen caerulescens	Blue goose		M					
Chen hyperborea	Snow goose		M					
Clangula hyemalis	Old squaw	W	W					
Dendrocygna bicolor	Fulvous tree duck				CW			

Table C-5. Continued.

Scientific name	Common name	1	2	3	4	5	6	7
Rallidae								
Coturnicops noveboracensis	Yellow rail						W	
Gallinula chloropus	Common gallinule					S		
Fulica americana	American coot		W			W		
Laterallis jamaicensis	Black rail				M	M	M	
Porphyrula martinica	Purple gallinule					S		
Porzana carolina	Sora				MW	MW		
Rallus elegans	King rail			P	P			
Rallus limicola	Virginia rail				MW	MW		
Rallus longirostris	Clapper rail				P			
Haematopodidae								
Haematopus palliatus	American oystercatcher			P				
Charadriidae								
Charadrius alexandrinus	Snowy plover			P				
Charadrius melodus	Piping plover			W				
Charadrius semipalmatus	Semipalmated plover			W				
Charadrius vociferus	Killdeer						P	
Charadrius wilsonia	Wilson's plover			S				
Pluvialis dominica	American golden plover			M			M	
Pluvialis squatarola	Black-bellied plover			W				
Scolopacidae								
Actitis macularia	Spotted sandpiper			M		M		
Arenaria interpres	Ruddy turnstone		W					
Bartramia longicauda	Upland plover						M	
Calidris alba	Sanderling			W				
Calidris alpina	Dunlin			WM				
Calidris canutus	Red knot			M				
Calidris mauri	Western sandpiper			WM				
Calidris melanotos	Pectoral sandpiper			M				
Calidris minutilla	Least sandpiper			W				
Calidris pusilla	Semipalmated sandpiper			WM				
Capella gallinago	Common snipe			W		W		
Catoptrophorus semipalmatus	Willet			P	P			
Limnodromus griseus	Short-billed dowitcher			WM				

Table C-5. Continued.

Scientific name	Common name	1	2	3	4	5	6	7
Scolopacidae (continued)								
Limnodrumus scolopaceus	Long-billed dowitcher			W				
Limosa fedoa	Marbled godwit			M				
Limosa haemastica	Hudsonian godwit			CM	CM	CM		
Micropalama himantopus	Stilt sandpiper			M				
Numenius americanus	Long-billed curlew			M				
Numenius phaeopus	Whimbrel			M				
Philohela minor	American woodcock					P		P
Tringa flavipes	Lesser yellowlegs			M				
Tringa melanoleuca	Greater yellowlegs			MW				
Tringa solitaria	Solitary sandpiper			M		M		
Tryngites subruficollis	Buff-breasted sandpiper			M				
Recurvirostridae								
Himantopus mexicanus	Black-necked stilt			C				
Recurvirostra americana	American avocet			M				
Phalaropodidae								
Phalaropus fulicarius	Red phalarope	W						
Steganopus tricolor	Wilson's phalarope			M				
Stercorariidae								
Stercorarius parasiticus	Parasitic jaeger	W						
Stercorarius pomarinus	Pomarine jaeger	W						
Laridae								
Chlidonias niger	Black tern		M	M				
Gelochelidon nilotica	Gull-billed tern		M	S	M			
Hydroporgne caspia	Caspian tern		W	W	W			
Larus argentatus	Herring gull	W	W	W				
Larus atricilla	Laughing gull		P	P				
Larus delawarensis	Ring-billed gull		W	W		W		
Larus marinus	Great black-backed gull	WC	WC					
Larus philadelphia	Bonaparte's gull	W	W	W				
Rynchops niger	Black skimmer		P	P				
Sterna albifrons	Least tern		S	S				
Sterna dougalli	Roseate tern		M	M				
Sterna forsteri	Forster's tern		P	P	P			
Sterna fuscata	Sooty tern	C						

Table C-5. Continued.

Scientific name	Common name	1	2	3	4	5	6	7
Laridae (continued)								
Sterna hirundo	Common tern	P	P	P				
Thalasseus maximus	Royal tern	S	S	S				
Thalasseus sandvicensis	Sandwich tern		S	S				
Xema sabina	Sabine's gull	P						
Columbidae								
Columbina passerina	Ground dove			P			P	
Zenaida asiatica	White-winged dove						W	W
Zenaida macroura	Mourning dove						P	P
Cuculidae								
Coccyzus americanus	Yellow-billed cuckoo							S
Coccyzus erythropthalmus	Black-billed cuckoo							M
Tytonidae								
Tyto alba	Barn owl						P	P
Strigidae								
Asio flammeus	Short-eared owl				C		C	
Bubo virginianus	Great horned owl							P
Otus asio	Screech owl							P
Speotyta cunicularia	Burrowing owl			C				
Strix varia	Barred owl					P		P
Caprimulgidae								
Caprimulgus carolinensis	Chuck-will's-widow							P
Caprimulgus vociferus	Whip-poor-will			W				W
Chordeiles minor	Common nighthawk			S			S	S
Apodidae								
Chaetura pelagica	Chimney swift							S
Trochilidae								
Archilochus colubris	Ruby-throated hummingbird				M	M		
Alcedinidae								
Megaceryle alcyon	Belted kingfisher					P		
Picidae								
Centurus carolinus	Red-bellied woodpecker							P
Colaptes auratus	Common flicker							P
Dendrocopos pubescens	Downy woodpecker							P
Dendrocopos villosus	Hairy woodpecker							P
Dryacopus pileatus	Pileated woodpecker					P		P
Melanerpes erythrocephalus	Red-headed woodpecker							P

Table C-5. Continued.

Scientific name	Common name	1	2	3	4	5	6	7
Picidae (continued)								
Picoides borealis	Red-cockaded woodpecker							P
Sphyrapicus varius	Yellow-bellied sapsucker							W
Tyrannidae								
Cantopus virens	Eastern wood pewee							S
Empidonax flaviventris	Yellow-bellied flycatcher							M
Empidonax minimus	Least flycatcher							M
Empidonax traillii	Traill's fly-catcher							M
Empidonax virescens	Acadian fly-catcher					S		S
Myiarchus cinerascens	Ash-throated flycatcher						C	C
Myiarchus crinitus	Great crested flycatcher							S
Muscivora forficata	Scissor-tailed flycatcher			W			W	
Nuttallornis borealis	Olive-sided flycatcher							M
Pyrocephalus rubinus	Vermilion fly-catcher			CW		CW		CW
Tyrannus dominicensis	Gray kingbird			S				
Tyrannus tyrannus	Eastern king-bird						S	S
Tyrannus verticalis	Western king-bird			W			W	
Sayornis phoebe	Eastern phoebe						W	W
Alaudidae								
Eremophila alpestris	Horned lark			CW			CW	
Hirundinidae								
Hirundo rustica	Barn swallow					S	S	
Iridoprocne bicolor	Tree swallow					W	W	W
Petrochelidon pyrrhonota	Cliff swallow					M	M	
Progne subis	Purple martin						S	
Riparia riparia	Bank swallow			M	M		M	
Stelgidopteryx rufi-collis	Rough-winged swallow				M	M	MW	MW
Corvidae								
Corvus brachyrhynchos	Common crow						P	
Corvus ossifragus	Fish crow			P	P	P		
Cyanocitta cristata	Blue jaw							P

Table C-5. Continued.

Scientific name	Common name	1	2	3	4	5	6	7
Paridae								
Parus bicolor	Tufted titmouse							P
Parus carolinensis	Carolina chickadee							P
Certhiidae								
Certhia familiaris	Brown creeper							W
Sittidae								
Sitta canadensis	Red-breasted nuthatch							W
Sitta carolinensis	White-breasted nuthatch							PC
Sitta pusilla	Brown-headed nuthatch							P
Troglodytidae								
Cistothorus platensis	Short-billed marsh wren					W	W	
Telmatodytes palustris	Long-billed marsh wren				P	P		
Thryomanes bewickii	Bewick's wren							W
Thryothorus ludovicianus	Carolina wren					P	P	P
Troglodytes aedon	House wren					W		W
Troglodytes troglodytes	Winter wren							W
Mimidae								
Dumetella carolinensis	Catbird						MW	MW
Mimus polyglottus	Mockingbird						P	P
Oreoscoptes montanus	Sage thrasher						CW	
Toxostoma rufum	Brown thrasher						P	P
Turdidae								
Catharus fuscescens	Veery							M
Catharus guttatus	Hermit thrush							MW
Catharus minimus	Gray-cheeked thrush							M
Catharus ustulatus	Swainson's thrush							M
Hylocichla mustelina	Wood thrush							S
Sialia sialis	Eastern bluebird						P	P
Turdus migratorius	Robin					W	W	W
Sylviidae								
Polioptila caerulea	Blue-gray gnatcatcher							P
Regulus calendula	Ruby-crowned kinglet							W
Regulus satrapa	Golden-crowned kinglet							W
Motacillidae								
Anthus spinoletta	Water pipit						W	

Table C-5. Continued.

Scientific name	Common name	1	2	3	4	5	6	7
Bombycillidae								
Bombycilla cedrorum	Cedar waxwing							W
Laniidae								
Lanius ludovicianus	Loggerhead shrike						P	P
Sturnidae								
Sturnus vulgaris	Starling						P	P
Vireonidae								
Vireo altiloquus	Black-whiskered vireo							C
Vireo bellii	Bell's vireo							CM
Vireo flavifrons	Yellow-throated vireo							MW
Vireo gilvus	Warbling vireo							M
Vireo griseus	White-eyed vireo							P
Vireo olivaceus	Red-eyed vireo							S
Vireo philadelphicus	Philadelphia vireo							M
Vireo solitarius	Solitary vireo							W
Parulidae								
Dendroica audoboni	Audobon's warbler							M
Dendroica caerulescens	Black-throated blue warbler							M
Dendroica castanea	Bay-breasted warbler							M
Dendroica cerulea	Cerulean warbler							M
Dendroica coronata	Myrtle warbler					W		W
Dendroica discolor	Prairie warbler						M	M
Dendroica dominica	Yellow-throated warbler							MW
Dendroica fusca	Blackburnian warbler							M
Dendroica magnolia	Magnolia warbler							M
Dendroica nigrescens	Black-throated gray warbler							CM
Dendroica palmarum	Palm warbler						W	W
Dendroica pensylvanica	Chestnut-sided warbler							M
Dendroica petechia	Yellow warbler					M	M	M
Dendroica pinus	Pine warbler							P
Dendroica striata	Blackpoll warbler							M
Dendroica tigrina	Cape may warbler							M
Dendroica virens	Black-throated green warbler							M
Geothlypis trichas	Yellowthroat					P		P
Helmitheros vermivorus	Worm-eating warbler							M

Table C-5. Continued.

Scientific name	Common name	1	2	3	4	5	6	7
Parulidae (continued)								
Icteria virens	Yellow-breasted chat						M	M
Limnothlypis swainsonii	Swainson's warbler					S		
Mniotilta varia	Black-and-white warbler							M
Oporornis agilis	Connecticut warbler							CM
Oporornis formosus	Kentucky warbler							M
Oporornis philadelphia	Mourning warbler							CM
Parula americana	Parula warbler					S		S
Protonotaria citrea	Prothonotory warbler					S		S
Seiurus aurocapillus	Ovenbird							M
Seiurus noveboracensis	Northern water-thrush						M	M
Seiurus motacilla	Louisiana water-thrush						M	M
Setophaga ruticilla	American redstart							M
Vermivora celata	Orange-crowned warbler							W
Vermivora chrysoptera	Golden-winged warbler							M
Vermivora peregrina	Tennessee warbler							M
Vermivora pinus	Blue-winged warbler						M	
Vermivora ruficapilla	Nashville warbler							M
Wilsonia canadensis	Canada warbler							M
Wilsonia citrina	Hooded warbler							S
Wilsonia pusilla	Wilson's warbler							M
Ploceipae								
Passer domesticus	House sparrow						P	P
Icteridae								
Agelaius phoeniceus	Redwinged blackbird					P	P	
Cassidix major	Boat-tailed grackle			P	P			
Dolichonyx oryzivorus	Bobolink						M	
Euphagus carolinus	Rusty blackbird					W	W	
Euphagus cyanocephalus	Brewer's blackbird						W	
Icterus bullocki	Bullock's oriole							CM
Icterus galbula	Baltimore oriole							M
Icterus spurius	Orchard oriole							S

Table C-5. Continued.

Scientific name	Common name	1	2	3	4	5	6	7
Icteridae (continued)								
Molothrus ater	Brown-headed cowbird						W	W
Quiscalus quiscula	Common grackle						P	P
Sturnella magna	Eastern meadow-lark				P		P	P
Sturnella neglecta	Western meadow-lark				W		W	W
Thraupidae								
Piranga ludoviciana	Western tanager							CM
Piranga olivacea	Scarlet tanager							M
Piranga rubra	Summer tanager							S
Fringillidae								
Aimophila aestivalis	Bachman's sparrow							P
Ammodramus henslowii	Henslow's sparrow					W	W	
Ammodramus savannarum	Grasshopper sparrow						W	
Ammospiza caudacuta	Sharp-tailed sparrow				W			
Ammospiza leconteii	LeConte's sparrow						W	
Ammospiza maritima	Seaside sparrow				P			
Calamospiza melanocorys	Lark bunting						CW	
Cardinalis cardinalis	Cardinal							P
Carpodacus purpureus	Purple finch							W
Chondestes grammacus	Lark sparrow						M	
Guiraca caerulea	Blue grosbeak						M	M
Hesperiphona vespertina	Evening grosbeak						W	W
Junco hyemalis	Slate-colored junco						CW	CW
Melospiza georgiana	Swamp sparrow					W	W	
Melospiza lincolnii	Lincoln's sparrow							CW
Melospiza melodia	Song sparrow						W	W
Passerculus sandwichensis	Savannah sparrow						W	
Passerella iliaca	Fox sparrow							CW
Passerina ciris	Painted bunting							M
Passerina cyanea	Indigo bunting						M	M
Pheucticus ludovicianus	Rose-breasted grosbeak							M
Pheucticus melanocephalus	Black-headed grosbeak							CW
Pipilo erythrophthalmus	Rufous-sided towhee							P
Pooecetes gramineus	Vesper sparrow							W
Spinus pinus	Pine siskin							CW

Table C-5. Concluded.

Scientific name	Common name	1	2	3	4	5	6	7
Fringillidae (continued)								
Spinus tristis	American goldfinch						W	W
Spiza americana	Dickcissel						M	
Spizella pallida	Clay-colored sparrow							CW
Spizella passerina	Chipping sparrow						W	
Spizella pusilla	Field sparrow						W	
Zonotrichia albicollis	White-throated sparrow							W
Zonotrichia leucophrys	White-crowned sparrow						CW	CW

Table C-6. Mammals of coastal Alabama (modified from Chermock et al. 1975 and Holliman 1979).

Scientific name	Common name	A[a]	B	C	D	E	F	G	H	I	J	K	L	M
Marsupialia														
Didelphis marsupialis pigra	Opossum			X	X	X	X	X	X	X	X	X		
Insectivora														
Blarina brevicauda carolinensis	Short-tailed shrew								X					
Cryptotis parva parva	Least shrew						X							
Scalopus aquaticus howelli	Eastern mole							X	X	X				
Chiroptera														
Eptesicus fuscus fuscus	Big brown bat													X
Lasiurus borealis borealis	Red bat													X
Lasiurus cinerus cinerus	Hoary bat													X
Lasiurus intermedius floridanus	Yellow bat													X
Lasiurus seminolus	Seminole bat													X
Myotis austroriparius austroriparius	Southeastern myotis													X
Nycticeius humeralis humeralis	Evening bat													X
Tadarida brasiliensis cynocephala	Brazilian free-tailed bat													X
Edentata														
Dasypus novemcinctus mexicanus	Nine-banded armadillo	X				X					X	X		
Lagomorpha														
Sylvilagus aquaticus littoralis	Swamp rabbit							X	X					
Sylvilagus floridanus mallurus	Eastern cottontail	X				X	X			X	X	X		
Sylvilagus palustris palustris	Marsh rabbit			X	X			X						
Rodentia														
Castor canadensis carolinensis	Beaver							X						
Geomys pinetis mobilensis	Southeastern pocket gopher										?[b]			
Glaucomys volans saturatus	Southern flying squirrel								X	X				
Myocastor coypus bonariensis	Nutria		X	X	X			X						
Mus musculus brevirostris	House mouse											X		
Neotoma floridana rubida	Eastern wood rat								X					
Ochrotomys nuttalli auerolus	Golden mouse								X					
Ondatra zibethicus rivalicius	Louisiana muskrat		X	X	X			X						
Oryzomys palustris palustris	Marsh rice rat		X	X	X			X						
Peromyscus gossypinus gossypinus	Cotton mouse								X	X				
Peromyscus polionotus ammobates	White-fronted beach mouse	X												

[a] A--Beach, sand dune; B--Saline marsh; C--Intermediate marsh; D--Fresh marsh; E--Salt-bush-saltflat; F--Savannah; G--Swamp; H--Mixed bottomland forest; I--Mixed upland forest; J--Pine; K--Urban; L--Marine; M--Transitional (Bats are found in many habitat types.)

[b] ?--Questionable occurrence

Table C-6. Concluded.

Scientific name	Common name	A	B	C	D	E	F	G	H	I	J	K	L	M
Rodentia (continued)														
Peromyscus polionotus polionotus	Oldfield mouse									?				
Peromyscus polionotus trissyllepis	Florala beach mouse	X												
Rattus norvegicus norvegicus	Norway rat											X		
Rattus rattus (3 subspecies)	Black rat											X		
Sciurus carolinensis carolinensis	Gray squirrel							X	X	X		X		
Sciurus carolinensis fuliginosus	Bayou gray squirrel								X	X				
Sciurus niger bachmani	Bachman fox squirrel									X				
Sigmodon hispidus hispidus	Hispid cotton rat						X							
Cetacea														
Balaenoptera physalia	Fin-backed whale												X	
Delphinus delphis	Common dolphin												X	
Globicephala macrorhyncha	Short-finned pilot whale												X	
Physeter catodon	Sperm whale												X	
Stenella plagiodon	Spotted dolphin												X	
Steno bredanensis	Rough-toothed dolphin												X	
Tursiops truncatus	Bottlenosed dolphin												X	
Sirenia														
Trichechus manatus latirostris	Manatee												X	
Pinnipedia														
Zalophus californianus	California sea lion												X	
Carnivora														
Canis latrans	Coyote							X						
Felis concolor coryi	Mountain lion							X	X					
Lutra canadensis canadensis	River otter		X	X	X			X						
Lynx rufus floridanus	Bobcat	X	X	X	X	X	X	X	X	X	X			
Mephitis mephitis elongata	Striped skunk					X	X	X	X	X	X			
Mustella frenata olivacea	Long-tailed weasel									X				
Mustella vison mink	Mink			X	X			X						
Procyon lotor varius	Raccoon	X	X	X	X	X	X	X	X	X	X	X		
Spilogale putorius putorius	Spotted skunk					X	X	X	X	X	X			
Urocyon cinereoargenteus floridanus	Gray fox			X	X	X	X	X		X	X			
Ursus americanus floridanus	Florida black bear							X						
Vulpes fulva fulva	Red fox					X	X			X	X			
Artiodactyla														
Odocoileus virginianus	White-tailed deer						X	X	X	X	X			

GLOSSARY

ADVECTION - The horizontal shifting of a mass of air, considered especially as a means for the transfer of heat.

ALLOCHTHONOUS - Materials or products transported into a system that were produced outside of the system.

ALLUVIAL - Deposited materials (sand, gravel) by streams.

ANTICLINE - Upfolds or arches in rocks.

ATP (ADENOSINE TRIPHOSPHATE) - A compound containing adenine, ribose, and three phosphates. It is the "common energy currency" for most cellular processes.

AQUIFER - A geologic formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs.

AUTOCHTHONOUS - Materials or products produced within a system.

AUTOLYSIS - Release of nutrients from dead plants and animals in the absence of microorganisms.

AUTOTROPHIC - Organisms that utilize light energy and simple inorganic substances to build complex substances.

BATHYMETRY - The measurement of ocean depths and the charting of the topography of the ocean floor.

BENTHOS - Consumers occupying bottom habitats in aquatic communities.

BIOCHEMICAL OXYGEN DEMAND - A measure of the quantity of dissolved oxygen used for the decomposition of organic matter by microorganisms.

CARAPACE - A continuous exoskeletal shield which covers the head and thorax.

CARBONATES - Rock consisting chiefly of carbonate minerals such as limestone and dolomite.

CARNIVORE - An organism that consumes primarily animal flesh.

CEPHALOTHORAX - The exoskeleton of some crustaceans in which the head and thorax are fused into a single unit.

CHLOROPHYLL *A* - The green pigment of plant cells that occurs in all photosynthetic cells including the blue-green algae.

CLASTIC - Broken or worn fragments or pre-existing minerals, rock particles by mechanical means.

CLIMOGRAPH - Graphic visuals relating two climatic variables within an area. For example, temperature compared to precipitation.

COASTAL PLAIN - The continental margin where exposed above sea level is relatively flat.

COELENTERATES - A group of aquatic animals regarded as a basic stock of higher animals. The group includes such animals as sea anemones, jellyfishes, and corals.

COLIFORM BACTERIA - Bacteria of the *Escherichia coli* group that commonly occur in the intestinal tract of man and animals. Their presence in water may indicate fecal pollution.

COOLING DEGREE DAYS - A term used to indicate energy requirements for air conditioning or refrigeration. One cooling degree day is assigned for each degree that the daily mean temperature departs above a base of 75°F.

COPEPOD - A group of crustaceans composed of small organisms that are usually planktonic or benthic.

CORIOLIS FORCE - Inertial forces generated by the rotation of the earth.

CRUSTACEA - A group of aquatic arthropods characterized by a hard exoskeleton, gills, and paired appendages.

DECAPOD - A group of crustaceans including such animals as crabs, shrimps and lobsters.

DECOMPOSERS - Organisms which degrade complex organic molecules into simpler substances.

DELTAFRONT - A narrow zone where deposition in deltas is most active, consisting of a continuous sheet of sand, and occurring at the effective depth of wave erosion.

DELTAIC - Pertaining to or characterized by a delta.

DISCHARGE - The rate of flow at a given moment in time, expressed as volume per unit of time.

DIURNAL TIDES - The occurrence of a tide once a day.

EBB TIDE - Falling tide.

ELUTRIATE ANALYSES - A method of mechanical analysis of a sediment in which the finer lightweight particles are separated from the coarser, heavy particles by means of a slowly rising current of air or water of known and controlled velocity, carrying the lighter particles upward and allowing the heavier ones to sink.

EMBAYMENTS - The formation of a bay, as by the sea overflowing a depression of the land near the mouth of a river.

EPIFAUNA - In benthic communities, those organisms living on the substrate surface, either attached or moving freely on the surface.

ESCARPMENTS - A long, continuous, cliff or relatively steep slope facing in one general direction.

ESTUARY - The seaward end or the widened funnel-shaped tidal mouth of a river valley where freshwater mixes with and measurably dilutes seawater and where tidal effects are evident.

EVAPORITE - Rocks formed by the evaporation of the solvent.

EXTRATROPICAL - The poleward movement of the belt of tropical easterly winds.

FACIES - The aspect, appearance, and characteristics of a rock unit, usually reflecting the conditions of its origins.

FECAL COLIFORM BACTERIA - Bacteria present in the intestine or feces of warm-blooded animals often used as indicators of the sanitary quality of water.

FERRUGINOUS - Containing iron.

FLOOD TIDE - Rising tide.

FLUVIAL - Of or pertaining to a river or rivers.

FORAMINIFERIDA - An ancient group of Protozoa found in all oceans and whose hard shell consists primarily of calcium carbonate.

GRABENS - A downdropped block of the earth's crust, bounded by faults.

HEATING DEGREE DAYS - A term used as an indicator of fuel consumption. One heating degree day is assigned for each degree that the daily mean temperature departs below a base of 65°F.

HERBIVORE - An organism that consumes primarily plant tissues.

HETEROTROPHIC - Organisms that utilize, rearrange and decompose complex materials.

HOLOPLANKTON - "Permanent plankton." Organisms that remain planktonic for their entire lives.

HOMOCLINE - A zone of tilted strata, in which the strata dips uniformly in one direction.

HYDROLYSIS - To break a chemical bond with the insertion of the components of water, $^{-}$H and $^{-}$OH, at the cleaved ends of a chain. The digestion of proteins is a hydrolysis.

HYDROMEDUSAE - Medusae life history stages of the hydrozoan coelenterates.

INFAUNA - In benthic communities, those organisms that dig into the substrate or construct burrows or tubes.

INTERFLUVES - The area between rivers.

INVERTEBRATE - All animals excluding vertebrates.

LENSES - Geologic deposits bounded by converging surfaces (at least one of which is curved), thick in the middle and thinning out toward the edges. Resembles a convex lens.

LITHOLOGY - The description of rocks.

MACROBENTHOS - Benthic organisms equal to or greater than 0.5 mm (0.02 inch) in size.

MEGALOPA - Second larval stage of many crustaceans.

MEIOBENTHOS - Benthic organisms smaller than 0.5 mm (0.02 inch) in size.

MEROPLANKTON - "Temporary plankton." That portion of plankton composed of specific life history stages of various organisms.

MINERALIZED - Converted to a mineral substance, or impregnated with mineral material.

MOLT - Periodic shedding of an external cuticle or skeleton as in crayfishes, crabs, and insects.

NITROGEN OXIDES - Contaminants generated by the oxidation of nitrogen compounds generally in fuel combustion and industrial processes.

OMNIVORE - An organism that consumes both plant and animal tissue.

OUTER CONTINENTAL SHELF - That part of the continental margin between the shoreline and the continental slope.

OXIDATION - Relative loss of electrons in a chemical reaction. Most biological oxidations are associated with the liberation of energy.

PARTINGS - Lineations. A lamina or very thin sedimentary layer, generally soft, following a surface of separation between thicker strata of different lithology; e.g. a shale break in sandstone, or a thin bed of shale or slate in a coal bed.

PERENNIAL STREAM FLOW - A stream or reach of a stream that flows continuously throughout the year and whose upper surface generally stands lower than the water table in the region adjoining the stream.

PHOTOCHEMICAL SMOG - Photochemical reactions forming ozone or other oxidants from impurities such as sulfur and nitrogen dioxide by the absorption of ultraviolet radiation from sunlight.

PHYTOMASTIGOPHORANS - Flagellated protozoans possessing plant-life characteristics.

PHOTOSYNTHESIS - Metabolic processes by which visible light is trapped and the energy used to synthesize energy rich compounds such as ATP or glucose.

PIEZOMETRIC SURFACE - An imaginary surface representing the static head of ground water and defined by the level to which water will rise in a well. The water table is a particular piezometric surface.

PLANKTON - Free-floating organisms of the sea and freshwater that move passively with water currents.

POSTLARVAE - Animal larvae usually less than 25 mm (1 inch) in length.

PRIMARY PRODUCTIVITY - The rate at which radiant energy is stored by photosynthetic and chemosynthetic activity of producer organisms in the form of organic substances that are used as food materials.

PRODELTA - The part of a delta that is below the effective depth of wave erosion, lying beyond the deltafront, and sloping gently to the floor of the basin into which the delta is advancing.

PROTOZOA - A group of single-celled organisms that perform all of life's essential functions within a single cell membrane.

RECTILINEAR TIDAL CURRENTS - Reversing currents.

RIPARIAN - Of, or pertaining to, or living on the banks of streams, rivers, lakes or tide waters.

SAFFIR/SIMPSON SYSTEM - Hurricane rating system according to intensity. It categorizes hurricanes on a scale of 1 to 5, with category 5 the most intense. Central barometric pressure, wind speed, and surge height are the factors which determine the categories.

SARCODINA - A group of protozoans whose primary mode of locomotion is by using pseudopodia ("false feet"). The group includes such organisms as amoebas, foraminiferans, and radiolarians.

SCYPHOMEDUSAE - Medusae life history stages of the scyphozoan coelenterates.

SILICIFIED - Has been replaced by silica.

SIPHONOPHORES - Highly specialized coelenterates which are polymorphic with a variety of modified larval stages. Included in this group is the Portuguese man-of-war.

SPAT - Larval oysters.

SPAWNING - A behavioral act that brings sperm and egg cells close together during reproduction.

SPIT - Bar or beach built out from the tip of the headland beach forming a projection out from the land mass.

STANDING CROP - The weight, or mass, at some instant in time, or a species or group of species defined by some limit.

SULFUR OXIDES - Contaminants generated by the oxidation of sulfur compounds generally in fuel combustion and ore refining.

SYZYGY - The nearly straight-line configuration of three celestial bodies (as the sun, moon, and earth during a solar or lunar eclipse) in a gravitational system.

TERRIGENOUS - Derived from the land or continent.

TROPHIC - Nourishment, food.

VERTEBRATE - Animals with bony or cartilaginous backbone.

ZOEAE - First larval stage of many crustaceans.

ZOOMASTIGOPHORANS - Flagellated protozoans possessing animal-like characteristics.

ZOOPLANKTON - The animal portion of the plankton.

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The Environmental Synthesis report consists of two parts. The first contains a detailed description of the natural environment of coastal Alabama relative to its biological, geological, and hydrological resources and processes. The second part presents a conceptual model of energy flow through major coastal ecosystems (freshwater, coastal terrestrial, estuarine and outer continental shelf) and interrelates them to modified and manipulated systems (urban, industrial, and agricultural) in Mobile and Baldwin Counties. Also included are detailed discussions and models of the estuarine ecosystem and one of its components, the marsh, as it relates to coastal Alabama.

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