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GULF COAST
DEEP WATER PORT FACILITIES STUDY

Appendix B
North Central Gulf Hydrobiological Zones

AD A091405

a report to

U. S. DEPARTMENT OF THE ARMY
VICKSBURG DISTRICT CORPS OF ENGINEERS

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Arthur D. Little, Inc.

Gulf Coast Deep Water Port Facilities Study

APPENDIX B

NORTH CENTRAL GULF HYDROBIOLOGICAL ZONES

A report to

U.S. Department of the Army
Vicksburg District Corps of Engineers
Vicksburg, Mississippi 39180

prepared under

Contract No. DACW 38-73-C-0027

1 Apr[redacted]73

ADL-C-75018-APP-B

Arthur D Little, Inc.

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ACKNOWLEDGEMENT

Arthur D. Little, Inc. (ADL) wishes to acknowledge the valuable assistance of Bio-Oceanic Research, Inc., New Orleans, Louisiana, who prepared this appendix (under ADL Agreement A-10207). Dr. Robert D. Groover directed the efforts of Bio-Oceanic staff members who contributed to this volume.

FOREWORD

Dissimilar hydrobiological zones of the North Central Gulf of Mexico have been delineated on a map of the region. The purpose of this Appendix is to discuss, on the basis of available information, man's activity and the physical and biological characteristics in each zone. The data are presented to aid evaluation of the potential environmental alterations resulting from deep water port development. The lack of certain types of data in various zones is also discussed.

INTRODUCTION

The North Central Region of the Gulf of Mexico is considered in this volume as the coasts of Louisiana, Mississippi, and Alabama, and their adjacent coastal waters to a depth of approximately 25-30 fathoms.

One of the dominant features of the inshore, shallow waters of the North Central Gulf of Mexico is the influence of freshwater runoff and stream discharge. These influence sedimentation, water turbidity, salinity, and, to some extent, other water-chemistry parameters. Of the many streams emptying into the Gulf of Mexico along its North Central portion, the most important is the Mississippi River. Great variability is the prime characteristic of the hydrological parameters of the inshore area.

Of prime importance to the three states is the large number of estuarine areas associated with the coastline. Numerous commercially important species such as shrimp, oysters, crabs, and various fish abound in these estuarine environments, and the estuaries serve as a nursery area during critical periods in the life cycles of many such species. Gunter (1967) estimated that estuarine-dependent species compose about 97.5% of the total commercial fisheries catch of the Gulf Coast states. Offshore waters serve as the spawning ground for commercially important species and support the adult populations of estuarine-dependent and other species important for human consumption and for the pet food, fish oil, and fish meal industries. Estuaries also support large numbers of fur-bearing mammals and migratory waterfowl.

Man's activity in the coastal zone is diverse. Of specific importance is the extensive offshore production of oil and natural gas off Louisiana and the numerous petroleum-related onshore activities. Each of the states has ports serving ocean-going vessels. In order of importance these ports are: New Orleans, Louisiana; Mobile, Alabama; and Pascagoula, Mississippi.

I. REGIONAL ATTRIBUTES OF HYDROBIOLOGICAL ZONES

A. INTRODUCTION

The single region under consideration is the North Central Region of the Gulf of Mexico, consisting of the coastal areas of Louisiana, Mississippi, and Alabama, and the adjacent offshore waters to a depth of approximately 25-30 fathoms.

An excellent publication which considers all the general attributes of this region is Hedgpeth's (1953) introduction to the zoogeography of the Northwestern Gulf of Mexico. The coastal region under consideration is a part of the large Gulf Coastal Plain, which is indented in this region by the Mississippi embayment, extending as far north as Cairo, Illinois. This plain gradually slopes beneath the waters of the Gulf of Mexico at a gradient of approximately 8 to 12 feet per mile, thus forming a broad continental shelf approximately 140 miles south of Louisiana.

The climate of the coastal area of this region is strongly influenced by the Gulf of Mexico and its sub-tropical latitude. Summers are characterized by prevailing southerly winds which provide moist, semi-tropical weather. During winter, the area is subjected alternately to tropical air and cold continental air typified by large and sudden drops in temperature. Along coastal Louisiana, the average maximum air temperature in January ranges from 62° to 68°F, and the maximum air temperature in July ranges from 74° to 90°F. Average rainfall along coastal Louisiana is 60.32 inches per year. Similar conditions prevail along coastal Mississippi with some freezing weather always occurring during the year. Rainfall ranges from 34.5 to 90 inches per year, and averages 59.9. The average annual temperature at Mobile, Alabama was 68°F during a 59-year period. Summer and winter temperatures averaged 81° and 53°F. Rainfall at Mobile averages about 62 inches per year. As discussed later, offshore water temperatures also have great annual fluctuations. Meteorological features of the coastal areas of the three states under consideration are adequately covered in their respective Gulf Estuarine Inventories. A recent environmental guide for the U.S. Gulf Coast prepared by the Environmental Data Service of the National Oceanographic and Atmospheric Administration (1972) gives considerable meteorological data for the region.

In the Gulf of Mexico, tidal fluctuation is less than the Atlantic and Pacific coasts. Along coastal Louisiana, the normal tide is diurnal (i.e., one high and one low during a tidal day of about 24 hours and 50 minutes), but is subject to extreme variation because of wind effects. The mean tidal level is from 0.4 to 1.2 feet and the tidal range is from 0.9 to 2.5 feet. In Mississippi Sound, the diurnal tides have a predicted range of approximately 1.5 feet and a mean tide level of 0.8 to 0.9 feet. The mean diurnal tide of the Alabama coastal area is about 0.5 to 1.8 feet.

B. GENERAL PHYSICAL CHARACTERISTICS

1. Hydrology

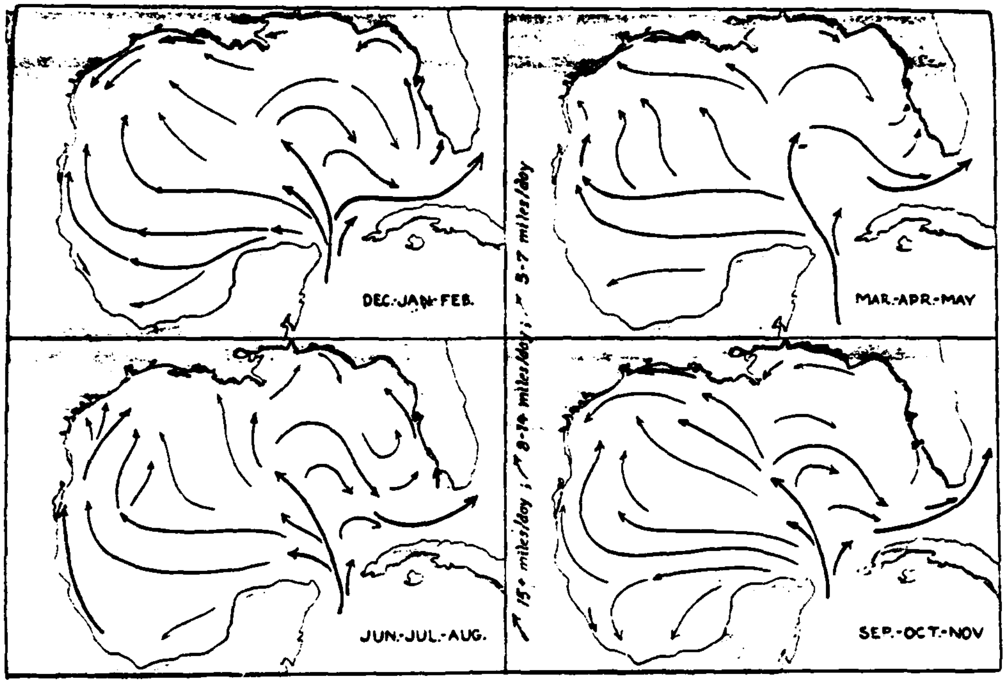
In this section, we give a general consideration of circulation. salinity, water temperature and flushing rates. These four interrelated factors are discussed with regard to their influence on marine and estuarine organisms, as well as their role in environmental modification.

Surface current patterns in the Gulf of Mexico vary during the year and are influenced, in part, by wind direction. Surface patterns for the Gulf as a whole are shown in Figure B-1 for four, three-month periods. The main Gulf current flows north through the Straits of Yucatan then bifurcates into a west to northwest branch and an east to southeast branch. Along the Louisiana coast currents move from east to west forming a dominant longshore current. East of the delta, along the Mississippi and Alabama coasts, surface currents are much more erratic. Surface current and wind patterns for the northwest part of the Gulf of Mexico are shown in more detail in Figure B-2. Note the dominance of a strong (greater than 10 knots per day) longshore current west of the delta and the more erratic patterns east of the delta, depending on the time of year. These strong longshore currents are responsible for sediment movement in a westerly and southwesterly direction and for the elongated pointed ends of barrier islands.

The main factors governing salinity variation are currents, climate and river discharge. These factors influence both bottom and surface salinities, but their effect is more noticeable at the surface. Because of variation in these factors along the Gulf Coast, particularly river discharge, it is difficult to generalize this parameter, especially in the important shallow nearshore waters of the continental shelf. Salinities of the open Gulf are generally more stable and do not vary appreciably from normal values of 35°/oo. Inshore waters are affected mostly by discharges of major rivers, such as the Mississippi and Atchafalaya. Geyer (1950) emphasized these variations in an area off Grand Isle. His results are discussed in the section dealing with Zone XII. Hedgpeth (1953), shows the relationship between Atchafalaya River discharge and salinities near Eugene Island. This relationship is inverse. As discharge increases, salinity decreases and, in some instances, may be reduced to zero. Figures B-3 and B-4 illustrate this relationship for a small region immediately east of the Mississippi River delta.

Meteorological and water current patterns are also important in controlling salinity but the most important factor along the Gulf Coast from Mobile Bay to Sabine Pass is freshwater runoff. The Gulf Estuarine Inventories of the three states contain large amounts of salinity data.

Along the North Central Gulf Coast surface temperature is reasonably constant (Figure B-5), about 84°F in summer and 65 to 68°F in winter, a difference of ± 20°F. These differences are also shown for several different regions in the Gulf in Figures B-6 and B-7. Temperature decreases with increasing depth but the rate is



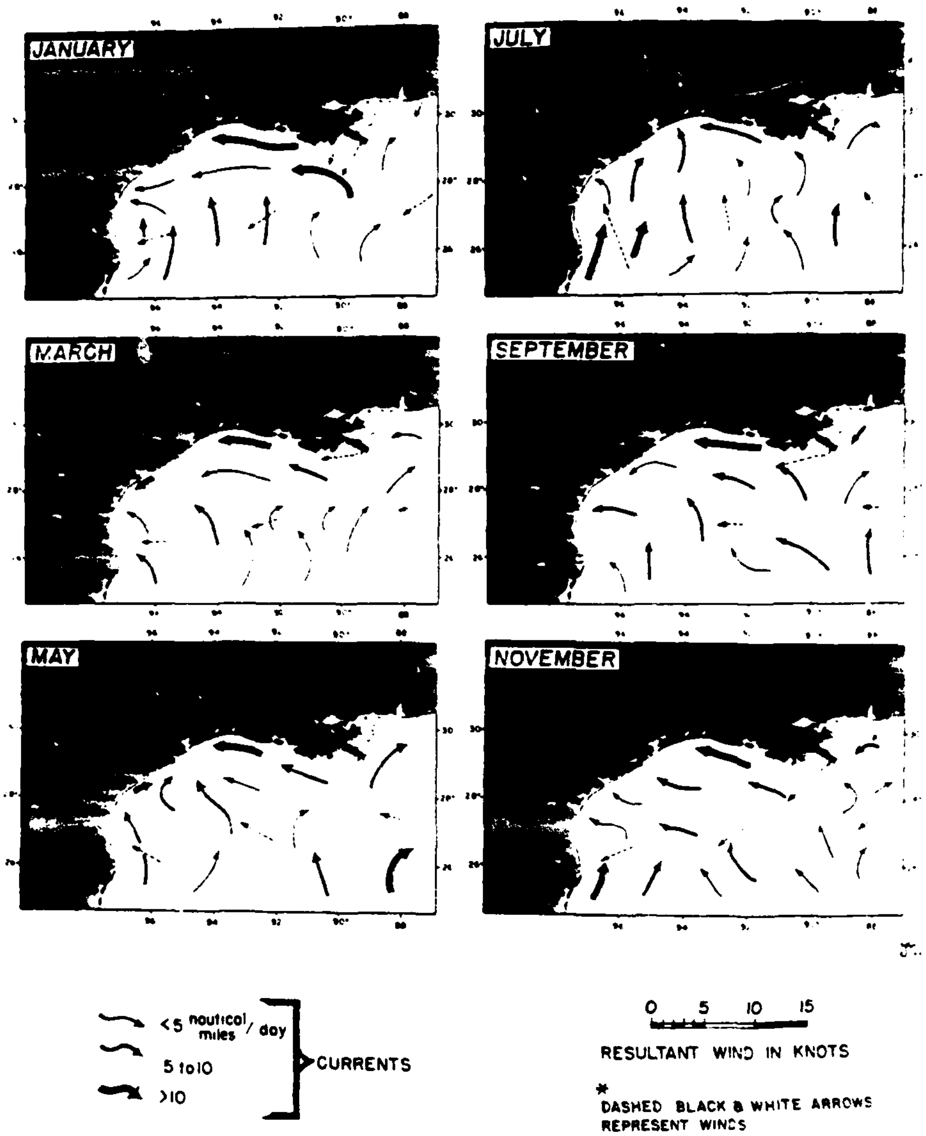
Streamlined freehand from Current Charts, Central American waters, U.S.H.O. Misc. 10, 690, 1-12. From Hedgpeth, 1953, p. 155, Fig. 26.

FIGURE B–1 SURFACE CURRENT PATTERNS IN THE GULF OF MEXICO

much more rapid in summer than winter. At some localities winter temperatures are higher than summer temperatures below a depth of 200 feet. The convergence of summer and winter temperature curves at one or more depths (Figure B-7) demonstrates "stable" year round temperature conditions.

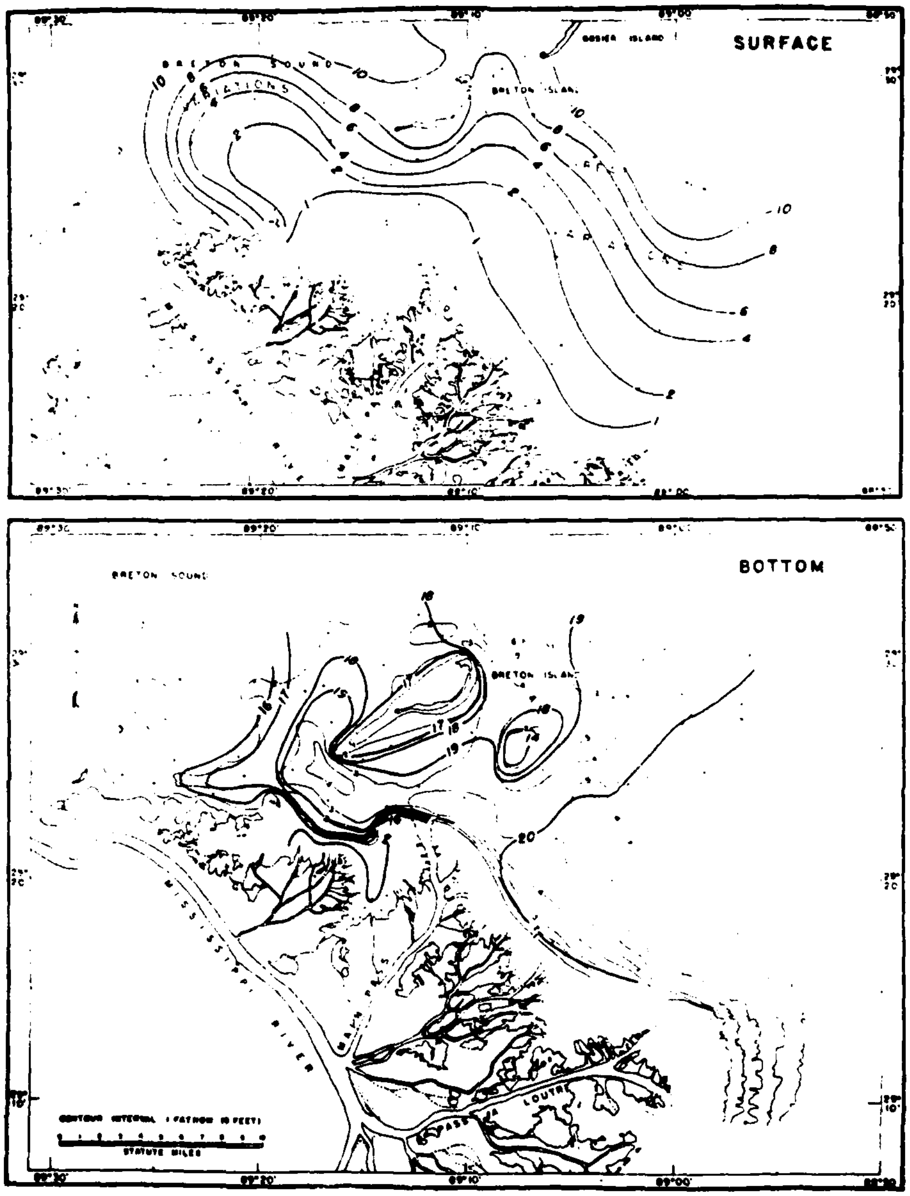
Environmentally the most critical aspects of stream discharge (i.e., flushing rates) are (1) addition of new sediment, (2) water turbidity and, (3) salinity variations. Deposition of sediment has a bearing on such factors as sediment stability and shoaling, both of which are considered later. Turbidity is the direct result of sediment discharge and varies with total stream load discharge into a given area. General effects of discharge on salinity have been considered above.

Numerous streams empty into the Gulf of Mexico along its north central portion but the most important is the Mississippi River. Data indicating drainage area, average water discharge, annual sediment discharge, annual rate of growth and



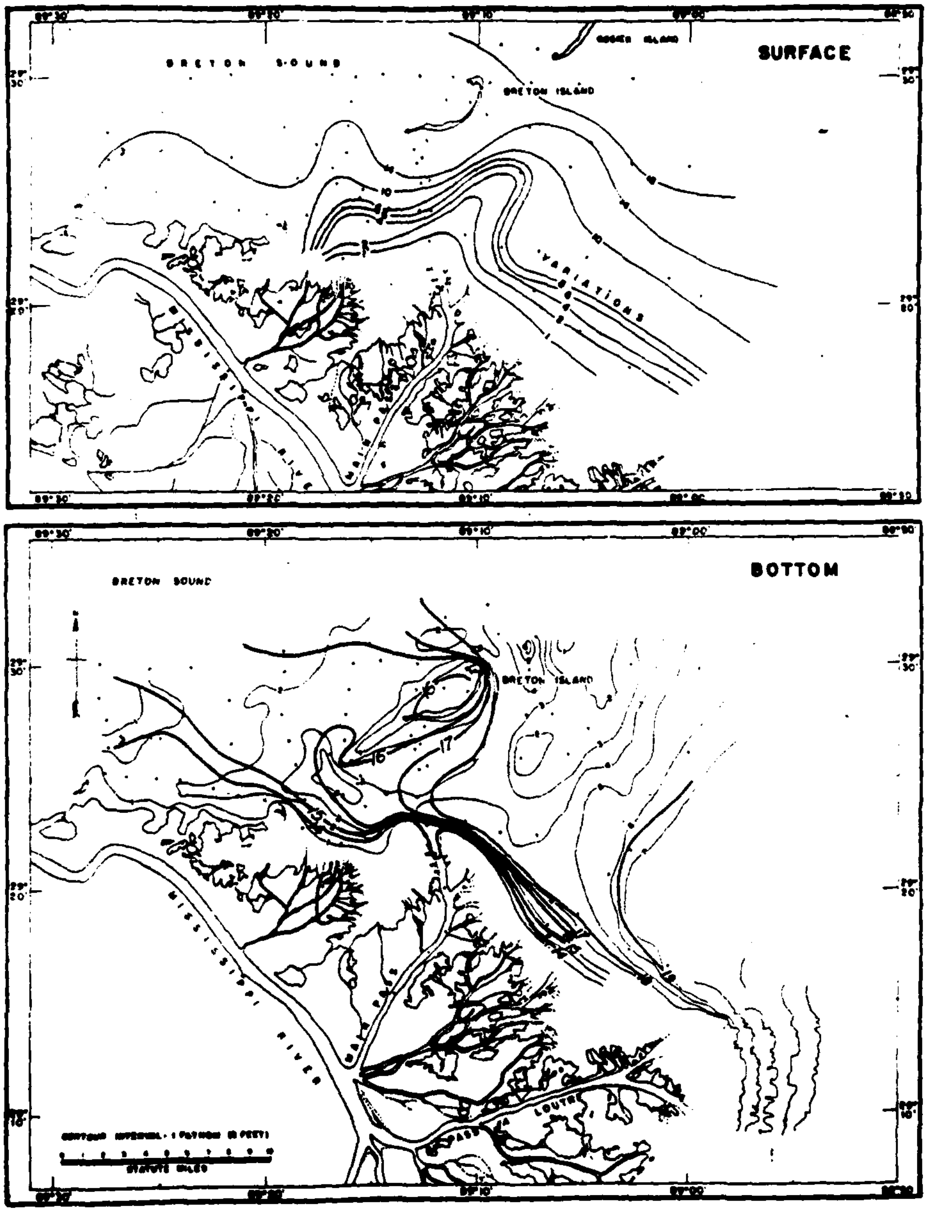
The winds are "resultant winds" computed from weather summaries. Currents are taken from current charts 10,690, 1-12, U.S. Hydrographic Office, based on ships data. From Curray, 1960, p. 230, Fig. 5.

FIGURE B–2 WINDS AND SEMIPERMANENT SURFACE CURRENTS



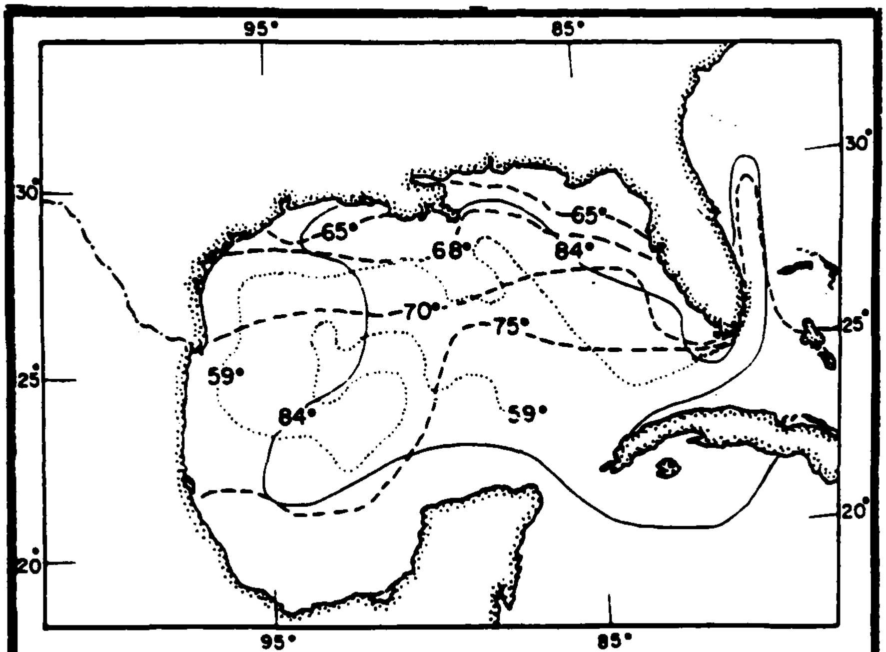
Concentration in parts per thousand as observed in 1952 during time of maximum river discharge (compiled by P.C. Scruton). From Parker, 1956, p. 304, Fig. 8.

FIGURE B–3 SPRING AREAL DISTRIBUTION OF CHLORINITIES



Concentration in parts per thousand as observed in 1951 during time of minimum river discharge (compiled by P.C. Scruton). From Parker, 1956, p. 303, Fig. 7.

FIGURE B–4 FALL AREAL DISTRIBUTION OF CHLORINITIES



SURFACE AND 200 METER ISOTHERMS IN THE GULF OF MEXICO

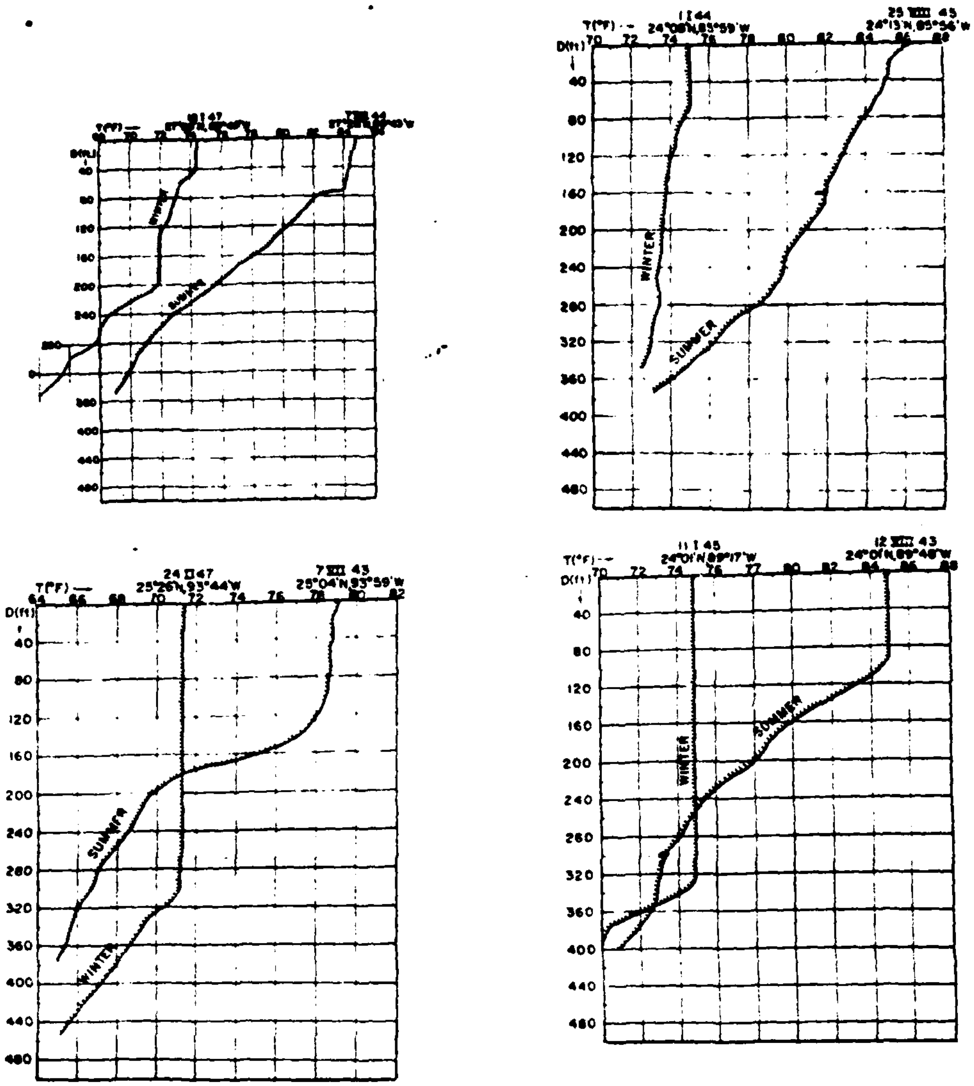
—— MAXIMUM SURFACE TEMP., °F.
---- MINIMUM SURFACE TEMP., °F.
······ AVERAGE TEMP., °F. AT 200 METERS DEPTH

Surface (maximum and minimum) and 200-meter (average) isotherms show warmer water closer to shore in east Delta region. Data taken from Fugilister (1947, 1954). From Parker, 1956, p. 365, Fig. 32.

FIGURE B–5 SURFACE AND 200-METER ISOTHERMS IN THE GULF OF MEXICO

subaerial area of the Mississippi River delta are included in Figure B-8. Because of the longshore current pattern on the western side of the delta, effects of sediment and water discharge cover a large area.

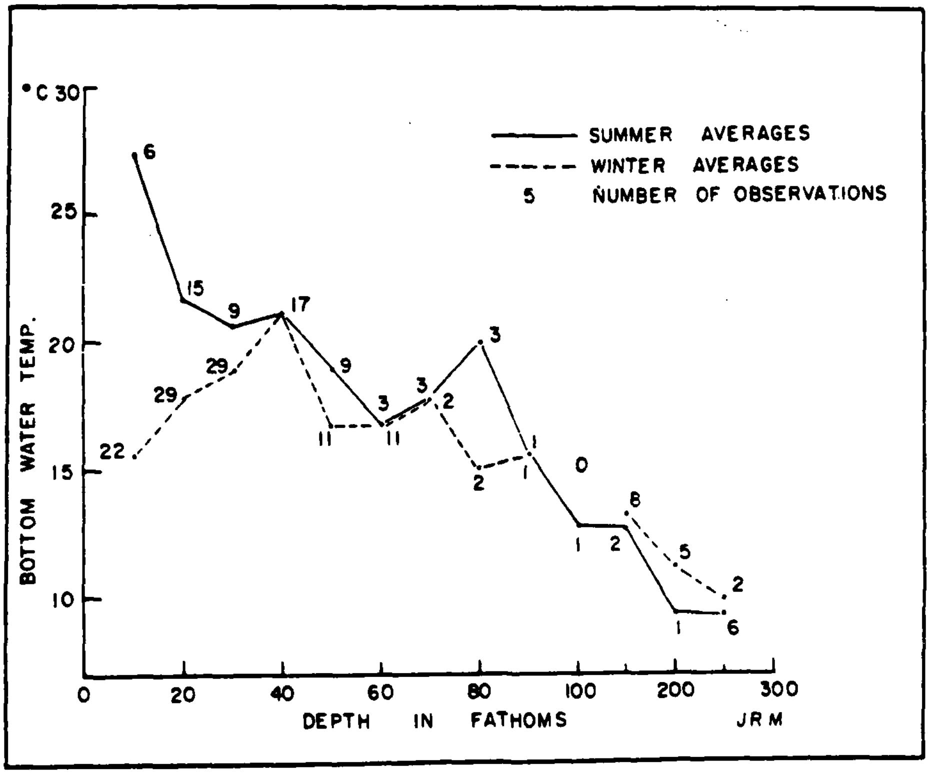
Another major stream flowing into the Gulf of Mexico along the Louisiana coast is the Atchafalaya River. Records for a five-year period (1944 through 1949) show a discharge between 50,000 and 600,000 cubic feet per second (Hedgpeth. 1953). This discharge is largely responsible for the sedimentological and biological character of Atchafalaya Bay and surrounding areas, and the reduced salinities of the area.



From Galtsoff, 1954, p. 134, Fig. 13.

FIGURE B–6 TYPICAL SUMMER AND WINTER BATHYTHERMOGRAMS

In summary, zones west of the Mississippi River delta are in an area of westward moving, strong longshore currents the year round. Zones east of the delta are in areas of moderate to light currents which flow toward the delta from September to February and away from the delta the rest of the year. Greatest fluctuations in salinities and temperatures occur in the nearshore zones (III, IV and XIII). Fluctuations of these parameters decrease offshore. Effects caused by sediment and freshwater addition are most pronounced near the points of discharge (i.e., mouths of rivers and streams).

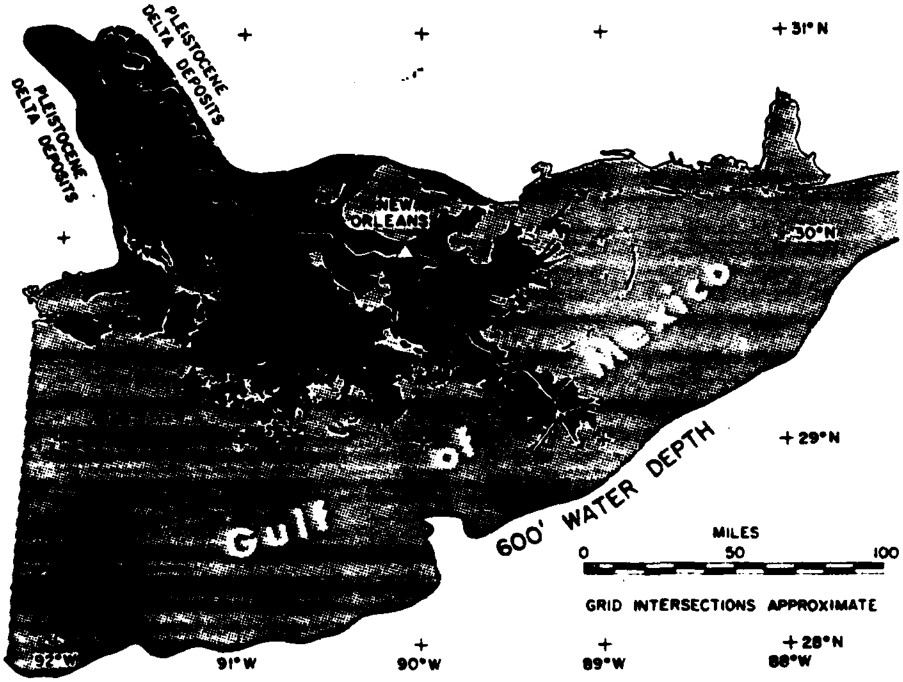


Northern Gulf of Mexico (1951-1955), period of intense biological shelf collections. Data from Springer and Bullis, 1956. Note convergence of temperature values at about 40 fathoms and again at 60 fathoms. From Parker, 1960, p. 321, Fig. 15.

FIGURE B–7 COMPARISON OF SUMMER AND WINTER BOTTOM-WATER TEMPERATURES

2. Geology

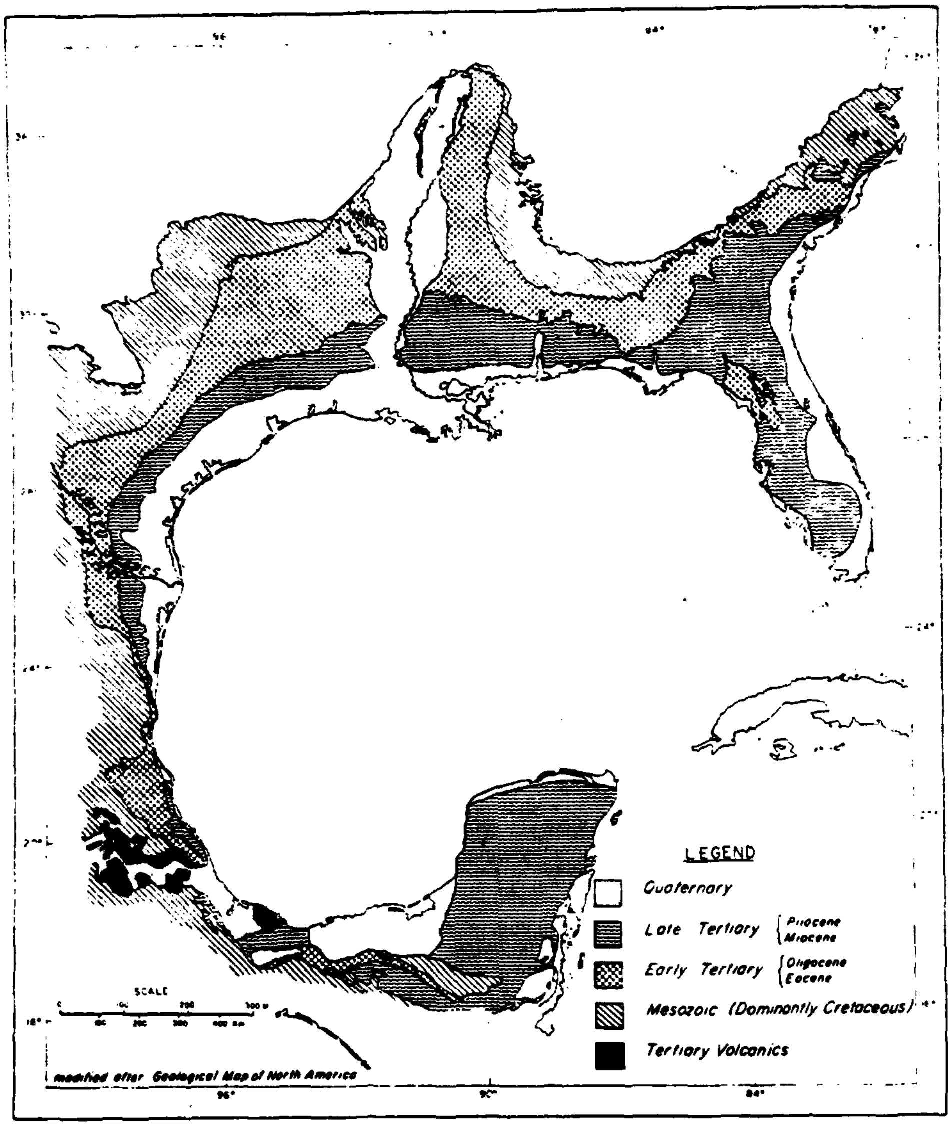
Geologically, the entire north central Gulf Coast is composed of rocks of Quaternary age. These rocks form a relatively narrow band of land characterized by low relief. Some coastal areas are near or slightly below sea level (swamps and marshes). Northward away from this coastal area rocks of older geological ages are encountered (Figure B-9). Distribution of different rock types in the Gulf Coastal Province is important, as is the geology of a large part of the North American continent, since these units are the sources of sediments currently deposited and distributed along the Gulf Coast.



COUNTRY: U. S. A.
SUBAERIAL AREA: 11,000 SQ. MILES
DRAINAGE AREA: 1,244,000 SQ. MILES
AVERAGE WATER DISCHARGE: 611,000 CU. FT./SEC.
ANNUAL SEDIMENT DISCHARGE: 516,900,000 TONS
ANNUAL RATE OF GROWTH: 300 FT.

From Shirley, 1966, p. 234.

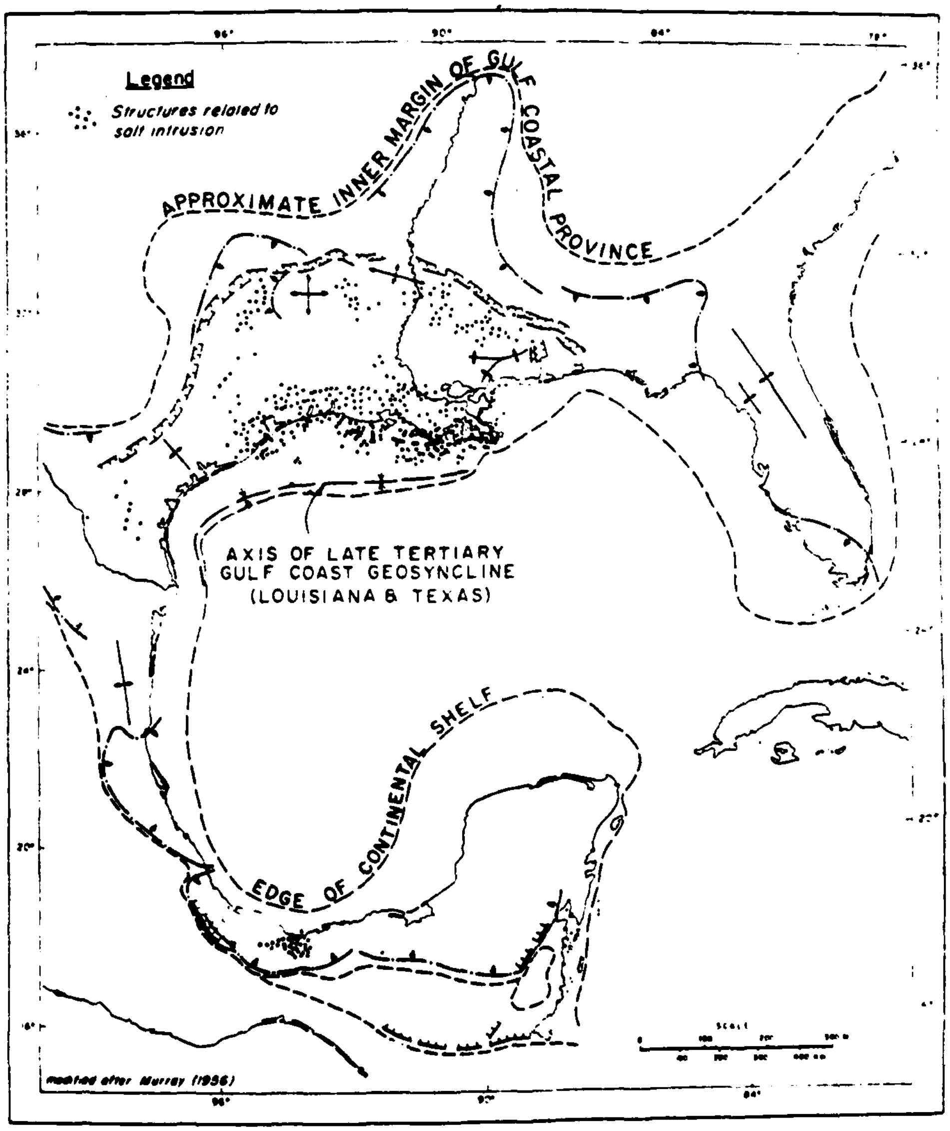
FIGURE B–8 MISSISSIPPI RIVER DISCHARGE



From Murray, 1960, p. 8, Fig. 2. After Atwater, 1959.

FIGURE B–9 GENERALIZED GEOLOGIC MAP OF THE GULF COASTAL PROVINCE

Another geological aspect of importance, considering environmental stability and effects on hydrobiological zones is the structural elements of the area. In terms of the whole North American continent, the region under discussion is classified structurally as the Gulf Coastal Province. This province extends outward to the continental shelf-slope break (± 100 fathoms). Basically rocks of the Gulf Coastal Plain exhibit an overall homoclinal dip towards the Gulf of Mexico (Murray, 1960, p.6). Superimposed on this structure are smaller domes, numerous fault systems and numerous structures related to the intrusion of salt (Figure B-10). Roughly paralleling and near the edge of the continental shelf is the axis of the Late Tertiary Gulf Coast Geosyncline. In general, late Tertiary and Holocene (Recent) units dip toward this axis forming a sedimentary structural arc from Florida to Mexico. Deformation to date has been due primarily to vertical movements in response to isostatic adjustments (Murray, 1960, p. 5).



From Murray, 1960, p. 9, Fig. 3. After Atwater, 1959.

FIGURE B–10 STRUCTURAL ELEMENTS OF GULF COASTAL PROVINCE

One of the most important geological aspects of the north central Gulf Coast is the delta of the Mississippi River. At the present time this delta extends almost to the edge of the continental shelf. On either side of the delta are submarine canyons, the Mississippi Trough off the mouth of Southwest Pass and the DeSoto Canyon off the southeast side of the delta (Lynch, *In* Galtsoff, 1953, p. 73-74). According to Uchupi and Emery (1968, p. 1163), neither of these canyons appear to be active at the present time.

To fully understand the role of the Mississippi River in the most recent history of the central Gulf Coast, one must realize that the position of this river's delta has changed several times in the last million or so years. Counting its present location, the delta of the Mississippi River has occupied seven different positions (Figure B-11a and B-11b). Equally important is the fact that the present location of the mouth of the Mississippi River is maintained only through elaborate control through leveeing by the U.S. Army Corps of Engineers. Left alone, the Mississippi would probably flow down the Atchafalaya channel from Baton Rouge southward. Past positions of the Mississippi Delta are responsible for physiographic and geologic features (Isles Derniers, Timbalier Island, Chandeleur Islands, etc.) present along the coast today.

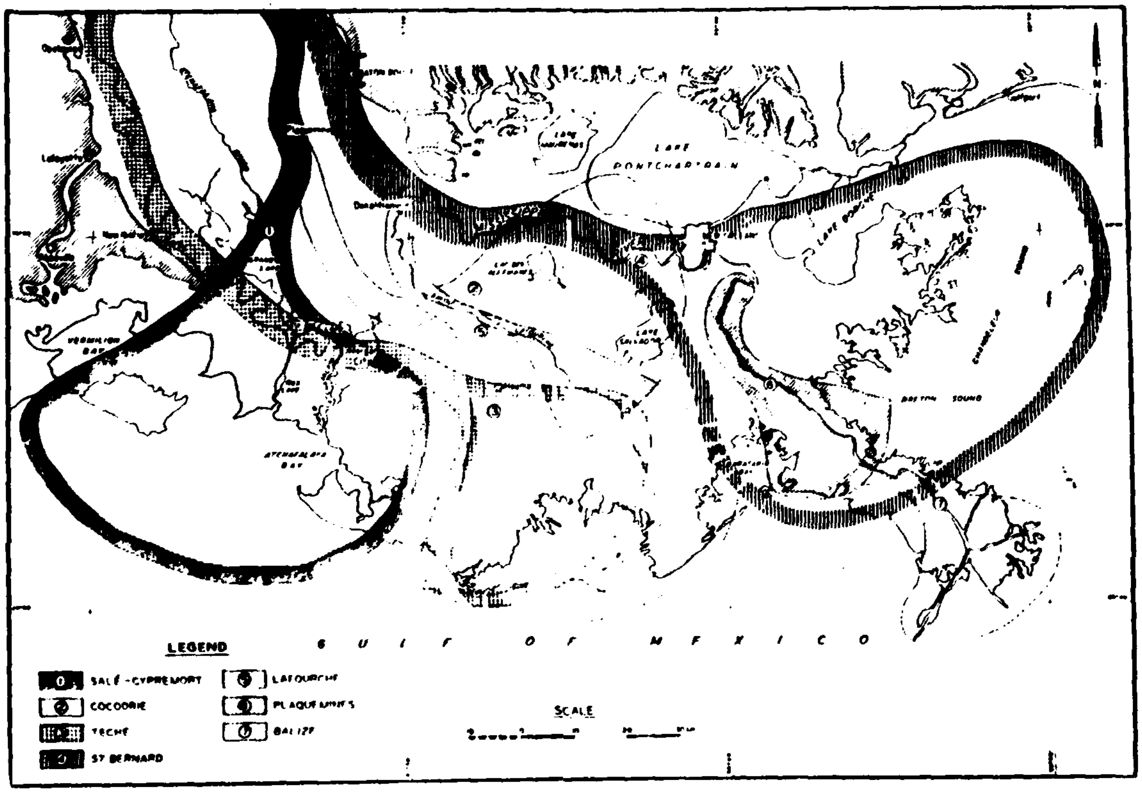
The Mississippi Delta region is subsiding, a feature characteristic of large river deltas. Abundant evidence of subsidence is given by Russell (1936). Subsidence and submergence is accelerated by leveeing of the river. The environmental consequences of levees will be discussed in a later section.

a. Physiography

In terms of shoreline classification the north central Gulf Coast is an alluvial coast. More specifically it is an entrenched and embayed compound deltaic plain west of the delta and a terraced deltaic coastal plain east of the delta (Price, *In* Galtsoff, 1954, p. 46). Beyond this simple classification it is convenient, for physiographic purposes, to divide the Gulf coastal region into the emergent (above sea level) region and the submergent (below sea level) region.

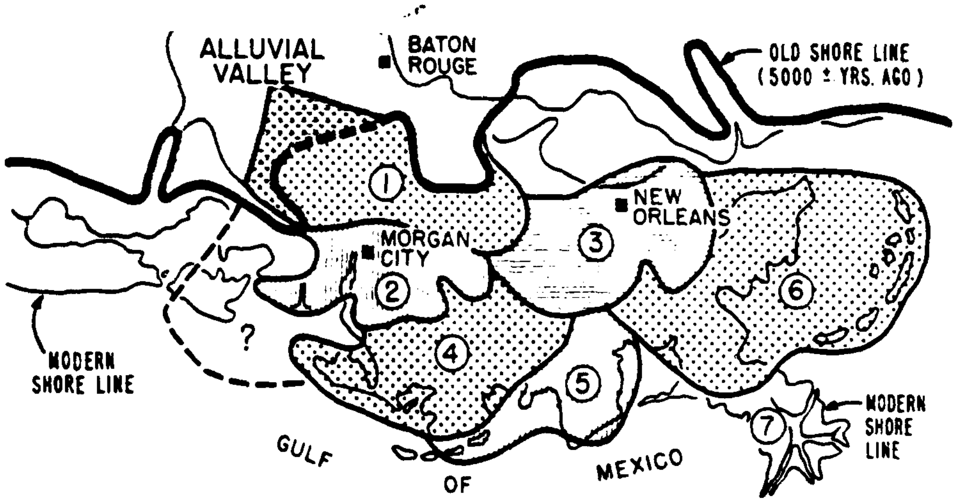
The emergent region is an area of broad alluvial terraces of Quaternary age with very little topographic relief. Width of this area varies, but is generally broad along the north central Gulf Coast because of the activity of rivers of various sizes. The majority of the present topographic relief is the result of the variable characteristics of the rock units composing various segments of this province. Different lithologies weather differently in similar climates, causing variations in topographic expression. Landforms in any area are closely related to (1) structural attitude of the rocks, (2) chemical composition and texture of the rocks, and (3) climatic conditions.

Submergent areas (continental shelf) exhibit even less relief than emergent areas (Murray, 1961, p. 493). The Mississippi River delta conveniently divides the submerged area into the West Florida Shelf and the Texas-Louisiana Shelf (Figure B-12). This shelf area is about 125 miles wide along the Texas-Louisiana coast



From Kolb and von Lopik, 1966, p. 22, Fig. 2.

FIGURE B–11a   MISSISSIPPI RIVER DELTAS

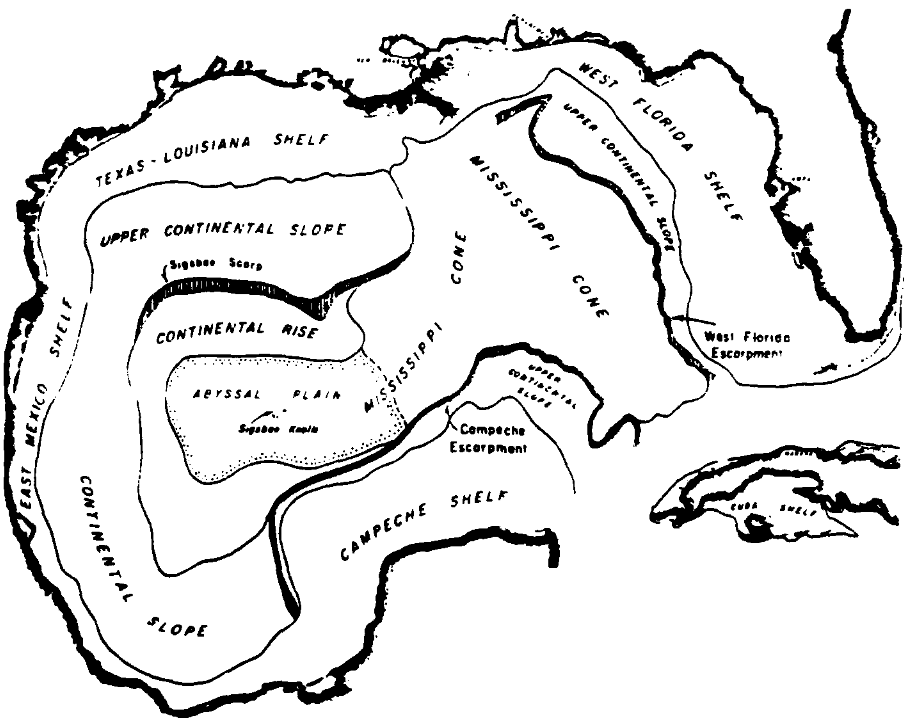


Imbricating Mississippi deltas, developed step bv step.
From Scruton, 1960, p. 100, Fig. 15.

FIGURE B–11b THE ALLUVIAL PLAIN IN COASTAL LOUISIANA

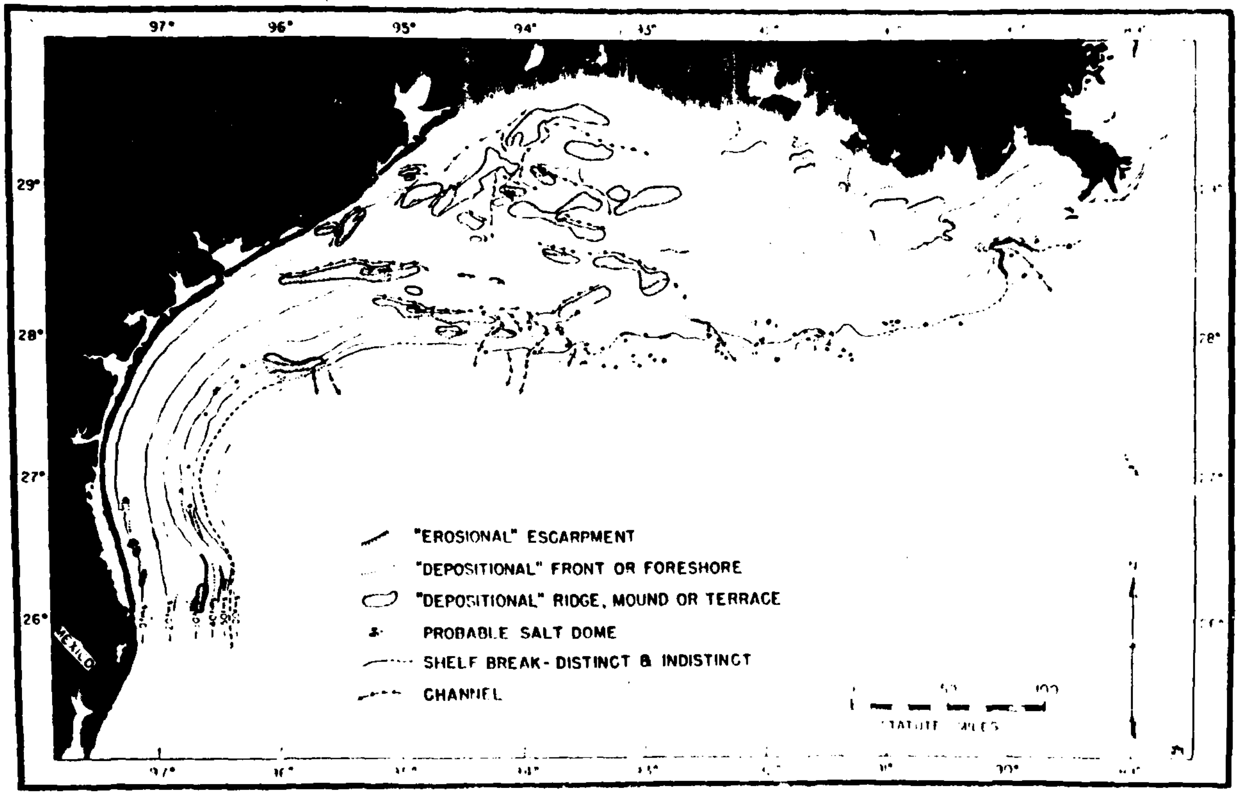
and slightly narrower near the Mississippi River delta and Mobile Bay. Topographically this shelf is relatively flat with some occasional canyons. The Mississippi Trough and DeSoto Canyon are the most prominent of these submarine trenches. Along the Texas-Louisiana Shelf are irregular, rounded, positive features which are probably topographic expressions of salt domes. A more detailed physiography of this portion of the shelf, illustrated in Figure B-13, shows that there is an area off Sabine Pass composed of a series of depositional highs dissected by channels, reflecting an area of slight irregularities in an otherwise flat surface. Arrows in these channels point towards topographically lower portions of the channel. According to Curray (1960, p. 225):

"The depositional features, ranging from 2 to 6 feet high, include both distinct ridges and slight steepening of the gradient called 'depositional fronts of foreshores.' The 'erosional' features are steep, distinct escarpments ranging from 6 to 90 feet in height. The higher and more spectacular of these escarpments occur on the seaward flanks of some of the salt-dome banks. Dredging showed they were cut into hard material, possibly bedrock, but no samples were retained in the dredges."



The major provinces shown in this figure are based on a study of the detailed surveys of the U.S. Coast and Geodetic Survey and the reconnaissance surveys of the Lamont Geological Observatory. From Murray, 1961, p. 509, Figure 8.12b. After Ewing, Ericson, and Heezen, 1956.

FIGURE B–12 PHYSIOGRAPHIC PROVINCES OF THE GULF OF MEXICO



Interpreted from published and unpublished soundings. From Curray, 1960, p. 229, Fig.4.

FIGURE B–13 PHYSIOGRAPHY OF THE CONTINENTAL SHELF AND UPPER CONTINENTAL SLOPE

b. Stratigraphic Sequence

Because of their great thickness, Palaeozoic rocks need not be considered, although it should be noted that they are generally referred to as the "basement rocks" in the Gulf Coast Province. General geologic usage of the term "basement rocks" or "complex" outside the Gulf Coast refers to strata of Precambrian age.

According to Murray (1960, p. 30) over 25,000 feet of fluviatile, marginal, and deltaic sediments (clays, carbonates and fine sands) accumulated in coastal Louisiana and Texas during the Cenozoic era. Deposits of both Cenozoic and Mesozoic age accumulated in arcuate belts of varying thicknesses along the Gulf Coast with depoaxes generally shifting gulfward from the Jurassic to the present. Depocenters (areas of maximum accumulation of sediments at any particular time) have moved back and forth along the Gulf Coast during the time interval so that successive centers of deposition are not generally superimposed.

The generalized stratigraphic sequence of the Gulf Coastal Province is shown in Figure B-14. In terms of volume of sedimentary rocks for the north central Gulf Coast Murray (1961, p. 283) indicates, in cubic miles: 4000 plus for the Quaternary, 101,400 for the Tertiary, 99,350 of Cretaceous age, 34,025 for the Upper Jurassic and 26,500 for the pre-Upper Jurassic, making a total of over 265,275 cubic miles of post-Palaeozoic sedimentary rocks in this region.

c. Structural Aspects

Movement of rock strata within the Gulf Coast Province is primarily vertical due to (1) density differences between sedimentary rocks (i.e., salt domes) and (2) isostatic adjustment to thick accumulation of sedimentary rocks. Basically this province is a south dipping homoclinal structure with four major types of structural features: (1) domes and anticlinal folds, (2) basins and synclinal folds, (3) faults and (4) salt domes and related superimposed features (Figure B-15). The two former structures occur inland and need not be considered further.

Faults are oriented both parallel and perpendicular to regional strike but the majority fall into the former category and are referred to as down-to-the-coast or down-to-the-basin fault systems (Figure B-16). Displacement ranges from very small amounts up to 6000 feet and was accomplished either as single or as periodic recurrent movements. Normal (gravity-tension) faults with dips of 35° to 70° are the dominant types. Angles of dip are lower in the onshore areas (in older strata) and become steeper in those faults as one approaches the coast and continental shelf (younger strata). These fault-system features, and resultant thickening of the sedimentary sequence through faulting, are illustrated in Figure B-17.

Faulting and other structural features are associated with salt domes. These domes are due to vertical movement of salt from deeply buried, thick beds of evaporitic minerals. In the Gulf Coast Province, the source of most of the slat is the pre-Upper Jurassic Louann salt beds. Deposition of this salt and other evaporitic minerals took place in a single, vast, widespread basin and is probably related geologically to the evaporitic sequences of the Upper Permian of West Texas and the central United States (Andrews, 1960). A more or less continuous bed of Louann salt is believed to underlie the entire Gulf Coastal Basin and to have had an original average bedded thickness of about 5000 feet. Murray (1960, p. 17) states:

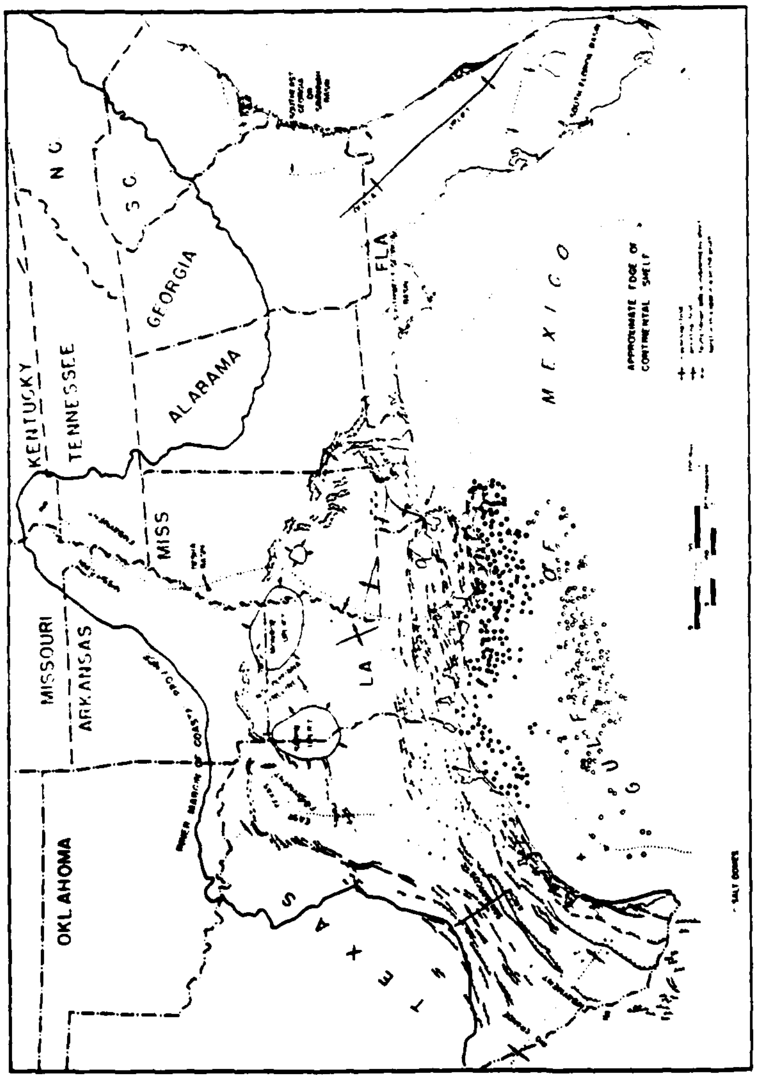
> "The salt structures occur as domal or anticlinal to ridge-like, diapiric folds of structural magnitude and of variable height and areal extent. More than 300 of these features occur in the northern Gulf region in Alabama, Mississippi, Louisiana and Texas and on the continental shelves of Louisiana and Texas"; (see Figure B-18).

These salt domes vary in size, but are commonly circular in shape and some have penetrated up to 25,000 feet of overlying sediments (Murray, 1960, p. 18). Some domes appear as tall, spire-like projections rising from salt ridges that are several miles deep, others exhibit a mushroomed cross-sectional profile. Faulting of sedimentary rocks (1) across, (2) peripheral, (3) tangential and (4) radial to these salt domes is relatively common.

SYSTEM	SERIES	[illegible]	
QUATERNARY	RECENT		
	PLEISTOCENE		
TERTIARY	PLIOCENE		
	MIOCENE		
	OLIGOCENE	VICKSBURG	
	EOCENE	JACKSON	
		CLAIBORNE	
		SABINE	WILCOX GROUP
	PALEOCENE	MIDWAY	
CRETACEOUS	GULFIAN	NAVARRO	
		TAYLOR	
		AUSTIN	
		EAGLEFORD	
		WOODBINE (TUSCALOOSA)	
	COMANCHEAN	WASHITA	
		FREDERICKSBURG	
		TRINITY	
	COAHUILAN	NUEVO LEON & DURANGO GROUPS OF MEXICO (HOSSTON-SLIGO)	
JURASSIC (UPPER)		COTTON VALLEY	
		HAYNESVILLE	
		SMACKOVER, INCLUDING NORPHLET FORMATION	LOUARK GROUP
JURASSIC (LOWER ? AND MIDDLE)		LOUANN SALT	
		WERNER FORMATION	
PRE-JURASSIC		MOREHOUSE - EAGLE MILLS FORMATIONS	

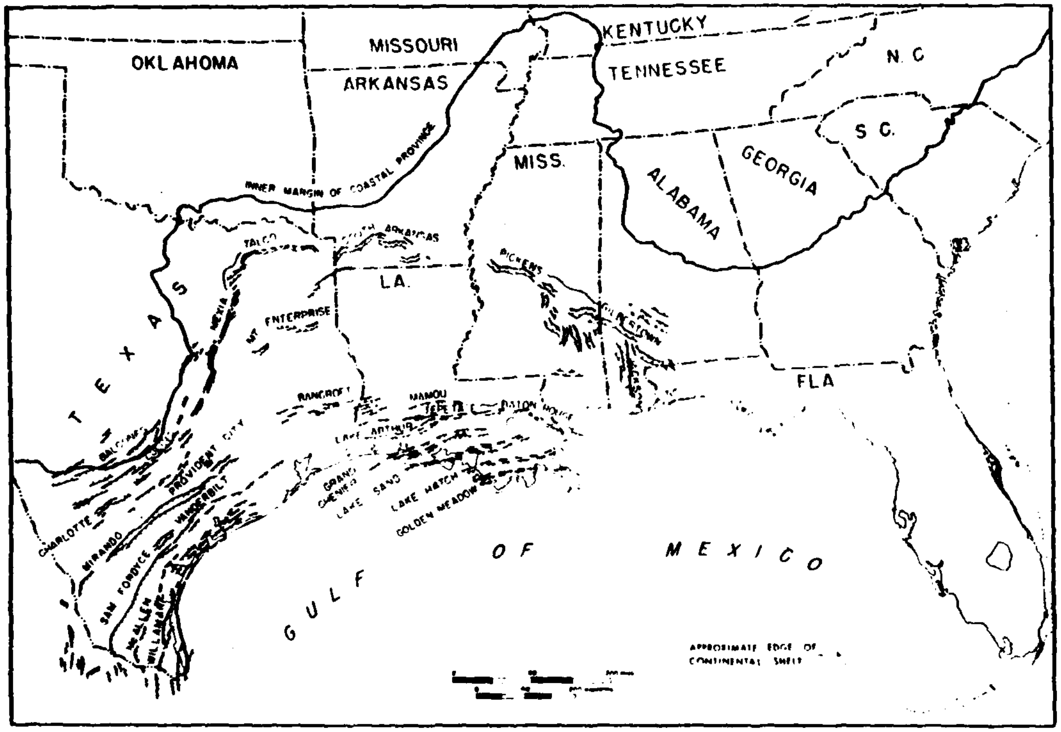
From Murray, 1960, p. 22, Fig. 14.

FIGURE B–14 GENERALIZED GEOLOGIC COLUMN OF THE GULF COASTAL PROVINCE



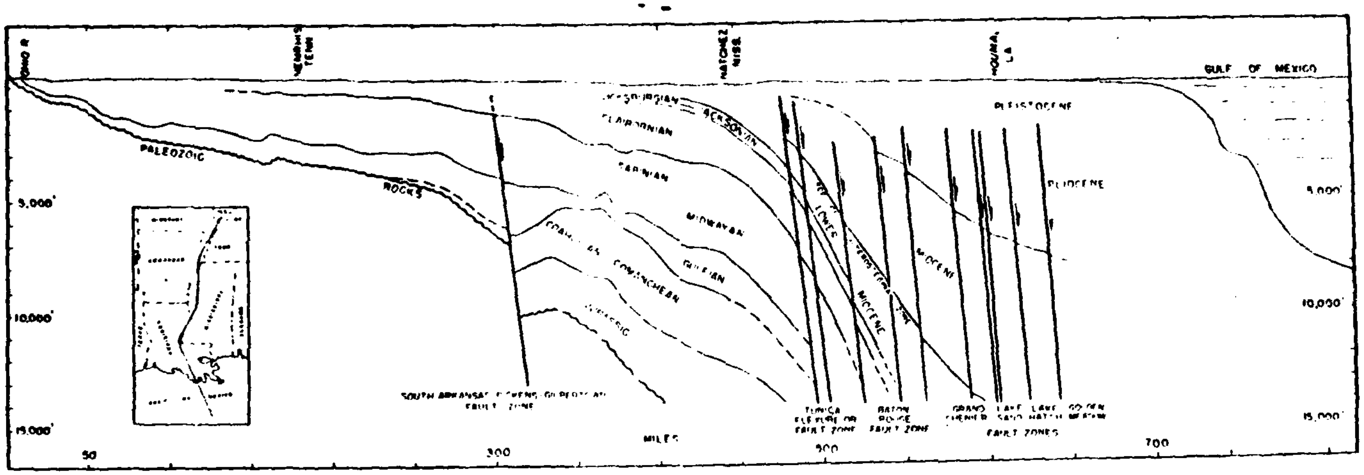
From Murray, 1960, p. 10, Fig. 4. After Murray, 1957.

FIGURE B–15 MAJOR STRUCTURAL FEATURES OF THE GULF COASTAL PROVINCE



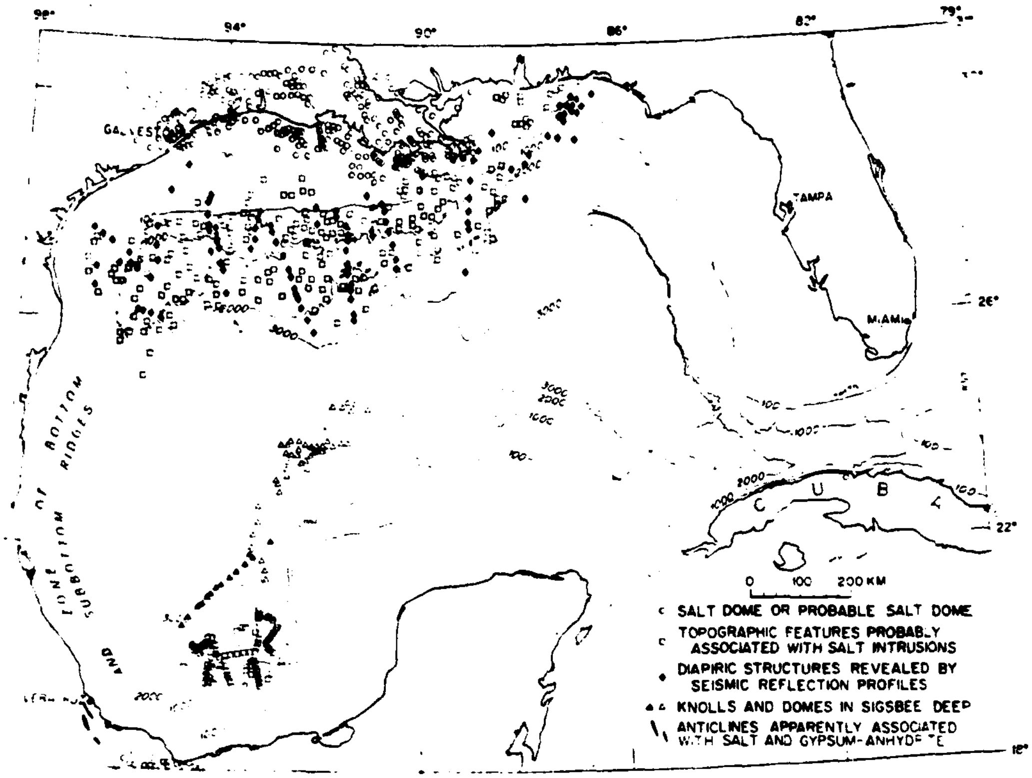
From Murray, 1960, p. 14, Fig. 7. After Murray, 1957.

FIGURE B–16 PRINCIPAL FAULT SYSTEMS OF THE GULF COASTAL PROVINCE



From Murray, 1960, pp. 16-17, Fig. 8. Modified from Fisk, 1944.

FIGURE B–17 DIAGRAMMATIC SECTION THROUGH THE MISSISSIPPI EMBAYMENT

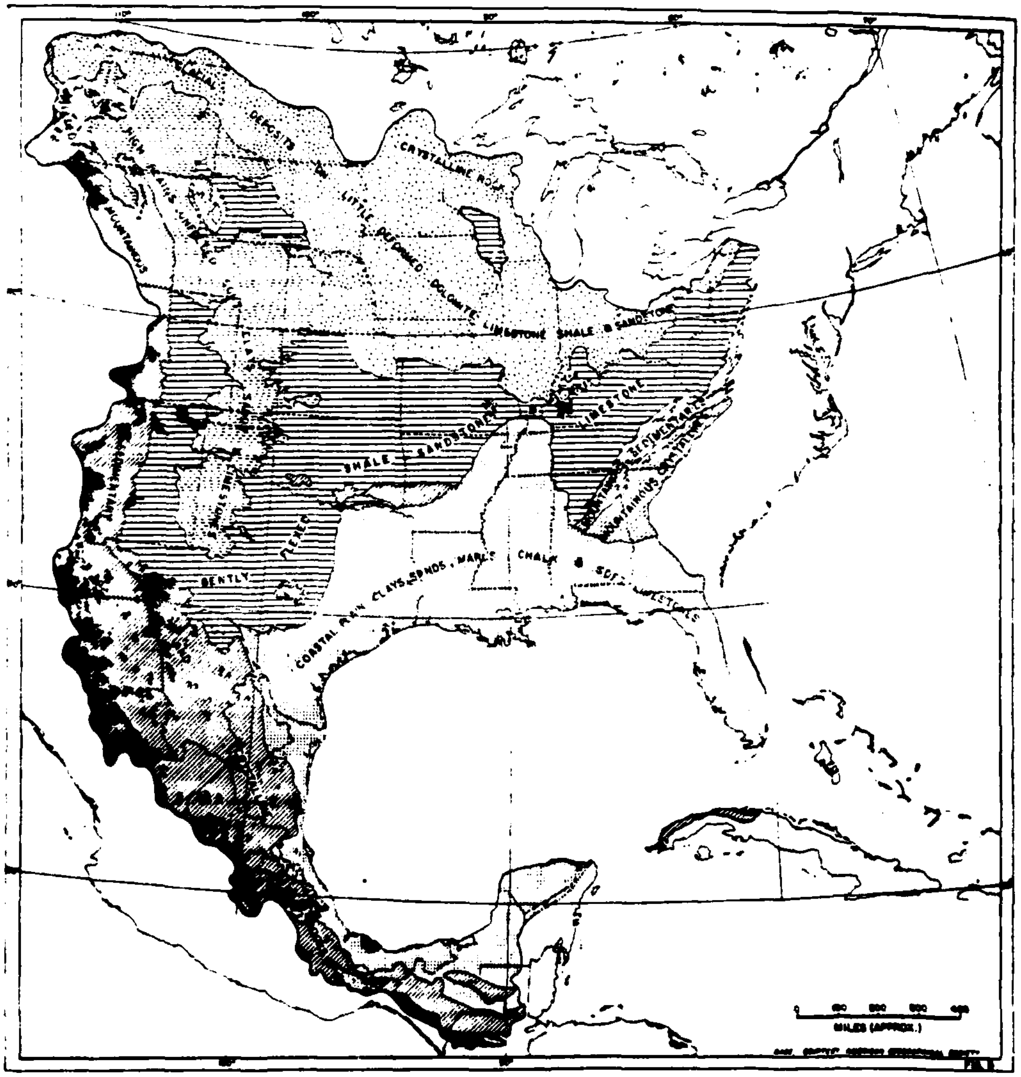


Compiled from writers' survey, from chart of Gulf of Mexico (Uchupi, 1967), and from publications by Creager (1953, 1958), Murray (1961, 1966), Moore and Curray (1963), M. Ewing and Antoine (1966), Antoine et. al. (1967), Harbison (1967), and Meyerhoff and Hatten (1968). Depth contours in meters. From Uchupi and Emery, 1968, p. 1191, Fig. 19.

FIGURE B–18 DISTRIBUTION OF DIAPIRIC STRUCTURES IN THE GULF OF MEXICO

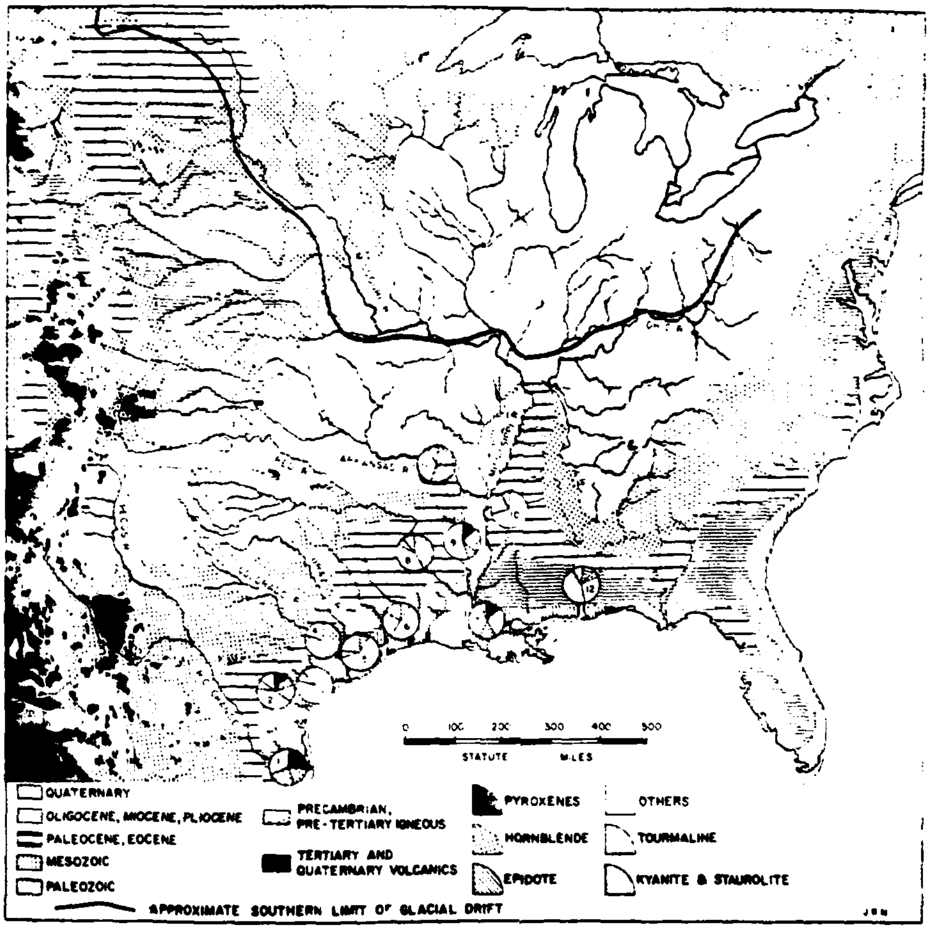
d. Sediments

A primary controlling factor in the distribution of benthic (bottom-dwelling) organisms (plants and animals) is the characteristics of the substrate (i.e., sediments or bedrock). Substrate characteristics are determined by a number of factors but of primary importance are: (1) types of sediments, (2) source, i.e., provenance of sediments and (3) distribution of sediments. Factors controlling sediment source are (1) geology of drainage basin or basins, (2) drainage patterns, (3) water currents, (4) climatic conditions in the drainage area, and (5) discharge and load of streams. Streams emptying into the Gulf of Mexico drain a very large area of the North American continent, thus the geology and climatic conditions of this whole area are important (Figure B-19). Variations in source areas are often reflected in heavy mineral composition of the sediment load of the streams. Therefore it is theoretically possible to identify sediment source. Figure B-20 indicates the proportion of different heavy minerals contributed to northern Gulf of Mexico sediments. These minerals, plus sand, silt, mud and dissolved salts are mixed with the loads of other streams in the shelf waters of the Gulf. This mixing produces a mosaic of heavy mineral and sediment types, depending on variations in composition of stream load and current patterns. A mosaic for the northwestern Gulf sediments is shown in Figure B-21. As shown, the Mississippi River dominates as a sediment source for



From Moody, 1967, p. 192.

FIGURE B-19 GULF OF MEXICO DISTRIBUTIVE PROVINCE

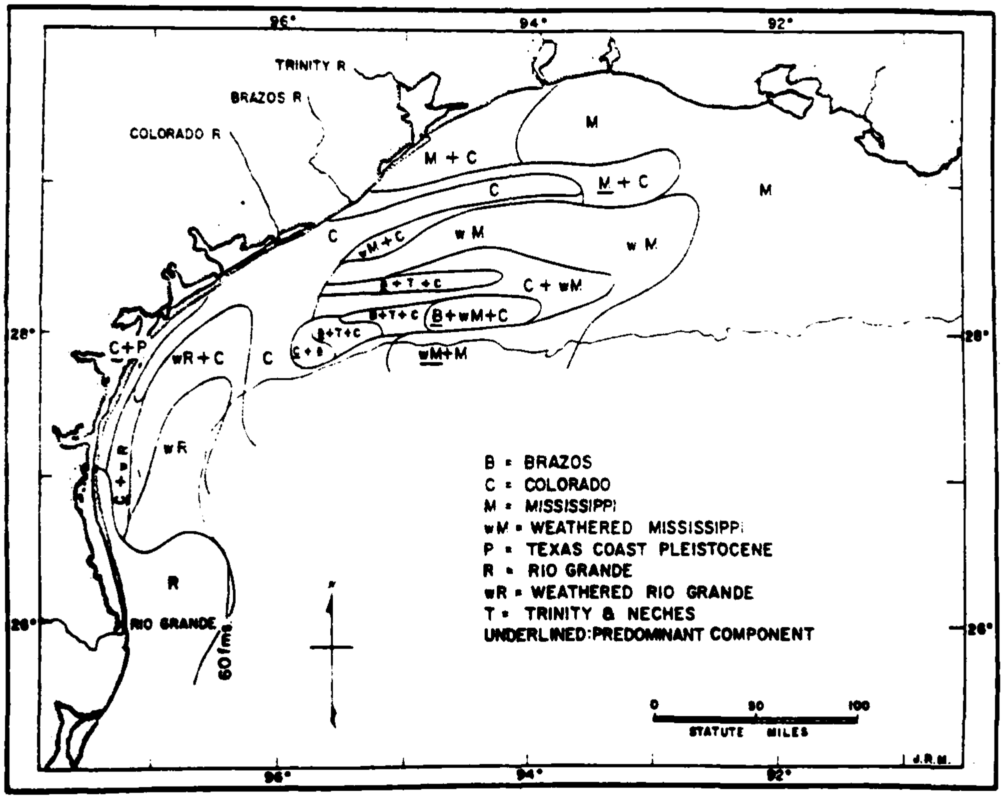


Source area, and heavy mineral composition of sediments supplied by principal rivers. Geology simplified from "Geological Map of North America", Geol. Soc. America, 1946. Mineral assemblages— (1) Rio Grande; (2) Nueces River; (3) Composite of streams between Nueces and Colorado; (4) Colorado River; (5) Brazos River; (6) Composite of Trinity, Neches, Sabine, and Calcasieu Rivers; (7) Mississippi River; (8) Red River; (9) Ouachita River; (10) Yazoo River; (11) Arkansas River; (12) Tombigbee River. From van Andel, 1960, p. 37, Fig. 2.

FIGURE B–20 REGIONAL GEOLOGY OF THE NORTHERN GULF OF MEXICO

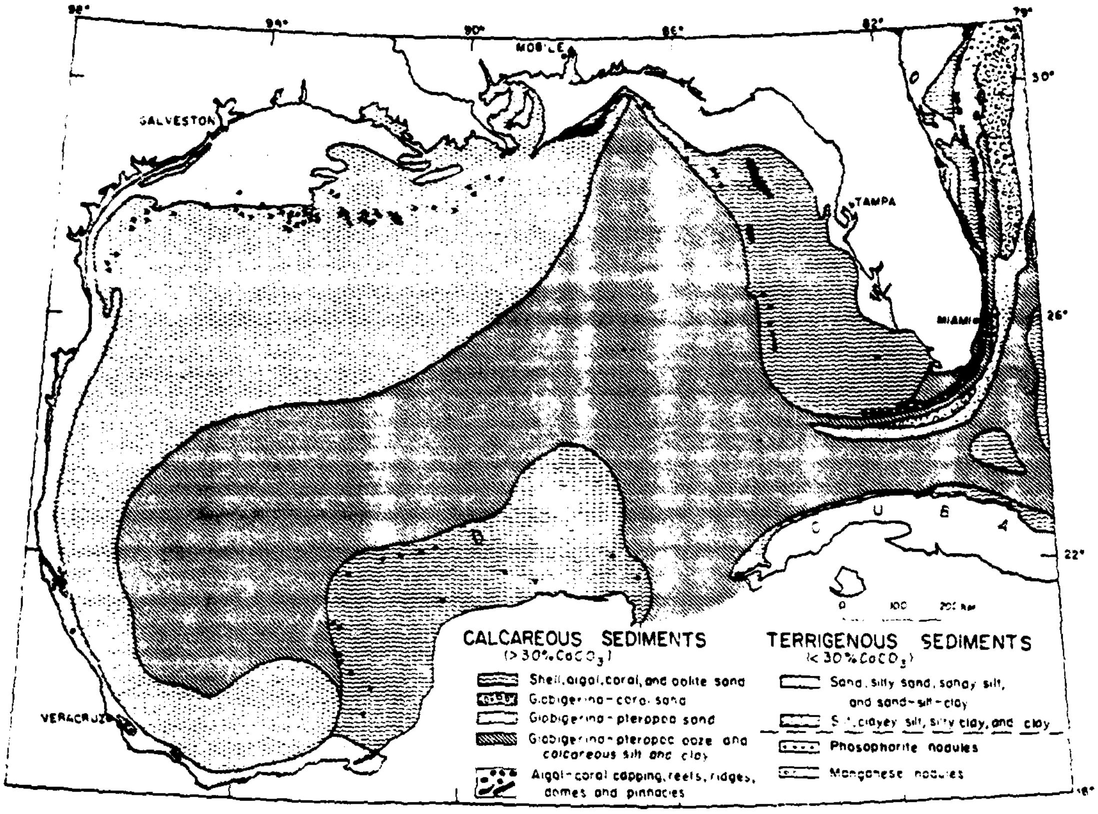
most of the shallow water area off Louisiana. This is due to the great quantities of sediment transported by the Mississippi and the strong western longshore currents along the shelf.

Basically there are two types of sediments, terrigenous (land derived) and chemical (precipitated from solution or through the action of organisms). Both types occur in the Gulf of Mexico but the dominant type is terrigenous such as sands, silts and muds. Distribution of these sediment types for the entire Gulf of Mexico is illustrated in Figure B-22. While this map indicates only three sediment types for the shelf areas, Curray (1960, p. 234, Figure 7), presents a map for the northwestern shelf of the Gulf of Mexico indicating areas of sand, mixed sands and muds, muds, and calcareous "reef" cappings. Curray's treatment is much more useful for present purposes.



Components are listed in order of quantitative importance; boundaries are approximate and based on Figs. 10-13 in van Andel and Poole, 1960. From van Andel, 1960, p. 45, Fig. 8.

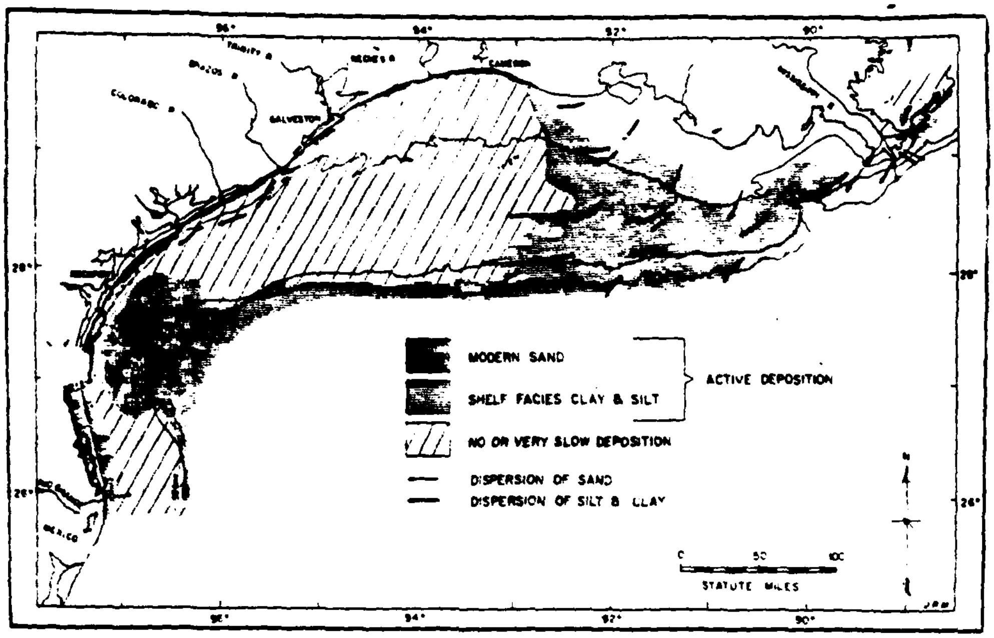
FIGURE B–21 SEDIMENT SOURCES AND MIXING IN THE WESTERN GULF PROVINCE



Based on data from Stetson (1953), Trask (1953), Gould and Stewart (1955), Scruton (1955), Thompson (1955), Ginsburg (1956), Parker and Curray (1956), Ludwick and Walton (1957), M. Ewing, et al. (1958), Creager (1958), Shepard (1960), Curray (1960), Harding (1964), Ludwick (1964), Pilkey et al. (1966), Pratt and McFarlin (1966), Lynts (1966), and unpublished material from Woods Hole Oceanographic Institution–U.S. Geological Survey Atlantic Continental Margin Program. From Uchupi and Emery, 1968, p. 1166, Fig. 2.

FIGURE B-22 SEDIMENT MAP OF THE GULF OF MEXICO

In addition to sediment type, it is also important to indicate shelf areas of active deposition versus little or no deposition and the basic environments of deposition in which these sediments accumulate. Figure B-23 indicates the former situation as well as sediment dispersion patterns for the northwestern Gulf. As can be seen from this figure, active deposition of clay and silt is dominant, while sand deposition occurs only in a very narrow band just east of Cameron, Louisiana, westward along the Texas coast. From about this same longitude (Cameron, La.), there is a large area where little, if any, sediment is being deposited, which is probably due more to bottom current patterns than to sediment source. Dominance of fine grained sediment (i.e., silt and clay) is due to the major movement of sediment from the Mississippi Delta westward (current pattern arrows, Figure B-23).



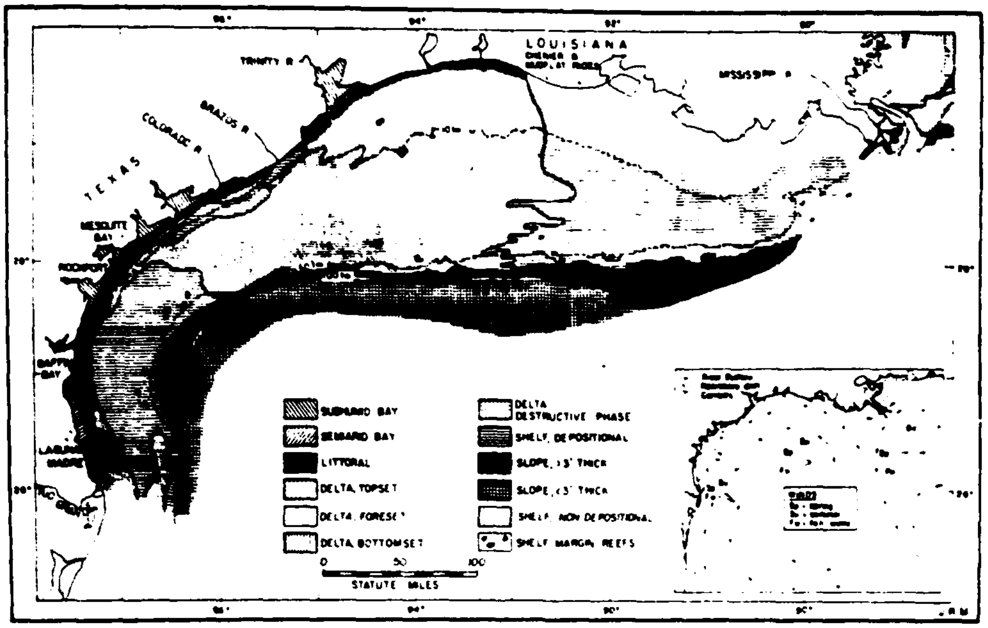
From van Andel, 1960, p. 54, Fig. 14.

FIGURE B–23 SEDIMENT SOURCES AND DISPERSION PATTERNS

General environments of deposition designated as facies are indicated in Figure B-24 for the continental shelf of the northwestern Gulf. The only area of topset, foreset, and bottom set beds of classical deltaic deposition is on the east side of the Mississippi Delta. Current patterns prevent this development south and west of the delta.

Sediments east of the delta as far as western Florida are described by Upshaw, et al. (1966). Mississippi Sound sediments are composed mostly of silt and clay muds, with some areas of fine or medium sands. Medium and coarse sands dominate the mainland beaches east of the Pascagoula River and along the barrier islands. Fine sands, silts, and clays are found along the mainland east of Pascagoula to and including Mobile Bay. The area seaward of the barrier islands are mostly fine sands except for a mud area just off Dauphin Island.

Particle size generally diminishes from the predominantly sandy bottom of Florida westward to the fine silts and clays of Mississippi. The zonal divisions just east of Mobile Bay were made principally on this basis.



Inset—generalized current pattern and wind distribution. From van Andel and Curray, 1960, p. 355, Fig. 7.

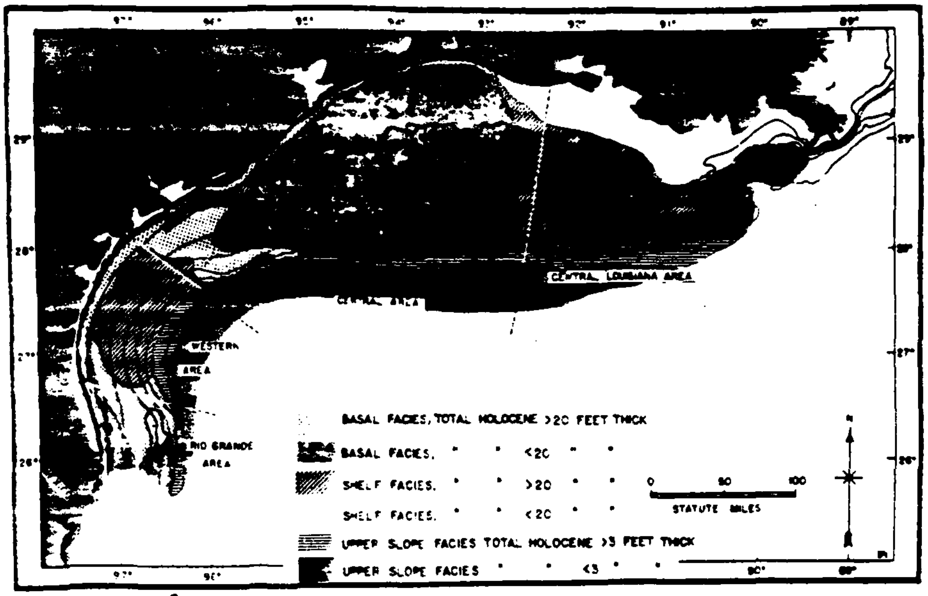
FIGURE B–24 REGIONAL FACIES DISTRIBUTION OF THE NORTHWESTERN GULF

Mississippi Sound is an area of active deposition; although actual rates of deposition have not been determined.

Thickness of Recent (Holocene) sediments on the northwestern continental shelf of the Gulf of Mexico range from less than three feet to more than 20 feet. Distribution of various sedimentary facies with respect to shelf, slope and basin and thicknesses are shown in Figure B-25. Along the Louisiana coast sediments of the shelf facies are dominant and accumulate in thicknesses of over 20 feet. Sediment thickness is related to sedimentation rate. Concerning sedimentation rate in the eastern Mississippi cone area, Huang and Goodell (1970, p. 2097) state:

> "Sedimentation rates have depended primarily on the rate of detrital influx and on fluctuation in sea level, and average 30cm/1000 years as determined by disequilibrium age determinations. The lower silty layers represent deposition during low sea-level stands and were deposited faster (34cm/1000 years) than the upper foraminiferal clays (22cm/1000 years)."

These rates refer to far offshore areas, slope and deep ocean basins. Generally sedimentation rates are higher in nearer shore areas.

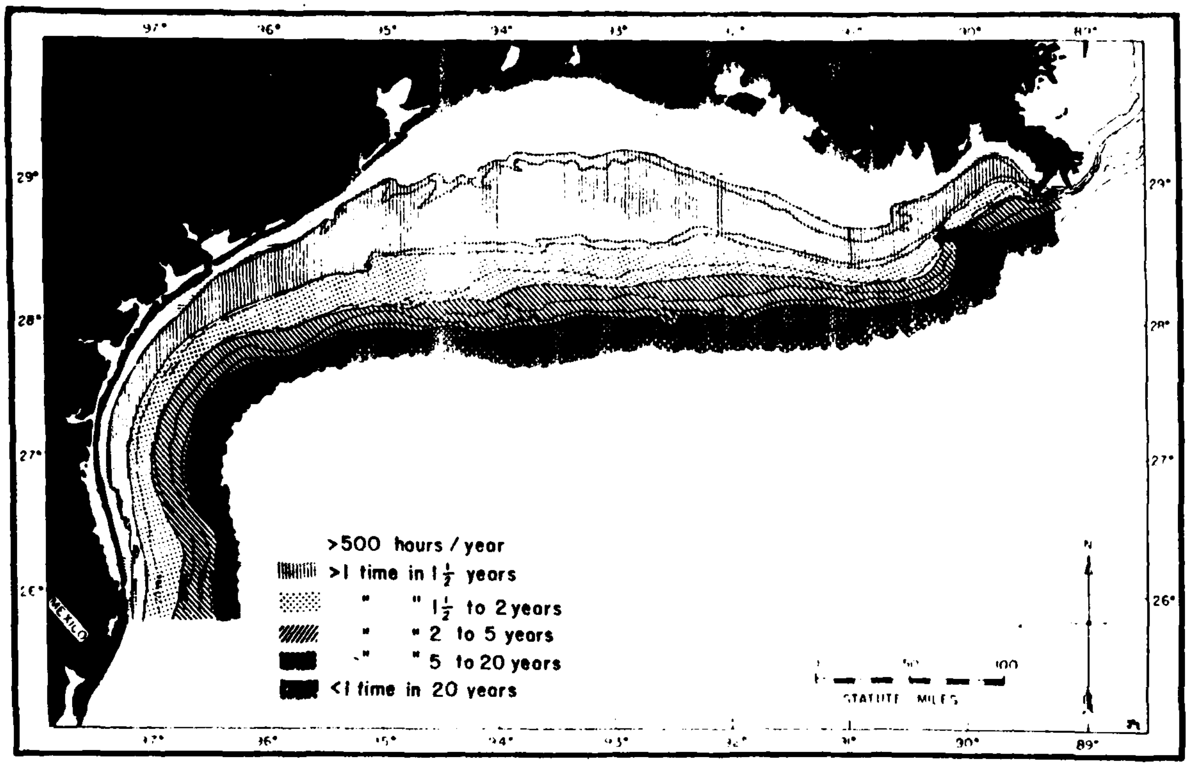


Order of magnitude thicknesses of the Holocene Series. From Curray, 1960, p. 251, Fig. 17.

FIGURE B–25 DISTRIBUTION OF FACIES

Sediment stability, effects of shoaling and water turbidity can be considered together, at least in a general sense. Stability (substrate stability) for one organism or function may not be stability for another organism or function. Parameters which are immediately obvious when considering stability are grain size, packing, degree of biogenic reworking, porosity and permeability, lateral and vertical movements of overlying or underlying water masses and the rate of addition of new sediment. These same parameters are also important to water turbidity and areas of shoal development. Figure B-26 is included to give some idea of the amount of energy available on the bottom of the northwestern Gulf Shelf, and shows those areas where there is sufficient energy in bottom currents created by wave surge to move sediments of fine sand size (0.125 mm to 0.25 mm in diameter) and the frequency of occurrence of such currents (ranging from more than 500 hours per year to less than 1 time in 20 years).

Some areas of possible shoaling were indicated as depositional ridges, mounds or terraces in Figure B-13. Regarding clarity of water, several workers (see Lynch *in* Galtsoff, 1974, p. 76) report that at a point 70 miles off the mouth of the



Bottom currents of 35 cm/sec. due to orbital movement associated with hurricane and normal wind waves. From Curray, 1960, p. 232, Fig. 6.

FIGURE B–26 PROBABLE FREQUENCY OF FINE SAND MOVEMENT BY WAVE SURGE

Mississippi River the water has a transparency nearly equal to the clearest ocean water known. This is as expected, because the majority of sediment added by the Mississippi River is moved westward along the continental shelf by longshore currents. In addition, although the Mississippi is a large river, its volume of discharge is very small compared to the volume of the Gulf of Mexico.

More study is needed before any general statements can be made about those aspects of the north central Gulf Coast.

As mentioned earlier, occurrence and distribution of organisms is controlled largely by the character of the substrate. Substrate alterations can produce changes in the biota which may not be realized for some time.

To briefly summarize this section on sediments it is appropriate to quote Moody (1967, p. 197) as follows:

> "We have seen that the Gulf of Mexico distributive province – with a land area of 2,130,000 square miles, climatically zoned from desert to rain forest, and drained by 100,000 miles of rivers which are activated by an average elevation of 2535 feet – discharges into the Gulf 1.2 million cubic feet of water per second which carries with it annually 0.09 cubic mile of solid detritus and more than 200 million tons of dissolved matter. This material is distributed at and below sea level in the never-ceasing search for equilibrium. The area of repose of this vast amount of earth debris is in a body of water of 570,000 cubic miles, mean depth of 4870 feet and area of 618,790 square miles."

e. Aquifers

Along any coastal region acquisition of freshwater is of primary concern. However, coastal regions may additionally have problems of the invasion of freshwater by saline marine waters.

Sources of subsurface freshwater along the north central Gulf coastal area are (1) alluvial deposits (gravels and sands) associated with deltaic deposition during Pleistocene and Holocene time, or (2) sands of Miocene and Plio-Pleistocene age. In some parts of the coastal region conditions exist which provide artesian wells, hence little or no pumping is required to obtain water. Fluctuations in the amount of available water (i.e., water table) depend on rainfall, runoff, evaporation, and rate of water use. The long history of deltaic deposition provides aquifers that are widely distributed, though often interconnected and discontinuous. Along the Mississippi River it is felt that most ground water comes from this stream because the water table appears to fluctuate as the river level varies (Cardwell and Rollo, 1960).

Marine waters have a higher density than freshwater because of their greater amounts of dissolved salts. This density difference means freshwater will be situated on top of saltwater just as oil occurs on top of water because of a density difference.

As long as pumping does not depress the freshwater level too much, there is little chance of marine water contamination.

Most freshwater for the Mississippi Gulf Coast comes from the Pascagoula and Graham Ferry formations. These rock units have provided artesian water for the coastal towns of Mississippi with little trouble from saltwater invasion.

These remarks are extremely general and will be of little use for any detailed planning regarding the environment. Before environmental alteration of any type is started, a competent hydrologist and/or ground water geologist familiar with local situations should be consulted.

C. RESIDENT AND TRANSIENT BIOTA

A dominant ecological feature of the three-state area is the extent of their estuarine areas. Though no single definition of an estuary will appropriately apply to all such areas, estuaries are essentially regions in which seawater is measurably diluted by land water drainage. Rounsefell (1963) states that an estuary is really an edge – a border between land and sea, the boundary of which can be neither accurately set nor defined. Estuaries are characterized by extremely variable hydrological and chemical parameters and their boundaries consistently change with tidal and other conditions.

The estuarine area of Louisiana is vast and encompasses 7,289,588 acres, of which 3,910,664 acres are marsh vegetation and 3,378,924 acres are surface water area.

The prime estuarine area of Mississippi is Mississippi Sound which is an elongate, relatively shallow body of water separated at many points from the Gulf of Mexico by a series of barrier islands. Four Mississippi estuaries adjoining Mississippi Sound are Bay St. Louis, the drowned valleys of the Pascagoula and Pearl Rivers and Biloxi Bay.

Estuarine areas of Alabama are located in Mobile and Baldwin Counties. The predominant estuarine area of Alabama is Mobile Bay which has a surface area of 264,470 acres and a drainage basin of 44,000 square miles. The total Alabama estuarine area covers 397,353 acres of open water and 34,614 acres of tidal marsh (Crance, 1971).

To accurately define the extent, importance, and condition of their respective estuarine areas, the three states participated in the recent Cooperative Gulf of Mexico Estuarine Inventory. As a result, two excellent volumes have been published by the Louisiana Wild Life and Fisheries Commission (1971), the first on Area Description and Biology and the second on Hydrology and Sedimentology. The Alabama Marine Resources Laboratory (1971) has also published the results of its inventory as two separate numbers on Area Description and Biology. Results of the estuarine inventory for Mississippi are available in mimeographed form (1972) but have not been formally published. These respective inventories are relied upon heavily in this report, but the bulk of data is beyond reproduction herein. These reports are highly recommended for specific information on selected, smaller areas within the North Central Region.

Estuaries are among the world's most productive natural environments. They support not only valuable commercial and sports fisheries, but also serve as nursery grounds where many species of fish and shellfish grow to near maturity.

Gunter (1967) reported that estuarine-dependent species account for about 97.5 percent of the total commercial fisheries catch of the Gulf states.

Commercial fish and shellfish landings of the Gulf states in 1965 totaled 1,463,000,000 pounds with a dockside value of $114,000,000 (Lyles, 1965). Louisiana led all other U.S. fishing ports in quantity landed.

In 1971 Louisiana led all states in volume of landings (1,396.2 million pounds). Mississippi was in fifth place with 397.6 million pounds. Louisiana was third in value of landings at $72.6 million following California and Alaska. Cameron, Louisiana led all other U.S. fishing ports in quantity landed.

U.S. shrimp fishermen in 1971 established a record value for shrimp with a volume of 387.9 million pounds valued at $166.6 million. Louisiana remained the leading producer with landings of 92.4 million pounds. In 1971 Louisiana, with 9.9 million pounds, was in second place following Maryland in oyster production. Landings of menhaden (1.6 billion pounds) in the Gulf States in 1971 were the largest on record.

Some species of marine animals are wholly estuarine, that is, they never leave estuaries during their life cycle. One of the most important species of this group is the common American oyster, *Crassostrea virginica.* Oysters will reproduce and grow at salinities higher than 10°/oo and the great majority of oysters are grown at salinities lower than 30°/oo. Oysters do best at lower salinities because of the prevalence of predators and diseases in more saline waters. Particularly the Gulf oyster drill, *Thais haemastoma,* and the microorganism, *Labyrinthomyxa marina* (formerly *Dermocystidium marinum*), have less detrimental effect in brackish waters. However, the recent work of Quick and Mackin (1971) indicates that high temperature is the most important factor contributing to high rates of parasitism by *Labyrinthomyxa marina* along the Gulf and Atlantic coasts of Florida. Incidence of infection increased almost linearly with temperature throughout the thermal range sampled (to 40°C). Incidence of disease, as compared to salinity, showed a decrease to either side of a peak in the 6-15°/oo range.

In Louisiana, the most important oyster producing areas are in a belt of estuarine water starting east of the delta in Lake Borgne and extending southward to a point slightly south of where the Chandeleur chain terminates at Breton Island.

There is then a hiatus around the mouth of the Mississippi River because of low salinity. In this area there are a few scattered beds, but no leases. West of the river, oyster beds are found in Barataria Bay and on westward. Location of Louisiana oyster beds is shown in Figure B-27. Newly settled oysters (spat) are obtained by oystermen east of the river from public beds maintained by the Louisiana Wild Life and Fisheries Commission and are transported to private leases east and west of the river. The locks at Empire and Buras, Louisiana were originally constructed for the passage of oyster luggers but now are used extensively by sportsfishermen and oil and gas personnel. The greatest acreage of private oyster leases in Louisiana are in St. Bernard Parish (36,939 acres), and Terrebonne Parish (20,347 acres). Table B-1 shows the acres of private and public oyster leases in Louisiana parishes.

In Mississippi coastal waters, oyster reefs are located across the entire state with the largest reefs near the western boundary. These are public reefs managed by the state. A few small areas of oyster bottom have been leased for private development, but production from these is negligible. Mississippi typically accounts for 13 to 17 percent of the oyster landings along the Gulf Coast. Table B-2 gives the acreage of Mississippi oyster reefs, and their location is shown in Figures B-28-B-30.

May (1971) has surveyed the oyster and oyster shell resources of Alabama. There are 3064 acres of natural oyster reefs in Alabama and the fishery is valued at $1,660,000 annually. The oyster shell dredging industry has an average annual sales of over $2,000,000. The distribution of buried oyster shell deposits in Mobile Bay is shown in Figure B-31.

Another species which heretofore has been considered a permanent resident of estuaries is the spotted seatrout *(Cynoscion nebulosus)*, frequently referred to as "speckled trout." This species is an important component of the commercial fishery and one of the most sought after game species. Since spotted seatrout are often caught around offshore oil and gas platforms, their permanent residency in estuaries may not be true.

Other important estuarine species show an alternation during their life cycle between brackish estuarine waters and high salinity "outside" waters. This is explained by Gunter (1967, p. 627) as "The Marine-Estuarine Life History." Numerous species of taxonomically unrelated animals including shrimps, the blue crab and many fishes spawn in high salinity water and the juveniles migrate to the estuarine "nurseries" at an early stage where rapid growth occurs.

The most important species of shrimp in terms of dollar value are the white *(Penaeus setiferus)* and brown shrimp *(P. aztecus)*. Lesser amounts of pink shrimp *(P. duorarum)* and seabob *(Xiphopeneus kroyeri)* are also harvested commercially.

A brief discussion of the life cycle of brown and white shrimp will exemplify their Marine-Estuarine Life History. Both species spawn and hatch in relatively deep, high salinity water. White shrimp spawn in more shallow water than brown, usually in depths from 25 to 100 feet. Brown shrimp spawn in water from 60 to 360 feet

TABLE B-1

PRIVATE AND PUBLIC OYSTER AREAS IN LOUISIANA

Parishes	Private[1]	Public	Oyster Seed Ground Reservation[2]	"Red Line" Area[3]
Calcasieu		1,200		
Iberia	701			
Jefferson	10,759		4,015[4]	
Lafourche	7,955			
Orleans	333			
Plaquemines	37,654		2,666[5]	
St. Bernard	36,939			
St. Mary	713			
St. Tammany	208			
Terrebonne	20,347		9,772	
Vermilion	709			
TOTAL	116,318	1,200	16,453	450,000 acres

1. Leased from the state, 1969.
2. Areas managed by the state, with open and closed seasons for the taking of seed oysters.
3. Areas of natural seed grounds in the parishes of Plaquemines and St. Bernard which have some remaining slow productive reefs and in which production of seed oysters is increased periodically by the planting of clam shell.
4. Part of the area is in Lafourche Parish.
5. Part of area is in St. Bernard Parish.

Source: From Louisiana Wild Life and Fisheries Commission, 1971, p. 17, Table 4.

TABLE B-2

OYSTER REEFS IN MISSISSIPPI

Name	1966 Area (Acres) Natural	Planted	Total
Point St. Joe	740	–	740
Bay St. Louis	170	82	252
Pass Christian	7,180	500	7,680
Biloxi Bay	350	–	350
Ocean Springs	180	–	180
Deer Island	4	–	4
Graveline Bayou	5	–	5
West Pascagoula	540	–	540
Bangs Lake	20	–	20
Point aux Chenes Bay	10	–	10
Middle Bay	5	–	5
	9,204	582	9,786

Source: From Cooperative Gulf of Mexico Estuarine Inventory and Study, Mississippi, 1972, Table 14, mimeographed report.

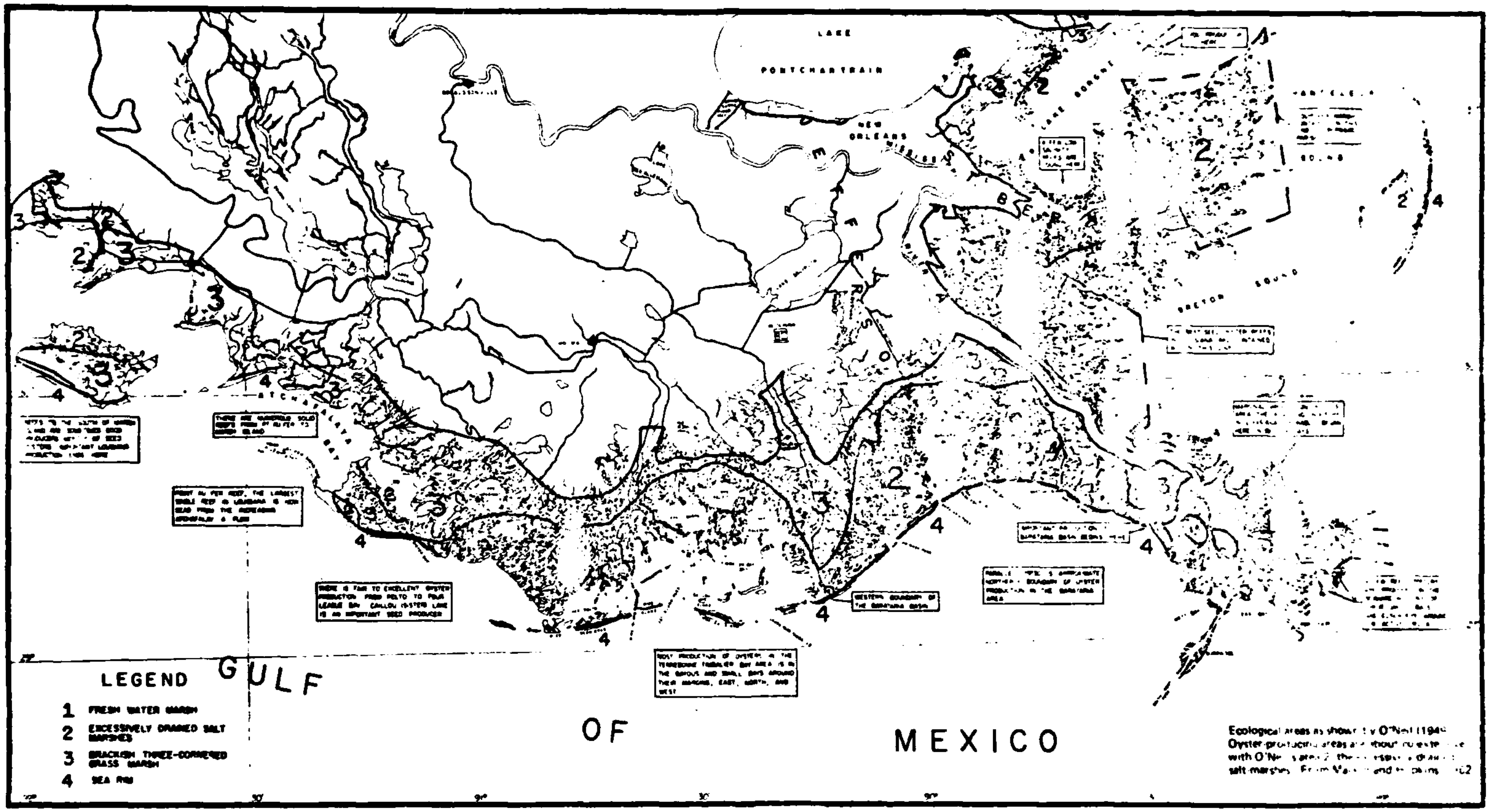
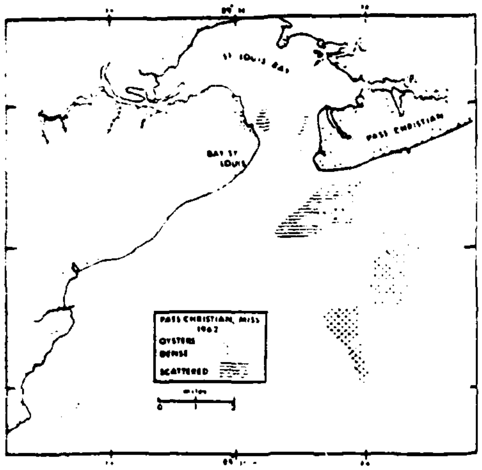
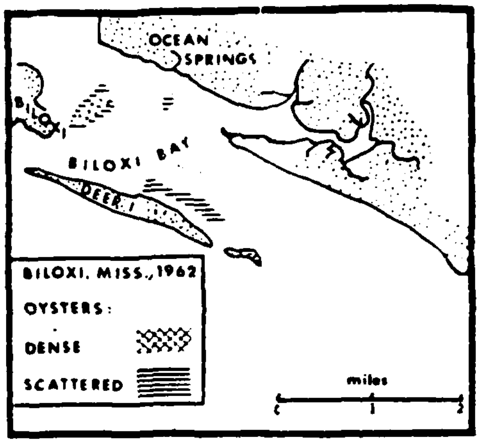


FIGURE B-27 PRINCIPAL OYSTER-PRODUCING AREAS OF LOUISIANA



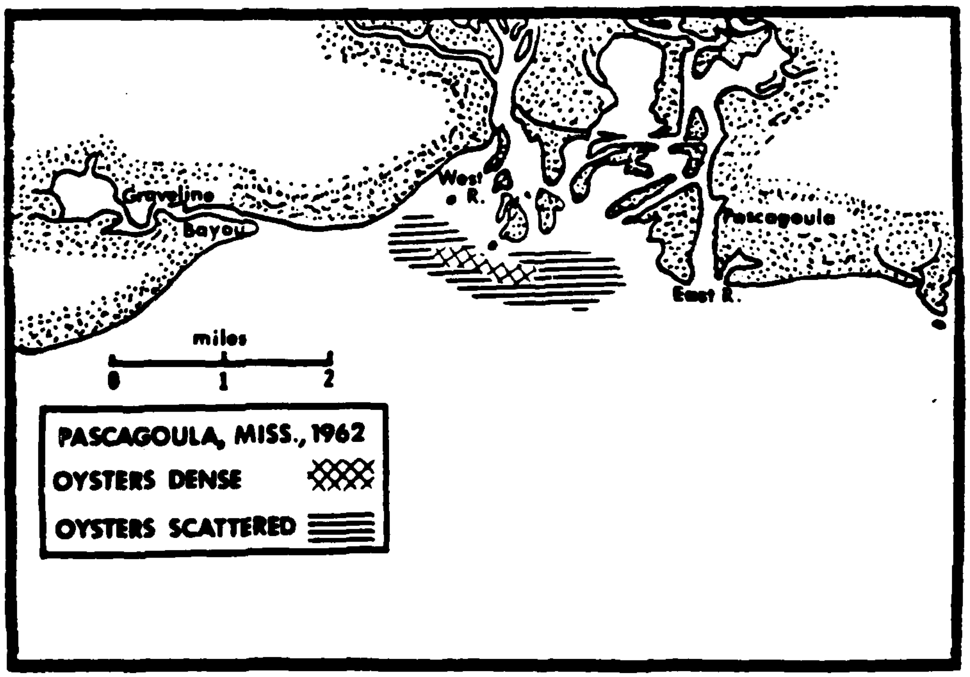
From Maghan, 1967, p. 7, Fig. 7.

FIGURE B–28 PASS CHRISTIAN OYSTER REEFS



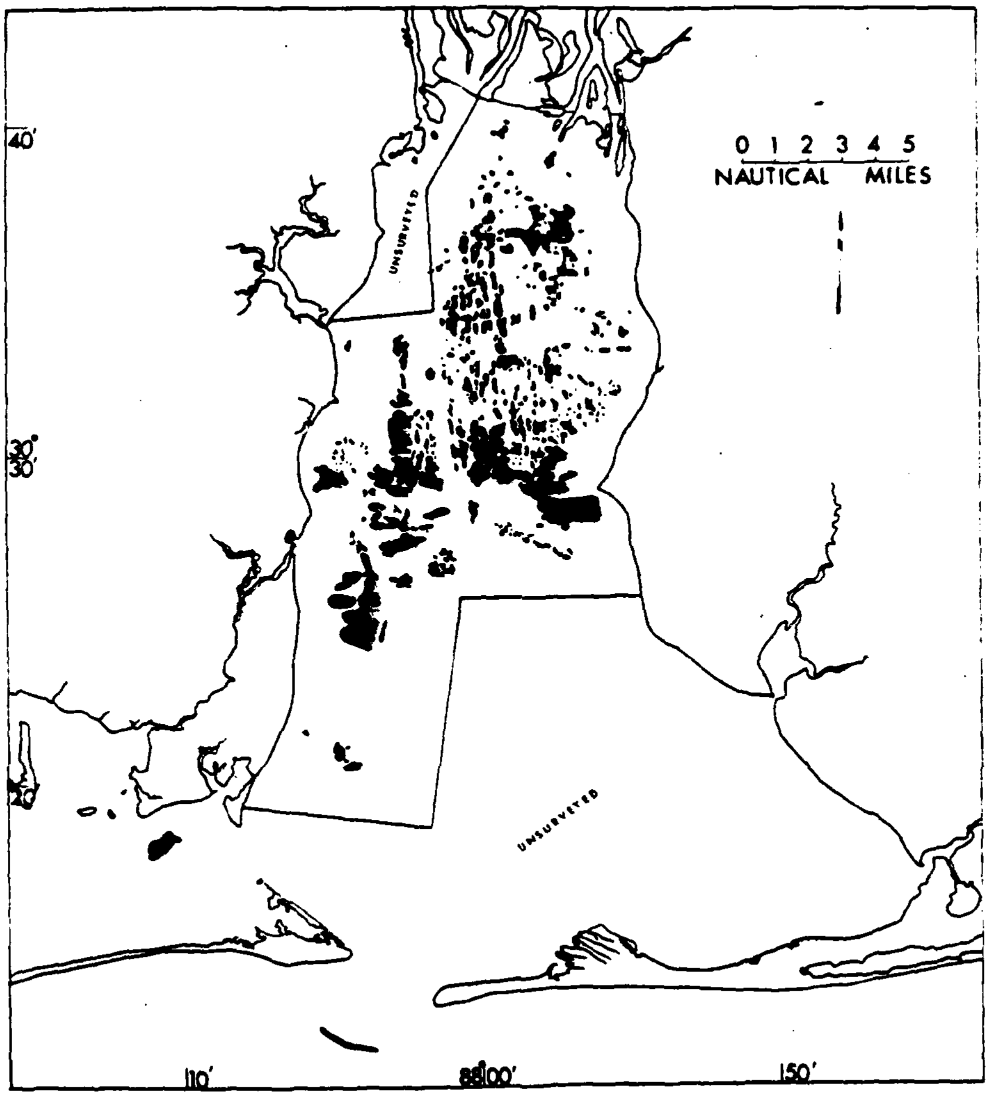
From Maghan, 1967, p. 6, Fig. 6.

FIGURE B–29 BILOXI OYSTER REEFS



From Maghan, 1967, p. 5, Fig. 5.

FIGURE B–30 PASCAGOULA OYSTER GROUNDS



Original surveys since 1965. From May, 1971, p. 17, Fig. 9. After data from Radcliff Materials, Inc., as reported by Ryan, 1969.

FIGURE B–31 DISTRIBUTION OF BURIED SHELL DEPOSITS deep. White shrimp spawning occurs from March to November and reaches a peak in June-July. Brown shrimp spawning occurs throughout the year, but there are two spawning peaks in early spring and the fall. Both species spawn their eggs directly into the water. They do not carry their eggs on their swimmerets as do crabs, crawfishes, river shrimp, and most other decapod crustaceans. After the eggs are spawned, they hatch in a few hours and the young shrimp spend the first 10-12 days of their existence as larvae floating in the offshore waters. By this time, the shrimp are called postlarvae. From this point on there is considerable variation in growth rate, which apparently is closely correlated with seasonal variation in water temperatures.

White shrimp postlarvae move inshore directly into the marshes and shallow estuarine areas where they mature. White shrimp increase in size at the rate of 12-27 mm per month in the winter, while in the summer they may grow as fast as 65 mm per month. Sexual maturity is reached at an approximate total length of 118 mm in males and 135 mm in females.

The small white shrimp then move out of the marshes and estuaries into deeper, more saline water. Most white shrimp are taken by commercial fishermen in shallow water and are thus commonly called "lake shrimp." The peak catch of white shrimp occurs during the late summer months. A few white shrimp remain and overwinter in the shallow estuarine areas before moving offshore.

Some investigators believe that the larvae and postlarvae of brown shrimp overwinter in deep water and enter the estuaries when the water begins to warm in the spring. The time of maximum abundance of postlarvae in the bays and inlets varies considerably. Brown shrimp reach sexual maturity at a total length of from 85-100 mm in males and 140 mm in females. Brown shrimp are taken in both shallow and deep waters, although larger shrimp are more characteristically taken by the offshore fleet.

The size of both species increases from the estuarine nursery grounds to the deep waters where, as mentioned earlier, spawning occurs. However, brown shrimp characteristically live in deeper water than whites.

Historically, white shrimp constituted the bulk of the catch in the early years of the fishery and, prior to 1940, constituted over 95 percent of the catch. Since World War II larger boats have been used and fishing in deeper waters has resulted in an increased take of brown shrimp. Brown shrimp now compose 60-70 percent of the total catch.

The life histories of brown and white shrimp have been documented by the efforts of numerous investigators over a period of many years. Summary biological data on these species are available in Cook and Lindner (1970), Lindner and Cook (1970) and Perez-Farfante (1969).

The blue crab *(Callinectes sapidus)* fishery is also economically important along the north central Gulf Coast. In Louisiana the blue crab fishery is fourth in dollar value, exceeded only by shrimp, menhaden and oysters.

Blue crabs mate in waters of low to moderate salinity around the passes between bays and sounds and in the open Gulf of Mexico. Fertile eggs are carried by the female and spawning and larval growth occur in saline waters. The juvenile crabs then move into low salinity waters. Ballard (1967) investigated various aspects of osmoregulation in blue crabs in Mississippi Sound and adjacent waters and observed that salinity and temperature affect osmoconcentration of the blood. There were differences between blood concentration in adult males and females with juvenile levels intermediate. This, along with reproductive habits, may explain the predominance of male blue crabs in fresh to slightly brackish waters.

Many other organisms besides shrimp and blue crabs possess the Marine-Estuarine Life History. The recent Cooperative Gulf of Mexico Estuarine Inventory participated in by the three states has as its goal, in part, to catalog the marine organisms in the estuarine areas.

During the Gulf Estuarine Inventory in Louisiana, 1390 trawl samples and 130 seine samples were collected at 82 trawl and 12 seine stations along the coast from April 1968 through March 1969. One hundred species of fishes and 19 species of invertebrates were collected. The bay anchovy was the most abundant fish collected. The bay anchovy, Atlantic croaker, largescale menhaden, Atlantic threadfin and spot accounted for over 90 percent of the total fishes caught. Brown and white shrimp and the blue crab were 90 percent of the total invertebrate catch. The investigators concluded that approximately 75 percent of the species of fishes and invertebrates collected are estuarine-dependent. The five most abundant fish, as mentioned above, and the three most abundant invertebrates are all estuarine-dependent.

During a similar inventory in Alabama, 20 trawl stations, five seine stations and four plankton stations were sampled monthly from January 1968 through March 1969 (Swingle, 1971). A total of 162 species of fish and 44 species of invertebrates were collected. The results were similar to those for Louisiana with the bay anchovy, croaker, and spot comprising 80.9 percent of the total fish catch.

Similar data for the Mississippi Gulf Estuarine Inventory has not been available for summation.

A list of the more common commercially important estuarine-dependent species of fishes is given in Table B-3.

One of the more important of these fishes is the menhaden. Menhaden perennially lead the Louisiana fishery in tons landed and rank second to shrimp in dollar value. In 1970 959,809,800 pounds of menhaden were taken by Louisiana commercial fishermen amounting to a value of $18,930,641. *Brevoortia patronus* (largescale menhaden) is the species most important in the commercial menhaden fishing industry of Louisiana. This species spawns in high salinity waters, enters the estuaries as larvae, and leaves the estuaries as juveniles. The commercial fishery for adults is in shallow shelf water generally in salinities above 20°/oo. Adults move into pure seawater ranging as far offshore as 25 miles and to a depth of 20 fathoms. The menhaden fishery is important to a much lesser extent off the coasts of Mississippi and Alabama.

TABLE B-3

SOME COMMON ESTUARINE-DEPENDENT SPECIES OF FISH

Scientific Name	Common Name
Trachinotus carolinus	Pompano
Mugil cephalus	Striped Mullet
Leiostomus xanthurus	Spot
Cynoscion nebulosus	Spotted Seatrout
Sciaenops ocellata	Red Drum
Cynoscion arenarius	White Seatrout
Pogonias cromis	Black Drum
Brevoortia patronus	Largescale Menhaden
Brevoortia smithi	Menhaden
Micropogon undulatus	Atlantic Croaker
Scomberomorus maculatus	Spanish Mackerel
Archosargus oviceps	Gulf Sheepshead
Paralichthys lethostigma	Southern Flounder

Zooplankton diversity and distribution were also investigated during the Louisiana Gulf Estuarine Inventory. A total of 681 samples from 28 collecting stations along coastal Louisiana were compared. A spring and fall maximum standing crop of zooplankton, exclusive of ctenophores, was evident. The spring maximum all along the coast occurred in May and the lowest monthly average was in February. In all samples where the ctenophore count was high, the count for all other zooplankters was low. The dominant zooplankter throughout the coastal region was the copepod, *Acartia tonsa.* In terms of numbers of individuals. *A. tonsa* exhibited a spring maximum and a winter low. *Labidocera aestiva* ranked second in copepod abundance. There was a direct correlation between salinity and species diversity; the lower the salinity the fewer species.

Plankton sampling during the Alabama Gulf Estuarine Inventory was mainly concerned with the collection of larvae of commercially important species of fishes and shrimp. Plankton data are not yet available from the Mississippi Inventory.

In estuarine areas, waterborne detritus from attached plants such as marsh grasses is, along with phytoplankton, part of the basic food supply for organisms in higher trophic levels. Estuaries are also very high in nutrients as compared to the fresh waters flowing in or the open marine waters beyond. These nutrients are typically recycled within the populations of plants and animals, in effect "binding" the nutrients to the estuarine ecosystem. In most estuaries the most important detritus-feeding benthic animals are mollusks, principally bivalves such as oysters. Additionally, other animals such as penaeid shrimp and the young juveniles of such fish as menhaden and mullet can feed directly on the rich accumulations of organic detritus in estuaries (Russell-Hunter, 1970).

Because of the importance of marsh vegetation in estuarine productivity, a goal of the Cooperative Gulf of Mexico Estuarine Inventory was to delineate the size, types and vegetation of the marsh areas of the respective states. Along the Louisiana coast the marsh border consists of four general types: saline marsh, brackish marsh, intermediate marsh, and fresh marsh. The major factors influencing the types and abundance of plant species in a marsh are edaphic factors such as soil salinity, soil type, drainage characteristics and elevation. These and other factors are interrelated but soil salinity, usually higher than surrounding water salinity, probably has the greatest influence. A vegetation map for the coastal marshes of Louisiana has been prepared (Chabreck, Joanen and Palmisano, 1968).

The major species of emergent marsh vegetation in coastal Louisiana is given in Table B-4. Note that Louisiana has almost four million acres of such vegetation. The dominant species of submerged vegetation in the Louisiana coastal area is *Ruppia maritima* (widgeon grass) which is found principally in brackish to more saline waters.

As part of the Gulf Estuarine Inventory, the marshes of Mississippi have been investigated by Eleuterius (1972). The dominant species in the marshes is *Juncus roemerianus* (needlerush). The 64,805 acres of coastal mainland marsh area contain approximately the following acreage of the major plant species: *Juncus roemerianus* (61,398 acres), *Spartina alterniflora* (2028 acres), *Spartina patens* (460 acres) and *Scirpus olneyi* (96 acres). More than 300 species of higher plants were found in the marshes with the greatest diversity occurring in the freshwater marshes.

The Alabama estuarine area has 34,614 acres of tidal marsh. The major species of aquatic vegetation in the five Alabama estuarine areas are listed in Table B-5.

Marsh and estuarine habitats also support a great variety and quantity of other animal life such as resident and migratory waterfowl and fur-bearing mammals. Table B-6 lists some of the more common migratory waterfowl which winter in the marshes of the region providing game for hunters.

The mottled duck *(Anas fulvigula)* is a resident species of waterfowl which nests and winters in the coastal area of Louisiana. The only game species of shorebird which winters in grassy marshes of the Louisiana coastal area is the common snipe *(Capella gallinago)*.

The Canada goose *(Branta canadensis)*, once a common winter resident of coastal marshes, has declined drastically in the last few years to just a few thousand migrants per year. It is believed that the Canada geese, while migrating southward,

TABLE B-4

MAJOR SPECIES OF AQUATIC VEGETATION IN COASTAL LOUISIANA

Marsh Types	Species Emergent Vegetation	Acres
Saline	Oystergrass *(Spartina alterniflora)*	862,973
	Glasswort *(Salicornia* sp.)	
	Black rush *(Juncus roemerianus)*	
	Black mangrove *(Avicennia Nitida)*	
	Saltgrass *(Distichlis spicata)*	
	Saltwort *(Batis maritima)*	
Brackish	Wiregrass *(Spartina patens)*	1,203,790
	Threecorner grass *(Scirpus olneyi)*	
	Coco *(Scirpus robustus)*	
Intermediate	Wiregrass *(Spartina patens)*	650,576
	Deer pea *(Vigna repens)*	
	Bulltongue *(Sagittaria* sp.)	
	Wild millet *(Echinochloa walteri)*	
	Bullwhip *(Scirpus californicus)*	
	Sawgrass *(Cladium jamaicense)*	
Fresh	Maiden cane *(Panicum hemitomon)*	1,193,325
	Pennywort *(Hydrocotyl* sp.)	
	Pickerelweed *(Pontederia cordata)*	
	Alligator weed *(Alternantheria philoxeroides)*	
	Bulltongue *(Sagittaria* sp.)	
	Water Hyacinth *(Eichhornia crassipes)*	
Total		3,910,664

Sources: From Vegetative type map of the Louisiana Coastal Marshes, 1968; and Louisiana Wild Life and Fisheries Commission, 1971, p. 10, Table 2.

are "shortstopped" by new, attractive refuges farther north. The Louisiana Wild Life and Fisheries Commission is presently evaluating the possibility of establishing non-migratory flocks of Argentinean waterfowl in Louisiana. These include the following: *Anas georgica* (yellow-billed pintail), *Amazonetta brasiliensis* (Brazilian teal), and *Netla peposaca* (rosy-billed pochard).

Bird mortality from oil spills has been negligible in the northern Gulf of Mexico, particularly compared to spills off the west coast of the United States or European waters. A detailed analysis of Louisiana birds from the standpoint of vulnerability to spilled oil has not been made, but a few general remarks will emphasize some critical factors. The discussion is restricted to Louisiana since Mississippi and Alabama do not produce offshore oil and gas.

TABLE B-5

MAJOR SPECIES OF AQUATIC VEGETATION IN THE ALABAMA ESTUARINE STUDY AREA

Estuary	Predominant species of emergent plants[1]	Total area (acres)[2]	Predominant species of submerged plants[1]	Total area (acres)[2]
Mississippi Sound	*Juncus roemerianus* *Spartina alterniflora* *Spartina cynosuroides* *Spartina patens* *Distichlis spicata*	11,762	*Diplanthera wrightii* found in scattered patches in the north portion of Portersville Bay.	Unknown
Mobile Bay	*Juncus roemerianus* *Spartina alterniflora* *Spartina patens* *Alternanthera philoxeroides* *Phragmites communis*	6,224	*Najas quadalupensis* *Vallisneria spiralis* *Zanichellia spiralis* *Potamogeton pulstris* *Nitella* sp.	5,000
Mobile Delta	*Alternanthera philoxeroides* *Phragmites communis* *Spartina cynosuroides* *Scirpus californicus* *Cladium jamaicense*	15,257	*Najas quadalupensis* *Vallisneria spiralis* *Potamogeton pusillus* *Heteranthera dubia* *Nitella* sp.	Unknown
Perdido Bay	*Juncus roemerianus* *Spartina alterniflora* *Spartina cynosuroides*	1,072	Unknown	Unknown
Little Lagoon	*Juncus roemerianus* *Spartina alterniflora* *Spartina cynosuroides* *Phragmites communis* *Cladium jamaicense*	299	Unknown	Unknown

1. Abundance of species based on information from Swingle (1971) and Baldwin (1957).
2. Includes the area of all species of plants including those not listed.

Source: From Crance, 1971, p. 28, Table 16.

TABLE B-6

COMMON SPECIES OF MIGRATORY WATERFOWL
IN THE NORTH CENTRAL MARSH REGION

Scientific Name	Common Name
Anas acuta	Pintails
Anas carolinensis	Green-winged Teal
Anas discors	Blue-winged Teal
Anas platyrhynchos	Mallards
Anas rubripes	Black Ducks
Anas strepera	Gadwalls
Anser albifrons	White-fronted Geese
Aythya affinis	Lesser Scaup
Aythya americana	Redheads
Aythya marila	Greater Scaup
Aythya valisineria	Canvasbacks
Bucephala albeola	Bufflehead
Bucephala clangula	Common Goldeneyes
Chen caerulescens	Blue Geese
Chen hyperborea	Snow Geese
Fulica americana	Coots
Mareca sp.	Widgeons
Mergus sp.	Mergansers
Spatula clypeata	Shovelers

First, some of the most vulnerable bird species do not occur in Louisiana except as accidental strays. This is particularly true of the family Alcidae (auks, murres, guillemots, and their allies), cold water birds which nest on rocky cliffs. Alcids are particularly vulnerable to oil on water and frequently comprise a substantial percent of birds killed by oil. Second, other vulnerable species, which includes those which float on water and dive for food, only winter in Louisiana and may be found in the northern Gulf in large numbers only during the colder months. This group includes grebes, loons, and diving ducks such as scaup ("dogris"), canvasbacks, redheads, etc. Third, many wintering waterfowl remain in refuges or management areas where they are protected by dikes and levees. Fourth, the terns and gulls, which are among the northern Gulf Coast's most common summer and winter residents, comprise only a small proportion of birds killed by large spills. Finally, there are some birds which might be affected by spills but there are no detailed observations; these include particularly the brown pelican, white pelican and man-o-war bird.

Two of the best known marsh animals are the Louisiana muskrat and the nutria which thrive in brackish marshes. The prime food for muskrats is threecorner grass *(Scirpus olneyi)* whereas nutria are less particular and feed on a variety of marsh vegetation. The nutria has been the prime fur-bearing mammal in Louisiana since 1961, replacing the muskrat as the leader. During the 1969-70 season, nutria accounted for 66.9 percent of the total fur value in the state and the muskrat for 22.7 percent of the total $6,855,770 produced that year. Other significant inhabitants of coastal marshes and swamps are raccoon, opossum, mink and otter. There has been a significant loss of these animals during the last few years through habitat deterioration such as hurricanes, land development, water control projects, and increased incidence of disease.

The only marine mammal occurring commonly in any of our zones is the bottle-nosed porpoise, *Tursiops truncatus.* It occurs in all zones, even in more saline portions of estuaries. An account of rarer cetaceans and a list of those whose range encompasses the Gulf of Mexico but have not actually been reported are given by Gunter (1954).

Marine turtles of the northern Gulf of Mexico which live in the open sea and come to beaches to lay their eggs include the leatherback *(Dermochelys coriacea),* ridley *(Lepidochelys kempii),* green *(Chelonia mydas),* and the loggerhead *(Caretta caretta).* They are all rare in our region. Diamond back terrapins occur in inshore estuarine waters.

There are no rare or endangered marine species in the region although alligators *(Alligator mississippiensis)* are found in freshwater marshes and occasionally enter brackish waters.

D. MAN'S ACTIVITIES

Man's activities in the coastal and offshore areas of the region are diverse and widespread. These activities can be broadly classified under three subheadings: Pleasure, Economic, and Detrimental. Activities for pleasure include hunting, sport fishing, camping, and the use of beaches for swimming and sunbathing. Tourism is not widespread in the coastal area except for the two major cities, New Orleans and Mobile, and to a lesser extent along the Mississippi Gulf Coast. Economic activities include commercial fisheries and the related shore plant installation, offshore oil, gas, and sulphur production, industry along the major rivers and port activities. The prime detrimental aspects of man's activities are domestic and industrial pollution. Assuming greater importance is the drainage and filling of productive marshlands for residential and commercial development.

Man's activities will be discussed more fully under the respective dissimilar hydrobiological zones.

II. ZONAL ANALYSIS

A. ZONE III

1. Summary

Zone III is a western marsh estuarine zone including a small portion of the east Texas coast and continuing eastward in Louisiana to the Bell Isle Canal (Figure B-32). This zone includes Sabine Lake whose center is the dividing line between Louisiana and Texas. Attributes of Sabine Lake are alluded to briefly in this report and, along with the Texas portion of Zone III, will be discussed in detail in the report prepared by TerEco Corporation.

Zone III is distinguished by the fact that it is west of the influence of major river systems (Mississippi and Atchafalaya) in Louisiana. Also, water exchange in the coastal region by tidal exchange is relatively small due to higher land elevations behind the beaches and few openings to the Gulf of Mexico. The coastal area is extensive marsh with few human population centers.

Water quality, particularly with regard to dissolved nutrients, could be a major problem in the future in the coastal area unless adequate preventive measures are undertaken. The area has been inadequately studied biologically. There is a very gradual slope to the continental shelf off Zone III. The 10 fathom mark lies, on the average, 35 miles offshore.

2. Physical Characteristics

a. Hydrology

Nineteen stations, mostly in inshore lakes, bayous, and passes, were sampled from December 1967 through April 1969 for hydrological and water chemistry data (Louisiana Wild Life and Fisheries Commission, 1971). Most of the data reported herein are from this report. Surface water temperatures range from 33.5°C in August to 11.0°C in January with an average annual water temperature of 22.0°C. Flushing patterns depend on freshwater runoff and stream discharge. Water exchange by tidal action is less in the western portion of this zone than in the eastern portion due to higher land elevations to the west, the relatively recent damming of waters, and the small number of openings between the Gulf and the marsh. The major freshwater streams of the zone are the Sabine, Calcasieu and Mermentau Rivers. Most drainage in the coastal area is by networks of canals rather than by natural bayous. The Sabine River has an average annual discharge of 8,187 cubic feet per second and the Calcasieu River has a discharge of 2,562 cubic feet per second. In this zone, longshore westward currents are dominant the year around.

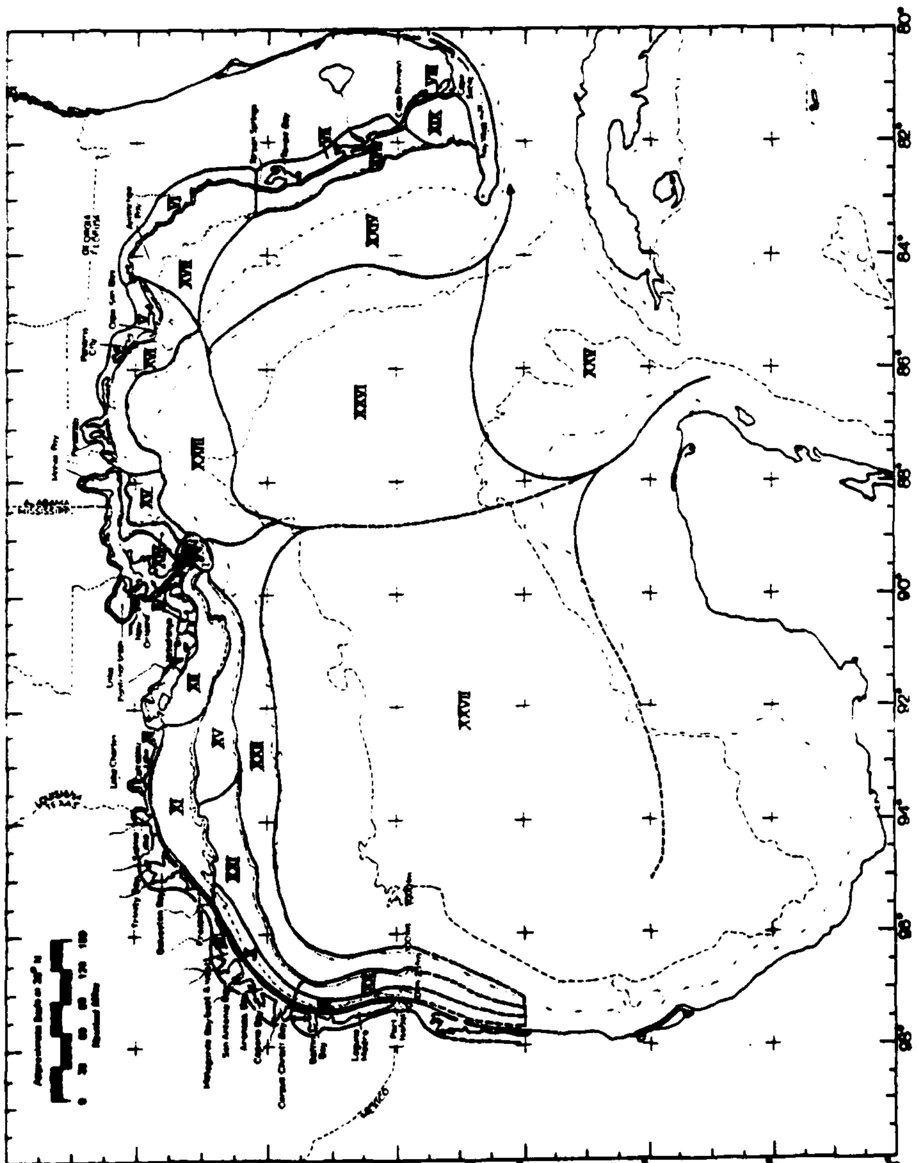


FIGURE B–32 DISSIMILAR HYDROBIOLOGICAL ZONES – GULF OF MEXICO

b. Geology

Zone III is an area of salt domes down to the basin faults and related structures. The shallow littoral environment of the zone is an area of slow sand accumulation (Figure B-23). Sufficient energy is available from bottom currents for more than 500 hours per year to move fine sand. Offshore bottom sediments are probably well oxygenated due to porosity and permeability. The predominant sediments in Lake Calcasieu are clayey silt and silty clay.

The Gulf shoreline from Sabine Pass to Calcasieu Pass is predominantly sand with varying amounts of shell. The seven miles of shoreline east of and adjacent to the Calcasieu River are composed of mud and silt. Eastward there are alternating areas of sand mixed with shell, mudflats, and predominantly sand. Characteristics of the Louisiana Gulf shoreline and bay-sound shoreline have been well documented in the National Shoreline Study (Army Corps of Engineers, 1971).

During the Gulf Estuarine Inventory, the highest monthly average turbidity reading was 0.9 feet in June and the lowest 2.2 feet in November. Turbidity fluctuated seasonally with salinity with lowest turbidity values occurring during periods of high salinity.

c. Chemistry

At the above-mentioned 19 stations the highest monthly average salinity was 20°/oo in November and the lowest, 5.2°/oo, in March. The average of all samples during the investigation was 8.9°/oo – the lowest average of all areas studied along the Louisiana coast during the Gulf Estuarine Inventory. In Calcasieu Lake, the largest lake in the zone, salinities ranged from 2.4 to 30.1°/oo. Salinities, influenced by freshwater discharge as well as current patterns, vary greatly seasonally.

The highest monthly average for dissolved oxygen in the zone was 9.6 ppm in March and the lowest 6.4 in August. Highest station averages were in Calcasieu River and Calcasieu Lake and the lowest in Sabine Lake. All station averages were within normal limits.

Of the six study areas considered during the Louisiana Gulf Estuarine Inventory, nitrate values were highest in the area encompassing Zone III and the sample average for the entire area was 13.50 μg-at/l. The highest concentrations of nitrate, and also nitrite, were in Sabine Lake.

Inorganic phosphate and total phosphorus values were also high. The annual inorganic percentage of total phosphorus for the study area was 28.6%.

3. Resident and Transient Marine Biota

The estuaries in this zone are older and more established than those to the east and include the Mermentau River basin and Calcasieu and Sabine Lakes. Fresh to brackish marshes dominate the coastal area and extend inward for distances up to 25 miles. The dominant plant species in the marsh are maiden cane, bulltongue, wiregrass, threecorner grass, and saltgrass.

Chamberlain (1959) evaluated waterfowl utilization of marsh vegetation at the Rockefeller Refuge in this zone. Birds were separated according to the type of marsh in which they were shot by hunters, 75% being from brackish marsh and 25% from fresh marsh. Gizzard contents were also examined. Seventeen different species of waterfowl were evaluated and seeds were the most important constituent of the diet. Forty-nine species of plants were identified from the gizzard contents indicating diverse usage of marsh vegetation as food for wintering waterfowl.

The zooplankton of this area was investigated during the Gulf Estuarine Inventory. Most of the samples were reportedly deficient as compared to other areas, both in quantity and number of species present. *Acartia tonsa* was the dominant zooplankter showing peaks in numbers in April and November. Trawl samples were also taken during this Inventory. Typical estuarine-dependent species were encountered.

Public oyster beds occur in Calcasieu Lake.

4. Man's Activities

The Parish of Cameron in 1967 had six wholesale and processing commercial fisheries shore plant installations employing at the season peak approximately 300 persons.

As mentioned earlier, Cameron, Louisiana led all U.S. fishing ports in quantity landed during 1971.

There are no major population centers along the coast in this zone. Lake Charles, approximately 35-40 miles inland, is located on the Calcasieu River and had a population in 1969 of 73,000. The Lake Charles Deep-Water Channel leading to the Gulf of Mexico has a controlling depth of 30 feet.

A large gas and oil field is located in White Lake in the western portion of Vermillion Parish.

Sandy shores along the western portion of this zone are widely used for sunbathing and other recreational activities. Sports fishing and hunting are widely practiced.

This zone contains several wildlife refuges including the Sabine Refuge and the Rockefeller Refuge.

B. ZONE IV

1. Summary

Zone IV includes the major portion of coastal Louisiana and the marsh-estuarine areas of Mississippi and Alabama. The zone is divided into two areas transected by the Mississippi River (Figure B-32) and its extensive levee system. The river itself and the port of New Orleans are discussed later in this report.

Included in this zone are the most extensive and highly productive estuarine areas of the Gulf Coast. The zone is fairly well known biologically with particular regard to the commercially important species of fish and shellfish. Lacking are sufficient systematic studies of phytoplankton and quantitative investigations of primary productivity. Also lacking throughout the zone and especially west of the Mississippi River delta are quantitative studies of the benthic macrofauna. Hydrological data is adequate for general conclusions.

Along the western boundary, this zone is distinguished from Zone III by the strong influence of freshwater discharge on the estuarine areas. There is less true beach and many more natural openings from the coastal area to the sea. Hydrologic features are more variable on a seasonal basis and there is a greater penetration of the coastal area by estuarine-dependent organisms. These attributes continue to the east on both sides of the Mississippi River delta. At its eastern extension there is a clear but gradual transition due to a change from muddy to sandy beaches and offshore sediment which, in turn, influences the turbidity of offshore waters.

East of the Mississippi delta, the zone has been extended seaward to the line of barrier islands off Louisiana (Chandeleur Islands) and Cat, Ship, Horn, Petit Bois, and Dolphin Islands off Mississippi and Alabama. Water outside these islands is more saline and the sediment becomes more sandy, both of which influence the distribution of organisms, especially the benthos.

Eutrophication due to nutrients and industrial discharge is apparently most pronounced in Mobile Bay and the Pascagoula area. However, detailed studies of water chemistry are lacking for most areas and may add additional areas to this list.

2. Physical Characteristics

a. Hydrology

It will be recalled from the previous section that surface current patterns vary during the year and depend, in part, on wind direction. West of the Mississippi River delta there is usually a dominant westward longshore current. East of the delta currents are much more erratic, varying seasonally. In general, flow is away from the land mass in the bays and estuaries east of the delta but differences in water density due to salinity, turbidity and temperature can cause some circulation within them. Tides in the zones are typically diurnal and moderate, but are subject to drastic modifications by wind action. Winds in the Mississippi Sound area are predominantly northerly and northeasterly during the summer. West of the delta, as exemplified by the Bayou Lafourche area, there are prevailing southeasterly winds from March to August. Autumn is a transition period and during winter prevailing northerlies are common. The winter season has the highest average wind speeds (NOAA, 1972).

Flushing rates are quite variable seasonally. Marsh areas are frequently flooded for long periods during prolonged periods of south and southeast winds. Conversely, large areas of shallow flats are frequently uncovered during periods of northerly winds.

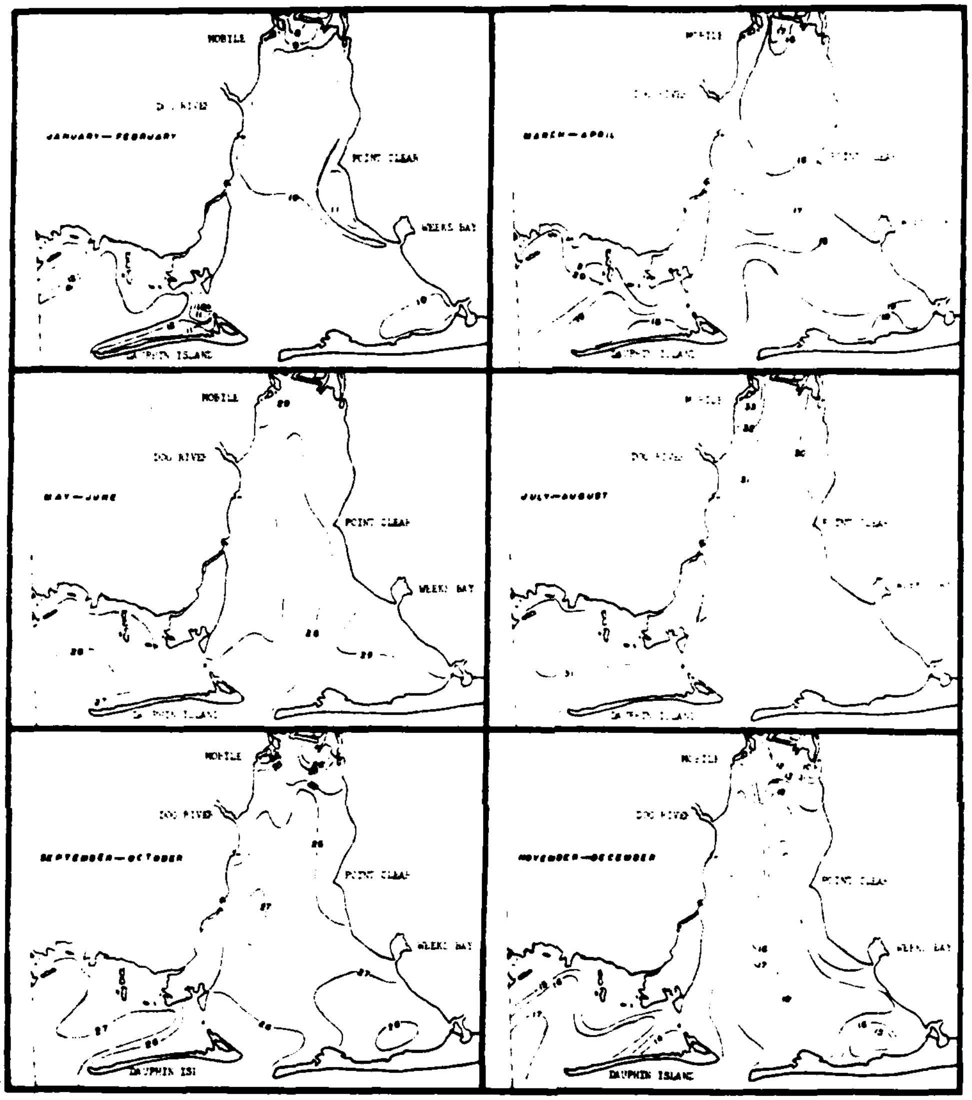
The Mississippi and Atchafalaya River systems have drainage areas of 1,228,900 and 87,570 square miles respectively and discharge annually into the Louisiana estuarine zone 478,029 and 169,300 cubic feet per second respectively. This represents over 89 percent of the total average annual discharge along the Louisiana coast. Other major Louisiana contributors to the annual discharge of freshwater into this zone are the Pearl, Amite and Tangipahoa Rivers and Bayous Teche and Lafourche. The Pearl River and the two bayous discharge directly into the Gulf whereas the Amite and Tangipahoa Rivers discharge into Lake Pontchartrain. The outlet from Lake Pontchartrain to Lake Borgne and Mississippi Sound consists of three channels – the Rigolets, Chef Menteur Pass, and the Mississippi River-Gulf Outlet via the Inner Harbor.

The Coastal Plain of Mississippi is dissected by four major drainage systems. The Pearl River forms the southern part of the boundary between Louisiana and Mississippi and is the largest river system in the state.

The Jourdan and Wolf Rivers and several bayous empty into Bay St. Louis. The Biloxi and Tchoutacabuffa Rivers and several bayous empty into Biloxi Bay. The Pascagoula River is the second largest river in the state. Many creeks, bayous and the Escatawpa River are among the tributaries of the Pascagoula River drainage system.

The major freshwater discharge into the Alabama estuarine areas of this zone are into Mobile Bay via the Mobile delta. The Mobile delta is open to Mobile Bay through the Mobile, Tensaw, Apalachee and Blakeley Rivers. This watershed contains approximately 44,000 square miles and has a mean discharge of over 58,636 cubic feet per second.

Surface water temperatures in the shallow estuarine waters are influenced heavily by air temperature and therefore fluctuate considerably. There are little differences between surface and bottom temperature except in the deeper areas of passes and rivers. Figure B-33 shows bimonthly isothermal maps of Mobile Bay and illustrates the seasonal fluctuation in water temperature. Throughout the zone the highest surface temperatures are usually reached in July-August and the lows in January-February. Records of water temperature in the estuarine areas of Mississippi show a variation of 3.4 to 36.5°C. Data collected during 1968 and 1969 from the



Mobile Bay and Mississippi Sound, Alabama. Combined data from 1963-64, 1965-66 (McPherson, 1970) and January 1968 through March 1969 (from Bault, In Press). From Crance, 1971, p. 29, Fig. 11.

FIGURE B–33 BIMONTHLY SURFACE ISOTHERMAL MAPS

Louisiana portion of this zone show that winter surface temperatures averaged 11.9°C, spring temperatures 20.4°C, summer temperatures 29.2°C, and fall temperatures 22.3°C.

b. Geology

In general, the geology of this zone is as discussed for Zone III with the exception that there are fewer faults and salt domes east of the Mississippi delta.

Sediments in this zone are highly variable, especially when a small, specific area is considered. In general, major differences occur at the interface between the Gulf and the estuarine areas and also near the mouths of major streams. Sediments are usually coarse near the Gulf and the barrier islands and fine in the upper estuaries.

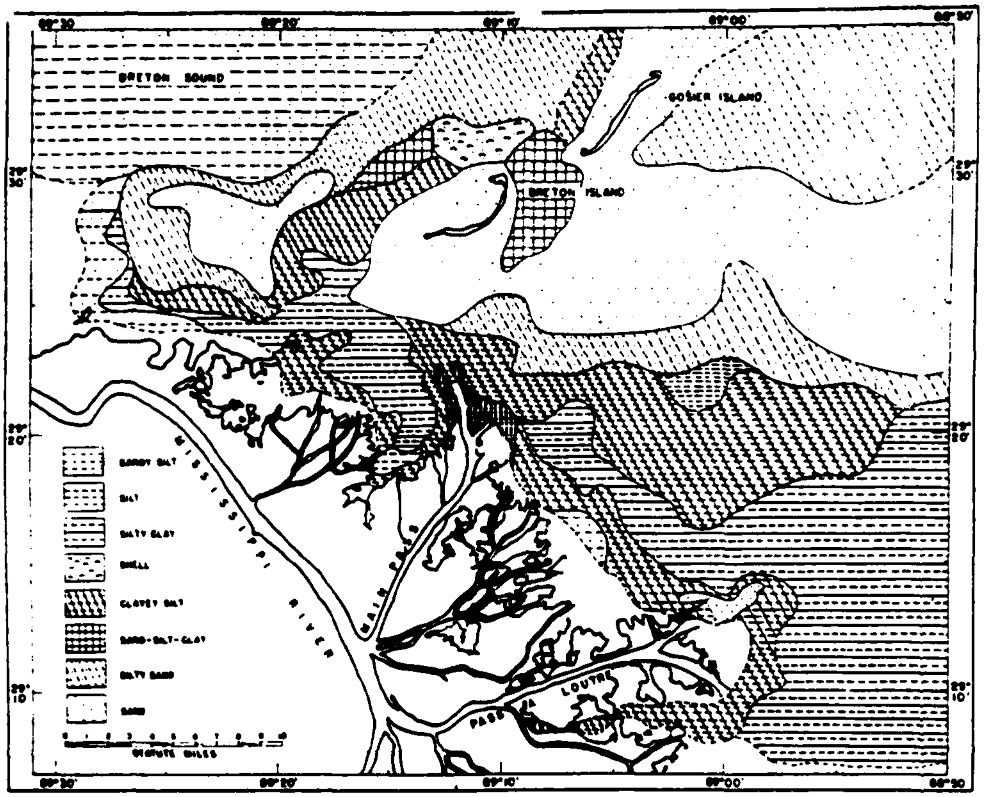
The main sediment type west of the Mississippi River delta is silty clay whereas east of the delta it is clayey silt. Moving westward from the delta, Barataria and Caminada Bays are predominantly clayey silt which integrates marshward into a silty clay. Terrebonne and Timbalier Bays are sandy silt and clayey silt. Atchafalaya Bay is predominantly clay silt and is, of course, greatly influenced by the Atchafalaya River whose sediment load is mostly silt and clay.

Figure B-34 illustrates the great variation in sediment types for the inshore east delta area. The predominant sediment type in Lake Borgne is clayey silt.

More than two-thirds of Mississippi Sound off the Mississippi coast is overlaid with mud (organic deposition). The mud overlays sand which is exposed near the barrier islands. Priddy et al. (1955) have described the sediments of Mississippi Sound and inshore waters.

The bulk of sediments in Mobile Bay are silty clays and clays as shown in Figure B-35. The major source of sediments is the Mobile River system which carries annually an average of 4.7 million tons of suspended sediment and an unknown amount of bed load to the estuary (Ryan, 1969).

Turbidity in this zone is naturally highly variable and relatively high turbidity is a natural phenomenon typical of estuarine areas. As mentioned earlier, there is a correlation between salinity and turbidity – low salinity coincides with high turbidity. Because of the shallow depths, wind generated waves also directly influence turbidity in this zone. Of 710 turbidity readings during the Louiisiana Gulf Estuarine Inventory, 23% had Secchi disc extinction readings of less than one foot and 70% were less than two feet. Specific data have not been available for the Alabama and Mississippi portion of this zone but general observations indicate that conditions would be similar to Louisiana.

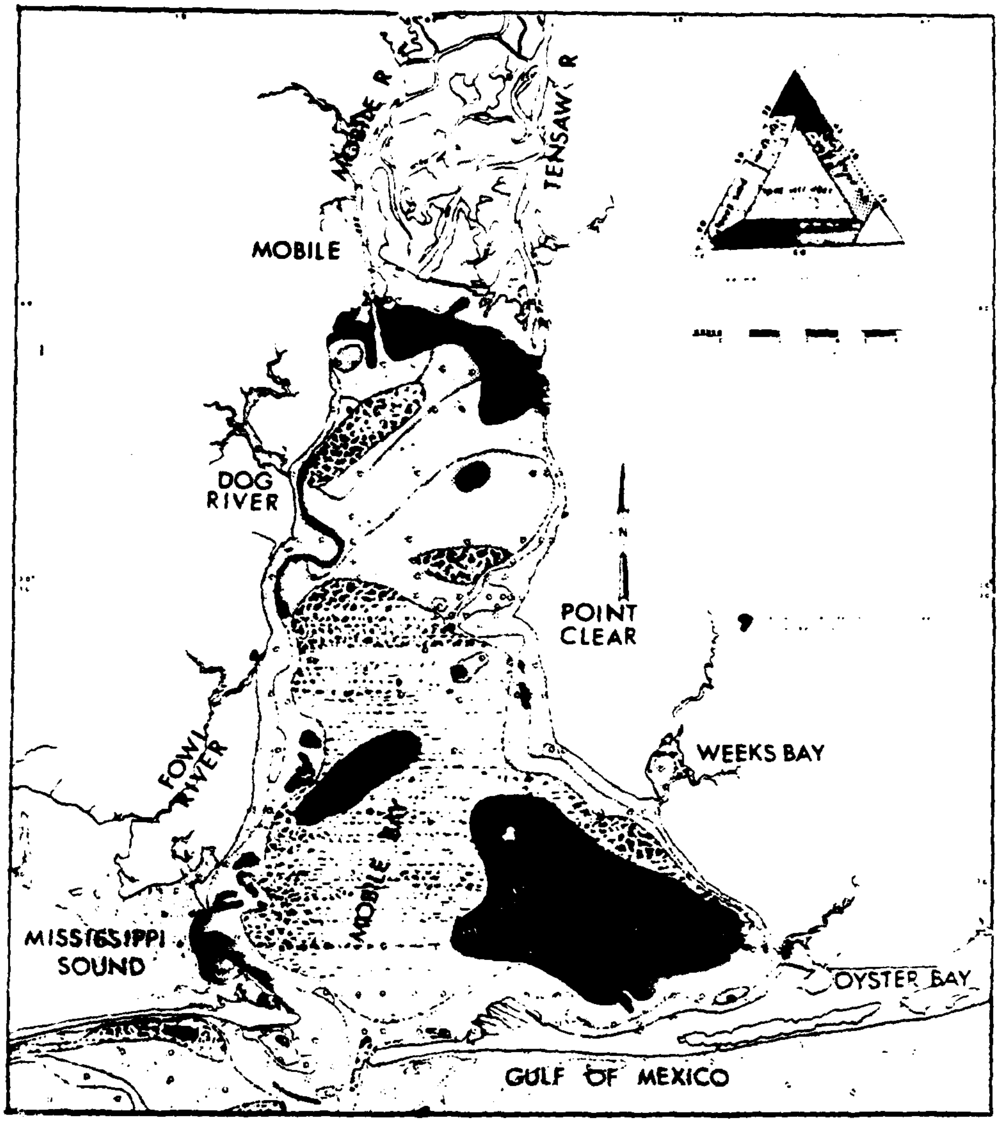


Determined by sand-silt-clay contents for inshore Delta region (compiled by Parker and D.G. Moore). From Parker, 1956, p. 302, Fig. 6a.

FIGURE B–34 AREAL DISTRIBUTION OF SEDIMENT TYPES

c. Chemistry

Salinities throughout this estuarine zone vary greatly seasonally. Due to shallowness of most of the estuarine area, differences between bottom and surface salinities are not significant except in ship channels, passes and other deep areas. Salinities are generally highest in the fall and lowest during the spring, correlating directly with peaks in stream discharge. During high discharges the Mississippi and Atchafalaya Rivers dilute salinities along more than one-half of the Louisiana coast. As an example of salinity variation, the highest monthly average reported for Barataria Bay, Louisiana is 28.0°/oo and the lowest 15.9°/oo. Even lower averages are reported for areas receiving more freshwater discharge such as Atchafalaya Bay. Seasonal effects on salinity have been given previously (Figures B-3 and B-4).



Modified from Ryan (1969).
From Crance, 1971, p. 11, Fig. 7.

FIGURE B–35 MOBILE BAY SEDIMENT TYPES

Dissolved oxygen in estuarine areas is usually above lethal limits. Periodically there are reports of extensive local fish kills. These usually are due to anoxia resulting from excessive BOD, which sometimes is due to phytoplankton blooms caused by excessive eutrophication. In the past, pesticides reportedly have been the cause of fish kills. As expected, dissolved oxygen levels are generally higher during the cool months and lowest during the warm months.

Extensive water quality data have been published as a result of the Louisiana Gulf Estuarine Inventory and do not bear repeating in detail herein. Grantham (1964) reported on water quality along an 80 mile stretch of the Pascagoula River and data for the western portion of Mississippi Sound has been collected by several investigators including Viosca (1938) and Gunter (1950).

In summarizing the available data on water quality for the entire zone, it appears that the most polluted areas are Mobile Bay and the Pascagoula estuarine area. Along coastal Louisiana, with the exception of stations immediately adjacent to the Mississippi and Atchafalaya Rivers, nutrient (nitrates, nitrites and phosphates) were highest in Sabine Lake (Zone III).

3. Resident and Transient Marine Biota

Much of the information on the biota of this marsh-estuarine zone has been summarized in the previous section and will not be repeated here. The respective Gulf Estuarine Inventories (cited earlier) of the three states summarize and add to our body of knowledge of this zone. Included below are selected papers on specific areas within the zone.

The area west of Grand Isle, Louisiana has been poorly studied biologically but the marine fauna of the Grand Isle area has been studied extensively through the years by many investigators. Behre (1950) published an annotated list of the fauna of the Grand Isle region. Because of its importance as a highly productive source of commercially important species of shrimp, oysters and crabs, the Barataria Bay estuarine area has been investigated considerably. Approximately one-third of Louisiana's annual blue crab catch is from these waters. Jaworski (1970), doing research for a doctoral dissertation, made an extensive survey of the blue crab fishery in Barataria Bay with particular reference to the influence of hydrological and other environmental factors on distribution and reproduction. To our knowledge, his study has not been published.

Kirby and Gosselink (1971) investigated the production and decomposition of salt marsh or oystergrass *(Spartina alterniflora)*, the dominant vegetation in the Barataria Bay salt marshes and the primary contributor of organic detritus. Net production was determined to be considerably higher than in comparable Atlantic coast marshes. Decomposition was also determined to occur rapidly which, along with high production, contributes great quantities of organic matter to the higher trophic levels in the study area.

Kirby and Gosselink (1972) also investigated the decomposition of *Spartina* detritus under laboratory conditions and concluded that a minimum critical size (approximately 111 microns or less) must be reached before maximum rates of decomposition occur.

Brkich and Gosselink (1971) studied phytoplankton productivity and community metabolism in Airplane Lake, a shallow estuarine lake in the Barataria Bay area. Community metabolism was assessed by establishing diurnal dissolved oxygen curves and phytoplankton production was measured by the light- and dark-bottle techniques and the C-14 method. Results were correlated with phytoplankton concentration as determined by chlorophyll analysis.

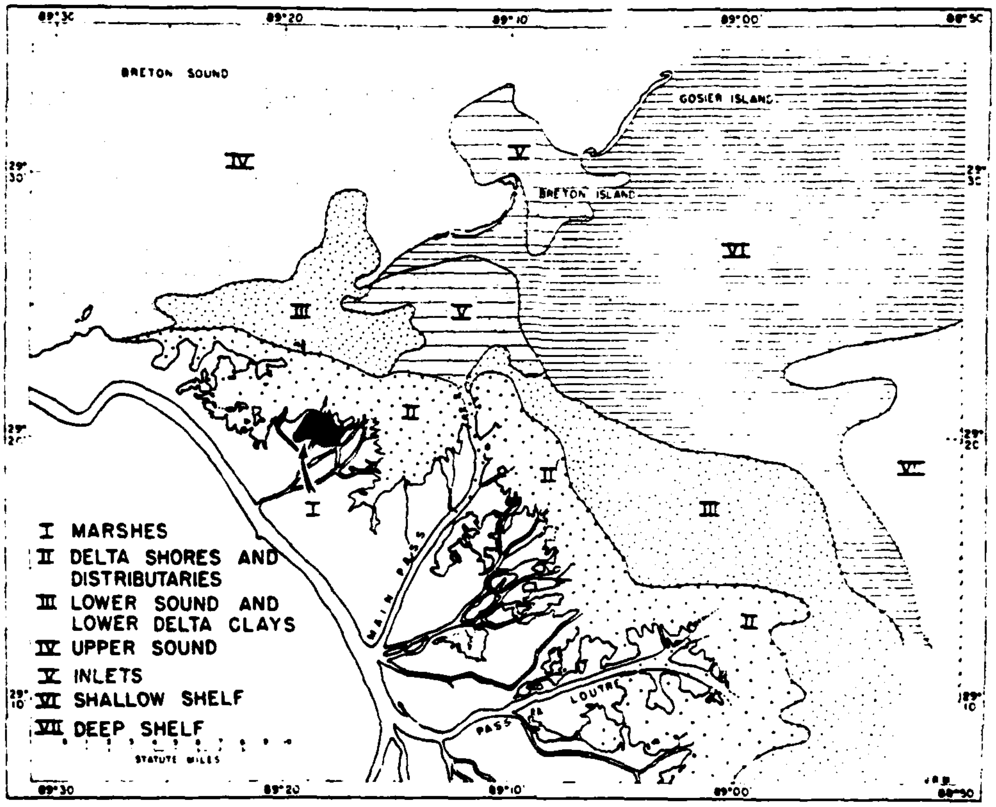
Community structure and production of epiphytic algae in the Barataria Bay area was investigated by Stowe and Gosselink (1971). The host plants for epiphytic algae are *Spartina alterniflora*, which comprises about 90% of the attached vegetation of the bay, and the black mangrove *(Avicennia nitida)*. A seasonal alteration was observed with two red algae, *Polysiphonia* sp. and *Bostrichia*, being dominant in the summer and the brown alga, *Ectocarpus* sp., and the green alga, *Enteromorpha* sp., being dominant in the winter. Winter species exhibited a greater density than summer species.

As a result of a three-year sampling program, Parker (1956) delineated eight macro-invertebrate assemblages in the east Mississippi delta region. These assemblages are indicators of sedimentary environments and basically fall into two major macrofaunal groups: (1) lagoons – enclosed, protected waters and, (2) open, unprotected shelf waters. Sediments of the study area have already been shown (Figure B-34). Figure B-36 shows seven of Parker's macro-invertebrate assemblages. The eighth assemblage is living oyster reefs which are scattered. These assemblages include portions of other zones discussed elsewhere in this report (Zones XIV and XV). For each assemblage, Parker lists the characteristic dominant species. One criticism of Parker's work is that much of his data and conclusions are based on the presence of dead shells in the samples rather than on the presence or absence of living organisms.

In a later paper (1960), Parker recognized 11 macro-faunal assemblages in the lagoons and estuaries along the northern coast of the Gulf of Mexico and eight assemblages on the continental shelf and upper continental slope to 500 fathoms.

In addition to the Gulf Estuarine Inventories, some of the best data on sportfishes of the zone come from studies of the Biloxi Marsh Complex, a state-owned Louisiana wildlife management area bordering Lake Borgne and bays adjacent to Mississippi and Chandeleur Sound. Fontenot and Rogillio (1970) investigated the life histories of estuarine sport fishes of the area for eight years terminating in June 1968. Catch of the various species was correlated with hydrological conditions and food habits. Spawning habits, movement data, and size data were also given.

During the study 68 species of fish representing 37 families and 14 orders were collected. The family Sciaenidae was the dominant family. This family contains many species of sport fish, some of which are the spotted seatrout *(Cynoscion nebulosus)*, spot *(Leiostomus xanthurus)*, Atlantic croaker *(Micropogon undulatus)*, black drum *(Pogonias cromis)*, and red drum or red fish *(Sciaenops ocellata)*. The sheepshead *(Archosargus probatocephalus)*, family Sparidae, also existed in abundance in the study area. Other common fishes were the striped mullet *(Mugil cephalus)*, menhaden *(Brevoortia patronus)*, and sea catfish *(Arius felis)*.



Macro-invertebrate assemblages in inshore Delta region. Marsh environment is of far greater extent, but area in black represents only part studied. From Parker, 1956, p. 312, Fig. 11.

FIGURE B–36 AREAL DISTRIBUTION OF ENVIRONMENTS

Ten species of fish disappeared and were not found during the latter half of the study. Their absence was attributed to salinity increases due to salt water intrusion after opening of the Mississippi River-Gulf Outlet. Included among these was the largemouth bass *(Micropterus salmoides)*.

Rounsefell (1964), in a preconstruction study of the estuarine area to be transversed by the Mississippi River-Gulf Outlet, collected hydrographic and biological data from April 1959 to March 1961 at selected stations between New Orleans and Breton Sound. He predicted a raise in salinities over most of the area, the salinity of Lake Pontchartrain increasing about 5°/oo and that of Lake Borgne about 2°/oo – predictions which have proven true by later studies (Fontenot and Rogillio, 1970).

The general ecological features of Lake Pontchartrain have been outlined by Darnell (1958; 1961). Darnell (1962) reported that over 300 animal species are currently known from Lake Pontchartrain but that only four species maintain large endemic populations as year around residents. These are *Rangia cuneata* (clam), *Rhithropanopeus harrisii* (crab), *Acartia tonsa* (copepod), and *Anchoa mitchilli* (fish). Later Morrison (1965) added *Mulinia pontchartrainensis* (mollusk) to this list. Most of the remaining dominant species exhibit the marine-estuarine life history and enter the lake on a seasonal basis. Darnell also concluded that detritus feeders are now among the most successful species in the lake.

The fishes of Lake Pontchartrain are well known through the efforts of Suttkus, Darnell and Darnell (1954). Some of the more abundant fishes in Lake Pontchartrain are *Anchoa mitchilli* (bay anchovy), *Brevoortia patronus* (Gulf menhaden), and *Micropogon undulatus* (Atlantic croaker). Other common species include *Trinectes maculatus* (hogchoker), *Bairdiella chrysura* (silver perch), *Cynoscion arenarius* (sand seatrout), *Arius felis* (sea catfish), *Menidia berylina* (silverside), and *Leiostomus xanthurus* (spot).

Less saline areas in the western portion of Lake Pontchartrain contain common freshwater species including *Ictalurus furcatus* (blue catfish), *Ictalurus punctatus* (channel catfish), and various sunfish.

Large invertebrates include blue crab, brown shrimp, and the mollusk, *Rangia cuneata*. Small oysters and spat are found in high salinity areas of the lake but there is no commercial fishery. *Rangia cuneata* is of considerable economic value for the shells are used locally as fill, an additive in concrete and in several other industrial processes. The clam shell industry is presently valued at over $12,000,000 annually (Louisiana Wild Life and Fisheries Commission, 1972).

The primary producers in the lake fall into two categories – the phytoplankton and the rooted vascular plants (seagrasses). The dominant seagrasses are *Ruppia maritima* and *Vallisneria spiralis*. According to Stern and Atwell (1968), *Coscinodiscus* (a diatom) is the most frequently occurring phytoplankter.

The sediments and microfauna of Mississippi Sound and portions of Mobile Bay have been studied by Upshaw et al. (1966).

Moore (1961) has studied the marine and brackish water mollusca of Mississippi. Four classes of mollusks have been found on the coast of Mississippi and the number of species is distributed as follows: Gastropoda, 80; Scaphopoda, 2; Pelecypoda, 78; Cephalopoda, 3; total, 163. The greatest number of species was found around the barrier islands on sandy substrata in water of relatively high salinity. The snail, *Polinices duplicatus*, was euryhaline. The mud bottom was rather barren but a few species such as *Callocardia texasiana* apparently preferred the mud bottom.

Lesley (1969) studied the benthic macrofauna of upper Bay St. Louis (unpublished material for master's degree) during the fall of 1968. The annelid, *Cistenides gouldii*, was the most abundant species. Also in abundance were two other annelids, *Loandalia americana* and *Heteromastus filiformis.*

Rangia cuneata is widely distributed throughout the low salinity portions of the Mississippi estuarine area. Significant beds have been found in Bay St. Louis and Biloxi Bay. The southern quahog *(Mercenaria campechiensis)* is scattered along the barrier islands in Mississippi Sound (Abbot, 1954).

Maghan (1967) prepared an excellent review of the Mississippi oyster industry based on literature research and interviews with state and local officials and oystermen.

Christmas and Gunter (1965) analyzed the catch in Mississippi waters of penaeid shrimp for the period 1959-1963 by area, species, size and seasonal abundance.

Dawson (1966) made a 15-month study on the gobies of Mississippi Sound and adjacent waters.

McIllwain (1968) has published on the seasonal occurrence of pelagic copepods in Mississippi Sound from collections made over a 15-month period. A seasonal distribution was observed with peak populations occurring in spring, summer and fall. Fifteen copepods were collected and 12 were identified to species and three only to genus. Nine of these were in the Order Calanoida, five in the Order Cyclopoida, and one in the Order Harpacticoida. Eighty-one percent of the individuals collected were in the Order Calanoida, 14 percent in the order Cyclopoida and 5 percent in the Order Harpacticoida. Only one species, *Acartia tonsa*, occurred the year around.

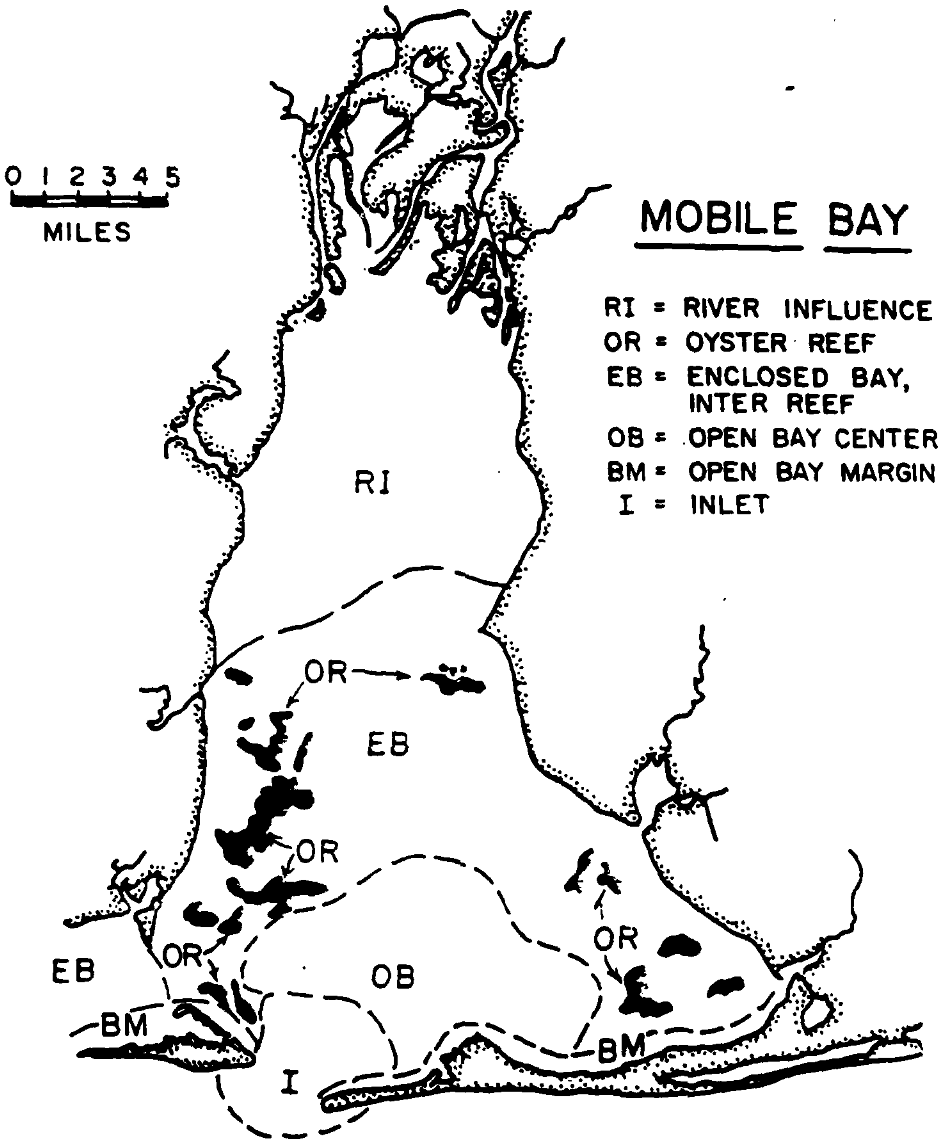
In addition to the Gulf Estuarine Inventory (Swingle, 1971), a comprehensive investigation of the fishes of Mobile Bay and the Gulf Coast of Alabama has been made by Boschung (1957).

The comprehensive study of the oyster reefs of Alabama by May (1971) has been discussed previously.

Crance (1969) has published a selected bibliography of papers dealing with Alabama estuaries.

Parker (1960) recognized six macrofaunal assemblages in Mobile Bay as shown in Figure B-37.

Mississippi Sound is bounded offshore by a series of barrier islands including Cat, Ship, Horn and Petit Bois Islands. The fauna and flora of Horn Island have been extensively investigated by Richmond (1962; 1968). Horn Island is approximately 13 miles long and from one-fourth to three-fourths miles wide. The longitudinal



Determined from A.P.I. collections, and Ritter, 1896. Note large extent of low-salinity river-influenced assemblage and enclosed bay assemblage as compared to small area of open bay and inlet. From Parker, 1960, p. 312, Fig. 8.

FIGURE B–37 AREAL DISTRIBUTION OF MACROFAUNAL ASSEMBLAGES

central portion of the island is covered irregularly by small groves of slash pine (*Pinus elliottii*). A total of 1,568 species of plants and animals are known from the island.

Humm (1956) has reported on the marine monocotyledenous plants ("sea grasses") of Mississippi Sound. Five species occur in abundance. *Ruppia maritima* (widegeon grass) is common along the mainland shore, especially in low-salinity bayous. Extensive beds of *Thalassia testudinum* (turtle grass), *Cymodocea manatorum* (manatee grass), and *Halophila engelmanii* occur as a mixture along the sound side of Ship and other islands in the sound. *Diplanthera wrightii* (shoal grass) usually occurs as separate beds and nearer the beach than the mixed zones of the three above genera.

Eleuterius (1972) has made a more extensive study of the submerged seagrasses of Mississippi Sound with emphasis on the habitats of the grass species. The same five species mentioned above were reported. The species present in greatest abundance was *Diplanthera wrightii* followed in order by *Cymodocea manatorum*, *Thalassia testudinum* and *Ruppia maritima*. *Vallisneria americana* (tape grass) was collected in brackish and freshwaters of adjacent rivers, creeks and bayous. The total surface area of Mississippi Sound in Mississippi is approximately 434,447 acres. Approximately 20,000 acres of submerged vegetation were located. The grass beds were located chiefly in a belt just north of the barrier islands which, in turn, are located some eight miles from the mainland. The bottom substrate supporting sea grass beds was generally firm sand or sandy mud, with or without shells. More than two-thirds of Mississippi Sound is overlaid with mud and is not suitable for plant colonization.

The shallow waters of the protected lee side of the Chandeleur Islands also support rich sea grass beds. Three species are common: *Thalassia testudinum*, *Cymodocea manatorum*, and *Diplanthera wrightii*. Humm (1959) concluded that, because of the greater transparency of the water, *Thalassia* and *Cymodocea* occur at greater depths among the Chandeleur Islands than in Mississippi Sound.

Humm and Caylor (1956) reported on the summer marine benthic algae of Mississippi Sound. Phytoplankton was not investigated. Seventy-seven species were collected and distributed taxonomically as follows: 27 species of Cyanophyta, 12 of Chlorophyta, 1 of Chrysophyta, 13 of Phaeophyta, and 24 of Rhodophyta. Indicating the paucity of investigations of the algal flora of Mississippi Sound, 66 of the 77 species represented new additions to the known alga flora of the Mississippi coast. Previous knowledge of the algal flora was limited primarily to the work of Taylor (1954).

Eleuterius (1972) analyzed the data of Humm and Caylor with regard to algal habitats. A majority of the species occurred attached to solid substrates provided by man's activities such as pilings, channel buoys, a sunken barge, and rocks. The remainder were on shell, shell fragments, and on the blades and exposed rhizomes of sea grasses.

Substratum is apparently a limiting factor for plant distribution (both sea grasses and algae) in Mississippi waters. Though detailed studies are lacking, by inference the same conclusions can be reached for the coasts of Louisiana and Alabama due to the lack of natural solid substrate. Taylor (1954) concluded that the 400 species of algae found in Florida waters were due primarily to the presence of a variety of solid substrate. Though not documented in the published literature, observations of numerous scientists indicate that the legs of offshore oil-producing platforms provide a suitable substratum for a rich and diverse attached algal flora in addition to many other organisms.

Humm and Darnell (1959) reported on the collection of 35 species of marine algae from the Chandeleur Islands. The species were distributed as follows: 19 species of Rhodophyta, 7 of Chlorophyta, 5 of Phaeophyta, and 4 of Cyanophyta. In comparing the algal flora of the Chandeleur Islands to previous collections in Mississippi Sound, it was noted that 21 of the 35 species (three-fifths) from the Chandeleurs had not been recorded in the Mississippi Sound collections. The authors tentatively suggested that the absence of many of the species from the Sound flora was not an accident of dispersal but rather a failure of establishment and survival. They postulated that a comparative study of the two environments would indicate sufficient differences in winter water temperature, salinity, and turbidity which would account for distributional differences.

The marine benthic algae of the Chandleur Islands was also investigated by Mullahy (1959) whose study essentially complemented that of Humm and Darnell (1959).

The marsh vegetation typical of this zone has been discussed previously. Additional pertinent references on marsh vegetation and ecology are Penfound and Hathaway (1938), O'Neal (1959) and Eggler, et al. (1961).

Lacking throughout the zone are systematic and quantitative studies of phytoplankton and primary productivity. One exception is the paper of Mulkana (1966) who reported on preliminary, quantitative studies of seasonal changes in the standing crop of plankton in Mississippi Sound. His observations indicated that inshore stations maintain a higher standing biomass with a gradual decrease toward offshore stations. On a seasonal basis, during the warmer part of the year, the reproductive and spawning activities of organisms contributed to a large standing biomass and to an increased nutrient and caloric value per unit weight of plankton sample.

Also lacking in the zone, especially west of the Mississippi River delta, are quantitative investigations of the benthic macrofauna.

4. Man's Activities

Since this zone includes coastal areas of each of the three states under discussion, man's activity is more diverse in this zone than any other.

Much of man's activity in this zone has been alluded to previously and will only be discussed briefly. Recreational activities common throughout this zone are hunting, sports fishing, camping, and boating. The trapping of fur-bearing mammals is widespread, particularly in the marshes of Louisiana.

The Louisiana portion of this zone has few natural sandy beaches used for recreational activity. An exception is Grand Isle, Louisiana. The 119 miles of shoreline around Lake Pontchartrain include about 47 miles which have been developed.

Along more than one-third of the Mississippi coastline wide sand beaches have been built in front of seawalls by pumping material in from nearshore shallow waters. A natural beach near Belle Fontaine is several miles long. Alabama has fine beaches on Dauphin Island and at Gulf Shores. Beach-related tourism is restricted, for the most part, to the Alabama and Mississippi beaches.

The estimated 1969 population of the Louisiana coastal parishes (counties) was 1,466,018. Orleans Parish, which is composed entirely of the city of New Orleans, was by far the largest parish with 690,521 inhabitants. The importance of New Orleans as a major world port will be mentioned later (Zone XIII). New Orleans is highly industrialized and contains numerous industries dependent on adequate water from the Mississippi River. Notable uses of the Louisiana coastal zone include oil and gas production and refining, sulphur and salt mining, commercial fishing and related shore plant installations. Numerous statistics related to the Louisiana coastal zone are included in the Louisiana Gulf Estuarine Inventory and a discussion of present and future use of the coast is given in the National Shoreline Study (Army Corps of Engineers, 1971).

The Mississippi Gulf Coast includes three counties: Hancock, Harrison, and Jackson. The 1990 projected population for the tri-county area is 553,180. The principal cities are Gulfport, Biloxi, and Pascagoula. Channels for oceangoing vessels are maintained into Gulfport and Pascagoula. Of the three cities, Pascagoula is the most heavily industrialized and is important in the ship industry. Man's activities along the Mississippi Gulf Coast and the problem of pollution are covered at length in the Mississippi Gulf Estuarine Inventory (1972).

The port of Mobile is served by a 40-foot deep ship channel and the principal imports are iron, aluminum and manganese ores, petroleum products and grain. In 1969 Alabama had 67 fishery wholesale and processing firms employing 1,470 individuals. The Mobile area is heavily industrialized whereas Baldwin County remains premarily agrarian. The population of Mobile and Baldwin counties is expected to reach 629,000 by 1995. Crance (1972) discussed in detail man's role in the estuarine areas of Alabama.

C. ZONE XI

1. Summary

Zone XI (Figure B-32) extends along portions of the Texas and Louisiana coasts from near the coastline to a depth of approximately 10-12 fathoms. The part of this zone off the Texas coast will be considered by TerEco, Inc. and the following discussion will be limited to waters adjacent to the Louisiana coast. The slope of the continental shelf is very shallow in this zone, the 10 fathom line averaging 35 miles off shore.

Recalling the attributes of Zone III, there is little freshwater influence in this zone; therefore this region is characterized by high salinities typical of open Gulf waters. Water circulation is from westerly longshore currents. Water quality is good. Sediments are sand and mixtures of silt and mud.

The zone is of major importance to the commercial fisheries industry of Louisiana, particularly that portion of the industry dealing with the catch of trash fish for fish oil extraction. The zone is poorly known biologically.

2. Physical Characteristics

a. Hydrology

Water depth increases gradually in this zone and the 10 fathom line lies about 35 miles offshore. Tides are generally diurnal with a mean range of 1 to 1.5 feet. Fluctuations due to wind can cause the mean to vary from 3.5 feet below to 4 feet above. Average current is westerly at about 0.6 to 1.0 knots. Monthly average sea temperatures range from 64.3°F in February to 85.5°F in August. The greatest extremes in water temperature occur only in the near-coastal waters (NOAA, 1972). Freshwater runoff is of minor importance in this zone.

b. Geology

This zone is characterized by a rather high concentration of salt domes, but probably not as high as in Zone XV (Figure B-18). Little or no active deposition of sediment occurs. Sediments of the zone are a combination of areas of sand surrounded by mixtures of silt and mud. Near shore sediments are mostly mud. The substrate is fairly stable and the water is of very low turbidity except in the near shore coastal waters.

c. Chemistry

Due to a minimal influence of freshwater and associated dissolved nutrients, water quality in this zone is good. Concentrations of dissolved solids should be typical of natural seawater. Salinities in the zone are always greater than 30°/oo.

3. Resident and Transient Marine Biota

As mentioned earlier, the port of Cameron led all U.S. fishing ports in volume (on a pound basis) of landings in 1971. Much of this volume is due to the large catch of menhaden in the waters of Zone XI. Other fish common in this zone include the black drum, redfish, flounders, and black mullet.

According to Parker's (1960) classification of the macrofaunal assemblages of the continental shelf and slope, this zone is in his "Inner Shelf, 2-12 Fathoms Assemblage." Parker considers this the most productive depth-zone in the Gulf having the largest number of individuals per unit area. The species of this assemblage, according to Parker, are quite constant from the eastern to western Gulf but two molluscan species are distinct off western Louisiana. These are *Chione intrapurpurea and Solen viridis.*

A search of the available literature indicates that, of the zones under consideration, this is one of the most poorly known.

4. Man's Activities

Commercial fishing and shrimping, as well as saltwater sport fishing, are widespread in this zone. The commercial fisheries industry is of major economic importance to the adjacent coastal area. The zone contains a number of highly productive subterranean gas fields and a few scattered oil-producing areas. Numerous pipelines transverse the bottom substrate.

D. ZONE XII

1. Summary

This zone, west of the Mississippi River delta, extends from the coastline of Louisiana seaward to a depth of approximately 10-12 fathoms. Freshwater discharge from the Mississippi River frequently affects the hydrology, chemistry, and sediments of the eastern portion of this zone. Likewise, the Atchafalaya River affects the near coastal waters of the central and western portions of this zone. Surface currents move along the coastline in a northwesterly then westerly direction. Sediments are a combination of mud, sand, and silt-mud mixture.

There is a lack of large amounts of hydrological and biological data for the zone as a whole. The major distinction of this zone from the preceding (Zone II) is the greater influence of freshwater discharge and a greater variability in hydrological and water chemistry data.

The zone is important to the commercial fishing industry and in offshore oil and gas production.

2. Physical Characteristics

a. Hydrology

The hydrology of this zone is similar to that of Zone XI, especially in the western portion. In the western portion the 10 fathom line is approximately 35 miles offshore. To the east this depth line is much nearer the coast due to the proximity of the Mississippi Trough, a submarine canyon just west of the present delta. Tides, winds and water temperatures are, in general, as discussed for Zone XI. Surface currents flow along the coastline in a northwesterly then westerly direction at speeds between 0.7 and 1.0 knots. Freshwater runoff influences the eastern part of this zone during periods of heavy discharge by the Mississippi River. On occasion, Mississippi River waters extend northward into Barataria Bay (Zone IV) in excess of 10 miles. Discharge of the Mississippi and its overall effect on the ecology of the offshore area is discussed more fully under Zone XIII. The Atchafalaya River no doubt has a similar influence on the central and western portions of this zone.

b. Geology

This zone has a relatively flat shelf with some depositional highs oriented more or less parallel to the coastline (Figure B-13). There are down-to-the-basin faults near the shoreline and abundant salt domes throughout the zone. Sediments are a combination of mud, sand, and silt-mud mixtures. The area of mud bottom is near the outer boundary (between Zones XII and XV) of this zone with two major patches of sandy bottom near or just inside the 10 fathom contour. The entire area is one of active sediment deposition. Bottom currents may reach a flow rate of 35 cm/second for more than 500 hours per year near shore. The frequency of such currents offshore is much less (usually only occurring one time every 1.5-2.0 years – see Figure B-26). Freshwater discharges influence water turbidity in this zone, especially in the eastern extent near the Mississippi River delta and at the mouth of the Atchafalaya.

c. Chemistry

Though little specific data is available, water quality is assumed to be good in this zone. Again, freshwater discharge is a factor near the mouths of major rivers. Reduced surface salinity and increased concentrations of nutrients (phosphates, nitrites and nitrates) are directly correlated with periods of high discharge, particularly when there are strong east to south winds. Geyer (1950) calculated salinity values from the chloride-ion contents of more than 700 water samples collected from drilling platforms during a period of 14 months in a zone paralleling the Louisiana coast for approximately 60 miles. The collection sites were 6-8 miles offshore and in depths varying from 40 to 50 feet. All collection sites were in Zone XII and ranged eastward from south of Timbalier Bay to the west Mississippi River delta area. Analysis of the data clearly demonstrated the existence of a wide salinity variation at each site and a well-defined correlation between salinity variations and Mississippi River discharge. Greatest variation occurred from January through March (salinity range 14 to 38°/oo) and the least during summer months (range 21 to 37°/oo, with most values clustered at the high salinity values).

3. Resident and Transient Marine Biota

The marine fauna of the offshore area in the vicinity of Grand Isle, Louisiana, has been studied extensively over the years by numerous investigators. Behre (1950) published an annotated list of the fauna of the area. Dawson (1966) reviewed the earlier literature and reported on his own 16-month ecological survey of the offshore waters of Grand Isle during 1958-60. Collecting to the 20 fathom depth, Dawson added some 84 invertebrate and 40 fish species to the known fauna of the Grand Isle area. Dawson concluded that the fauna remained incompletely investigated even after 35 years of study by himself and many others.

Parker (1960) would place the macrofauna of this zone in the "Inner Shelf, 2-12 Fathoms" assemblage, but the benthic organisms of the zone have never been quantitatively investigated.

This zone is an important contributor to the commercial fisheries of the coastal zone and serves, along with Zone XV, as a spawning ground for shrimp and other species which exhibit the marine-estuarine life history discussed previously.

4. Man's Activities

Commercial fishing activity for shrimp and finfish is widespread in the zone as is sports fishing which is very common around offshore oil platforms. Offshore activity involved in the production of oil and, to some extent, natural gas is widespread throughout the zone. Numerous pipelines leading to onshore facilities are common in the bottom substrate.

E. ZONE XIII

1. Summary

Zone XIII is delineated by the area where fresh water from the mouth of the Mississippi predominates over the salt water. The zone is more or less circular and includes the open Gulf immediately off the river's main distributaries where the water may be almost fresh at the surface and saline at the bottom. This zone is entirely within Plaquemines Parish.

The delta extends out from the gently curving border of the northern Gulf toward the continental slope, joining the narrowest part of the continental shelf in the Gulf of Mexico (Figure B-32).

The attached vegetation of Zone XIII is predominatly freshwater.

Man's activities include shipping, oil, gas and sulphur production, commercial and sports fishing, and hunting.

2. Physical Characteristics

a. Hydrology

Zone XIII is dominated by freshwater flowing from the mouth of the Mississippi River. The mean discharge for the 15-year period from 1953 through 1967 was 478,000 cubic feet per second. The maximum discharge recorded from 1932-1967 was 1,977,000 cubic feet per second, and the minimum 85,000 cubic feet per second. High water normally occurs in March, April, and May and low water in September, October, and November.

During periods of low river discharge, the channels of the distributaries are not completely filled with river water and salt water enters the bottom of these channels forming "salt wedges." Flow in the salt wedges is gentle, usually oscillating with the tides, although at times a net upstream flow occurs, presumably caused by entrainment of the salt water by the outflowing fresh water. A salt wedge is found in all distributaries, regardless of whether they are dredged or undredged. During high river stages the salt wedge is excluded from the river channel. The presence or absence of the salt wedge influences sedimentation rates both at the mouths of the distributaries and upstream in the channel.

As the freshwater issues from the passes, it expands laterally, gradually decelerates, and mixes vertically with salt water at least in cases where the salt wedge intrudes into the channel (Wright and Coleman, 1971). Characterization of the mixing process when the salt wedge is flushed out of the river is more difficult, and Wright and Coleman believe this situation is not adequately explained by any existing model.

Currents off the mouths of the Mississippi River distributaries are complex. Scruton (1956) summarized circulation in the inshore area northeast of the delta, an area which includes parts of Zones IV and XIV, but which must be considered together for this particular purpose. The area includes the effects of fresh water from Baptiste Collette, Main Pass, Pas A Loutre, as well as smaller distributaries. The principal feature of interest is an estuarine-like pattern of seaward flow of low salinity surface waters and a net transport of deeper water landward. Vertical salinity gradients vary according to river flow. The circulation in this area was examined in more detail in the spring of 1970 by Murray et al. (1970) who analyzed data which resulted from monitoring an oil spill from a production platform northeast of Main Pass. Distribution of the oil slicks from this spill was influenced more by wind than any other single factor; however brackish water masses, forming rip lines with water of normal Gulf salinity, often served as natural barriers preventing oil from going ashore. Visual observation of these rip lines (sometimes called, more technically, "interfacial lines") suggested downwelling which accumulated a thick line of oil and debris. The single instance when oil washed ashore occurred during a two-day period when a thin layer of freshwater and a strong southeast wind allowed the slick to spread to Breton Island.

Data for currents of the open Gulf at the mouth of the river are limited mostly to surface observations. The recent studies of Wright and Coleman (1971) and Murray et al. (1970) used various remote sensing techniques which are also limited to surface observations. A persistent northward drift of surface waters of the open Gulf originally described by Sverdrup et al. (1942) opposes the prevailing winds in winter and is reinforced by prevailing winds in summer. This prevailing current component tends to limit the seaward extent of turbid Mississippi River waters.

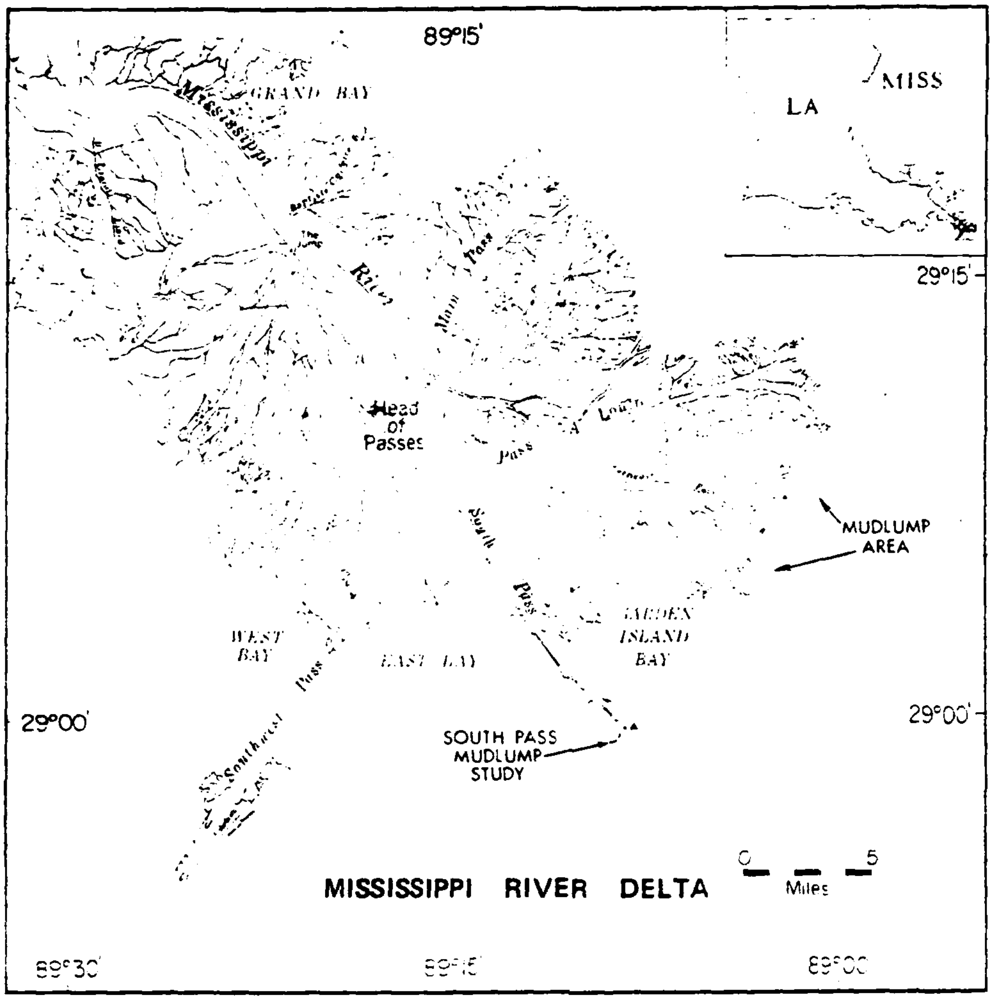
The lateral distribution of Mississippi River water is primarily due to wind and semi-permanent currents. This in itself is only a crude division since many currents which seem to be independent of wind direction were originally set up by prolonged wind action distant from the point of observation. Scruton (1956) likens the effect of the Mississippi River on the Gulf to that of a small pipe1/4" by 3/16," emptying into a tank 32 feet long, 24 feet wide and 10 feet deep. The discharge from the pipe moves back and forth depending on how the water in the tank oscillates.

This dilution effect may not be so important in shallow shelf waters since there is some evidence that low salinity as far west as Galveston, Texas, may be due to the Mississippi and other rivers to the west whose discharge is carried westward by Gulf currents. Scruton's tank model, which has been widely quoted, emphasizes dilution effects for the Gulf as a whole but on shelf waters the Mississippi has very significant effects on salinity and turbidity in Zones IV, XII, XIII, and XIV.

b. Geology

Mudlumps are surface mainifestations of upward displacement of shelf and pro-delta clays which intrude later into coarser sediments deposited by the Mississippi. They form at the mouths of passes which empty into relatively deep water, e.g. Pass A Loutre, Southeast Pass, South Pass, and Southwest Pass. They do not form at the mouth of distributaries which empty into shallow bays such as Baptiste Collette and Main Pass. Figure B-38 from Morgan et al. (1968) shows the mudlump areas at the mouth of the major distributaries. The details of mudlump formation and structure are interesting geologically but for regional analysis, their main significance is that they "constitute a discontinuous fold belt or zone which partially circles the modern delta for a distance of about 45 miles." Rates of movement of mudlumps were shown in one instance by a bore hole casing which moved vertically 12 feet in 5 years. Other casings were stable during this period so that some folds appeared to be dormant.

Sediments off the mouth of Pass A Loutre, Main Pass, and the area to the north were shown in Figure B-34. Most of this area is discussed in sections on other zones. In Zone XIII the relevant sediments are mostly various mixtures of silt and clay. Sand is not an important component of the sediments near the river distributaries and, in fact, has not been a component of the suspended sediments in the river since the levee, lock, and dam construction.



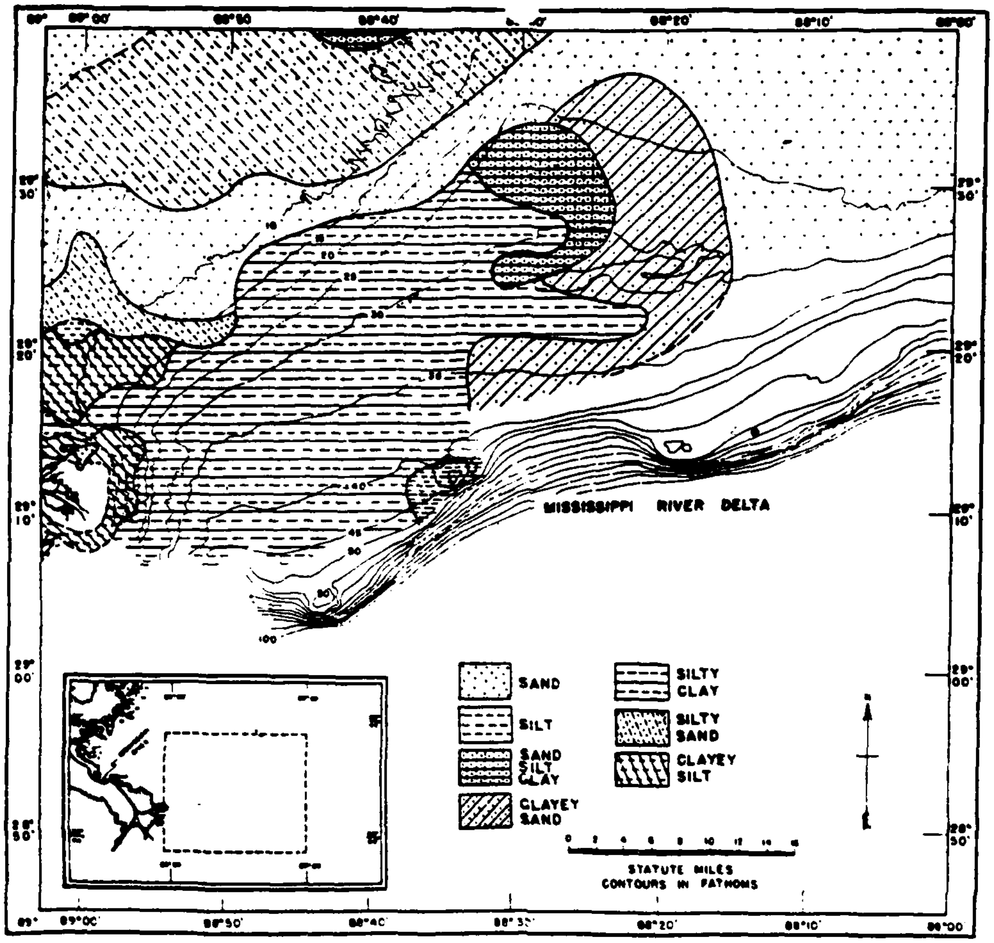
From Morgan et al., 1968, p. 146, Fig. 1.

FIGURE B–38 AREAS OF MUDLUMP DEVELOPMENT AT MAJOR DISTRIBUTARY MOUTHS

Figure B-39 shows sediments off the Pass A Loutre-Southern Pass System. Silts and clays predominate from the mouths of the distributaries to the edge of the continental shelf. Sand gradually becomes more dominant to the east as sedimentation rates decrease.

c. Chemistry

Chemical data will be included in the next section in conjunction with discussion of phytoplankton.



Determined by sand-silt-clay contents of offshore Delta region (compiled by Parker and D.G. Moore). From Parker, 1956, p. 302, Fig. 6b.

FIGURE B–39 AREAL DISTRIBUTION OF SEDIMENT TYPES

3. Resident and Transient Marine Biota

Riley (1937) analyzed chlorophyll, soluble phosphorus, soluble copper, particulate organic matter (by loss-on-ignition) and surface salinity. Stations occupied were off the mouth of the Mississippi (Zone XIII), farther north in the open Gulf (Zones XXII and XXIII), at the mouth of Mobile Bay, and in a line about parallel to the Chandeleur Islands (Zones IV, XIV, and XV). Riley concluded that the Mississippi River has a noticeable effect on phosphorus levels in the Gulf (phosphorus is usually one of several important limiting factors in marine productivity) and high phytoplankton content near the river's mouth is due to the influence of the river. Thomas and Simmons (1960) measured phytoplankton productivity by C^{14} uptake, chlorinity, temperature, suspended solids, Secchi disc measurements, inorganic phosphate, soluble silicas, and soluble Kjeldahl nitrogen. Their stations extended into Zones XIV and XV.

Thomas and Simmons, using a more sophisticated technique of productivity measurement, arrived at essentially the same conclusions as Riley, that the nutrients from the Mississippi contribute significantly to high production off its mouth. This study covered an inshore area off Pass A Loutre, Main Pass, and just north of Breton Island in Breton Sound.

Surface phytoplankton production was quite variable, from 0-57 ug C/l/day and sometimes varied as much as sevenfold from one day to the next at a given station. The summary data show a productivity equal to or greater than that of highly productive tropical or subtropical waters. During periods of high river discharge, productivity increased at the more seaward stations, which correlated with higher dissolved phosphate and Kjeldahl nitrogen.

Surface phytoplankton productivity was compared to organic carbon concentration in pro-delta sediments. Thomas and Simmons concluded that rate of sedimentation from organic carbon produced by phytoplankton was relatively minor compared with organic carbon in sediments. At the time, the authors did not realize the entire significance of their finding. The high levels of organic carbon in the detritus of Mississippi River waters could contribute to total animal production in the area without being involved with the intermediate step of phytoplankton productivity.

Two hundred species of phytoplankton were identified, of which most were diatoms. A river assemblage found in the river plume and Blind Bay consisted of *Cyclotella, Melosira*, and *Navicula*. An open Gulf population consisted of species of *Nitzchia, Thalassionema, Thalassiothrix, Skeletonema, Asterionella*, and *Chaetoceros* and was associated with Gulf and plume stations. Breton Sound had an open Gulf assemblage (Thomas and Simmons, 1960).

The contribution of the Mississippi River to pollution in the Gulf of Mexico is still poorly known although many municipalities discharge untreated or poorly treated wastes into the river. Much of the organic matter is oxidized by natural processes and does not affect Gulf waters. Insecticides and heavy metals are a more serious problem.

Endrin pollution in the Mississippi was investigated from 1964 to 1967 (U.S. Dept. of the Interior, 1969) after endrin was determined to be responsible for fish kills. The studies did not extend to the Gulf of Mexico; the main source of the pollution was identified and the situation corrected. However, insecticides from aerial spraying in agricultural areas are believed to be a major source of pollution; and the failure to reintroduce brown pelicans at Rockefeller Refuge (Zone III) has been attributed to chlorinated hydrocarbons (La. Wild Life and Fisheries Commission, 1972).

Custodi (1971) studied mercury levels in the Gulf area and concluded that mercury carried to the Gulf of Mexico was precipitated in sediments off the mouth of the Mississippi River. These results are similar to those of Huggett, et al. (1971) and are a strong indication that estuaries, particularly the mouths of large rivers, may become depositories for pollutants carried by the rivers. Heavy metal pollution is an active area of current research as indicated by the programs of papers presented at scientific meetings.

The marsh vegetation of Zone XIII consists of plants associated with fresh to slightly brackish water. The upper boundaries of Zone XIII on either side of the delta were delineated by vegetation as shown on the map by Chabreck et al. (1968). Plants "integrate" chemical and physical conditions over a period of time and thereby indicate environmental changes better than occasional measurements of other parameters.

The following description of delta vegetation is taken from O'Neil (1949). The first plant to appear on newly formed delta mudflats is the strictly freshwater *Scirpus americanus*. If water flow is abnormally low, stands of *S. americanus* will not appear healthy, but brackish water species still do not become well-established. Duck potato *(Sagittaria platyphylla)* and roseau cane *(Phragmintes communis)* also invade bare mud. Farther up the distributaries where natural levees begin to form, cattail *(Typhus latifolia)* and cutgrass *(Zizaniopsis miliacea)* appear with *Phragmites*. On older ponds where some accumulation of vegetation occurs, widgeon grass *(Ruppia maritima)* and gray-duck moss appear. Aligator grass *(Alternanthera philoxeroides)* is also present. Where the natural levees are formed high enough to rise above normal flood and tide action, the crest of the levee supports willow *(Salix rugia)*, hackberry *(Celtis laevigata)*, and cottonwood *(Populus deltoides)*. The marsh is still freshwater, maintained by freshwater flowing through passes in the levee. Alligator weed may become very common and ponds may support coontail *(Ceratophyllum demersum)* and banana lily *(Castalia flava)*.

Above this zone in the areas near Baptiste Collette on the east side of the delta and Tiger Pass on the west side, the water again becomes brackish because of choking off of passes, which are now called bayous. The appearance of black rush *(Juncus roemerianus)* salt grass *(Distichlis spicata)*, and honey mangrove *(Avicennia nitida)* mark the transition from Zone XIII.

The macro-invertebrate benthos falls into Parker's "Area II, Delta Shores and Distributaries." The only marsh studied by Parker was a brackish marsh, as indicated by the presence of the snails, *Littorina irrorata* and *Neritina reclivata*. The fauna of the lower delta has not been reported in detail, although O'Neil (1949) refers to the area in his studies of muskrats and Parker lists *Cambarus* sp. (probably *Procambarus clarki)* as being common in freshwater marshes.

The delta front and lower distributaries does not have a very rich benthic fauna, as is typical of low salinity areas. Oyster reefs are found mainly north of Baptiste Collette; the principal bivalves are *Macoma mitchelli*, *Mulinia lateralis*, *Rangia cuneata;* the principal snails *Anachis obesa* and *Littoridina sphinctostoma;* and the principal polychaete *Lumbrineris bilfilaris.*

4. Man's Activities

Shipping is an important activity in Zone XIII as the ships enter the mouth of the Mississippi through this zone. Large ships use South Pass and Southwest Pass; the safety fairways, minimum channel depths, and navigational aids are found on standard Coast and Geodetic Survey charts. Pass A Loutre and Main Pass are used extensively by offshore oil and gas vessels, the shrimp and oyster industry, and sports fishermen. Baptiste Collette is scarcely navigable except by shallow draft vessels. Pilot Town, one of the few settlements in the area, owes it existence to shipping interests.

Oil and gas production facilities are found throughout the zone, particularly in East Bay and off Pass A Loutre. There is a sulphur "mine" in Garden Island Bay.

Oyster production is minor at the mouth of the river and there are no leased bottoms. Shrimp are taken in fair numbers in the bays between the distributaries. The large river shrimp, *Macrobrachium acanthurus,* occurs here and was once proposed as the basis of a new fishery, but apparently the populations are not sufficiently dense and stable for commercial exploitation.

5. Mississippi River – Mouth to Baton Rouge

Though not included in Zone XIII, brief mention should be made of the Mississippi River and its importance as a waterway for oceangoing vessels and as a source of freshwater for drinking and industrial purposes.

The Mississippi is the source of drinking water for approximately 1,500,000 people in the area south of Baton Rouge and also the water source for more than 60% of the wet industry in Louisiana – a use of approximately two billion gallons per day.

The Mississippi River is improved for ocean-going navigation from its mouth to Baton Rouge and the lower Mississippi is first in the nation in annual ton-miles of freight. A project of the Army Corps of Engineers, which is essentially complete, provides for a 40-foot deep channel in the Mississippi River and Southwest Pass from the Gulf of Mexico to Baton Rouge. Thirty foot depths are maintained in South Pass with a channel width of 450 feet. Channel widths in Southwest Pass are 800 feet, 1,000 feet from the Head of Passes to the Port of New Orleans, and 500 feet through the Port of New Orleans and to Baton Rouge. Additionally the Port of New Orleans is served by the Mississippi River-Gulf Outlet with a depth of 36 feet and a channel width of 500 feet. The Port of New Orleans is one of the major ports of the world but suffers from lack of available space for future expansion of dockside facilities.

A continuing decline is reported in use of the Mississippi by commercial fishermen due to ecological changes resulting, in part, from flood control and navigation programs. Also pertinent are the effects of domestic sewage and industrial effluent outfalls.

In Louisiana, the Mississippi River is leveed almost to the mouth; thus little of the local drainage actually reaches the Mississippi River (U.S. Department of the Interior. 1969). Gunter (1956) has discussed in general terms the effects of leveeing. He concluded that present flood heights are 7 to 10 times higher than before leveeing since the river has been cut off from its vast overflow areas. In his opinion, the following harmful events have resulted from flood control by leveeing: water is wasted, the river has a faster flow and deeper channel, aquatic life is destroyed in the river, land is wasted, and swampy areas and their attendant wildlife are destroyed. The greatest loss, according to Gunter, is the loss of land – approximately 730,000 tons/year wash into the Gulf of Mexico. Much of this formerly aggraded the swamps of the floodplain and the marshes of the lower delta.

The Army Corps of Engineers (1971) reports that for the period 1949-1963, salt water was detected as far upstream as Kenner, Louisiana (river mile 114) on three occasions. The salt water interface (salinity of 9.06°/oo) occurred at a depth of 53 feet in 1952, 55 feet in 1953, and 65 feet in 1956. During periods of low flow, the tide is noticeable for 200 miles upstream from the Gulf of Mexico.

Probably due to adverse and sometimes dangerous sampling conditions, there are few studies of the biota of the lower Mississippi, and none to our knowledge from New Orleans to the mouth of the river.

F. ZONE XIV

1. Summary

Zone XIV is located on the inner continental shelf and extends from the barrier islands off the east Louisiana delta and off Mississippi Sound to the 10-12 fathom mark (Figure B-32).

More detailed investigations are needed on both hydrology and water chemistry. Sediments are more sandy than in Zone XII which has similar water depths west of the Mississippi River delta. Toward the shore this zone differs from Zone IV by greater salinity and sediment type and is further distinguished from Zone XV by the benthic fauna which is typical of the shallow continental shelf.

Man's activity in the zone includes oil and gas production which is limited to Louisiana waters, commercial fishing, and sports fishing.

2. Physical Characteristics

a. Hydrology

Surface currents move westward across this zone and form a counterclockwise gyre, reinforced by water from adjacent sounds, to become entrained in the eastward flow from off the Mississippi River delta (Upshaw, et al., 1966). This zone is also the source of high salinity water which enters the bottom of passes between the barrier islands and supplies the saline water which invades some of the estuarine waters of Louisiana by way of the Mississippi River-Gulf Outlet.

b. Geology

The geology of this zone shows a decrease in salt domes and related structures and fewer faults proceeding in a northeastward direction. There is considerably more sand in the sediments than in Zone XII, encompassing similar depths west of the delta. Regardless of differences in available energy, the ratio of sand can be expected to increase with increasing distance from sources of finer sediments.

c. Chemistry

Salinity is high and normal open Gulf salinities are reached a short distance from the passes. Water quality would be expected to be good throughout this zone.

3. Resident and Transient Marine Biota

The shallow waters off the Chandeleurs support scattered populations of clams *(Mercenaria campechiensis)* and scallops (*Aequipecten* sp.), but not of sufficient density to allow commercial exploitation. Parker designates the benthic fauna of this zone as "Area VI, Shallow Continental Shelf." It includes the mollusks *Cantharus cancellaria, Dinocardium robustum, Dosinia discus, Oliva sayana, Donax tumidus, Nassarius acuta* and *Olivella mutica.* Other benthic forms commonly found are *Renilla mulleri, Luidia clathrata* and *Mellita quinquiesperforata.* Zone XIV includes spawning grounds of both *Penaeus aztecus* and *P. setiferus* and supports populations of various other crustaceans such as *Callinectes similis* and *Squilla empusa.*

4. Man's Activities

Oil and gas production continues in Zone XIV about midway up the Chandeleur chain. Shrimping is important with an active offshore brown shrimp fishery. Sports fishing decreases in this zone where there are no oil and gas platforms.

G. ZONE XV

1. Summary

Zone XV is an offshore zone in waters with depths from 10-12 fathoms to 25-30 fathoms. The zone (Figure B-32) is divided by the mouth of the Mississippi River and its major area of influence (Zone XIII) into a westward extension (offshore western Louisiana) and an eastern extension (offshore eastern Louisiana, Mississippi, and Alabama).

The water quality and salinity of the zone are typical of open Gulf waters. The zone is distinguished from other zones by its stable high salinity and characteristic bottom fauna. As discussed herein, Parker (1956) believes a distinct assemblage of bottom-dwelling animals is encountered at approximately 13 fathoms and greater depths.

Importance of the zone to man includes the offshore production of oil and natural gas, particularly west of the Mississippi River delta, and commercial fishing. The catch of brown shrimp in this zone has been widespread in recent years.

2. Physical Characteristics

a. Hydrology

Hydrological data for two sites in this zone have been reported by the Environmental Data Service of NOAA (1972) and excerpts will suffice as being typical of the eastern and western extensions of this zone. The two sites are (1) Bayou Lafourche area – about 18 miles south-southeast of the mouth of Bayou Lafourche with water depths in the immediate vicinity of 15-25 fathoms; and (2) the Mobile-Pascagoula area – about 40 miles southwest of the entrance to Mobile Bay with water depths in the immediate vicinity of 15-25 fathoms.

Surface currents west of the Mississippi River delta generally parallel the coastline moving northwesterly to westerly at speeds between 0.7 and 1.0 knots. Currents east of the delta are more erratic and vary seasonally (Figures B-1 and B-2). Surface currents in the Mobile-Pascagoula area flow toward the west during most of the year at speeds of 0.5-1.0 knots. The flow weakens in April and then tends to reverse direction with speeds around 0.5 knot. Flow toward the west resumes in July (NOAA, 1972).

Tides in both the eastern and western extensions of this zone are chiefly diurnal with a mean range of 1-2 feet in the west. Data on waves and meteorological conditions have been reported by NOAA (1972). The effects of freshwater discharge are minimal in both extensions of this zone. At the Bayou Lafourche site some 18 miles offshore, monthly mean sea-surface temperature ranged from a low of 67.1°F in February to a high of 85.4°F in August. The sea-surface water was warmer than the overlying surface air for all months but April and May. At the Mobile-Pascagoula site, the lowest monthly mean sea-surface temperature was 62.7°F in February and the highest 85.0°F in August.

b. Geology

Salt domes are very numerous west of the Mississippi River delta but fewer in number to the east (Figure B-18). The western-most extension of this zone is an area of little or no active sediment deposition and the sediment is sand, silt and mud. Along the shelf-slope break is a line of calcareous mounds which are particularly noticeable west of the delta. East of the delta the area of Carbonate sediments begins near the juncture of Zones XV and XVI. A large portion of the eastern half of the zone contains a sandy substrate but there is considerable variation in sediment type. Figure B-34 shows sediment variation for portions of Zones XIV and XV. In terms of sediment movement this zone, particularly the western portion, has the best energy available from bottom currents of any of the zones under consideration (Figure B-26). Sediment stability is high and turbidity low in this zone.

c. Chemistry

Indicating the minimal effects of freshwater, the lowest monthly mean salinity at the Bayou Lafourche site was 32.5 in June and the lowest at the Mobile site was 32.7 in September (NOAA, 1972). Though little specific data is available on other parameters, water quality should be high in this zone and typical of the open Gulf.

3. Resident and Transient Marine Biota

The benthic community falls into Parker's "deep continental shelf" area. Parker staes that there is a distinct faunal "break" at 13 fathoms and proposes as a possible reason that at this depth the animals are not subjected to the intermittent seasonal cooling in winter, as is typical of more shallow waters, thus allowing more tropical components to enter the fauna. Diagnostic species of bivalves are *Cyclopecten manus*, *Chione clenchi*, *Yoldia solenoides*, and *Nucula proxima*. Several echinoderms and corals are common as well as bryozoans and several less numerous mollusks. Large invertebrates typical of trawl samples are *Penaeus aztecus*, *Squilla empusa*, *Pitar cordata*, and the fish, *Prionotus rubio*. The presumably burrowing "lobster," *Calocaris hirsutimana*, is found in this zone (Boesch and Smalley, 1972).

This zone no doubt serves as the spawning ground for many important species of estuarine-dependent fish and shellfish.

4. Man's Activities

This zone is of considerable importance to the commercial fisheries of the tri-state area. Much of the increase, as discussed earlier, in annual brown shrimp catch is due to trawling in the deeper waters of this zone. Offshore oil and natural gas production is widespread in the western extension of this zone. East of the Mississippi River delta production is limited to waters near the delta itself and just outside the Chandeleur Islands. At the present time there is no production off Mississippi and Alabama.

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